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# Managing for Safer Food

## The Economics of Sanitation and Process Controls in Meat and Poultry Plants

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## Abstract

Sanitation and process control costs increased the costs of producing meat and poultry by about 0.5 percent in the period preceding the promulgation of the Pathogen Reduction/Hazard Analysis and Critical Control Point (PR/HACCP) rule of 1996. However, there was no benefit in trying to avoid these costs. Large slaughter plants and all further-processing plants with poor performance of sanitation and food safety process controls were more likely to exit their industries than other plants. Moreover, the fraction of costs required for sanitation and process control was about the same for large plants as for small plants, suggesting that larger plants were no better able than small plants to absorb sanitation and process control costs. Results also suggest that PR/HACCP raised wholesale meat and poultry prices by about 1 percent.

**Keywords**: Food safety, production cost, manufacturing plant survival.

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# Contents

# Executive Summary

The U.S. Department of Agriculture has been responsible for ensuring sanitation and process controls in meat plants since 1906. This report estimates that the cost of performing those tasks amounted to about 0.5 percent of costs: 0.2 cents per pound for poultry and 0.6 cents per pound for beef. However, the cost of not performing sanitation and process controls may have been higher, in that plants that failed to maintain required sanitation and process controls were more likely than others to go out of business. Additionally, this report projects the costs of the Pathogen Reduction Hazard Analysis (PR/HACCP) rule of 1996. This most recent effort to assure wholesome meat and poultry products mandates the use of a HACCP food safety process control program by all meat and poultry slaughter and processing plants and established maximum thresholds for the presence of pathogens in meat products. This regulation is estimated to raise a plant's costs of production by about 1.1 percent: 0.4 cents per pound for poultry and 1.2 cents per pound for beef.

The U.S. Department of Agriculture (USDA) began inspecting exported pork bellies for trichinae and live cattle, hogs, and sheep as well as discretionary meat items for diseases and defects in 1890. The Federal Meat Inspection Act of 1906 required USDA to ensure that slaughter and processing plants performed an appropriate amount of sanitation. Regulations based on the Wholesome Meat and the Wholesome Poultry Products Acts of 1967 and 1968 raised the bar on sanitation standards by compelling plants to adhere to 15 types of sanitation and process control standards.

Concern over the presence of harmful pathogens in meat and poultry increased among some experts during the 1960s and 1970s when the National Academy of Sciences published a report in 1969 on the presence of *Salmonella* in poultry. Subsequently, the American Public Health Association filed and then lost a 1972 Supreme Court case that petitioned the court to declare *Salmonella* an adulterant. In 1977, the consulting firm Booz-Allen expressed concern in a report to USDA about the presence of *Salmonella* and other harmful pathogens in meat and poultry.

USDA's Food Safety and Inspection Service (FSIS) developed voluntary and mandatory quality control programs in the late 1970s and formalized them in regulations in the early 1980s. Plants that participated in these programs identified and monitored control points and took over much of FSIS's responsibility for ensuring the performance of the Sanitation and Process Control Program (SPCPs) in exchange for greater regulatory flexibility and reduced inspector overtime costs. However, only about 5 percent of all plants ever adopted a voluntary Total Quality Control program, the most comprehensive quality control program introduced by FSIS.

Public fears over the wholesomeness of meat and poultry products accelerated during the 1980s with an outbreak of *E. coli* 0157:H7 poisonings in McDonalds restaurants in 1982, 49 deaths attributed to *Listeria moncytogenes* and 2,200 cases of *Salmonella* poisoning in Chicago during the later 1980s, and 4 children's deaths from an outbreak of *E. coli* 0157:H7 at Jack-in-the-Box restaurants in Washington and other Northwestern States in 1992 and 1993. In response, FSIS promulgated regulations requiring safe handling of ready-to-cook and ready-to-eat meat and poultry, declared *E. coli* 0157:H7 an adulterant in ground beef and began testing products for it, and issued the Pathogen Reduction Hazard Analysis and Critical Control Point (PR/HACCP) rule.

The use of a HACCP food safety process control program was the central feature of the PR/HACCP rule. Other components included mandatory testing for *E. coli* and *Salmonella* to verify that meat and poultry processes are under control as well as mandatory sanitation and process control standards. A HACCP program comprises the following elements: (1) an assessment of all hazards, (2) identification of critical points necessary for maintaining food safety, (3) the setting of critical limits for each critical control point (CCP), (4) development of procedures to monitor each CCP, (5) determination of corrective actions, (6) implementation of a recordkeeping system, and (7) establishment of verification procedures.

Meat and poultry process control programs help ensure the food safety quality of a firm's production, can yield a longer shelf life, and encourage repeat purchases, but can also raise costs.

To see how much costs may have changed, we estimated a cost function with process control effort as one of the arguments in an approach similar to Antle's. Results show that performance of sanitation and process control tasks on average increased plant costs in six of the eight industries. A 50-percent improvement in sanitation and process control performance, i.e., reduction in SPCPs, caused plant costs to rise an average of 1.2 percent. Hog slaughter and processed poultry plants had the highest cost increases, and processed meat had the lowest. Cattle slaughter showed a minuscule drop in costs, while cured/cooked pork had a 1.5-percent decline in costs. Note, that Antle pointed out in 2000 that this estimate likely understates food safety quality control costs because plants likely perform other tasks to enhance food safety.

We also found that costs dropped as sanitation and process control performance dropped, and plant size rose in all eight industries, but significantly so only in processed poultry, suggesting modest diseconomies of scale in sanitation and process controls. This means that increased performance of sanitation and process control tasks increases costs more in larger plants than in smaller ones. However, this small increase in costs for larger plants does not offset the sizeable returns to scale (lower costs) arising from increased plant size alone. These findings are important in that an increase in the number of sanitation and process control tasks would likely benefit neither small nor large plants.

Even though it is costly to perform sanitation and process control tasks, plants continued to do them. Our findings (chapter 5) may explain why. These results suggest that large slaughter plants and all meat processors in the 90th percentile of unperformed/poorly performed sanitation and process control tasks (about twice the mean number of unperformed/poorly performed sanitation and process control practices) have an increased likelihood of exiting the industry. Only small slaughter plants could reduce their likelihood of exiting an industry by poorly performing sanitation and process control tasks.

After finding empirically that performance of sanitation and process control practices correlates with HACCP tasks, we estimated the costs of HACCP regulation. We found that imposition of HACCP would increase industry variation in process control performance. For example, plants with about twice the mean level of poorly performed HACCP tasks (about the 90th percentile of quality control effort) would have an average of $500,000 in lower process control costs than plants at the industry mean performance level. These savings suggest that incentives to reduce process control effort may be stronger under HACCP and may require an increase in enforcement actions to maintain regulatory compliance.

We estimated that HACCP plans and their implementation would raise meat and poultry prices by about 1.1 percent, i.e., 0.4 cents per pound for poultry and 1.2 cents per pound for beef. The 1.1-percent increase in meat and poultry costs that we project may sound small and is to the consumer, but to the producer it is quite large. Meat and poultry plants have little direct control over meat input prices; yet, meat and poultry inputs amount to anywhere from about 80 percent (cattle slaughter) to 50 percent (sausages) of all costs. Thus, for meat and poultry plants, the cost of the PR/HACCP rule ranges from between 2.2 and 5.5 percent of controllable costs, i.e., nonmeat costs.

These estimates of the costs of HACCP to the industry are more than seven times larger than the original FSIS-estimated costs of the PR/HACCP rule. Even so, the estimated costs reported here are less than one-half the drop in health care costs associated with reductions in foodborne illnesses that accrue to the U.S. economy due to implementation of the PR/HACCP rule. This estimate is based on an assumed 20-percent reduction in foodborne illnesses due to PR/HACCP and a Landefeld and Seskin value of a statistical life, the most conservative health care cost savings estimate provided by USDA's Economic Research Service.

## Acronyms in This Report

| | |
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| APHA | American Public Health Association |
| CCP | Critical control point |
| CDC | Centers for Disease Control and Prevention |
| EFD | Enhanced Facilities Database |
| EPA | Environmental Protection Agency |
| FMIA | Federal Meat Inspection Act of 1906 |
| FSIS* | refers to the USDA food safety agency that preceded FSIS |
| FSIS | Food Safety and Inspection Service |
| HACCP | Hazard Analysis and Critical Control Point |
| LRD | Longitudinal Research Database of the Center for Economic Studies at the Bureau of the Census |
| MIA | Meat Inspection Act of 1890 |
| NAS | National Academy of Sciences |
| NELS | New Line Speed Inspection System |
| NTIS | New Turkey Inspection System |
| PBIS | Performance Based Inspection System |
| PPIA | Poultry Products Inspection Act |
| PQC | Partial Quality Control programs |
| PR/HACCP | Pathogen Reduction Hazard Analysis and Critical Control Point Rule of 1996 |
| RTI | Research Triangle Institute |
| SIC | Standard Industrial Classification |
| SIS | Streamlined Inspection System |
| SOP | Standard Operating Procedure |
| SPCP | Sanitation and process controls practices |
| SSOP | Sanitation standard operating procedures |
| TQC | Total Quality Control programs |
| USDA | U.S. Department of Agriculture |
| WMA | Wholesome Meat Act of 1967 |
| WPPA | Wholesome Poultry Products Act of 1968 |

*Chapter 1*

# Introduction

Food safety regulation of meat and poultry plants has been controversial. Plant operators have long argued that food safety regulation raises their production costs and imposes proportionately higher costs on small plants than on large ones. Some consumers and public health advocates, on the other hand, assert that an absence of food safety regulation encourages plants to sell products that may be harmful to humans. Despite this controversy, there have been few studies of the economic effects of food safety regulation on meat and poultry slaughter and processing plants. This report aims to address that deficiency.

The Federal Meat Inspection Act (FMIA) of 1906 mandated that the U.S. Department of Agriculture (USDA) inspect cattle, hogs, and sheep for animal diseases, verify that carcasses are fit for human consumption, and ensure the cleanliness of slaughter and processing plants. More recent regulations stemming from the enactment of the Wholesome Meat Act (WMA) of 1967 and the Wholesome Poultry Products Act (WPPA) of 1968 charged the Food Safety and Inspection Service (FSIS) of USDA with the responsibility of monitoring plant performance of a detailed set of sanitation and process controls practices (SPCPs).[1] Between 1967 and 1996, FSIS took a series of steps toward devoting more of its resources to the control of pathogens in meat and poultry. Then, in 1996, it promulgated the Pathogen Reduction/Hazard Analysis and Critical Control Point (PR/HACCP) rule. This regulation mandated the use of a HACCP food safety, process control program by all meat and poultry slaughter and processing plants and established a set of pathogen performance standards to which raw meat and poultry products were required to adhere.

The brief regulatory history illustrates a progressive but discontinuous march toward regulatory oversight designed to reduce cases of foodborne illnesses. In this report, we focused on the costs of food safety regulation. Policymakers, meat and poultry plants, consumers, and others want to know how much food safety regulation costs. Moreover, they want to know how costs change and who pays those costs as food safety regulatory requirements change. For example, does food safety regulation favor large or small plants? Additionally, if food safety process control tasks are costly, are plants with larger food safety process control costs penalized? Further, does food safety process control performance change under alternative food safety regulatory regimes?

The main purpose of this report is to examine the cost implications of food safety regulation under the regulatory authority vested in FSIS stemming from the FMIA, WMA, WPPA, and PR/HACCP rule. We started by establishing the historical context within which food safety regulation exists. Then, we examined the production costs of SPCPs and the effect of SPCP performance on plant survival. Finally, after establishing that food safety process control performance under the regulations associated with the WMA and WPPA is correlated with food safety process control performance under PR/HACCP, we projected the costs of PR/HACCP from estimated costs of SPCPs.

The report differs from other analyses in several ways. To our knowledge, there have been no economic studies of food safety regulation that have been cast in a historical context nor any studies of the effect of food safety regulation or control measures on plant survival. Additionally, we are aware of no reports showing the relationship between performance of SPCPs under WMA and WPPA and performance of HACCP tasks under PR/HACCP. There have also not been any cost studies of SPCPs, but there have been such studies of PR/HACCP. The first of these studies (Knutsen et al., 1995, and FSIS, 1996) used accounting methods and projected labor requirements to provide preliminary cost estimates of PR/HACCP. Recently, Antle (2000) estimated costs based on a cost function analysis and

[1] The acronym SPCP refers to the type of cleanliness standards in place prior to 1996 and includes both sanitation and process control tasks. A process control task may be to keep raw and finished products in separate areas.

Boland et al. (2001) published the costs of PR/HACCP for 50 meat plants in the Great Plains.

Like Antle (2000), we took a cost function analysis approach. Our work differs from Antle (2000) in that we used a direct measure of food safety, process control effort that likely understates food safety, quality control costs because food safety quality depends on factors other than process controls. Antle's (2000) measure of food quality, on the other hand, likely overstates food safety, quality control costs because food quality includes nonhealth-related factors. Combined, the two studies provide a window within which the costs of PR/HACCP likely fall.

We cast our analysis in a historical context in order to illustrate the progression of events that led up to enactment of the PR/HACCP rule of 1996. We argued that PR/HACCP marked an acceleration of a long-term trend toward devoting more effort to protecting the public from unobservable foodborne pathogens. Viewed in this way, implications about the effects of food safety regulation prior to promulgation of PR/HACCP differ from those under PR/HACCP only in scale.

The analysis is based on the Census Bureau's 1992 Longitudinal Research Database (LRD*)* and Food Safety and Inspection Service's 1992, 1997, and 2001 Enhanced Facilities Database (EFD). It also uses a database containing SPCP and HACCP performance data obtained in private correspondences with FSIS personnel.[2] We relied on 1992 data for much of the analysis because this was the only year for which both SPCP and Census data were available.

This report is the first in a series of planned reports on the costs and technologies associated with food safety process control. This report provides some long-term economic implications of food safety regulation based on the performance of SPCPs under WMA of 1967 and WPPA of 1968. These implications are still valid under the PR/HACCP rule of 1996 because the two regulatory regimes are linked. A planned report on the costs of PR/HACCP based on plant survey results will discuss the short-term plant costs of adhering to the requirements of PR/HACCP. Other reports will investigate the adoption and performance of various types of food safety technologies.

The LRD has detailed establishment records for all manufacturing establishments for 1963 and 1967-97. We used the 1992 data for the cost analysis of SPCPs because 1997 LRD data were not available at the time of the analysis and percent-deficient SPCPs were available only for 1992. Data records include physical quantities of meat production, number of employees, electricity use and dollar values of worker's wages, plant shipments, material costs, fuel use, plant assets, and many other items. The LRD also notes ownership and location of establishments.

Researchers can access LRD records for research purposes only at a Census facility. Additionally, stringent disclosure requirements dictate that researchers can publish only aggregated information. We follow those same disclosure rules for FSIS data. Any references to specific company or plant names are based on publicly available records, and not on any Census or FSIS source.

The EFD details animal counts by animal species, types of production processes, plant names, and, until 1997, meat and poultry production volume. Since FSIS identifies plants by the same plant number for each of its databases, we matched these EFD data with the SPCP data and HACCP performance data.

The report proceeds as follows. In the second and third chapters, we reviewed some key food safety regulatory policies and key events. In the fourth and fifth chapters, we used the performance of SPCPs as a measure of process control effort to investigate the costs of food safety process controls and whether it is profitable to reduce performance of them. Finally, in chapters 6 and 7, we compared plant regulatory performance of SPCPs with performance of tasks under the PR/HACCP rule and estimated the costs of PR/HACCP, based on our estimated costs of SPCPs.

[2] SPCP performance data are based on inspection tasks as specified in the Inspection System Guide of FSIS. The inspection tasks are pre-operational and operational sanitation and process control tasks as detailed in the Performance Based Inspection System.

*Chapter 2*

# Pre-HACCP Food Safety Regulation

USDA, through its food safety agency, FSIS, has played a significant role in regulating meat and poultry quality and safety since 1890. During the 1880s, European countries began restricting American pork and livestock imports out of fear of trichinosis in pork and animal diseases in livestock. American meatpackers, fearing that they would lose export sales, petitioned the U.S. Congress for a way to guarantee the safety of American exports. After several years of effort, meatpacker lobbying efforts resulted in the Meat Inspection Act (MIA) of 1890. The MIA granted USDA the authority to inspect livestock, salted pork, and bacon intended for export and to quarantine animal imports to ensure that diseased animals were not imported. However, this legislation had many loopholes, so Congress strengthened it with more stringent legislation in 1891 that required the inspection of cattle for export and cattle, hogs, and sheep in interstate commerce for animal diseases, such as hog cholera and tuberculosis. The law also required all fresh beef for export to have a certificate verifying that the meat had come from inspected cattle and the inspection of pork products for trichinosis and some other animal diseases. To comply with this legislation, FSIS* inspectors made direct visual inspections of the animals and meat products and used microscopes to check for unwanted bacteria.[1] The MIA was further amended in 1895 to prevent the diversion into commerce of condemned carcasses and parts.

During the 1890s and early 1900s, inspectors examined an ever-increasing number of animals and volume of pork but did not monitor the cleanliness of packing plants. By some accounts, sanitation in plants became very inadequate, setting the stage for Upton Sinclair's novel, *The Jungle*. This book raised anxiety in the United States, but, according to Wiser et al. (1986), it was the international reaction that caused the most concern among meatpackers. Fearing lost export sales, meatpackers lobbied for legislation that would assuage European food safety concerns. In response, Congress enacted the Federal Meat Inspection Act (FMIA) of 1906. This legislation did reduce concerns in export markets but was mainly directed at the domestic market, covering all meat plants that shipped products across State lines and to export markets. It greatly increased expenditures for Federal meat inspection activities and mandated that FSIS* inspect live cattle, hogs, sheep, and goats just prior to slaughter and their carcasses after slaughter. Legislation also required FSIS* to inspect meat further-processing lines to ensure proper sanitation and required producers to affix a label indicating that the meat was FSIS* inspected on all domestically shipped products.[2] If an inspector condemned a meat product, then that meat required a stamp of condemnation and had to be disposed of in the presence of an inspector. Since legislation mandated that meat products sold across State lines must pass inspection, the FMIA served as a vehicle for ensuring product wholesomeness and the Federal Government became a guarantor of meat quality and safety. Inspection also took place in plants selling products within State boundaries, but State agencies monitored these plants.

Poultry products were not covered under FMIA, probably because chickens were often raised in backyards and home butchered. With the advent of more commercial poultry slaughter and processing plants, the Federal Government instituted a fee-for-service inspection system. Processors participated in this program in order to assure the public that their products were wholesome.

Rising demand and the possibility of the use and sale of meat from sickly animals by some unscrupulous producers prompted Congress to mandate compulsory

[1] The USDA agency responsible for the inspection of meat and poultry products became an independent agency of USDA known as the Food Safety and Inspection Service in 1981. This agency had previously been called the Food Safety and Quality Service and, under various names, has been part of USDA operations since the FMIA of 1906. We use FSIS* to refer to the USDA food safety agencies that preceded FSIS.

[2] The 1891 act required labels to be affixed to products for export.

inspection in the Poultry Products Inspection Act (PPIA) of 1957. As with meat products, Federal inspectors used clinical symptoms and conditions as an indicator of disease conditions and visual and olfactory inspection as an indicator of animal and poultry meat microbiological safety.

Guaranteeing truthful labeling regarding product formulation became markedly more complex after World War II. FSIS* had long been concerned about the use of water, vegetable protein, and other nonmeat fillers that could be used by processors as cheap replacements for meat without being readily detected by consumers. However, concern about the use of these fillers increased after the war because frozen pizzas, prepackaged hamburgers, ham products, and other processed meat products made their way into grocery store meatcases. Later, poultry followed this path.

FSIS*'s meat and poultry food safety and labeling assurance inspection program became even more complicated with further changes in meat and poultry processing. *Silent Spring* by Rachel Carson and other books during the 1960s heightened consumer awareness of the presence of pesticides and other residues in food. In 1963, a congressionally mandated FSIS* study showed that: (1) few States had strong inspection programs, (2) there was a lack of uniformity among States concerning inspection requirements, and (3) sanitary conditions varied widely among State-inspected plants. In response, Congress amended the FMIA and PPIA with the WMA of 1967 and the WPPA of 1968.

## Wholesome Meat Act of 1967 and Wholesome Poultry Products Act of 1968

The WMA and WPPA amendments greatly expanded FSIS*'s statutory authority over the number of establishments inspected, enhanced enforcement powers, and increased the detail with which FSIS* carried out inspections. These acts increased the number of establishments inspected in three ways. First, they increased the range of establishments over which FSIS* had authority by mandating that FSIS* has authority over renderers, food brokers, animal food manufacturers, freezer storage concerns, transporters, retail outlets, and wholesalers in addition to slaughter plants and processing plants. Today, FSIS* inspects more of the processing and slaughter operations of these types of establishments than plants defined by the Census Bureau to be either an animal slaughter or meat processing plant.

The acts also granted FSIS* indirect oversight of State-inspected plants and direct monitoring of foreign exporters by requiring that State inspection systems and the systems of foreign country facilities of meat and poultry exporters to this country be at least equal to the Federal system. The "at least equal to" clause meant that FSIS* had to ensure that State-inspected systems and plants exporting products to the United States met FSIS* standards. This "at least equal to" clause had a huge effect on FSIS*'s inspection load. Shortly after enactment of the WMA and WPPA, 24 States discontinued State poultry inspections and 17 States decided not to pursue State meat inspection, so FSIS* had to take over their former responsibilities. Due to changes stemming from the WMA and WPPA, the number of State-inspected plants dropped by about 30 percent to 5,219, forcing plants without State inspection to seek FSIS* regulation or go bankrupt. Combined, the number of plants switching from State to Federal inspection and normal plant entries raised the number of federally inspected plants by about 50 percent to 7,093 over the 1972-76 period (Booz-Allen, 1977).

The WMA and WPPA also provided stronger enforcement tools. Regulations based on these mandates permitted product detentions, the withdrawal of inspection services from offending plants, and injunctions and investigations of allegations of food safety violations. However, Booz-Allen (1977) asserted that enforcement powers remained weak, in that violations depended on the presence of a meat or poultry inspector.

Booz-Allen maintained that many very small processing plants had inspectors present onsite only part of the time for a periodic plant inspection. Thus, although these plants were supposed to comply with the law all of the time, they could operate under potentially unsanitary conditions when the inspector was not present, enabling them to potentially ship products that did not meet FSIS* standards. Additionally, the penalties themselves were much weaker than they appeared. Plant inspectors commonly detained products that failed to meet FSIS* standards and withheld inspection services until sanitary conditions were met. However, since quality control managers in companies usually issued similar directives, these practices were really only usual control measures and, thus, just a normal cost of doing business.

Other enforcement measures had more coercive power but may have been less effective. The WMA and WPPA permitted the FSIS* to shut down a plant by canceling the meat or poultry grant (a license to sell meat or poultry) if the plant tried to bribe an inspector, failed to destroy condemned meat, or had unsanitary conditions that led to adulterated products. However, this enforcement tool may have been much weaker than it appeared. Booz-Allen (1977) indicated that FSIS* preferred to negotiate weaker agreements rather than seek permanent denial of inspection services because experience from court proceedings shortly after enactment of WMA and WPPA showed that judicial hearings were too protracted to be an effective deterrent. For example, FSIS* threatened 20 firms with closure after they tried to bribe FSIS* inspectors in the early 1970s. However, none of these firms ever did close. Rather, out-of-court settlements permitted them to terminate some of their employees but remain in operation. Booz-Allen (1977) also suggested that the threat of criminal penalties also proved to be ineffective, as FSIS* successfully prosecuted only 26 out of 90 cases in 1977.

Regulations based on the WMA and WPPA also described the terms under which meat or poultry products could be classified as adulterated, permitted the FSIS* to establish tolerance levels for adulterants, and addressed mislabeling issues. The acts defined adulterated products as those products processed under unsanitary conditions, lacking a valuable ingredient, or containing harmful substances, chemical pesticides, or diseased meat or poultry. Under this broad definition, FSIS* defined pesticides as adulterants in the 1960s and *E. coli* 0157: H7 as an adulterant in raw ground beef in the 1990s. For ready-to-eat products, such as luncheon meats, the detection of this pathogen or any other pathogen of public health concern, such as *Listeria monocytogenes* or *Salmonella*, could be the basis for declaring the product adulterated.

Having meat or poultry identified as adulterated is costly for meat and poultry plants because adulterated products must be condemned, appealed, or reconditioned to correct for the adulterating condition, for example, to kill *E. coli* 0157: H7. A condemned product requires disposal, while an appealed product can be retained and reconditioned for an alternative use, such as cooked products. Regardless of final use, precise records of all adulterated products must be maintained and the final dispositions of adulterated products generally yield much lower revenue than products that pass inspection.

Labeling requirements were instituted to ensure product consistency, meaning that labels had to correctly specify the contents of a given product and similar products had to meet uniform standards. For example, an item labeled “chili con carne” had to meet maximum fat and minimum meat content standards in order to pass inspection. Substitution of other products for ingredients on labels or in compensation of the amounts mandated by code was considered misbranding and a violation of the law, possibly resulting in punitive measures.

Regulations based on the WMA and WPPA also outlined 15 sanitary processes that formed the basis for a new direction in FSIS* meat and poultry inspection. Requirements differed from plant to plant but generally included good management practices and such commonly accepted food safety practices as the prevention of raw products from coming into contact with cooked products and processed products from coming into contact with walls, floors, ceilings, rails, etc. Other stipulations included requiring operations, procedures, clothing, and utensils to be clean and sanitary and handwashing by employees before touching an exposed meat product or after handling a dirty shipping container.

As a way to ensure hygienic facilities, the regulations also mandated that FSIS* approve blueprints in advance of construction and examine the facilities and equipment outlined in those drawings before granting inspection. To have an FSIS*-approved facility, plants had to have an ample water supply, efficient drainage, and other basic infrastructure. FSIS*-approved equipment had to have contact surfaces constructed of stainless steel or some other rust-resistant material and that could be cleaned of all microbial contamination.

By 1992, the sanitation and process controls practices (SPCP) requirements had evolved into a computer-generated scheduling process called the Performance Based Inspection System in which FSIS process-control inspectors examined plants for five types of sanitation and five types of process control activities. The sanitation activities included pre-operation sanitation of facilities, assembled and disassembled equipment, product-handling equipment, sanitation of operations, and proper handling of contaminated and adulterated products. Process control activities included water supply/sewage disposal, facilities sanitation/personal hygiene, pest and rodent control, receipt and control of incoming material, and product handling and preparation. There were also specific requirements for particular products and product integrity concerns. Cooking time and temperature controls for roast beef and other cooked products and requirements for fermented, smoked, and other processed products became particularly important as the production of processed products became a larger share of the products inspected by FSIS*.[3]

Inspection enforcement took the following form. Process control inspectors periodically made rounds in the plant to verify compliance and examined all available records. Inspectors designated poorly performed operations as deficient tasks and held or condemned products for serious violations. If the deficiencies were particularly egregious or if the number of deficiencies relative to total operations was excessive, then the inspector asked the plant manager to make corrections. If operations remained deficient, inspectors had the authority to retain and condemn the product and temporarily prevent the use of rooms and equipment that could contaminate the product. No other actions could immediately be pursued. In the longer term, FSIS* had the authority to withdraw inspectors for serious, persistent violations but, due to the protracted nature of court hearings, was unable to use this tool successfully (Booz-Allen, 1977).

## Voluntary Quality Control Programs

The WMA and WPPA greatly expanded FSIS*'s responsibilities in terms of the number of inspected facilities, types of inspection tasks, and administrative oversight, but according to Booz-Allen (1977), provided little additional funding for inspectors. Moreover, FSIS* was becoming increasingly aware that it needed to target more of its resources toward food safety rather than nonfood safety activities in processing, such as product formulations. Thus, since regulatory provisions yielded a framework for giving incentives to plants to administer their own process control programs, FSIS initiated several voluntary programs. FSIS envisioned that, under these programs, inspectors would verify the accuracy of records rather than directly monitor net weights, product formulations, etc.

[3] The Inspection System Guide details each of the 10 sanitation and process control activities.

Starting in the late 1970s, FSIS* instituted five voluntary programs—Total Quality Control (TQC), Partial Quality Control (PQC), Streamlined Inspection System (SIS), New Line Speed Inspection System (NELS), and New Turkey Inspection System (NTIS)—that shifted some of the inspection workload to plants in exchange for either a relaxation of inspection frequency or increased line speeds. FSIS* could also require a plant to adopt a PQC program if a sanitation, process control, or product quality deficiency persisted.

## Total Quality Control Programs

FSIS* instituted the TQC program in 1980. Under this program, the responsibility for documenting process control matters for food safety and nonhealth meat and poultry standards set by FSIS* fell to the plant. FSIS* continued to inspect products for compliance with the statutes, but focused more on the written documentation, with occasional, but scheduled, hands-on verification of compliance.

To qualify, plants had to design and implement a quality control program that encompassed all aspects of the plant's production processes from ante-mortem to post-mortem inspection. TQC plans typically dealt with the treatment of incoming raw materials, processing procedures, important food safety targets for processing operations, and action limits for plant quality control personnel. The FSIS regulations also required plants to specify sanitizing rinses and other inputs or devices used to control product wholesomeness or product quality.

Both FSIS and processing plants could gain from having a TQC program. FSIS benefited by easing the burden on inspection resources, while plants benefited from greater flexibility in establishing a quality control program most suitable to the plant's circumstances. For example, TQC processing plants could more quickly introduce new products due to expedited approval procedures, ship products without direct inspector presence, and did not have to pay for inspector overtime if the FSIS inspector's time exceeded the normal 8-hour workday.[4] TQC plants could also use a special logo that advertised their quality control program.

[4] U.S. law requires USDA inspectors to be present for some operations, such as slaughtering animals in order to make an ante-mortem or post-mortem inspection of every animal/carcass.

Plants had to meet several requirements before FSIS would recognize their plant-administered TQC programs. First, the plants had to demonstrate their ability to monitor the quality of their production by demonstrating the independence of quality control from production. So, plants had to have at least one full-time person whose primary responsibility was quality control, who reported to a manager whose responsibilities were not predominantly production-related, and who had authority to halt production or stop product shipments if production did not meet TQC standards. A plant without at least one full-time quality control person had to outline the responsibilities of the person in charge of the quality control program.

Plants also had to detail the manner in which their TQC programs would function and had to show how assorted components of the quality program could maintain compliance with health and nonhealth standards established by FSIS. The components of a TQC plan usually included raw material controls and process control points at assorted points in the production process. For process control points, plants specified tolerances and the nature of corrective actions in the event that tolerances were breached.

The FSIS inspector's role changed in TQC plants to one in which he or she used plant production records and in-plant observations to verify plant compliance with regulatory requirements and consulted with plant management.[5] As a result, each TQC plan had a description of the plant's quality control actions, the nature and frequency of tests, the types of charts and other records, and the length of time for which TQC records would be maintained. A plant also had to agree to maintain all of the analyses and information generated by its quality control system such that the records could easily be monitored for compliance. FSIS, in turn, emphasized accurate recordkeeping and expected appropriate action when a product exceeded or reached a tolerance limit.

## Partial Quality Control Programs

Partial Quality Control programs emerged during the 1970s as a way for establishments to better control plant sanitation and processes or parts of processes and accurately adhere to net weight, labeling, and other economic and public health safety requirements of individual products.[6] Many PQC programs, particularly the economic programs, were voluntary, but FSIS mandated many public health programs, such as those for the production of cooked roast beef. FSIS inspectors monitor all PQC programs.

Plants with PQC programs had to fully document how they dealt with a particularly troublesome node of production that periodically got out of control and threatened the wholesomeness, quality, or economic value of the product. For example, if an inspector noticed condensation coming from the ceiling adjacent to an exposed product, then the plant could have been required to continuously address the problem or chosen voluntarily to develop a PQC program to demonstrate process control. With a PQC program, a plant could determine the expected variability of the problem and then address it on a statistical basis.

Plants voluntarily choosing PQC programs faced new regulatory requirements but also realized some benefits. FSIS required that plants have a written PQC program that outlined the nature and frequency of tests and detailed raw material controls, critical checks, and control limits. In exchange, plants benefited from the expertise of the specially trained, more highly skilled FSIS inspectors specializing in quality control.

All PQC programs for slaughter plants were voluntary. As with processors, PQC programs could be used to address economic and public health quality. Programs included finished product, preoperational sanitation, and carcass presentation standards. Three special quality control programs for poultry—the SIS, NELS, and NTIS—required PQC programs for poultry eviscerating lines.

## Streamlined Inspection, New Line Speed Inspection, and New Turkey Inspection Systems

The SIS shifted routine tasks that affected nonfood safety from inspectors to plant employees. FSIS felt that plants producing branded products had a strong incentive to ensure their products would have no visible, unpalatable defects. So, plant employees, working

[5] Inspectors selected for TQC programs received specialized training, particularly in statistical process control, and received a premium salary for their work.

[6] Economic qualities—including product weight, fat, and other measurable attributes that consumers can observe or otherwise believe to be present in similar products—often lead to different prices.

under FSIS supervision, detected and then trimmed meat defects that affect product economic quality but did not affect or harm public health safety.

FSIS established preventive systems of nonfood safety process control for broilers and cornish hens with the NELS and for turkeys with the NTIS. Under these slaughter process control systems, the establishment had to: (1) demonstrate compliance with regulatory requirements by identifying process control points that were important to regulatory compliance, (2) set realistic standards for these points and observe them frequently enough to ensure compliance and identify the action that would be taken if a standard was not met, (3) maintain records of observations that FSIS could monitor to verify compliance, (4) have quality control personnel that reported to supervisors who were independent of production and had the authority to halt production or shipment of products if necessary, and (5) make owners, operators, or designees available for consultation with FSIS.

Plants using SIS, NELS, and NTIS systems benefited by being permitted to increase line speeds beyond the FSIS-mandated speed of 70 birds per minute, while FSIS benefited by shifting bird dressing requirements to plant personnel from FSIS staff. By 1995, about 22 percent of all poultry slaughter plants used the SIS, NELS, and NTIS. This percentage included 45 broiler and cornish hen slaughter plants and 27 turkey slaughter plants. There is no detailed information on the size of these plants.

## How Total and Partial Quality Control Programs Vary by Plant Size

Table 2.1 shows the number of Total and Partial Quality Control programs for processing and hoofed animals and poultry slaughter. The adoption of Total Quality Control programs may be a better indicator of plant commitment to public health quality control because TQC programs were entirely voluntary while Partial Quality Control programs could be either voluntary or mandated. Moreover, since TQC programs dealt with the entire plant, use of these programs illustrates the willingness of plants to adopt programs that control overall plant operations. Also, since plants used PQC programs to address specific problem areas in the plant, large plants, due to their more complex operations, likely had more such programs per plant. Finally, note that if a PQC was required for a particular process and the plant was a TQC plant, then the plant incorporated the PQC program into its specifications for its TQC program.

An inherent feature of all voluntary programs is that plants adopt a program only if the benefits exceed the costs of adoption. For plants with TQC and other quality programs, these benefits included a reduction in overtime costs, more rapid introduction of new products, scheduling flexibility, and, in the case of poultry, faster line speeds. If these cost reductions exceeded the costs of the program, then a plant would not adopt the program. The low overall adoption rates for TQC programs (table 2.1) suggest that the costs of program adoption exceeded the benefits for most plants.

Table 2.1 also shows that adoption of TQC programs was much weaker for slaughter operations. This is not surprising because TQC and PQC programs dealt with post-mortem meat and poultry processing practices. As such, slaughter plants benefited from the program only if they had cut-up or further-processing operations.

Second, as plant size increased, there was a striking increase in the percentage of plants, particularly further-processing plants, using TQC programs. For further-processors, participation increased from 2.4 percent of plants in the smallest plant category to 21.4 percent in the largest one. This makes a lot of sense. One of the chief benefits granted to plants with TQC programs was permission to introduce new products prior to formal approval of all the necessary labels, greatly reducing the time from product development to product introduction. This savings of time and money favored large plants because new product introductions were costly for small plants.

Another benefit of TQC was more flexibility in scheduling for FSIS inspections. FSIS inspectors were required to be present for some operations, and if these operations occurred outside of normal operating times, the plant was required to pay the overtime costs of the inspector. In TQC plants, many of these tasks were allowed to occur without an FSIS inspector's presence, but documentation had to be accurately maintained prior to final inspection and release by FSIS. So, added flexibility meant that plants could avoid paying the inspector overtime and, perhaps, more efficiently schedule production. This benefit probably helped larger plants more than smaller ones because large plants typically have more complex operations calling for greater labor specialization. This greater specialization permits less leeway in scheduling, making inspector flexibility more attractive. Additionally, inspector overtime costs could be greatly reduced by a plant's becoming a TQC plant. Finally, plants with TQC programs could apply labels stating that products were produced under a TQC program, but this benefit was not widely used.

The costs of TQC programs appear to have been higher for smaller plants. Smaller plants are less likely to have quality control personnel devoted only to product quality, so a TQC program would require them to hire such a person. Since the small plant may have lower revenues over which to spread fixed costs, average costs go up.

Adoption of TQC programs is important to current policy for two reasons. First, the program was very similar to Hazard Analysis and Critical Control Point (HACCP) programs and other process control measures related to public health. These similar elements—i.e., the use of sanitation programs, the monitoring of critical control points with FSIS verification, and flexibility in designing food safety process control program—suggest that the cost differences between the two would be small.

There are some differences, however, the terms of enforcement being the most striking. Whereas FSIS can shut down a plant if it does not fulfill the requirements of its HACCP program, it could not shut down a TQC plant for failing to adhere to its TQC plan as long as the product was not adulterated. FSIS could force a TQC plant that was not practicing its quality program to relinquish its TQC status, however. Another difference was that TQC encompassed more than food safety control practices while HACCP deals only with food safety. Furthermore, FSIS clarified the rules related to enforcement for HACCP.

## Summary

This chapter shows that efforts to regulate meat and poultry for public health reasons began in the 1890s but only recently began to emphasize these elements. In the 1980s, FSIS introduced the TQC, PQC, SIS, NELS, and NTIS programs that shifted some of the inspection burden to plants in exchange for more flexibility in regulatory requirements in the case of TQC and PQC programs and increased line speeds for the SIS, NELS, and NTIS systems. FSIS also granted TQC plants the right to apply a label to its products stating that the plant used an approved quality control program. At the same time, these programs applied the same sanitation and other regulatory requirements to all establishments, regardless of the type of program.

Although there were some apparent benefits from participation in an FSIS-sponsored quality control program, industry showed only a modest interest. By 1992, less than 5 percent of all plants had adopted a TQC program, and the number of PQC programs for public health purposes as a share of total plants was only 36.4 percent. These were both voluntary and mandatory, and there could be more than one per plant. Large meat processors were the most likely plants to adopt a TQC program, with almost 20 percent of all large plants having such a program. Slaughter plants had much lower adoption rates. Still, larger slaughter plants were more likely to adopt TQC than smaller ones. This low adoption rate could explain why FSIS made the adoption of HACCP programs mandatory. Note, the higher adoption rate of larger plants does not mean that small plants had less effective process control programs, only that large plants derived more benefits from such programs.

**Table 2.1—Total and Partial Quality Control programs as shares of plants, 1992[1]**

| Size of plant | Total plants | Total Quality Control programs | | Partial Quality Control: Nonfood safety | | Partial Quality Control: Food safety | |
|---|---|---|---|---|---|---|---|
| | *Number* | *Number* | *Percent* | *Number* | *Percent* | *Number* | *Percent* |
| Processing plants: | | | | | | | |
| Pounds of meat— | | | | | | | |
| Fewer than 500,000 | 3,516 | 83 | 2.4 | 438 | 12.5 | 471 | 13.4 |
| 500,000 - 999,999 | 462 | 16 | 3.5 | 150 | 32.5 | 186 | 40.2 |
| 1 million - 9.9 million | 1,063 | 76 | 7.1 | 764 | 7.1 | 687 | 64.6 |
| 10 million - 99 million | 475 | 63 | 13.3 | 964 | 202.0 | 601 | 127.0 |
| 100 million or more | 56 | 12 | 21.4 | 163 | 291.0 | 85 | 152.0 |
| Total | 5,572 | 250 | 4.5 | 2,479 | 44.5 | 2,030 | 36.4 |
| Hoofed animal slaughter plants: | | | | | | | |
| Number of hoofed animals— | | | | | | | |
| Fewer than 1,000 | 330 | 2 | 0.7 | 33 | 10.0 | 72 | 21.8 |
| 1,000 - 9,999 | 337 | 3 | 0.9 | 20 | 5.9 | 144 | 42.7 |
| 10,000 - 99,999 | 187 | 1 | 0.5 | 91 | 48.6 | 110 | 58.8 |
| 100,000 - 999,999 | 90 | 3 | 3.3 | 111 | 123.0 | 99 | 110.0 |
| More than 1 million | 46 | 3 | 6.5 | 155 | 337.0 | 85 | 185.0 |
| Total | 990 | 12 | 1.2 | 410 | 41.4 | 510 | 51.5 |
| Poultry slaughter plants: | | | | | | | |
| Number of birds— | | | | | | | |
| Fewer than 10,000 | 72 | 0 | 0.0 | 14 | 19.4 | 33 | 45.8 |
| 10,000 - 999,999 | 50 | 0 | 0.0 | 12 | 24.0 | 10 | 20.0 |
| 1 million - 9.9 million | 61 | 2 | 3.3 | 114 | 187.0 | 41 | 67.2 |
| 10 million - 49.9 million | 130 | 2 | 1.5 | 118 | 90.8 | 34 | 26.2 |
| More than 50 million | 53 | 2 | 3.8 | 74 | 140.0 | 31 | 58.5 |
| Total | 366 | 6 | 1.6 | 332 | 90.7 | 149 | 40.7 |

[1] There can be more than one Partial Quality Control (PQC) program per plant, but only one Total Quality Control program. Since large plants have more operations, it is reasonable that they should have more PQC programs. TQC programs are voluntary, and there were significant outlays. They had to apply for prior approval and then get modified FSIS inspection. PQC programs could be voluntary or required and also required prior approval but no special FSIS changes in personnel.

*Chapter 3*

# The Shift to a New Regulatory Paradigm

The public health community has known since the 1960s that foodborne bacteria, such as *Salmonella,* can cause human illness. This concern led the American Public Health Association (APHA) to file a lawsuit asking the court to declare *Salmonella* an adulterant and requiring that a warning label giving cooking instructions be affixed to the package. However, the Supreme Court in 1972 ruled against the suit, saying that APHA presented no evidence showing that *Salmonella* was any more likely to be present in poultry than in any other food product, and that it is common knowledge to cook meat and poultry adequately. However, FSIS and the general public became more cognizant of the virulence of pathogenic bacteria in the 1980s when a series of foodborne illness outbreaks gained prominent news coverage. The first one, an outbreak of *E. coli* 0157:H7, occurred in an Oregon McDonalds in 1982. The incident produced no fatalities, but a number of customers became ill with bloody stools and other symptoms. Just as publicity over that incident began to subside and experts began to feel the incident was unique, a second outbreak occurred in Michigan and other States. These events and several additional ones involving one roast beef and four ground beef incidents convinced the Centers for Disease Control and Prevention (CDC) that the outbreaks were meat related (Griffen and Tauxe, 1991).

Other pathogens also soon caught the public's attention. In 1988, the television program *60 Minutes* featured a segment on the health effects and sources of *Salmonella.* Although this naturally occurring organism is found in many raw and cooked products, the program focused on the poultry industry. The *60 Minutes* program brought the issue to the public's attention and precipitated consumer demands for change. In response, the poultry industry promoted the development and testing of counter current scalders, bird washes, chlorine rinses, and other pathogen-reducing technologies that significantly reduced *Listeria monocytogenes,* *Salmonella*, and *Campylobacter* levels in chicken products (Waldroup et al., 1992). These and other newer technologies were then rapidly and voluntarily adopted by the industry. However, according to recent FSIS findings, *Salmonella* still is present on about 20 percent of all young chickens, and Mead et al. (1999) of the CDC estimated that *Salmonella* caused 1.3 million illnesses and 550 deaths in 1997. The Economic Research Service estimated the 1997 cost of *Salmonella* cases at about $2.4 billion (*www.ers.usda.gov*, January 2002). Cost estimates include lost wages and medical expenses. *Salmonella* poisoning comes from a variety of foods, including meat, poultry, and eggs, as well as from pet handling. The contribution from meat, poultry, and eggs is uncertain.

The potential health effects of other pathogens also gained notice. As reported by Farber and Peterkin (1991), *Listeria monocytogenes* caused the most deaths ever recorded for a foodborne illness in Chicago when 142 known cases resulted in 48 deaths in 1985. Roberts and Pinner (1990) estimated that *Listeria monocytogenes* caused 1,350 illnesses and 510 deaths nationwide in 1986, and Mead et al. (1999) estimated that the pathogen caused about 2,500 illnesses and 500 deaths in 1997. Evidence of the health effect of *Listeria monocytogenes* led FSIS to declare it an adulterant in cooked meat or poultry, assign it a zero tolerance, and begin testing for it in 1989 (Peter Perl, *Washington Post Magazine*, January 16, 2000).

*Listeria monocytogenes*, like *Salmonella,* is a commonly occurring bacteria that is killed in the cooking process. The bacteria finds hospitable surroundings on soft cheeses and other dairy products from unpasteurized milk, seafood, dry and semi-dry fermented sausages, deli meats and poultry, and other ready-to-eat dairy and meat and poultry products. However, if reintroduced onto the product from the environment after cooking or if the product is not thoroughly cooked, it can be deadly, particularly for fetal/newborns, elderly adults, and immuno-compromised people. A 1998 outbreak caused by the presence of *Listeria monocytogenes* in hot dogs and deli meats from a Sara Lee plant killed 15 people and sickened over 100.

Less well known as a source of foodborne illness is *Campylobacter*. Epidemiologists had trouble determining the public health consequences of this pathogen until the mid-1980s when scientists were first able to grow it in laboratories. Today, however, *Campylobacter* is recognized as the most common cause of foodborne illness. Mead et al. (1999) estimated that about 100 people died and 2.0 million people became sick due to *Campylobacter* infections in 1997.

Living in the intestine of the infected animal and spreading to the surface at slaughter, *Campylobacter* is extremely common in poultry. It contaminated about 80 percent of all poultry products at the retail level in 1991 (Skirrow and Blaser, 1992, p. 4), making consumption of it in undercooked poultry or through cross-contamination the most common way of contracting a sporadic *Campylobacter* infection (Tauxe, 1992, p. 12). People can also get *Campylobacter* from contaminated drinking water, unpasteurized milk, or raw or undercooked meat.

## Large Outbreak of Foodborne Illnesses Focuses Public Attention on Food Safety

Public awareness of the threat to human health posed by pathogenic bacteria skyrocketed when an *E. coli* 0157:H7 poisoning seized public attention in January 1993. In this incident, 4 people died and more than 500 became sick, mainly in Washington, Idaho, and Nevada. After studying the epidemic, public health officials in Washington, DC, and at the CDC identified the consumption of hamburgers at Jack-in-the-Box fast-food restaurants as the source. In Washington State, where the largest outbreak occurred, the investigation suggested that Jack-in-the-Box employees cooked hamburgers below the State standard of 155 degrees Fahrenheit and in some instances below the 140 degrees Fahrenheit recommended by the Food and Drug Administration (*Federal Register* announcement, 1996).

Following the Jack-in-the-Box outbreak, FSIS began to take a new approach to its public health mission. Since pathogens are not visible to the human eye, the visual inspections that prevented diseased animal meat from entering the food supply proved to be of questionable effectiveness against unseen pathogens. So, FSIS began to focus more of its attention on pathogen testing and sanitation and process controls.

FSIS was particularly concerned about the presence of *E. coli* 0157:H7. It established a zero tolerance level in ground hamburger because fewer than 50 organisms are believed to be able to cause serious illness. To support this policy, FSIS began testing 5,000 1-ounce samples of raw hamburger per year for *E. coli* 0157:H7. These tests for *E. coli* 0157:H7 in raw meat and those for *Listeria monocytogenes* in cooked products cannot ensure that all meat is free of either pathogen, but the tests are intended to encourage firms to make stringent efforts to prevent pathogens of public health significance from being present and growing in their products.

The penalties for finding pathogens are severe. FSIS asks, but cannot mandate, the plant to recall its products and issues a press release. If the plant refuses to recall the products, FSIS can seize the product. Although these options are costly, it could also be very costly not to recall products. For example, if an outbreak were to occur and be traced back to the offending plant, then the plant's owner could face ruinous legal liability claims and the plant would risk a loss of reputation and could possibly be held liable for damages.

As a way to better control pathogens, FSIS began to seriously consider the use of a Hazard Analysis and Critical Control Point (HACCP) process control system in the early 1990s and began a pilot program with a limited number of plants to determine its effectiveness. This was not a new idea. Many restaurants, such as McDonalds and Jack-in-the-Box, required HACCP of their suppliers, and several meat and poultry firms, such as Excel, already used it in their plants (Ollinger, 1996). Indeed, Booz-Allen, in its 1977 report, had recommended the use of a quality control program with many of the elements of a HACCP program. Later, the National Academy of Sciences (1985, 1987, and 1991), the National Advisory Committee on Microbiological Criteria for Foods (1988), and the General Accounting Office (in a series of reports in the early 1990s) called for the use of HACCP systems in the meat industry.

The Pathogen Reduction/Hazard Analysis and Critical Control Point (PR/HACCP) rule, initially proposed by FSIS on February 3, 1995, incorporated many elements of the HACCP programs recommended by other organizations. It differed from the traditional inspection and control systems in that it considered the production process in its entirety and focused on prevention rather than merely on detection and adjustment. FSIS based its plan on these seven criteria: (1) assessing all hazards, (2) finding all critical control points, (3) setting critical limits for each critical control point (CCP), (4) developing procedures to monitor each

CCP, (5) determining corrective actions, (6) implementing a recordkeeping system, and (7) establishing verification procedures (Unnevehr and Jensen, 1996).[1] Besides having elements consistent with these criteria, FSIS proposed to hold plants responsible for failure to implement and maintain their HACCP systems.

## Food Safety Under the Pathogen Reduction HACCP Rule

FSIS published the final PR/HACCP rule on July 25, 1996. The rule was phased in over a 3-year span starting in January 1998. The largest plants (more than 500 employees) had to comply by the end of January 1998, small plants (10-499 employees) had until January 1999, and very small plants (fewer than 10 employees or annual sales fewer than $2.5 million) had to conform by the end of January 2000. All plants had to have sanitation standard operating procedures (SSOPs) in place by January 1997, regardless of size.

The principal element of the rule was the development of a HACCP plan for each FSIS-defined product group that clearly established and controlled CCPs in the plant's production system. There were other important components, however. First, PR/HACCP required meat and poultry establishments to develop and implement written SSOPs. Second, it mandated that slaughter plants conduct generic *E. coli* microbial tests in order to verify that fecal contamination was under control. Finally, in order to verify that their HACCP systems were controlling pathogens, the PR/HACCP rule established *Salmonella* performance standards for slaughter and ground meat and poultry plants.

In conjunction with the PR/HACCP rule, FSIS eliminated several formerly necessary requirements. For example, FSIS no longer required prior approval for equipment installations or plant construction (*Federal Register*, 1996). Changes that did affect the HACCP plan or food safety, however, did require a revised HACCP plan.

The PR/HACCP rule requires plants to identify CCPs, take responsibility for implementation and control of their HACCP programs, maintain performance records, and adopt plans for action should processes get out of control. PR/HACCP also stipulates that each plant must complete a HACCP plan for each of its manufacturing processes (e.g., raw beef not ground). This plan contains a flow chart that notes all possible hazards for each step of the production process. Additionally, these plans include critical limits, monitoring procedures, corrective actions, recordkeeping methods, and verification procedures for each CCP.

## HACCP Programs Under PR/HACCP

The new PR/HACCP program shares similar characteristics and features with the TQC program that it superseded. PR/HACCP, like TQC, requires that plants take responsibility for implementation and control of food safety process control, maintain performance records, and adopt a plan for action in the event that a process gets out of control. TQC plants were also required to identify control points, while a HACCP plan calls for identification of critical control points. Additionally, FSIS inspectors ensure plant compliance by verifying written records and plant activities. PR/HACCP deviates from the TQC program in that TQC programs dealt with aspects of food quality not specific to food safety and were voluntary, while the HACCP programs required under PR/HACCP deal only with food safety and are mandatory. Hence, if a plant did not adhere to the requirements of the TQC, FSIS could cancel the plant's status as a TQC plant, causing the plant to revert back to the traditional inspection method, but the plant could continue meat or poultry production as long as FSIS found the product not to be adulterated. However, since PR/HACCP requires use of a HACCP program, a plant can be temporarily shut down for failing to adhere to its HACCP plan, regardless of whether FSIS found its products to be adulterated. The plant can resume operations as soon as it adheres to its HACCP plan.

## Sanitation Procedures and HACCP Under PR/HACCP

FSIS has required plants to perform sanitation and process control tasks since Congress passed the Wholesome Meat Act (WMA) of 1967 and Wholesome Poultry Products Act (WPPA) of 1968. However, the PR/HACCP rule shifted legal responsibility for adhering to sanitation standard operating procedures (SSOPs) to the plant by requiring that a plant official with overall site authority accept responsibility for them. In their SSOPs, plants must: (a) identify operational and pre-operational procedures that, at a minimum, include the cleaning of all surfaces that contact meat or poultry; (b) identify individuals responsible for daily sanitation activities, and (c) maintain

[1] CCP refers to any part of the production process where food safety is at risk.

records showing that the plant is adhering to their SSOPs. The main difference between these requirements, which were issued within a specific regulatory scheme alongside the HACCP requirements, and those under the WMA of 1967 and WPPA of 1968 is that plant personnel are now legally responsible for maintaining records and adhering to sanitation SSOPs.[2]

## *Salmonella* and Generic *E. Coli* Testing Under PR/HACCP

The PR/HACCP rule included both pathogen testing requirements and the development and implementation of HACCP plans. Pathogen testing marked a sharp departure from previous practices by establishing tolerance levels for *Salmonella* and generic *E. coli* and then permitting plants to use any means available to meet the tolerance. Failure to meet the tolerance could result in a plant shutdown. HACCP plans under PR/HACCP were enforced in much the same way as existed for sanitation and process controls under WMA and WPPA. Under each program, plants have a set of tasks that they are required to perform and that FSIS verifies. The main difference is that under PR/HACCP, there are structures codified for both sanitation and food safety that previously were not as detailed.

FSIS enforcement actions changed to reflect the implementation of new pathogen performance standards. PR/HACCP required all slaughter plants to conduct microbial tests for generic *E. coli*, and all slaughter and ground meat plants to adhere to *Salmonella* standards. Slaughter plants conduct their own generic *E. coli* tests. The number of tests depends on production volume. For example, cattle slaughter plants have to take one sample per 300 carcasses, while broiler plants are required to take one sample per 22,000 birds. Plants failing to meet the generic *E. coli* standard must discover and correct the cause of the failure or face increased FSIS scrutiny of facilities, products, and plant compliance with their HACCP plan SSOPs. FSIS may also perform more product testing. If plant performance is deemed unsatisfactory, FSIS can remove its inspectors.

FSIS conducts *Salmonella* tests, uses the results as a measure of overall plant process control, and can deem a failure to meet the standard as one of the bases for declaring a product to be adulterated. The testing process takes a random selection approach that gives plants several chances to meet the standard before enforcement actions are taken. If a plant fails the first test, it must complete a second round of tests after it modifies its process. If the plant fails that round, then again, it must undergo another round of testing after it modifies its processes. Failure to pass on the third attempt constitutes failure to maintain sanitary conditions and failure to maintain an adequate HACCP plan and will cause FSIS to suspend inspection services. The suspension remains in effect until the plant submits a detailed action plan to correct the HACCP plan and outlines the other measures taken by the plant to reduce the prevalence of pathogens.

It has been rare for plants to fail *Salmonella* compliance testing. Only about 100 out of the approximately 2,050 slaughter and grinding plants tested up to 1999 failed to pass the first test and only 22 of these 100 plants failed their first two tests. Failure to comply after two tests would have led to increased enforcement review, but 19 of these plants passed the third test and continued production. These 19 plants included 1 for ground turkey and 7 for ground beef, and 4 hog slaughter, 6 broiler slaughter, and 2 cow and bull slaughter plants. Supreme Beef and one other ground beef plant and one cow and bull slaughter plant failed three tests, and FSIS suspended them, meaning that plants retained the right to inspection services if the suspension was lifted.

The suspension of inspection services at Supreme Beef was quite controversial and prompted a lawsuit to overturn FSIS's right to suspend inspection services for failure to comply with the *Salmonella* standard. The Fifth Circuit Court ruled that the *Salmonella* standard was invalid because it constituted regulation of the characteristics of raw materials and not regulation of sanitary conditions in the plant, as suggested by FSIS. Although FSIS has authority to regulate the characteristics of raw materials, the meat trimmings contaminated with *Salmonella* in this case came from a plant that had passed FSIS inspection. The Supreme Beef decision led FSIS to modify its enforcement program. A news release published on the FSIS website (fsis.usda.gov, April 2, 2002) indicated that the Supreme Beef decision does not prevent FSIS from suspending inspection services or withholding marks of inspections for failure to develop and implement SSOPs and HACCP plans. The decision affects only enforcement of the *Salmonella* standard but not FSIS's ability to test for *Salmonella*.

[2] Under the WMA and WPPA, managers were also responsible for sanitation in that their plant had to meet appropriate sanitary conditions for the production of meat and poultry products.

## Performance Under the WMA of 1967 and WPPA of 1968 and PR/HACCP

FSIS inspectors have monitored sanitary conditions since the enactment of the WMA and WPPA and now also verify performance of HACCP tasks. Under the WMA and WPPA, FSIS assigned critical deficiencies to plants that did not perform or had poorly performed essential sanitation and process control tasks. The data used here were developed especially for this report by FSIS and are defined as the number of critically deficient sanitation and process control practices divided by all such practices. Critically deficient sanitation and process controls practices are either failures to perform or poorly perform tasks that are most important to reducing health risks to consumers. There are also minor and major deficiencies not deemed to be as high of a risk to human health and are not considered in this report.

Table 3.1 shows how percent critical sanitation and process controls practices (percent critical deficiencies) vary by type of industry and plant size. Table 3.1 includes the mean critically deficient sanitation and process control tasks as a share of total sanitation and process control tasks for selected industries. All plants in the tables have animal slaughter, processing, or animal slaughter and processing operations, but most do not derive a majority of their income from the manufacture of meat products or animal slaughter. Plants in industries with SIC codes that begin with 20 have food manufacturing as their primary business, those starting with 51 are mainly distributors, and those leading off with 54 have retail marketing as their major interest.[3] The table shows that poultry slaughter plants have the highest number of percent critically deficient sanitation and process controls. Other data in the table include mean plant sales in 1999, mean plant pounds of meat produced in 1996 (such data do not exist for 1999) and the number of establishments. The table does not include very small plants, those with fewer than 10 employees or sales of less than $2.5 million, because they had not converted to HACCP by 1999 and, thus, had not been inspected when the data became available.

Table 3.2 shows how critical sanitation and process control deficiencies vary by plant size for slaughter and processing plants. The data indicate that the very smallest plants had about a third the percentage of critical deficiencies as the largest plants, and there exists a trend in which larger plants, in general, had a greater share of critical deficiencies than smaller ones.

[3] All of the businesses in tables 3.1 and 3.2 process meat or slaughter animals or do both. However, they may be classified as a distributor because the plant derives most of its revenue from distribution. For these facilities, meat processing or animal slaughter operations are secondary businesses.

## Summary

In chapter 2, we discussed food safety regulatory history up to about 1990. This chapter presented a chronology of foodborne illness outbreaks that increased the public's awareness of such illnesses and discussed major regulatory changes during the 1990s. Current food safety regulation has its roots in the Federal Meat Inspection Act (FMIA) of 1906 and the amendments to the FMIA enacted through the WMA and WPPA of 1967 and 1968. Rather than being a complete break from the past, promulgation of the PR/HACCP rule of 1996 marked an acceleration in the long-term shift in regulatory focus away from visual animal and meat inspection and toward efforts dealing with the threat of foodborne illness posed by harmful pathogens.

The principal element of the PR/HACCP rule of 1996 was the use of a mandatory HACCP program. Other aspects of the rule included the use of sanitation procedures, a *Salmonella* standard to verify the effectiveness of the HACCP program, and mandatory generic *E. coli* testing to ensure compliance with the zero fecal matter standard. The mandated HACCP plan had been recommended to FSIS by various organizations since the 1970s. It included: (1) assessing all hazards, (2) finding all critical points, (3) setting critical limits for each critical control point (CCP), (4) developing procedures to monitor each CCP, (5) determining corrective actions, (6) implementing a recordkeeping system, and (7) establishing verification procedures (Unnevehr and Jensen, 1996).

Compliance with sanitation and process controls under WMA and WPPA varied according to product market and plant size. The share of critically deficient sanitation and process control tasks was much higher for poultry slaughter than for other plants. Segmenting the data into five size categories showed that smaller plants had a lower share of critically deficient sanitation and process control tasks than their larger competitors. The range varied from larger plants having three times more for red meat animal slaughter to about twice as many for meat processing.

**Table 3.1—Percent critically deficient SPCPs for selected industries[1]**

| Industry | SIC[2] | Total facilities | Plant mean: 1996 pounds of meat and poultry | Plant mean: Estimated 1999 sales | Plant mean: 1992 critically deficient SPCP |
|---|---|---|---|---|---|
| | | *Number* | *Millions* | *Millions $* | *Percent* |
| Red meat slaughter | 2011 | 201 | 225.7 | 198.2 | 4.0 |
| Meat processing | 2013 | 652 | 23.8 | 48.6 | 2.8 |
| Poultry slaughter and processing | 2015 | 82 | 203.0 | 113.6 | 5.7 |
| Frozen meals, pizza, etc. | 2038 | 85 | 19.3 | 51.0 | 1.6 |
| Grocery distributor | 5141 | 107 | 15.6 | 103.6 | 2.2 |
| Frozen food distributor | 5142 | 25 | 9.1 | 49.5 | 2.1 |
| Poultry products distributor | 5144 | 55 | 54.4 | 98.1 | 3.6 |
| Meat products distributor | 5147 | 462 | 7.5 | 34.5 | 2.3 |
| Meat and fish markets | 5421 | 117 | 15.3 | 12.1 | 2.1 |

[1] Data include only those plants that existed in 1992, had converted to HACCP, and were being inspected by FSIS in 1999. These include the large and small plants but not the very small plants.
[2] SIC codes are based on Enhanced Facilities Database estimates.

Source: U.S. Department of Agriculture, Food Safety and Inspection Service.

**Table 3.2—Percent critically deficient SPCPs for selected sizes of meat and poultry plants[1]**

| Volume | Plant mean: Plants | Plant mean: 1992 output | Plant mean: 1999 output | Plant mean: 1999 estimated sales | Plant mean: 1992 critically deficient SPCP |
|---|---|---|---|---|---|
| | | *Number* | *Number* | *Million $* | *Percent* |
| Hoofed animal slaughter plants: | | | | | |
| Number of hoofed animals per year— | | | | | |
| Fewer than 1,000 | 59 | 36,887[2] | 399 | 4.7 | 2.0 |
| 1,000-9,999 | 76 | 8,212 | 3,773 | 7.5 | 2.7 |
| 10,000-99,000 | 78 | 36,403 | 43,254 | 23.5 | 3.1 |
| 100,000-1 million | 66 | 194,334 | 332,274 | 135.5 | 4.8 |
| More than 1 million | 49 | 1,864,332 | 2,477,539 | 774.0 | 6.5 |
| | | *Dollars* | *Dollars* | | |
| Only meat-processing plants: | | | | | |
| Value of output in dollars per year— | | | | | |
| Fewer than 2.5 million | 127 | 15.8 | 17.2 | 1.3 | 2.3 |
| 2.5 million - 9.9 million | 117 | 2.8 | 3.1 | 6.3 | 2.4 |
| 10 million - 49 million | 288 | 12.6 | 14.3 | 23.3 | 2.7 |
| 50 million - 100 million | 85 | 33.0 | 35.6 | 70.6 | 3.6 |
| More than 100 million | 73 | 72.9 | 89.1 | 206.6 | 4.2 |
| | | *Number* | *Number* | | |
| Bird slaughter volume: | | | | | |
| Number of birds per year— | | | | | |
| Fewer than 2.5 million | 61 | 0.55 | 0.44 | 31.9 | 3.1 |
| 2.5 million - 7.4 million | 33 | 4.62 | 5.42 | 90.9 | 2.9 |
| 7.5 million - 34.9 million | 48 | 15.1 | 15.0 | 115.6 | 4.6 |
| 35 million - 50 million | 88 | 31.7 | 37.2 | 156.3 | 7.0 |
| More than 50 million | 59 | 53.3 | 69.0 | 178.7 | 8.6 |

[1] Data include only those plants that had converted to HACCP and were being inspected by FSIS in 1999, and existed in 1992. These include the large and small plants but not the very small plants.
[2] Some plants made transitions from plants slaughtering thousands of animals in 1992 to plants with miniscule slaughtering operations in 1999.

Source: U.S. Department of Agriculture, Food Safety and Inspection Service.

*Chapter 4*

# Process Control Effort and Plant Costs

Several studies show that HACCP requirements comprise a sizeable share of nonmeat input costs for meat and poultry slaughter and processing plants (Boland et al., 2001; Antle, 2000; and Knutson et al., 1995). These findings are not surprising. Process control is a costly yet necessary component of business operations.

A central element of the PR/HACCP rule enacted in 1996 was the use of sanitation and process controls practices (SPCPs). As discussed earlier, these SPCPs were not new to meat and poultry slaughter and processing plants. The Wholesome Meat Act of 1967 and the Wholesome Poultry Products Act of 1968 mandated that FSIS ensure food safety quality (product wholesomeness) by establishing a set of best sanitation and process controls practices, such as disassembling and sanitizing equipment and preventing rat infestations. These safety operations were not particularly onerous tasks, forming the basis for some recommended food industry process control programs, such as Best Management Practices. FSIS enforced compliance by monitoring performance and then backing up its performance rating with the possibility of a temporary plant closure due to noncompliance.[1] However, enforcement remained weak—the percentage of critical deficiencies still exceeded 30 percent in some plants in 1992.

FSIS had limited enforcement powers to ensure compliance with SPCPs. Rather than permanently closing a plant for chronic failure to meet operational sanitation standards, FSIS relied on its inspectors to temporarily shut down production until the plant corrected deficient sanitary operations and then permitted plants to resume operations. These actions are similar to those that a plant's own quality control manager would use if the plant encountered quality problems.

The marketplace itself may be a stronger enforcer of sanitary conditions than FSIS. Most of the time, consumers cannot detect whether there are harmful bacteria or pathogens in the meat that they consume. However, if a product causes consumer illness and the producer is identified, the result could be plant bankruptcy or, at the least, diminished profitability.[2] Recall the industry exit of Hudson Meats after it sold hamburgers contaminated with *E. coli* 0157:H7 or the problems encountered by Sara Lee after *Listeria moncytogenes* found in its products killed several people and sickened others (Perl, 2000). Thus, even though sanitation controls impose costs, plants are likely to incur those costs if they are necessary to remain profitable and viable. In this respect, adherence to FSIS's SPCPs may be thought of as a proxy for process control effort.

The purpose of this chapter is to evaluate the effect of percent critically deficient SPCPs on plant costs and to assess whether the costs vary with plant output. The analysis follows Antle (2000) who integrated a quality control supply function into a cost function. It differs from Antle (2000) in that it uses the percent critically deficient (poorly performed) SPCPs as a measure of food safety process control effort, while Antle (2000) uses a hedonic measure that captures all food quality. Hedonic measures use product characteristics to provide unbiased estimates.

Christiansen and Haveman (1981) and numerous others have documented a productivity loss associated with regulation. More specifically, Klein and Brester (1997) have described the potential for food safety regulation to adversely affect productivity. SPCP requirements should be no different. Unless lax quality control effort leads to an excessive number of product condemnations and other production losses, plant costs should rise because

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[1]Recall that meat and poultry products shipped in interstate commerce must pass inspection by the Federal meat inspector. By denying inspector services, FSIS could force the plant to close until it complied.

[2] This is not to say that a perfect linkage exists between food safety and plant survival or profitability. Buzby et al. (2001) found little evidence that the legal liability system acts as a deterrent to producing unwholesome food. They state: "The product liability system provides firms with incentives to control hazards in food primarily when the hazards are easily identifiable, a foodborne illness can be traced to the firm, and ill people or their families are compensated by the firms responsible for the contamination."

effort devoted to SPCPs requires inputs of labor and materials but does not increase output.

Antle (2001) points out that use of percent critically deficient SPCPs likely understates food safety quality control costs because plants undertake measures other than SPCPs to provide food safety. A plant could perform all of its SPCPs yet sell products containing harmful contaminants, or it could be very lax in its SPCPs and sell products free of contaminants. However, most food scientists would agree that SPCPs reduce the likelihood of selling products contaminated with harmful substances.

Antle (2001) also argues that hedonic measures of food quality likely overstate food safety quality control costs because these measures capture all food quality costs. Antle (2000) controls for some aspects of quality related to nonfood safety, but it is unlikely that he captures all such attributes. So, percent critically deficient SPCPs provide a lower bound estimate of food safety quality costs, while Antle's (2000) measure provides an upper bound estimate of food safety quality costs.

Percent critically deficient SPCPs can be interpreted as a measure of failure to adequately perform certain tasks or as an indicator of process control effort.[3] Variation of percent critical deficiencies in a cost function analysis provides a measure of the cost of SPCPs. We proceed by establishing a model of plant costs that includes a test for the cost of SPCPs for eight meat and poultry slaughter and processing industries. Then, we estimate the cost of critical deficiencies and examine the economies of scale in the sanitation and process control effort.

## A Model of Plant Costs

Plants add value to products in order to earn higher profits from product sales. Perceived value includes ease of preparation, type of meat cut, product wholesomeness, cooking convenience, and many other factors. We model value-enhancing attributes as a function of plant costs, where:

$$C = f(Q, P_i, I, V), \qquad (4.1)$$

and C is total cost of production, Q is meat or poultry output, P is factor prices, I is the type of animal or meat input, and V is value-enhancing product attributes (value attributes).

Ignoring value for now, we specify a translog cost function with output and factor prices in log form:

$$\begin{aligned} \ln C = {} & \alpha_0 + \delta_0 I + \sum_i \beta_i \ln P_i + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln P_i * \ln P_j \\ & + \gamma_Q \ln Q + \frac{1}{2}\gamma_{QQ}(\ln Q)^2 + \sum_i \gamma_{iQ} \ln Q * \ln P_i \\ & + \sum_i \delta_{1i} I * \ln P_i + \delta_{2Q} I * \ln Q + \xi. \qquad (4.2) \end{aligned}$$

A commonly prescribed way to accommodate multiple outputs in cost function analyses is to convert plant output into a vector of outputs of different products and then estimate a multiproduct cost function (Baumol et al., 1982). However, some plants do not produce some products and the log of zero is undefined. Additionally, this approach is not appropriate for measuring product wholesomeness. Thus, we did not use the multiproduct cost function. Rather, we followed an approach used in the analyses of railroads (Caves et al., 1985), trucking (Allen and Liu, 1995), airline industries (Baltagi et al., 1995), meat (Antle, 2000, and MacDonald et al., 2000), and poultry (Ollinger et al., 2000) and modeled costs as driven by a single output and a vector of product characteristics.

The model most closely follows that of Antle (2000) who integrated Rosen's (1974) model of a competitive industry with differentiated product demand into the quality-adjusted cost function model developed by Gertler and Waldman (1992). As mentioned earlier, it differs from Antle (2000) in that we use a measure of process control effort (percent critically deficient SPCPs) as a proxy for food safety, while he used an unbiased estimator of food quality and then controlled for nonfood safety quality attributes. Since our measure likely understates food safety quality and the measure that Antle (2000) used likely overstates food safety quality, the two measures combined provide a window within which food safety process control costs likely fall.

We append (V) to the translog cost function as a specific right-hand-side argument. It is described as follows:

$$\begin{aligned} V = {} & \sum_k \alpha_{1k} v_k + \frac{1}{2}\sum_k \alpha_{2k} (\ln v_k)^2 + \sum_k \sum_j \alpha_{3kj} \ln v_k \ln v_j + \\ & \sum_i \sum_k \alpha_{4ik} \ln v_k P_i + \sum_k \alpha_{5k} \ln v_k \ln Q, \qquad (4.3) \end{aligned}$$

[3] Although one plant may have adequate process controls yet sell products with pathogens and another plant may have the opposite characteristics, a good process control program will, on average, lead to better control of potentially harmful pathogens.

where V is the value associated with producing a particular product mix and taking greater care in producing a wholesome product, $\alpha_{1k}$ measures the value of producing a particular attribute, $\alpha_{2k}$ indicates how a value attribute changes with changes in that attribute, $\alpha_{3kj}$ indicates how value changes with interactions with other types of value attributes, and $\alpha_{4ik}$ and $\alpha_{5k}$ capture how the costs of value attributes change with factor prices and output.

Plants add value by undertaking additional processing steps, such as increasing processing, using higher grade animals, or providing greater assurance of product wholesomeness. Empirically, several researchers (Antle, 2000; MacDonald et al., 2000; and Ollinger et al., 2000) have found that product mix affects plant costs. Antle (2000) found that food safety quality affects plant costs.

All slaughter plants produce animal carcasses. For some slaughter plants, carcasses are the final product and are shipped to further-processors for cut-up and consumer packaging. However, most slaughter plants had cut-up operations that could produce ground meat or poultry, meat or poultry parts, or other products by 1992. Further-processing plants, such as sausage-making operations, also offer different degrees of processing. Some provide fully cooked or ready-to-eat products, such as luncheon meats, while others produce sausage links and other ready-to-cook products.

Animals raised specifically for meat, such as steers, heifers, and young chickens, typically yield a greater percentage of higher valued meat cuts and have more uniform sizes than animals raised for other purposes. Thus, animal type affects processing costs by changing production practices and may reflect a different product mix available from the carcass.

Consumers can distinguish between various meat cuts and other quality differences (e.g., marbling and fat content), but it is much more difficult for them to discern food safety quality (e.g., whether pathogens are present). Yet, plants ignore food safety quality at their peril. Recall the exit from the meat industry of Hudson Meats in 1998 after its products sickened numerous people, and the millions of dollars in losses at Jack-in-the-Box and Sara Lee lost after they sold meat products that killed several people and sickened many others (see, e.g., Perl, 2000). Events like these have led Jack-in-the-Box, McDonalds, and other restaurants and grocery chains to demand stringent process control programs at their meat suppliers (Ollinger, 1996). Other meat and poultry vendors may not have the resources or may not see the need to enforce stringent standards and, thus, may accept a lower level of assurance that the product was produced in a manner to reduce the potential for pathogens. Nevertheless, even suppliers to these buyers must consider food safety quality or potentially be exposed as a supplier of products with low food safety quality. Other buyers may not need a stringent process control program if they use meat or poultry for high-temperature cooking operations.

Food-processing experts assert that SPCPs reduce the potential for cross-contamination of meat or poultry. Proper sanitation includes cleaning and sanitizing disassembled equipment and cutting implements and preventing rodent infestations and the mixing of cooked and uncooked meat, ready-to-eat and unprocessed meat, etc.

## Estimation Issues

Following standard practice, we impose symmetry and homogeneity of degree one, such that $\beta_{ij}=\beta_{ji}$; $\alpha_{ki} = \alpha_{ik}$; $\gamma_{Qi} = \gamma_{iQ}$; $\delta_{1i}= \delta_{i1}$ ; $\delta_{Q2}= \delta_{2Q}$; $\alpha_{4ik} = \alpha_{4ki}$; $\alpha_{5kQ} = \alpha_{5Qk}$; for all i , j, and k and $\Sigma\beta_i=1$, $\Sigma\beta_{ij}= \Sigma\gamma_{Qi}=\Sigma\alpha_{4ik}=\Sigma\alpha_{5kQ}=0$. Since all variables are divided by their mean values, the first order factor price terms ( $\beta_i$ ) can be interpreted as cost shares at mean values. The other coefficients capture changes in factor prices, output, plant characteristics, and technology with deviations from sample mean values.

Differentiating ln (C) with respect to the logs of the factor prices yields four output-constant factor demand equations that can be used to estimate input cost shares (equation 4.4). We estimate the longrun cost function jointly with the factor demand equations in a multivariate regression system. Since factor shares add to one, the capital share equation is dropped to avoid a singular covariance matrix:

$$\frac{\partial InC}{\partial \mathrm{In} P_i} = \frac{P_i\, X_i}{C} = \beta_i + \delta_{1i}\, P_i + \sum_j \beta_{ij} \mathrm{In} P_i + \gamma_{Qi} \mathrm{In} Q + \sum_k \alpha_{4ik} v_k . \tag{4.4}$$

The derivative of the cost function with respect to value attributes yields the cost elasticity with respect to a value attribute (equation 5). The coefficient for the first-order output term, $\alpha_{1k}$, gives the cost elasticity with respect to value attribute k at the sample mean. The coefficient on the second-order output term, $\alpha_{2k}$, indicates how the cost of value attribute k changes with changes in attribute k. Other coefficients show how attribute k changes with changes in attributes j, factor prices, and output:

$$\varepsilon_{cv} = \frac{\partial lnC}{\partial lnv_k} = \alpha_{1k} + \alpha_{2k} \ln v_k + \alpha_{3kj} \ln v_j + \sum_i \alpha_{4ki} \ln P_i + \alpha_{5k} Q. \qquad (4.5)$$

Value-enhancing attributes include process control effort and the processing of products beyond carcasses and simple processing. The coefficient $\alpha_{3kj}$ indicates how the production of the attribute $v_j$ affects the cost of production of attribute $v_k$, i.e., how a change in $v_j$ affects the cost of producing $v_k$. The coefficient $\alpha_{5k}$ indicates how plant size affects the cost of production of the value attribute, $v_k$. Economies of scale in the sanitation and process controls effort occur when the cost of such effort declines with plant size. Note, economies of scale take place when larger plants have lower costs per unit than smaller plants.

## Data

Data come from two FSIS datasets and the Longitudinal Research Database (LRD) of the Center for Economic Studies at the Bureau of the Census. One of the FSIS datasets, obtained in a personal conversation with an FSIS representative, contains information on percent critical deficiencies for all establishments inspected by FSIS in 1992. FSIS inspects all processing plants for their SPCPs and defines an SPCP as critically deficient if a major task is poorly performed. If the task is not performed on a repeated basis, then the inspector discusses the problem with the plant manager. There are also less severe infractions of SPCPs that an inspector may note, but these are not deemed major tasks and thus are not considered here as critically deficient tasks.

Many observers of FSIS inspection activities believe that some variance exists in the way inspectors measure process controls, i.e., a critical deficiency to one inspector may not be one to another. While this is likely to be the case, we have no reason to believe that there is a systematic bias in these data. Thus, it appears unlikely that random reporting differences will affect statistical results.

The other FSIS dataset, the Enhanced Facilities Database for 1992, contains detailed information on the numbers and types of animals slaughtered, SIC codes, pounds of meat or poultry produced, whether a plant produced meat or poultry, and categorical data on process types for each plant inspected by FSIS.

The LRD provides detailed records of all individual manufacturing establishments with more than 20 employees. Although the LRD has data for every year up to 2002, we use only 1992 data because it was matched to the FSIS dataset containing percent critical deficiencies. LRD data provide detailed information on the physical quantities and dollar amounts of many different product shipments, physical quantities and prices paid for materials and employment, energy costs, the book value of capital, and other detailed financial microdata. The file also notes ownership and location information.

Data from the Census of Manufacturers include a rich set of variables that measure semi-finished and finished products. Semi-finished products include animal carcasses, whole birds, cut-up birds, turkey parts, boxed beef and pork, poultry products in wet and dry ice bulk containers, and chicken traypacks. Further-processed products include frankfurters, cooked and smoked hams, pork sausage links, and hamburger patties.

The data include the 3,200 meat and poultry plants reporting in the 1992 Census of Manufacturers. Products include semi-processed products, such as boxed beef, from slaughtered animals, and further-processed products, such as bologna, ham, or poultry frankfurters, from either animals or raw meat or poultry. These plants include Federal- and State-inspected meat plants. The FSIS datasets have only plants inspected by the Federal Government, but these plants produce the vast majority of meat and poultry products consumed in the United States.

Researchers can use LRD data only for research purposes, may not divulge information on any individual plant or firm, and may publish only aggregated information. This report, therefore, identifies aggregated statistical data and the coefficients from regression analyses covering hundreds of establishment records. Any references to specific company or plant names are based on publicly available information and not on any Census source.

We combined the LRD data with the FSIS data by matching on ZIP Code and name and verifying the record based on plant output and product type. The combined dataset includes all Census establishment data and FSIS data from the EFD and the dataset containing percent critically deficient SPCPs for each matched plant. The matching procedure linked 2,579 plants from the LRD to plants from the EFD. The unmatched plants from the LRD included manufacturing plants inspected by Sate inspectors, egg products establishments (SIC 20159), and plants that could not be matched.[4] Unmatched plants from the EFD were mainly nonmanufacturing establishments.

We further reduced the dataset of 2,579 plants by including only plants that generated at least 50 percent of their revenue from beef (SIC 20111), pork (SIC 20114, 20116, and 20117), other processed meat—animal inputs (SIC 20110), cured/cooked pork (SIC 20136), sausages (SIC 20137), other processed meat—raw meat inputs (SIC 20130), chicken slaughter (SIC 20151), and poultry processing (SIC 20155). Additionally, since FSIS does not report percent critically deficient SPCP data for slaughter-only operations, we deleted these plants. From this dataset containing 2,276 plants, we dropped all other plants that lacked essential data to yield a final dataset with 1,729 observations.

## Variable Specifications

Table 4-1 provides definitions of model variables. Explanatory variables include factor prices (labor, meat input, other material, and capital), plant output, input type, product mix, and process control.

We define labor, meat inputs, and nonmeat material factor prices (PLAB, PMEAT, and PMAT) and output (Q) as shown in table 4.1. Following Allen and Liu (1995), we define the price of capital (PCAP) as the opportunity costs of investing in plant and equipment. This definition is imperfect because existing machinery and building costs are reported at book, rather than real, values. Additionally, capacity is a measure of full capacity; but it is unlikely that all establishments are producing at full capacity for all years.

Input type (INPUT) is a dummy variable defined as one for specific animal input type for the cattle, hog, and poultry slaughter plants and zero otherwise.[5] For the other industries, it is defined as one for plants that slaughter animals and zero otherwise. Input type for cattle slaughter is one for plants that process cows and bulls and zero for other types of cattle, such as steers and heifers; for hogs it is one for sows and boars and zero otherwise; and for poultry it is one for young chickens and zero otherwise.

Product mix (MIX) captures the relative value of producing a particular product attribute. We set variable MIX to one minus the share of boxed beef and hamburger output for cattle slaughter, one minus the share of carcass outputs for hog slaughter, and one minus the share of whole bird outputs for poultry. The residual for the slaughter industries is bulk items for cattle slaughter and processed products for hog and poultry slaughter. Bulk items include animal carcasses, while processed products include meat cuts and ground meat. Since it is less costly to produce bulk products than processed products, MIX should negatively affect total costs for cattle slaughter and have a positive effect in hog and poultry slaughter.

Product mix (MIX) for further-processors equals one minus the share of sausages for the industry designated as other meat processors. For the other further-processors, MIX is the share of smoked pork products for the cured/cooked pork products industry, one minus the share of fresh sausages for the sausage industry, and one minus the share of poultry frankfurters and poultry hams and luncheon meats for the processed poultry industry. There were insufficient data to create a product mix variable for the meat processing from animal inputs industry. We include MIX variables for processing plants as a control variable for market type and make no hypotheses *a priori* regarding signs.

We use the percent critically deficient SPCPs (DEF) as a measure of process control effort. As noted in the previous chapter, FSIS has several classes of critically deficient process control tasks. The percent-deficiencies used in this report refers to percent-critical sanitation and process control deficiencies. A critical deficiency is a failure to adequately perform an operation that FSIS deems essential to plant sanitation and process control and is discussed with plant manage-

[4] SIC is an acronym for Standard Industrial Classification.

[5] Costs would likely differ even if animals and raw meat inputs were identical. The available mix of products from raw meat inputs and animals varies, suggesting that animal input type may also be serving as a proxy for certain types of plant outputs.

ment prior to its assignment. More deficiencies imply that plants are using fewer resources for SPCPs than competitors with lower percent-deficiencies. Since resources are costly, a rise in percent-deficiencies should negatively affect plant costs.

There are other possible measures of process control performance. As discussed in chapter 2, plants can have Total Quality Control (TQC) or Partial Quality Control (PQC) programs. The adoption of a TQC program does not necessarily imply that the plant will have a superior process control program over another, however. Rather, adoption occurs if the potential benefits provided by FSIS, such as reduced inspector overtime costs, outweigh the additional regulatory costs of program implementation. PQC programs are not satisfactory because they cover only part of a plant's operations. Moreover, rather than being strictly voluntary, these programs could be imposed on the plant by FSIS to correct a particularly persistent process control problem. Besides TQC and PQC programs, one could think that product recall data would be a good measure of process control effort. However, this also is unsatisfactory. The chief drawback is that FSIS does not test all products. Rather, it takes only a random sampling. Thus, the absence of a recall could imply that a plant's products were not tested or that food safety quality was satisfactory.

Data on product mix and pounds of output came from FSIS and the Census of Manufacturers. For each observation, we used Census of Manufacturers' data when those data were available and FSIS data if Census data were missing. Percent-deficiencies and animal inputs came from FSIS. The labor costs, number of employees, meat costs, pounds of meat inputs, value of materials, and value of machinery and buildings came from Census. Each observation had data for each variable, except for some plants, particularly those in the industries defined as other meat processors from animal inputs and meat processors from raw meat inputs.

Plants with missing data were dropped unless they had data on plant output and the combined value of meat and nonmeat input costs. For these plants, we multiplied the industry average meat input share of total meat and nonmeat material costs times total plant meat/nonmeat material costs to determine plant meat input costs. Nonmeat material costs were then defined as total plant meat/nonmeat material costs minus estimated meat input costs. Similarly, we estimated pounds of meat inputs by multiplying the industry-average ratio of meat inputs to meat output times plant meat output.

## Estimation and Tests for Model Selection

We use a nonlinear iterative, seemingly unrelated regression procedure. This approach accounts for likely cross-equation correlation in the error terms (a change in one cost share affects the others). The capital cost share equation was dropped because the sum of all cost shares must equal one. All dependent and explanatory variables are normalized by their sample means. Thus, first-order coefficients can be interpreted as elasticities at sample means.

Economists prefer a likelihood ratio test to a test of statistical significance of a single variable, because in a translog cost function, each variable has many interaction terms, making any single variable a poor measure of variable importance. We used a Gallant-Jorgenson (G-J) likelihood ratio test to evaluate whether a selected variable affects production costs. In this test, a less restricted model containing a variable of interest (maintained hypothesis) is compared with a more restricted model lacking the variable of interest (alternative hypothesis). If the difference in the G-J statistic (chi-square statistics) exceeded a critical value, then the maintained hypothesis was rejected, leading one to conclude that the variable of interest may affect costs.[6]

Table 4.2 provides the maintained and alternative hypotheses, degrees of freedom between the maintained and alternative hypotheses, and model chi-square test results. The acronyms describing the test and maintained hypotheses are based on the variable names from equation 4.2, so P,Q,I,M, and D represent input prices, output, type of animal input (INPUT), product mix (MIX), and percent-deficient SPCPs (DEF). Degrees-of-freedom is the difference in the number of parameters between the maintained and alternative hypotheses. The number of model variables is given in the footnotes to the table.

[6] The difference in the values of the objective function equals $N*S(\alpha, v)_R$ - $N*S(\alpha^1, v^1)_u$, where $S(\alpha, v)_R$ is the minimum value of the objective function of the restricted model, $S(\alpha^1, v^1)_u$ is the minimum value of the objective function of the unrestricted model, and N is the number of observations. SAS prints out the difference between the most and least restricted modes.

We started by testing the most restrictive alternative hypothesis, model PQ—prices (P) and output (Q)—against the least restrictive hypothesis, PQIM which has the 12 variables associated with animal input (INPUT) and product mix (MIX) in addition to prices and output. This test determined whether INPUT and MIX affect plant costs. PQIM could not be rejected for cattle slaughter, hog slaughter, cured/cooked pork, and sausage. Then, we added INPUT to PQ to create PQI in order to evaluate the importance of MIX to PQIM. PQIM still could not be rejected for cattle and hog slaughter and sausage. Next, we added MIX to PQ to form PQM and compared PQIM with PQM in order to determine the importance of INPUT. We could not reject PQIM for cattle slaughter and cured/cooked pork. These test results suggested that PQIM was unambiguously the best model for cattle slaughter because that model could not be rejected in any case. We also selected PQIM for cured/cooked pork because PQIM performed better than PQM and provided a modestly better, but not significant, explanation of model variance than did PQI.

For the remaining industries, we added MIX or INPUT to PQ to form PQI and PQM and repeated the process. First, we tested PQ, the alternative hypothesis, against the less restrictive maintained hypothesis (PQM). We could not reject PQM for hog and poultry slaughter, sausages, and other processed meat from raw meat inputs. Then, we tested PQ against the maintained hypothesis of PQI. We could not reject PQI for hog and poultry slaughter and sausages. We concluded that PQM was the best model for processed meat from raw meat inputs because there was no input variable, INPUT, and we selected PQ for poultry processing because G-J tests reject PQI and PQM. Other test results were more ambiguous, but we chose PQM over PQI for hog and poultry slaughter and sausages because PQM provided a modestly better explanation (higher chi-square statistic) of model variance. Finally, we used PQ for other processed meats from animal inputs.

Summarizing our selection of a preferred model, we use PQIM for cattle slaughter, PQM for other meat processing from raw meat inputs, and PQ for poultry processing and other meat processing from animal inputs because they are unambiguously the best fitting models. For the other industries, we based model selection on their chi-square statistics. Models chosen because they provided marginally better fits were PQIM (versus PQI) for cured/cooked pork processing and PQM (versus PQI) for hog and poultry slaughter and sausages.

Finally, we added percent-deficient SPCPs to the preferred model to see if it affected costs. For cattle slaughter and cured/cooked pork, we added the eight restrictions from percent-deficiencies (DEF) to PQIM to form PQIMD. Proceeding similarly for other models, we formed PQMD for hog and poultry slaughter, sausages, and other processed meat from raw meat inputs and created PQD for other processed meat from animal inputs and poultry processing. In pair-wise G-J tests, PQIMD was tested against the alternative hypothesis of PQIM for cattle slaughter and cured/cooked pork; PQMD was tested versus the alternative hypothesis of PQM for hog and poultry slaughter, sausages, and other processed meat from raw meat; and PQD was tested against the alternative hypothesis of PQ for other processed meat from animal inputs and poultry processing. We rejected PQIMD for cattle slaughter and cured/cooked pork, PQMD for hog and poultry slaughter, processed meat from raw meat inputs, and sausages, and PQD for the other industries at the 99-percent level of significance.

The rejection of DEF means that we cannot have a 99-percent level of confidence that DEF affects model costs. However, this does not mean that we cannot draw implications from parameter estimates of DEF because regression parameters always provide an estimate of the parameter mean.

## Parameter Estimates

Appendix tables 4.A.1 to 4.A.8 contain the first-order coefficients (first column), own-factor price quadratic terms (diagonal terms), and the interactions among factor prices and other factor prices and nonprice terms (above the diagonal) for slaughter and processing plants. There are no terms below the diagonal because they are identical to those above it.

The first-order coefficients and some of the key second-order terms are shown in table 4.3. The coefficients for the first-order input price terms can be interpreted as cost shares at sample means. Plants that slaughter animals tend to produce a large volume of bulk products, such as carcasses. Further-processors, on the other hand, take carcasses and other bulk raw meat inputs and transform them into sausages, hams, and other further-processed products. Thus, slaughter plants should have a higher share of their costs from meat inputs and less from materials and labor than the further-processors. Factor shares (coefficients on the first-order input price terms) show that this is the case. Meat dominates other costs for all industries, particularly cattle slaughter, and is greater for slaughter plants in general than for further-processors. Since meat processors do more extensive processing of niche products, they have higher labor and other materials shares. Hog and poultry slaughter typically process meat to a greater extent than cattle slaughter, but less than further-processing and thus have lower (animal) meat input shares than cattle slaughter and higher shares than the further-processors (MacDonald et al., 2000, and Ollinger et al., 2000).

Factor shares for cattle slaughter, hog slaughter, and poultry slaughter are consistent with those reported by MacDonald et al. (2000) and Ollinger et al. (2000). There are no corresponding studies of meat and poultry further-processors to provide a comparison.

The FSIS data enabled us to distinguish between cattle and cow plants in cattle slaughter and hog and boars versus barrows in hog slaughter. These data, as reflected in the variable INPUT, show that cow and bull slaughter plants have significantly higher costs than steer and heifer plants. Cows and bulls are typically much older and a different size than steers and heifers. They are also more likely than steers and heifers to be converted into ground beef than boxed beef. Hogs and boars for hog slaughter was not significant and was dropped.

The signs on the first-order product mix variables are consistent with the expectations outlined earlier but were not statistically significant. Output is significant in all cases, suggesting that the direct effect of output on plant costs is important.

## Product Mix

We use product mix variables to control for production costs for particular product markets. Some of these variables reflect submarkets that have clear cost differences relative to other segments of their general product market, while other variables represent markets that have less obvious cost differences from their overall market. Thus, we can project costs for some variables *ex-ante* but not for others. Coefficients for the product mix variables are shown in table 4.3 and the appendix tables.

Product mix for cattle slaughter equals the share of carcasses and other bulk beef products, such as organ meats. Bulk product producers should have lower costs than producers of boxed beef and hamburger because bulk products require little processing beyond slaughtering the animal. Results (table 4.3) are consistent with this assertion. The negative coefficients on MIX and the MIX quadratic term (the interaction with itself) means that bulk product plants have lower costs than plants that do more processing and that costs decline at an increasing rate as bulk share increases. The negative effect of greater bulk processing on plant costs is consistent with both MacDonald et al. (2000) and Antle (2000), who found that greater processing increased plant costs.

Product mix for hog and poultry slaughter is defined as the share of further-processed products, such as chicken traypacks, pork sausages, and pork or poultry parts. Plants with a greater share of these processed products should have higher costs than other plants doing less processing. Results (table 4.3) show that this is the case at sample mean values (the coefficient on MIX is positive). The negative quadratic term for hogs shows that costs increase at a slower rate as hog slaughter plants do more processing, while the positive coefficient for poultry suggests that costs increase at a faster rate as processing increases. These results differ from Antle (2000) who found that costs decreased with greater processing. We attribute this difference to some of the differences in the data noted in the next subsection.

The product mix variable for the further-processors controls for particular product markets. Results (table 4.3) show that costs increase with a greater share of nonsausage products for the industry called “further meat processors from raw meat inputs” and rise with a greater share of cooked luncheon meats and frankfurters for the sausage industry. Results (table 4.3) for cured/cooked pork products show that costs decline as the share of cooked products rises. The models for the other industries—processed poultry and processed meat from animal inputs—do not employ MIX variables.

## Economies of Scale

The first-order coefficient on the output term provides a measure of economies of scale at the sample mean, while the coefficient on the second-order output term indicates how returns to scale change as output increases. First-order coefficient values greater than one suggest decreasing returns to scale, while values below one indicate increasing returns to scale.

Table 4.3 presents the necessary variables for computing economy of scale estimates. The coefficients reported on the first- and second-order output coefficients for hog and poultry slaughter (0.96 for hog and 0.82 for poultry first-order terms) are consistent with MacDonald et al. (2000), Ollinger et al. (2000), and Antle (2000). Since the first-order term indicates economies of scale and the second-order term shows the change in economies of scale with output, results suggest very strong increasing returns to scale in poultry slaughter that increase with output and near constant returns to scale that are diminishing with output in hog slaughter.

Results for cattle slaughter indicate greater returns to scale than those reported in MacDonald et al. (2000) but are in line with those reported in Antle (2000). Our results and those of Antle (2000) indicate that returns to scale become stronger with an increase in output, while those for MacDonald et al. (2000) report the opposite. Although all of these studies used the LRD, there are important differences that may explain the diverse results. First, the data used in this analysis includes all cattle slaughter plants, making it about twice as large as those used by MacDonald et al. (2000) and Antle (2000). Second, this study covers only 1992, while Antle (2000) includes 1987 and 1992 data and is stratified by output and MacDonald et al. (2000) covers 1963-92. Third, access to FSIS data enabled us to isolate cow from steer/heifer slaughter plants, while neither Antle (2000) nor MacDonald et al. (2000) had these data. Results suggest that returns to scale are much weaker for cow and bull plants than steer and heifer plants (the sum of the coefficients on Q and the interaction between INPUT and Q) and are approximately equal to those reported in MacDonald et al. (2000) for all slaughter plants and higher than those in Antle (2000).

Except for sausages, returns to scale for the processing industries are not as large as for the slaughter industries. Although there are no other studies for comparison, one might expect more modest returns to scale because products are much more specialized and production runs of any particular product are often limited by market size. Indeed, it is surprising to note that results for sausages suggest strong returns to scale at the sample mean. However, these economies of scale diminish rapidly as output increases and are almost exhausted for plants three times larger than the average plant.

## Percentage of Deficient SPCPs

The key terms for an examination of the effect of percent-deficiencies on plant costs are the coefficients on the first- and second-order percent-deficiency terms.[7] If the first-order term is negative, then costs drop as percent-deficiencies rises. The estimated coefficient on the second-order percent-deficiency term indicates the rate at which costs change as percent-deficiencies change.

Using sample mean values for all variables except percent-deficient SPCPs and then varying the percent-deficient SPCP level from one-half to four times the sample mean, we calculate an average cost index that shows how costs vary with deficiency levels for all industries (table 4.4). Costs declined with an increase in percent-deficient SPCPs for hog and poultry slaughter and sausages, both categories of other processed meat, and processed poultry. The decrease in costs at four times sample mean deficient SPCPs varied from 4.9 percent of costs in hog slaughter to 0.5 percent of costs in other processed meats from animal inputs (table 4.4). The increase in costs at four times sample mean percent-deficient SPCPs for cattle slaughter was about 1 percent and for cured/cooked pork about 3.5 percent (table 4.4). Note that there are actually very few plants with four times the mean percent-deficiencies. Plants of this type account for less than 2 percent of all plants and range from about 6 percent of all plants in the “other” meat inputs industry to almost zero for hog slaughter and cured/cooked pork.

Cost differences at four times mean deficiency levels are quite large compared with the relatively low costs of labor in meat and poultry slaughter and processing, suggesting an incentive to underinvest in SPCPs. Yet, most plants have very low percent-deficient SPCP levels. As shown in table 4.4, percent-deficient SPCPs range from about 9 percent of all SPCPs in hog slaughter to about 2 percent of all SPCPs in other processed meat from raw meat inputs. At four times the sample

[7] Recall that percent-deficient SPCPs fail to affect model fit at the 99-percent level of significance because of large standard errors relative to the parameter mean. The large standard errors means that percent-deficient SPCPs may have a substantially different effect on plant costs for some plants than what would be implied by the parameter mean, which indicates how the average plant may have fared.

mean, percent-deficient SPCPs would vary from 36 percent of all SPCPs in hog slaughter to 8 percent in processed meat from raw meat inputs. The average at four times the sample mean value is 19.6 percent.

There are two plausible explanations as to why most plants have lower than 10 percent-deficient SPCP levels. First, FSIS can take actions against plants with excessively high percent-deficient SPCP levels and would likely refuse inspection services for extremely high violation levels. Second, and perhaps more important, poor performance of SPCPs in a manufacturing plant can reduce product shelf-life and affect product quality in obvious ways, by discouraging meat or poultry purchases.

Interestingly, results for cattle slaughter and cured/cooked pork suggest that costs drop as the percent-deficient SPCP level declines. Although cattle slaughter costs drop almost imperceptibly, there is a 3-percent decrease in costs for cured/cooked pork. We speculate that plants with high percent-deficient SPCP levels in the cured/cooked pork industry have an excessive number of product condemnations and products requiring reprocessing, causing an increase in costs as percent-deficient SPCPs rises.[8] In this industry, inadequate process controls can seriously undermine product quality. For example, time and temperature and curing atmosphere controls are critical for a degree of product cooking and curing that can kill pathogens and provide other product qualities. If these controls are not properly monitored, final products must be scrapped, reworked, or sold at a much lower price than that possible for consumer products.

## Percentage of Deficient SPCPs and Plant Output

The coefficient on the interaction of percent-deficient SPCPs and output (DEF and Q) in the parameter summary table (table 4.3) and appendix tables 4.A.1-4.A.8 shows how the costs of percent-deficient SPCPs varies with output. The negative coefficient suggests that the elasticity of costs with respect to output declines as percent-deficient SPCPs rises for all industries. Since the parameter is significant only for poultry processing, one should not place a high degree of confidence in the reliability of parameter estimates. However, since there is a consistent decline with output across all meat and poultry industries, we can say that, on average, there are economies of scale in percent-deficient SPCPs, e.g., diseconomies of scale in sanitation and the process control effort.[9]

Consider cattle slaughter at sample mean values. The elasticity of costs with respect to percent-deficient SPCPs at sample mean values is 0.006. This means that a 100-percent increase in percent-deficient SPCPs leads to a 0.6-percent increase in total plant costs at sample mean values. However, at two times sample mean output and all other variables at their sample mean values, the elasticity of costs with respect to percent-deficient SPCPs is 0.0053 [elasticity = 0.006-0.001*ln (2)]. In other words, a 100-percent increase in output means that the larger plant has only a 0.53-percent increase in total costs relative to its smaller competitor. Thus, costs decrease at a slower rate as plant size increases. Since the coefficient on the interaction of percent-deficient SPCPs and output is negative in all industries, our results suggest that all eight meat and poultry industries experience a reduction in the rate of cost decrease as size increases for a given level of percent-deficient SPCPs.

Table 4.5 presents the cost elasticity of percent-deficient SPCPs of plants at the industry mean percent-deficient SPCPs and one-half the industry mean, the industry mean, and twice the industry mean plant output levels. As shown, the cost elasticities are higher for smaller plants in all industries. This means that an increase in percent-deficient SPCPs results in a larger cost reduction for larger plants than for smaller ones. Conversely, it means that larger plants will find it more costly to reduce percent-deficient SPCPs than smaller plants, i.e., the cost of process control decreases as plant output decreases or the cost of process control rises increases as output increases. However, the diseconomies of scale present in food safety process control effort moderates but does not eliminate the decline in the cost of producing the next pound of meat that accrues from scale economies for larger size plants.

[8] Process control costs increase labor and perhaps material costs but reduce product condemnations and enhance product appeal to the consumer. It is likely that the costs of process control effort are greater than the cost of product condemnations would be in its absence because the producer also benefits from product appeal. Nevertheless, the cost of product condemnations can exceed the cost of process control effort, particularly if a modest increase in percent-deficiencies leads to a large increase in product condemnations.

[9] Note that the small coefficient suggests that these diseconomies are quite small when compared with scale economies stemming from greater output.

This finding is consistent with Antle (2000). It is also in line with Williamson (1985), who asserts that, as plants grow in size, the bureaucratic structure needed to maintain operations becomes more difficult to control due to information bottlenecks and that these costs eventually overwhelm any benefits of economies of scale stemming from further growth. This may be particularly true for the process control effort, if specialization in process control functions reduces production worker diligence toward maintaining product process control.

## Conclusion

We examined the effect of a measure of food safety process control (percent-deficient SPCPs) on plant costs in the meat and poultry slaughter and processing industries with a cost function model based on Antle (2000). Like Antle (2000), who found that food quality is costly, our results show that SPCPs, on average, raise plant costs. The results reported here, however, are not as statistically reliable as we would like because the explanatory variable, percent-deficient SPCPs, has large standard errors. Additionally, unlike Antle's (2000) measure of food quality, we examine SPCP performance. Although SPCPs are a component of most process control programs, plants do undertake other actions to ensure food safety, suggesting that our results may be lower than all the costs that plants incur for food safety, process control.

The SPCPs required by FSIS are not particularly onerous. Rather, they are similar to general manufacturing principles and would likely be components of any food safety, standard process control program. Thus, we viewed percent-deficient SPCPs as a measure of negative process control effort. Our findings suggest that costs declined with percent-deficient SPCPs, i.e., rose with process control effort, in six of the eight meat and poultry industries examined and that one of the remaining industries had almost no change in costs.

We also found a statistically insignificant but consistently negative relationship between output and the percent-deficient SPCPs in all eight industries. This means that an increase in output decreases the cost of percent-deficient SPCPs and that a decrease in output increases the cost of percent-deficient SPCPs, implying that it would be more costly for a large plant to reduce percent-deficient SPCPs than for a small plant. In other words, the cost of process control effort increases with output. These so-called diseconomies of scale in the sanitation and process control effort (the higher cost of sanitation and process control as plant size increases) are consistent with Williamson (1985), who argues that, at some point, the bureaucratic costs of managing a larger plant operation swamp any economies of scale accruing to larger plant size and result in an increase in plant costs.

An FSIS representative (communication of June 13, 2002) offers one plausible explanation for our statistically weak results. He says that FSIS inspector responsibilities shifted from working with frontline production personnel to ensure clean facilities to more of an inspection-verification system in which the inspector dealt mainly with management. Under either system, a deficiency would have been accounted for similarly and percent-deficiencies would offer a measure of process control effort. However, various procedures could coexist as FSIS phased in one system to replace the other. Additionally, different inspectors may have slightly different standards for a critical deficiency. Combined, these inspection attributes suggest that an alternative measure of process control effort may be appropriate. For this measure, percent-deficiencies would be defined as one or more dummy variables of percent-deficiency levels rather than a continuous function. This research is left to the future because access to the LRD at the Bureau of the Census is not possible at this time.

**Table 4-1—Cost function variable definitions**

| | |
|---|---|
| **Independent variables** | |
| PLAB | Price of labor = (total plant labor costs) / (total employees). |
| PMEAT | Meat input price = (liveweight animal costs + raw meat input costs) / (liveweight pounds+raw meat input pounds). |
| PMAT | Cost of other material inputs = (energy costs + packing and packaging cost + other material costs) / (pounds of liveweight meat + pounds of raw meat). |
| PCAP | Price of capital = (OPPORTUNITY + NEW) / CAPACITY, where OPPORTUNITY = (machinery rental price) * (machinery book value) + (building rental price ) * (building book value); NEW is the cost of new machinery and buildings; CAPACITY is buildings and machinery book value minus all retirements. Machinery (Building) rental prices (Bureau of Labor Statistics) are costs per dollar of machinery (buildings) expenditure. |
| Q | Output of meat products, in thousands of pounds. |
| INPUT | One for plants that slaughter cows and bulls, sows and boars, or young chickens for cattle, hog, or poultry slaughter plants, zero otherwise; one for cured/cooked pork, sausage, or processed poultry plants that slaughter, zero otherwise. Not used for other industries. |
| MIX | Cattle: 1- ((boxed beef + hamburger)/meat shipments); hogs: 1-(carcass products/ meat shipments); poultry: 1-(whole birds or parts in bulk containers/meat shipments); processed meat from live animals: no suitable data; processed meat from raw meat: 1-(sausages/meat shipments); cured/cooked pork: 1-(bacon+ smoked ham+other smoked pork)/meat shipments; sausages: 1-(fresh sausage/meat shipments); and processed poultry: 1-(poultry frankfurters + poultry hams and luncheon meats)/(meat shipments). |
| DEF | Average deficient (poorly performed) sanitation and process control tasks as a percentage of all such tasks. |
| **Dependent variables** | |
| COST | Sum of labor, meat, materials, and capital factor costs. |
| LABOR% | (salary and wages + supplemental labor costs) / COST. |
| MEAT% | (purchased poultry costs + packed meat costs) / COST. |
| MAT% | (energy costs + packing and packaging cost + other material costs) / COST. |
| CAPITAL% | (OPPORTUNITY + NEW) / COST. See above for definitions. |

**Table 4.2—Hypothesis tests for meat and poultry slaughter and processing[1]**

| Hypotheses | | d.f. | Model chi-square | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Slaughter plants | | | Further-processing plants | | | | |
| Maintained | Alter-native | | Cattle | Hog | Poultry | Cured, cooked pork | Sausage | Other meat-animal input | Other meat-raw meat | Poultry processing input |
| PQIM[2] | PQ | 12 | 43* | 61* | 19 | 33* | 29* | n.a. | n.a. | 12 |
| PQIM | PQI | 7 | 22* | 38* | 9 | 9 | 15+ | n.a. | n.a. | 9 |
| PQIM | PQM | 6 | 21* | 3 | 9 | 15+ | -6 | n.a. | n.a. | 8 |
| PQM | PQ | 6 | n.a. | 60* | 13+ | n.a. | 35* | n.a. | 74* | 9 |
| PQI | PQ | 5 | n.a. | 25* | 13+ | n.a. | 14+ | n.a. | n.a. | 3 |
| PQD | PQ | 6 | n.a. | n.a. | n.a. | n.a. | n.a. | 7 | n.a. | 10 |
| PQMD | PQM | 7 | n.a. | 8 | 4 | n.a. | 9 | n.a. | 15 | n.a. |
| PQIMD | PQIM | 8 | 3 | n.a. | n.a. | 17+ | n.a. | n.a. | n.a. | n.a. |

Notes: * Reject tested hypothesis at the 99-percent levels; + reject tested hypothesis at the 95-percent level. n.a. = not applicable. Degrees-of-freedom is abbreviated as d.f. P is factor prices, Q is output; I is animal input; M is output mix; D is percent-deficient SPCPs.

[1] PQ has 15 estimated parameters and PQIM, PQI, PQM, PQIMD, PQMD, and PQD have 27, 20, 21, 35, 28, and 22 parameters, respectively.

[2] P, Q, I, M, and D represent input prices, output, input type, product mix, and percent-deficient SPCPs.

**Table 4.3—First-order and selected second-order parameter estimates from the best cost function model in the slaughter and processing industries**

| Variable | Slaughter plants | | | Further-processing plants | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cattle | Hog | Poultry | Pork-cured/ cooked | Sausage | Other meat- animal input | Other meat- meat input | Processed poultry |
| | | | | First-order terms | | | | |
| INPUT | 0.336** | n.a. | n.a. | 0.119 | n.a. | n.a. | n.a. | n.a. |
| | (0.150) | | | (0.126) | | | | |
| PLAB | 0.105*** | 0.130*** | 0.195*** | 0.176*** | 0.217*** | 0.132*** | 0.178*** | 0.236*** |
| | (0.016) | (0.011) | (0.008) | (0.008) | (0.007) | (0.011) | (0.006) | (0.015) |
| PMEAT | 0.797*** | 0.700*** | 0.634*** | 0.624*** | 0.499*** | 0.776*** | 0.613*** | 0.522*** |
| | (0.200) | (0.012) | (0.010) | (0.009) | (0.006) | (0.010) | (0.006) | (0.016) |
| PMAT | 0.062*** | 0.120*** | 0.124*** | 0.141*** | 0.208*** | 0.056*** | 0.165*** | 0.198*** |
| | (0.013) | (0.009) | (0.007) | (0.004) | (0.004) | (0.012) | (0.006) | (0.018) |
| PK | 0.036* | 0.050* | 0.047*** | 0.059*** | 0.076*** | 0.036*** | 0.044*** | 0.044** |
| | (0.020) | (0.014) | (0.007) | (0.009) | (0.006) | (0.013) | (0.006) | (0.019) |
| MIX | -0.051 | 0.009 | 0.046 | -0.081 | 0.015 | n.a. | 0.009 | n.a. |
| | (0.060) | (0.085) | (0.047) | (0.063) | (0.051) | | (0.023) | |
| DEF | 0.006 | -0.032 | -0.018 | 0.029 | -0.009 | -0.003 | -0.024 | -0.029 |
| | (0.030) | (0.028) | (0.033) | (0.032) | (0.025) | (0.026) | (0.020) | (0.045) |
| Q | 0.857*** | 0.962*** | 0.819*** | 0.945*** | 0.858*** | 0.950*** | 0.926*** | 1.013*** |
| | (0.050 | (0.021) | (0.038) | (0.042) | (0.024) | (0.024) | (0.019) | (0.042) |
| | | | | Selected second-order terms | | | | |
| PLAB* | 0.001 | 0.005** | 0.006* | 0.00095 | 0.0001 | 0.0014 | 0.00038 | 0.002 |
| DEF | (0.002) | (0.002) | (0.003) | (0.002) | (0.001) | (0.001) | (0.001) | (0.002) |
| PMEAT* | -0.002 | -0.005** | -0.005 | -0.00005 | -0.0003 | -0.0008 | -0.00016 | -0.001*** |
| DEF | (0.002) | (0.002) | (0.004) | (0.002) | (0.001) | (0.001) | (0.001) | (0.003) |
| PMAT* | -0.0002 | -0.001 | 0.001- | 0.0001 | -0.0002 | -0.001 | -0.00002 | 0.001 |
| DEF | (0.001) | (0.002) | (0.003) | (0.001) | (0.001) | (0.001) | (0.001) | (0.003) |
| PK* | 0.0012 | 0.001 | -0.002 | -0.0008 | 0.0004 | 0.0004 | -0.0002 | -0.002 |
| DEF | (0.002) | (0.003) | (0.003) | (0.002) | (0.001) | (0.001) | (0.001) | (0.003) |
| Q* | -0.001 | -0.005 | -0.0003 | -0.009 | -0.002 | -0.001 | -0.000 | -0.014** |
| DEF | (0.004) | (0.004) | (0.010) | (0.008) | (0.005) | (0.004) | (0.003) | (0.006) |
| DEF* | 0.001 | -0.005 | -0.007 | 0.002 | -0.0006 | -0.0002 | -0.004 | 0.0002 |
| DEF | (0.004) | (0.006) | (0.010) | (0.006) | (0.004) | (0.004) | (0.003) | (0.007) |
| INPUT* | *0.080** | n.a. | n.a. | 0.033 | n.a. | n.a. | n.a. | n.a. |
| Q | (0.038) | | | (0.059) | | | | |
| Q*Q | -0.002 | 0.006 | -0.020 | 0.029 | 0.044** | 0.021 | 0.035*** | 0.078*** |
| | (0.009) | (0.007) | (0.022) | (0.033) | (0.021) | (0.016) | (0.011) | (0.015) |
| MIX* | 0.006 | 0.010 | 0.002 | -0.003 | -0.015*** | n.a. | -0.005 | n.a. |
| Q | (0.010) | (0.017) | (0.007) | (0.008) | (0.005) | | (0.003) | |

Notes: Numbers in parentheses are standard errors.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.
n.a. = not applicable.

**Table 4.4—Average cost index for selected percent-deficient SPCP levels relative to sample mean percent-deficient SPCP level using industry mean values**

| Industry | Model | Plants | Mean percent deficient SPCPs | Cost index for plants at these percent-deficient SPCP levels relative to costs at industry mean percent-deficient SPCP levels | | | |
|---|---|---|---|---|---|---|---|
| | | | | Half mean | Mean | Twice mean | Four times mean |
| | | *Number* | *Percent* | *-Index relative to mean-* | | | |
| Cattle slaughter | PQIMD | 230 | 3.70 | 0.996 | 1.00 | 1.004 | 1.010 |
| Hog slaughter | PQMD | 307 | 9.16 | 1.021 | 1.00 | 0.977 | 0.951 |
| Poultry slaughter | PQMD | 155 | 8.33 | 1.011 | 1.00 | 0.986 | 0.968 |
| Cured, cooked pork | PQIMD | 117 | 5.53 | 0.985 | 1.00 | 1.017 | 1.035 |
| Sausage | PQMD | 257 | 4.25 | 1.006 | 1.00 | 0.993 | 0.986 |
| Other processed meat (animal inputs) | PQD | 288 | 2.17 | 1.002 | 1.00 | 0.997 | 0.995 |
| Other processed meat (raw meat inputs) | PQMD | 546 | 2.00 | 1.016 | 1.00 | 0.982 | 0.963 |
| Processed poultry | PQD | 129 | 3.95 | 1.021 | 1.00 | 0.980 | 0.960 |
| Average | | | | 1.007 | 1.00 | 0.992 | 0.983 |

Notes: Percent-deficient SPCPs = number of sanitation and process control violations divided by the total number of sanitation and process control activities. A lower value implies more process control effort. A lower cost index value implies a lower cost for the same level of effort devoted to sanitation and process control activities.

**Table 4.5—Estimates of the elasticity of costs with respect to percent-deficient SPCPs at sample mean percent-deficient SPCPs for selected plant sizes in various slaughter and processing industries**

| Industry | Plant output | | |
|---|---|---|---|
| | One-half mean | Mean | Twice mean |
| | | *Elasticities* | |
| Cattle slaughter | 0.0067 | 0.006 | 0.0053 |
| Hog slaughter | -0.0285 | -0.032 | -0.0355 |
| Poultry slaughter | -0.0178 | -0.018 | -0.0182 |
| Cured, cooked pork | 0.0352 | 0.029 | 0.0228 |
| Sausage | -0.0076 | -0.009 | -0.0104 |
| Other processed meat (animal inputs) | -0.0023 | -0.003 | -0.0037 |
| Other processed meat (raw meat inputs) | -0.0219 | -0.024 | -0.0261 |
| Processed poultry | -0.0193 | -0.029 | -0.0387 |
| Average | -0.0070 | -0.010 | -0.0130 |

## Appendix tables

### Appendix table 4.A.1—Cattle slaughter cost function parameter estimates

| Variable | First-order | PLAB | PMEAT | PMAT | PK | MIX | DEF | Q(lbs) |
|---|---|---|---|---|---|---|---|---|
| Intercept | -0.350** | | | | | | | |
| | (0.140) | | | | | | | |
| INPUT | 0.336** | 0.050*** | 0.060*** | 0.013 | -0.030 | 0.024 | 0.025 | 0.080** |
| | (0.150) | (0.015) | (0.020) | (0.013) | (0.020) | (0.041) | (0.020) | (0.038) |
| PLAB | 0.105*** | 0.056*** | 0.056*** | 0.020*** | -0.020** | 0.001 | 0.001 | 0.022*** |
| | (0.016) | (0.001) | (0.003) | (0.006) | (0.009) | (0.003) | (0.002) | (0.003) |
| PMEAT | 0.797*** | | 0.089*** | 0.063*** | 0.030*** | 0.001 | -0.002 | 0.023*** |
| | (0.200) | | (0.010) | (0.005) | (0.008) | (0.004) | (0.002) | (0.003) |
| PMAT | 0.062*** | | | 0.053*** | -0.011 | 0.001 | -0.0002 | 0.004* |
| | (0.013) | | | (0.005) | (0.007) | (0.003) | (0.001) | (0.002) |
| PK | 0.036* | | | | 0.001 | -0.003 | 0.0012 | -0.005 |
| | (0.020) | | | | (n.a.) | (0.004) | (0.002) | (0.003) |
| MIX | -0.051 | | | | | -0.110 | 0.012* | 0.006 |
| | (0.060) | | | | | (0.010) | (0.007) | (0.010) |
| DEF | 0.006 | | | | | | 0.001 | -0.001 |
| | (0.030) | | | | | | (0.004) | (0.004) |
| Q (lbs) | 0.857*** | | | | | | | 0.002 |
| | (0.050) | | | | | | | (0.009) |

Notes: Numbers in parentheses are estimated standard errors. All variables are standardized at their mean, so first-order terms can be interpreted as elasticities at their sample means. Sample size = 230 observations. n.a. = not available.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.

### Appendix table 4.A.2—Hog slaughter cost function parameter estimates

| Variable | First-order | PLAB | PMEAT | PMAT | PK | MIX | DEF | Q(lbs) |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.332*** | | | | | | | |
| | (0.040) | | | | | | | |
| PLAB | 0.130*** | 0.031*** | 0.029*** | 0.008* | 0.010 | 0.012** | 0.005** | 0.015*** |
| | (0.011) | (0.010) | (0.008) | (0.005) | (0.010) | (0.006) | (0.002) | (0.002) |
| PMEAT | 0.700*** | | 0.106*** | 0.098*** | 0.021*** | -0.015** | -0.005** | 0.009*** |
| | (0.012) | | (0.008) | (0.005) | (0.005) | (0.007) | (0.002) | (0.003) |
| PMAT | 0.120*** | | | 0.086*** | 0.004 | -0.003 | -0.001 | 0.003* |
| | (0.009) | | | (0.005) | (0.007) | (0.005) | (0.002) | (0.002) |
| PK | 0.050* | | | | -0.015 | 0.006 | 0.001 | (0.003) |
| | (0.014) | | | | (n.a.) | (0.008) | (0.003) | (0.003) |
| MIX | 0.009 | | | | | -0.018 | 0.010* | 0.010 |
| | (0.085) | | | | | (0.020) | (0.007) | (0.017) |
| DEF | -0.032 | | | | | | -0.005 | -0.005 |
| | (0.028) | | | | | | (0.006) | (0.004) |
| Q (lbs) | 0.962*** | | | | | | | 0.006 |
| | (0.021) | | | | | | | (0.007) |

Notes: Numbers in parentheses are estimated standard errors. All variables are standardized at their mean, so first-order terms can be interpreted as elasticities at their sample means. Sample size = 307 observations. n.a. = not available.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.

**Appendix table 4.A.3—Chicken and turkey slaughter cost function parameter estimates**

| Variable | First-order | PLAB | PMEAT | PMAT | PK | MIX | DEF | Q(lbs) |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.181*** | | | | | | | |
| | (0.036) | | | | | | | |
| PLAB | 0.195*** | 0.068*** | 0.071*** | 0.009 | -0.006 | 0.003 | 0.006* | 0.029*** |
| | (0.008) | (0.014) | (0.009) | (0.006) | (0.012) | (0.002) | (0.003) | (0.004) |
| PMEAT | 0.634*** | | 0.155*** | 0.082*** | -0.002 | -0.004* | -0.005 | 0.029*** |
| | (0.010) | | (0.011) | (0.007) | (0.007) | (0.003) | (0.004) | (0.005) |
| PMAT | 0.124*** | | | 0.081*** | -0.008 | -0.002 | 0.001 | 0.005 |
| | (0.007) | | | (0.006) | (0.006) | (0.002) | (0.003) | (0.003) |
| PK | 0.047*** | | | | 0.016 | 0.003 | -0.002 | -0.005 |
| | (0.007) | | | | (n.a.) | (0.002) | (0.003) | (0.004) |
| MIX | 0.046 | | | | | 0.007 | 0.007 | 0.002 |
| | (0.047) | | | | | (0.011) | (0.007) | (0.007) |
| DEF | -0.018 | | | | | | -0.007 | -0.0003 |
| | (0.033) | | | | | | (0.010) | (0.010) |
| Q (lbs) | 0.819*** | | | | | | | -0.020 |
| | (0.038) | | | | | | | (0.022) |

Notes: Numbers in parentheses are estimated standard errors. All variables are standardized at their mean, so first-order terms can be interpreted as elasticities at their sample means. Sample size = 155 observations. n.a. = not available.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.

**Appendix table 4.A.4—Translog cost function parameter estimates of producers of processed meat products from live animals**

| Variable | First-order | PLAB | PMEAT | PMAT | PK | DEF | Q(lbs) |
|---|---|---|---|---|---|---|---|
| Intercept | 0.067 | | | | | | |
| | (0.043) | | | | | | |
| PLAB | 0.132*** | 0.071*** | 0.081*** | 0.037*** | -0.026* | 0.0014 | 0.020*** |
| | (0.011) | (0.014) | (0.011) | (0.011) | (0.014) | (0.0010) | (0.005) |
| PMEAT | 0.776*** | | 0.136*** | 0.088*** | 0.033*** | -0.0008 | 0.020*** |
| | (0.010) | | (0.012) | (0.011) | (0.011) | (0.0010) | (0.005) |
| PMAT | 0.056*** | | | 0.033** | 0.018 | -0.0010 | -0.0055 |
| | (0.012) | | | (0.014) | (0.014) | (0.0010) | (0.0050) |
| PK | 0.036*** | | | | -0.025 | 0.0004 | 0.0055 |
| | (0.013) | | | | (n.a.) | (0.0010) | (0.0050) |
| DEF | -0.003 | | | | | -0.0002 | -0.001 |
| | (0.026) | | | | | (0.0040) | (0.004) |
| Q (lbs) | 0.950*** | | | | | | 0.021 |
| | (0.024) | | | | | | (0.016) |

Notes: Numbers in parentheses are estimated standard errors. All variables are standardized at their mean, so first-order terms can be interpreted as elasticities at their sample means. Sample size = 288 observations. n.a. = not available.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.

**Appendix table 4.A.5—Translog cost function parameter estimates of producers of processed meat products from packed meat**

| Variable | First-order | PLAB | PMEAT | PMAT | PK | MIX | DEF | Q(lbs) |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.043<br>(0.036) | | | | | | | |
| PLAB | 0.178***<br>(0.006) | 0.018**<br>(0.007) | 0.029***<br>(0.006) | 0.030***<br>(0.006) | 0.019***<br>(0.007) | 0.006***<br>(0.001) | 0.00038<br>(0.00100) | 0.0137***<br>(0.0020) |
| PMEAT | 0.613***<br>(0.006) | | 0.140***<br>(0.010) | 0.144***<br>(0.009) | 0.033***<br>(0.006) | 0.0065***<br>(0.0010) | -0.00016<br>(0.00100) | 0.010***<br>(0.002) |
| PMAT | 0.165***<br>(0.006) | | | 0.129***<br>(0.010) | -0.015**<br>(0.006) | 0.003***<br>(0.001) | -0.00002<br>(0.00100) | -0.0003<br>(0.0020) |
| PK | 0.044***<br>(0.006) | | | | 0.001<br>(n.a.) | 0.0035***<br>(0.0010) | -0.0002<br>(0.0010) | 0.004<br>(0.003) |
| MIX | 0.009<br>(0.023) | | | | | 0.002<br>(0.006) | 0.016<br>(0.025) | -0.005<br>(0.003) |
| DEF | -0.024<br>(0.020) | | | | | | -0.004<br>(0.003) | -0.003<br>(0.003) |
| Q (lbs) | 0.926***<br>(0.019) | | | | | | | 0.035***<br>(0.011) |

Notes: Numbers in parentheses are estimated standard errors. All variables are standardized at their mean, so first-order terms can be interpreted as elasticities at their sample means. Sample size = 546 observations. n.a. = not available.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.

**Appendix table 4.A.6—Translog cost function parameter estimates of producers of cured/cooked pork products**

| Variable | First-order | PLAB | PMEAT | PMAT | PK | MIX | DEF | Q(lbs) |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.054<br>(0.039) | | | | | | | |
| INPUT | 0.119<br>(0.126) | -0.0078<br>(0.0230) | 0.0032<br>(0.0270) | 0.0007<br>(0.0130) | 0.0039<br>(0.0260) | 0.053<br>(0.262) | -0.096<br>(0.096) | 0.033<br>(0.059) |
| PLAB | 0.176***<br>(0.008) | 0.075***<br>(0.015) | 0.049***<br>(0.012) | -0.003<br>(0.006) | -0.023*<br>(0.014) | 0.005***<br>(0.002) | 0.00095<br>(0.00200) | 0.029***<br>(0.004) |
| PMEAT | 0.624***<br>(0.009) | | 0.122***<br>(0.017) | 0.088***<br>(0.009) | 0.015<br>(0.012) | 0.0055***<br>(0.0020) | -0.00005<br>(0.00200) | 0.030***<br>(0.005) |
| PMAT | 0.141***<br>(0.004) | | | 0.089***<br>(0.011) | 0.002<br>(0.008) | -0.0013<br>(0.0020) | -0.0001<br>(0.0010) | 0.006***<br>(0.002) |
| PK | 0.059***<br>(0.009) | | | | 0.006<br>(n.a.) | 0.0018<br>(0.0020) | -0.0008<br>(0.0020) | -0.007<br>(0.005) |
| MIX | -0.081<br>(0.063) | | | | | -0.010<br>(0.009) | -0.0004<br>(0.0020) | -0.003<br>(0.008) |
| DEF | 0.029<br>(0.032) | | | | | | 0.002<br>(0.006) | -0.009<br>(0.008) |
| Q (lbs) | 0.945***<br>(0.042) | | | | | | | 0.029<br>(0.033) |

Notes: Numbers in parentheses are estimated standard errors. All variables are standardized at their mean, so first-order terms can be interpreted as elasticities at their sample means. Sample size = 117 observations. n.a. = not available.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.

**Appendix table 4.A.7—Translog cost function parameter estimates of producers of sausage products**

| Variable | First-order | PLAB | PMEAT | PMAT | PK | MIX | DEF | Q(lbs) |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.036<br>(0.039) | | | | | | | |
| PLAB | 0.217***<br>(0.007) | 0.045***<br>(0.012) | 0.040***<br>(0.007) | 0.016***<br>(0.005) | 0.011<br>(0.001) | 0.006***<br>(0.002) | 0.0001<br>(0.0010) | 0.039***<br>(0.004) |
| PMEAT | 0.499***<br>(0.006) | | 0.1553*<br>(0.0090) | 0.124***<br>(0.007) | 0.0087<br>(0.0060) | 0.006***<br>(0.002) | -0.0003<br>(0.0010) | 0.031***<br>(0.003) |
| PMAT | 0.208***<br>(0.004) | | | 0.1407***<br>(0.0070) | -0.0007<br>(0.001) | -0.002<br>(0.001) | -0.0002<br>(0.0010) | 0.014***<br>(0.002) |
| PK | 0.076***<br>(0.006) | | | | -0.019<br>(n.a.) | 0.002<br>(0.002) | 0.0004<br>(0.0010) | -0.006**<br>(0.003) |
| MIX | 0.015<br>(0.051) | | | | | 0.007<br>(0.011) | -0.003<br>(0.003) | 0.015***<br>(0.005) |
| DEF | -0.009<br>(0.025) | | | | | | -0.0006<br>(0.0040) | -0.002<br>(0.005) |
| Q (lbs) | 0.858***<br>(0.024) | | | | | | | 0.044**<br>(0.021) |

Notes: Numbers in parentheses are estimated standard errors. All variables are standardized at their mean, so first-order terms can be interpreted as elasticities at their sample means. Sample size = 257 observations. n.a. = not available.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.

**Appendix table 4.A.8—Translog cost function parameter estimates of processed poultry producers**

| Variable | First-order | PLAB | PMEAT | PMAT | PK | DEF | Q(lbs) |
|---|---|---|---|---|---|---|---|
| Intercept | 0.002<br>(0.061) | | | | | | |
| PLAB | 0.236***<br>(0.015) | 0.083***<br>(0.021) | 0.107***<br>(0.016) | 0.052***<br>(0.010) | -0.028*<br>(0.016) | 0.002<br>(0.002) | 0.023***<br>(0.005) |
| PMEAT | 0.522***<br>(0.016) | | 0.164***<br>(0.019) | 0.116****<br>(0.010) | 0.059***<br>0.013) | -0.001***<br>(0.003) | 0.010<br>(0.006) |
| PMAT | 0.198***<br>(0.018) | | | 0.085***<br>(0.009) | -0.021**<br>(0.010) | 0.001<br>(0.003) | -0.011**<br>(0.005) |
| PK | 0.044**<br>(0.019) | | | | -0.011<br>(n.a.) | -0.002<br>(0.003) | 0.024***<br>(0.006) |
| DEF | -0.029<br>(0.045) | | | | | 0.0002<br>(0.0070) | -0.014**<br>(0.006) |
| Q (lbs) | 1.013***<br>(0.042) | | | | | | 0.078***<br>(0.015) |

Notes: Numbers in parentheses are estimated standard errors. All variables are standardized at their mean, so first-order terms can be interpreted as elasticities at their sample means. n.a. = not available. Sample size = 129 observations.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.

*Chapter 5*

# Sanitation and Process Control Deficiencies and Plant Exits

Several studies (Boland et al., 2001, and Antle, 2000) show that meat and poultry process control practices comprise a sizeable share of nonmeat input costs for meat and poultry slaughter and processing plants. These findings are not surprising. Food scientists assert that process control practices serve as a foundation for reducing the threat of pathogens in meat and poultry products and are essential for normal business operations. If food safety process control is important to food quality, then plants that reduce food safety process control actions may face adverse repercussions in the marketplace. The purpose of this chapter is to examine the effect of food safety process controls on longrun profits. We use plant survival as a measure of profitability.

Consumers base their purchasing decisions on a wide variety of attributes, such as food safety quality, tastiness, cost, and appearance. Some consumers may be particularly concerned about food safety and might repeatedly purchase higher priced, branded products offered by manufacturers that emphasize product quality in their advertising. Attributes that consumers cannot measure directly, such as food safety, require a brand or another form of certification to denote product quality and consistency. Other consumers, however, may value food safety and consistency less highly and will choose a nonbranded product with a lower price. Thus, firms selling similar products at different quality levels and prices will coexist in the marketplace if they deliver an acceptable level of quality at a reasonable price. Plants selling similar quality products must have identical prices. If a plant sells a high-price product relative to product quality or a lower quality product relative to price, then it must eventually exit the industry. In this chapter, we examine the profit-quality relationship in terms of plant exits and food safety quality. We use performance of SPCPs as a measure of food safety quality.

Food safety is a particularly difficult product attribute to convey to consumers because it cannot be directly observed. Consumers learn about this quality by either eating the food themselves or by observing the consequences of others. Even then, consumers may not know food safety quality. There may be a lag of days or even weeks before a foodborne illness exhibits symptoms, and those symptoms are often “flu-like,” making it difficult for consumers or health care practitioners to identify the source of their illness. So, consumers often do not go to the doctor for confirmation of a foodborne illness and mistakenly attribute a foodborne illness to another food, the environment, or, in the case of unbranded products, to some unknown producer. This imperfect linkage between the source of foodborne illness and the product enables some producers to invest less in process control than they would if this attribute were perfectly revealed. This incentive may be particularly relevant for producers of generic products whose products are commingled by the buyer with other purchased products, making it difficult for a consumer or buyer to identify the seller.

Lawrence et al. (2001) assert that large slaughter plants are more likely to be one of only a few or even the only supplier to a buyer, and meat and poultry processors sell unique or branded products. Moreover, since their production volume is much higher than that of smaller plants, the chance of any single consumer becoming sick is much greater. Thus, we hypothesize that small animal slaughter plants can gain economic benefits by reducing effort devoted to SPCPs because they sell in smaller volumes and may be more likely than larger plants to sell generic products mixed with products from other plants. We further hypothesize that large slaughter plants and further-processors must more diligently practice SPCPs because their products can more readily be identified. We use SPCP performance ratings as recorded by the Food Safety and Inspection Service (FSIS) as a measure of effort devoted to process control.

We consider slaughter and processing as distinct industries. According to the Bureau of the Census data, the main products for slaughter plants are carcasses, bulk meat and poultry parts, ground meat and poultry, and other, mainly generic, raw meat and poultry products.[1] Processing industries produce more distinct products, such as sausages and smoked hams, which are often branded.

## Economic Framework

Antle (2000) demonstrates that food safety quality is costly. However, if buyers can easily detect food safety, then meat and poultry firms may find it necessary to closely monitor product contamination.

Oscar Mayer, Sarah Lee, and other further-processors make large financial investments in product quality and brand awareness promotions. Nelson (1970, 1974, and 1978) has argued and Milgrom and Roberts (1986) have shown that firms make these long-term investments in order to earn a reputation for producing quality products. In the meat and poultry industries, Ollinger (2000) and Buzby et al. (2001) provide evidence of reputation effects associated with product wholesomeness.

Losing a reputation for producing safe products can be very costly. Customers do not expect to contract a foodborne illness from products they consume and may severely punish a plant that fails to provide wholesome food. For example, Hudson Meats had to sell its hamburger operations after one of its plants was found to have produced hamburgers contaminated with *E. coli* 0157: H7. Additionally, Sara Lee lost hundreds of millions of dollars when it was identified as the source of products contaminated with *Listeria monocytogenes* that killed several people (Perl, 2000).

A plant could continuously clean its facilities and test each animal for excessive bacteria and pathogens in order to verify pathogen control. However, the costs of maintaining such rigorous standards are extremely high and may be unnecessary. Holmstrom (1979 and 1982) reminds us that moral hazard is an asymmetry of information among individuals that results from an inability to observe individual actions, suggesting that manufacturers know more about their products than consumers. Moreover, Barzel (1982) argues that buyers do not learn all of a product's quality attributes because measurement is costly. And Klein and Leffler (1981) argue that firms adhere to higher quality standards only if the expected present value exceeds the expected shortrun gains from product deception. Thus, plants will invest only enough resources in product quality to avoid being detected as a seller of off-quality products.

Lawrence et al. (2001) observed that meat and poultry processing plants often produce branded, specialty, and single-source products that can be linked to the supplier through its label or relationship to the retailer. Thus, these producers must be very diligent about maintaining product quality. Plants that slaughter hoofed animals and produce carcasses, on the other hand, usually sell nonbranded, generic products, making plant identification much more difficult. As with further-processed products, consumers must first identify food as a source of an illness and then recognize the food that caused the illness. If the product was either branded or unique, then the source is identified. If not, the consumer must remember the store where the food was purchased, then the store has to identify the plant that produced the product. If the store purchases identical products from different suppliers, then the source of foodborne illness cannot be determined, but if there is only one provider, then the supplier is known.

It may be easier to identify a large rather than a small slaughter plant. Suppose there are 1,000 consumers of products from plant A and only one consumer of product from plant B. Only 0.1 percent of the consumers of plant A production need to become sick from a foodborne illness and then correctly identify food and type of food as the source of the sickness for the plant to lose its reputation for producing pathogen-free food. However, 100 percent of the consumers of plant B production need to make the same connection for it to lose its reputation.

Tracing the source of a foodborne illness to the plant may also be more successful for large rather than for small slaughter plants. Some stores, restaurants, and wholesalers sell thousands of pounds of meat or poultry per year. These buyers often prefer to lower their transaction costs by purchasing meat or poultry from only one slaughter plant because only large plants have the capacity to meet demand for their products (Ollinger, 1996). However, if large buyers do purchase meat or poultry from small plants, then they must co-

[1] Throughout this chapter we define a slaughter plant as a plant that slaughters an animal and then sells the carcass or cuts the carcass into large components for shipment as boxed beef, trimmings, ground beef, large cuts of meat, and consumer-ready products. The essential feature of the slaughter plant is that an animal is slaughtered at the facility.

mingle products with products from other suppliers, making it difficult to identify the source of an unwholesome product. Summarizing, small slaughter plants should be less likely than large plants to be identified as the source of unwholesome products. All further-processors, on the other hand, can be identified as a source of unwholesome products if a particular type of meat or poultry is identified as the source of a foodborne illness. Thus, longrun profits should be higher for small slaughter plants with a greater percentage of deficient SPCPs and further-processors and large slaughter plants with a lower percentage of deficient SPCPs.

## An Empirical Model of Plant Exits

Economic theory suggests that a plant will exit its industry when profits in year t, $\pi_t$, are less than the discounted value of the plant at the end of the period, $e^{-rt}V_{t+1}$, minus the current value of the plant, $V_t$. Thus, a plant will exit an industry when $\pi_t < V_t - e^{-rt}V_{t+1}$.

We follow Anderson (1998) and Muth (2001) who modeled profits and a reduced form of the profit function in the following way:

$$\pi_{it} = P(PD_t, MS_{ijt})*Q_t - C(T_{i,k,t}, D_{i,t}, M_{i,m,t}, F_{i,l,t}), \quad (5.1)$$

and

$$\pi_{it}^* = \pi(PD_t, MS_{ijt}, T_{i,k,t}, D_{i,t}, M_{i,m,t}, F_{i,l,t}), \quad (5.2)$$

where PD is product demand, MS is market structure, T is plant technology, D is percent SPCP deficiencies, M is plant product market, and F is company effects.

We cannot observe longrun profitability, but we do know that plants must exit an industry when the discounted value of profits, $\Pi_t$, are less than zero. Consequently, we define $Y_i = 1$ if the plant "i " existed in 1992 but did not exist in 1996, and define $Y_i = 0$ if it existed in both 1992 and 1996. Then, we use a Probit regression to examine the determinants ($X_i$) that may be correlated with the likelihood of a plant exiting. Since plants with negative profits must exit the industry, we write:

$$E(Y|X) = Prob(Y_i = 1) = Prob(\Pi_i < 0) \text{ and} \quad (5.3)$$

$$\Pi_i = \beta' X_i + \varepsilon_i, \quad (5.4)$$

where $X_i$ is a vector of factors affecting profits and $\varepsilon_i$ is the error term:

$$\begin{aligned} Prob(Y_I = 1) &= Prob(\beta' X_i + \varepsilon_i < 0) \\ &= Prob(\varepsilon_i < -\beta' X_i) \\ &= Prob(\varepsilon_i > \beta' X_i) && (5.5) \\ &= 1 - F(B' X_i), && (5.6) \end{aligned}$$

where E is the expectation operator, β is a vector of parameters to be estimated, and $F(B'X_i)$ is the cumulative distribution. Marginal effects are estimated separately as:

$$= \frac{\partial E[Y|X]}{\partial X} = \{\frac{dF(\beta' X)}{d(\beta X)}\}\beta = f(\beta' X)\beta, \quad (5.7)$$

where f (.) is the standard normal density function that corresponds to the standard cumulative distribution, F(.). (For technical details, see Greene, page 643.)

## Model Specification

Profits vary with demand conditions. If consumer demand for meat or poultry products declines, then industry profits likewise should decline. However, all plants would be affected equally by a drop in demand if the market is national. Koontz et al. (1993) argue that boxed beef prices are determined on a national rather than a local level. Empirically, Anderson et al. (1998) provide no evidence that demand conditions affect plants differently. Hence, we assume competitive markets exist and that price differences for identical products do not exist.

Azzam and Schroeter (1995) argue that cattle markets are subject to imperfect competition, permitting larger purchasers to earn higher profits. Ward and Bliss (1989) assert that forward contracting for cattle by larger packers in concentrated markets can reduce animal availability for smaller purchasers and drive up the prices for other purchasers. However, unpublished census data show that large meatpackers pay higher prices for animals, suggesting that forward contracting is simply a way to guarantee an ample supply of inputs and that large meatpackers select higher quality animals. Empirically, Morrison-Paul (2000) found no evidence of market power in either the input or output markets in her study of the cattle slaughter industry, and Anderson et al. (1998) found that very small regional market share and market structure and forward contracting effects in their model of cattle slaughter plant exits. Due to these results, we consider market structure effects for slaughter plants but expect only a modest effect, if any, on plant survival. Meat processors purchase generic packed meat products and compete in a national product market, so they should not be affected by market structure effects.

MacDonald et al. (2000), Duewer and Nelson (1991), and Ward (1993) in cattle slaughter, Ollinger et al. (2000) in poultry slaughter, MacDonald and Ollinger (2000) in hog slaughter, and our results for meat processing (chapter 4) show that economies of scale is a key determinant of plant cost structure. Thus, large plants should be less likely to exit the industry since they, on average, have lower costs than smaller ones.

Plant capital embodies past and recent technological change. Since existing knowledge cannot be destroyed and new knowledge accrues, new technology must, on average, represent an advancement over older plant technology. For plant survival, this means that newer plants should be less likely to exit an industry than older plants because they should be able to accommodate the most recent technological advancements. However, Dunn et al. (1988) found that new plants often fail because they underestimate technological demands of the market. Thus, there may be a nonlinear relationship between plant age and plant survival.

MacDonald et al. (2000) found that about half of all bacon, ham, sausages, and other pork products were produced in slaughter plants in 1982, whereas only about 30 percent of these products were produced in slaughter plants in 1992. This change indicates a shift toward plant specialization that likely contributed to the lower costs of production reported by MacDonald et al. (2000) over the 1963-92 period. Since greater specialization implies fewer products and processes, we expect plant exits to rise as the number of plant processes rises and, in the slaughter industry, as the share of slaughter production declines.

Percent-deficient SPCPs reflect adherence to good manufacturing practices and should indicate the process control effort practiced by the plant. However, since conforming to such standards is costly (Klein and Leffler, 1981), firms adhere to higher standards only if the expected present value exceeds the expected shortrun gains from selling a low-quality product. Thus, firms making large investments to build brand awareness must also have a lower percentage of deficient SPCPs, suggesting that a higher percentage of deficient SPCPs encourages plant exits.

Consumers cannot readily identify the food manufacturer of nonbranded products. Raw beef, pork, and, to a lesser extent, poultry are usually sold under store brands and come from multiple suppliers, obscuring supplier identity. Thus, if consumers are displeased with a product, they must stop buying all products of that type, e.g., ground beef from all producers. In terms of the performance of sanitation and process control tasks, this means that slaughter plants have a weaker incentive to comply with SPCPs than do processors, and slaughter plants that are better able to avoid detection have less incentive than others. Since small plants are more likely to be one of many suppliers to a buyer and process controls are costly, an increase in the percentage of deficient SPCPs should reduce small plant exits. However, a high percentage of deficient SPCPs may induce large slaughter plants to close because large plants are more likely to be a single supplier to a buyer and, given their greater production volume, more likely to cause a foodborne illness if they fail to produce pathogen-free food.

Different product markets may have different survival prospects because of unique factors, such as processing technologies and final product demand conditions. Thus, we control for processing operations.[2] We also control for possible company-wide effects since plants owned by firms may achieve synergies with companion plants. However, firms may be more likely to close these plants if demand drops and the firm can reduce its cost of production by shifting all production to other facilities. Thus, the effects of being a multiplant firm cannot be determined *a priori*.

## Data

Data include the 1992 percent-deficient SPCP data and the 1992 and 1996 Enhanced Facilities Database (EFD) for all meat and poultry slaughter and processing plants (primarily SIC 2011, 2013, and 2015). Both of these datasets were discussed in chapter 4. Since slaughter plants and further-processors have substantially different operations, we split this sample into

[2] In 1992, FSIS identified a number of different processing operations conducted in plants. These data are reported in the Enhanced Research Database and can be interpreted as a fundamental manufacturing process underlying particular types of products and their associated product markets.

separate data sets for slaughter plants (any plant that slaughtered animals) and further-processors (plants in SIC 2011, 2013, or 2015 with no slaughter operations). Slaughter plants that do no processing of animal carcasses were dropped from the sample because FSIS does not report SPCPs for them. FSIS has a different inspection program for these plants.

The data from the EFD that are useful for this chapter include the number and type of slaughtered animals, SIC codes, pounds of meat or poultry produced, plant age, and categorical data on plant manufacturing processes. The EFD defines pounds of production as further-processed products, such as hot dogs, plus semi-processed raw meat products, such as boxed beef but not bulk slaughter products, such as carcasses.

Since some plants produce only carcasses or sell some output as carcasses, we defined output as equal to pounds of carcasses plus pounds of further-processed and semi-processed products. We converted number of animals slaughtered to pounds of meat and poultry carcasses by multiplying the number of slaughtered animals times the average animal liveweight meat production for that species as reported in the 1992 Longitudinal Research Database (LRD) by a 60-percent conversion rate from liveweight to raw meat for cattle, hogs, sheep, and goats and a 100-percent conversion rate for chicken and turkeys. For each plant, total meat from slaughtered animals equaled the total amount of meat coming from all animal species slaughtered by the plant. The liveweight pounds per animal species as reported in the LRD in 1992 are 1,128 pounds for cattle, 249 pounds for hogs, 154 pounds for sheep and goats, 4.4 pounds for chickens, and 21.6 pounds for turkey.

## Variable Specifications

The dependent variable ($Y_i$) was set at one if the plant existed in the EFD in 1992 but not in 1996 and set at zero if it existed in both the 1992 and 1996 EFD datasets.[3] OUTPUT is the total amount of semi-processed and processed meat and poultry and the estimated pounds of meat from slaughtered animals.

Other variables are defined as follows. PLANTAGE equals 93 (representing 1993) minus the year in which FSIS issued a meat grant or a poultry grant to the plant. All plants are at least 1 year old. A meat or poultry grant from FSIS gives meat or poultry plants the right to be inspected by FSIS and to produce, sell, and ship meat or poultry in both intrastate and interstate commerce. MULTSPECIE was set to one for plants slaughtering more than one animal species and set to zero otherwise.

The variables PROCESSES and SHSLAUTER reflect plant specialization. PROCESSES was coded as one if a slaughter plant used one or more or if a further-processing plant used two or more of the following processes: sausagemaking, production of ready-to-eat product, production of cured products, production of cooked but uncured products, or production of dry-cured products. If PROCESSES was not one, it was coded as zero. SHSLAUTER was pounds of slaughtered animal meat divided by the sum of processed and semi-processed meat and meat from slaughtered animals.

Table 5.1 shows a jump in the exit rates for the larger slaughter and all processing plants that fall in the 90th percentile of percent-deficient SPCPs. Below the 90th percentile, there is little apparent change in exit rates as the percentage of deficient SPCPs rises. Thus, we suspect that exit rates are a discontinuous function of percent-deficient SPCPs and set DEF90 at one for plants that fall in the 90th percentile of percent-deficient SPCPs and at zero otherwise.

The market variables for the slaughter plant model include a dummy variable equal to one for chicken plants and zero otherwise (CHIK) and other similarly defined dummy variables for turkey plants (TURK) and cattle slaughter plants (BEEF). For processors, the variables SAUSAGE, READY-TO-EAT, CURED, COOKED-UNCURED, CURED-UNCOOKED, and DRYCURED were set equal to one if the plant produced sausage, ready-to-eat, cured, cooked but uncured, cured but uncooked, or dry-cured products, respectively, and set at zero otherwise.

Three variables are used in the slaughter model to capture market structure effects: SHREGION, HERFREGION, and HERFREGION/SHREGION (see Anderson et al., 1998, for a similar formulation). SHREGION is the market share of the plant in the FSIS regional circuit, HERFREGION is the Herfindahl Index in the FSIS regional circuit, and HERFREGION/SHREGION provides a measure of a plant's relative dominance in the FSIS regional circuit, i.e.,

[3] Sometimes plants switch from Federal to State inspection programs. We have no way of identifying these plants and count them as exiting.

whether or not it is located on the industry fringe. Note, the Herfindahl Index is a measure of market power and equals the sum of the squares of firm market shares.

## Results for Slaughter Plants

Table 5.1 illustrates how plant exits vary by the percentage of deficient SPCPs and plant size for slaughter plants. Reading down the table, exit rates are higher for the smallest slaughter plants with lower percentage of deficient SPCPs and the larger plants with a higher percentage of deficient SPCPs. These data are consistent with the hypotheses that: (1) small plants with a high percentage of deficient SPCPs benefit from the lower production costs associated with lower quality control effort, and (2) large slaughter plants with a high percentage of deficient SPCPs are penalized for selling poor-quality products.

Table 5.2 contains the results of the Probit regressions for slaughter plants. The log likelihood of the model is significant at the 99-percent level and the pseudo $R^2$ is 0.07.[4] Variables include technology, market, company, and market structure effects and interactions of output with other independent variables. A Wald test (table 5.2) shows that plant technology variables are jointly significant at the 99-percent level and market effect have a 95-percent level of significance. Neither company nor the market structure effects are jointly significant.

All the technology, market, and company effect variables are significant except those for plant age and the beef market. None of the market structure variables are significant.

Marginal effects are particularly important because they indicate how a marginal change in a variable affects the outcome. DEF90 is of particular interest and is consistent with expectations. It and its interaction with output are significant. These results suggest that very small plants in the 90th percentile of percent-deficient SPCPs are less likely to exit than their larger competitors. However, as plant size increases, the advantage enjoyed by plants in the 90th percentile dissipates until they reach about the mean plant size. After the mean plant size, high deficiency levels make it more likely to exit the industry. These results make sense. Production from small slaughter plants often cannot be directly linked to the supplier because products are co-mingled with identical products from other suppliers, obscuring the source of off-quality products. As pointed out by Libecap (1992), these slaughter plants have a strong incentive to minimize effort devoted to tasks like SPCPs because these tasks are costly and the consequences of failing to perform them are borne by the industry. However, this is not the case for large slaughter plants. As pointed out earlier, these plants are more likely to be a single supplier to a large restaurant chain or grocery store because those buyers prefer to minimize their transaction costs by dealing with a single seller (Ollinger, 1996). This single-supplier relationship makes it much easier to trace products to a supplier, forcing producers to perform quality control more diligently. Additionally, small plants produce much less product per hour than large plants, so an unsanitary condition that persists for an hour affects a much smaller volume of output and is consumed by fewer customers, reducing the likelihood of causing sickness.

Marginal effects are particularly important because they indicate how marginal changes affect outcomes. For DEF90, marginal effects suggest that plants in the 90th percentile of percent-deficient SPCPs are 35 percent less likely to exit. However, the effect diminishes with plant size. For a plant equal to about the industry mean plant size, the percent-deficient SPCPs have no effect on plant survival. For plants larger than the industry mean, plants in the 90th percentile of percent-deficient SPCPs are more likely to exit the industry.

We turn now to the other marginal effects. The negative signs on the coefficients for the marginal effects of output are consistent with MacDonald et al. (2000) and Ollinger et al. (2000). They indicate that a 10-percent increase in plant size reduces the likelihood of exiting the industry by about 1 percent. Positive coefficients on the coefficients for the multi-species, processes, and slaughter interacted with output are also consistent with results by MacDonald et al. (2000) and Ollinger et al. (2000). These results suggest that slaughter of more than one animal species, the use of more than one further-processing operation by small slaughter plants, and strict specialization in slaughter by large plants encourage plant exits. The marginal effects on share of slaughter suggest that a 10-percent increase in pounds of meat from slaughtered animals as a share of output reduces the likelihood of exiting by about 2 percent.

[4] Pseudo $R^2$ = 1 minus the ratio of the log likelihood estimate of the final model to that of the most restrictive model.

Company effects and market structure variables were not jointly significant. The market structure result is consistent with Anderson et al. (2000) and Morrison-Paul (2000). We also tested percent-deficient SPCPs as a continuous variable and found that it was modestly significant. These results are available from the author. Finally, we considered vertical and horizontal integration across plants and the share of meat inputs from a plant's main animal input as a share of meat from all animal inputs, but they were insignificant.

## Results for Processing Plants

Table 5.1 shows how plant exits vary by the percentage of deficient SPCPs and plant size in the processing industries. As shown, exit rates increase with percent-deficient SPCPs for all size categories. These results are consistent with the hypothesis. Since further-processors typically produce branded and unique products that can readily be traced back to the producer (Lawrence et al., 2001), buyers can, and do, penalize plants for selling poor-quality products.

Table 5.3 contains the results for the Probit regression of plant exits over the 1992-96 period in further-processing industries. The plant technology variables include output, plant age, number of processes, and the dummy variable for plants falling in the 90th percentile of percent-deficient SPCPs. Plant product markets are represented by dummy variables for specific plant processes used to produce sausage, cured, cooked and uncured, cured and uncooked, and dry-cured products. Company effect variables include whether the plant is part of a firm that owns multiple plants producing meat or poultry products.

The technology variables—output, output squared, plant age, and whether or not the plant had more than two further-processing operations or falls in the 90th percentile of percent-deficient SPCPs—were jointly significant at the 99-percent level. Market effects were jointly significant at the 95-percent level of significance but company effects were not. Output, number of processes, the 90th percentile of deficient SPCPs, and the dummy variables for cured and cooked/uncured products were significant.

Results are consistent with previous research. The negative sign on the marginal effect of output is consistent with cost function results for the processing industries that show economies of scale exist in production. Results suggest that a 100-percent increase in plant size would lead to a 5-percent decrease in the likelihood of exiting the industry.

There is no current evidence for the cost effectiveness of specialization in meat processing, but results suggest that it pays to specialize. The marginal effects of the PROCESS term shows that plants with more than two processes were about 8.1 percent more likely to exit the industry.

Of most interest is the DEF90 variable. The magnitude of the coefficient for the percentage of deficient SPCPs suggests that plants with a percentage of deficient SPCPs in the 90th percentile have a 5-percent higher likelihood of exiting the industry than other plants. The positive sign on percent-deficient SPCPs for further-processors (in sharp contrast with the negative sign for small slaughter plants) suggests that plants falling in the 90th percentile of percent-deficient SPCPs are more likely than other plants to exit the industry, regardless of plant size. Why might this be so? As suggested earlier, further-processors can be much more easily linked to production of pathogen-tainted products than slaughter plants because further-processed products are more likely to be either branded or a specialty item (Lawrence et al., 2001). Slaughter products, on the other hand, are often generic and commingled with products from many suppliers by a buyer, obscuring the identity of the producer.

We also tested percent-deficient SPCPs as a continuous variable and considered vertical and horizontal integration dummy variables for a multiple-plant firm. The continuous percent-deficient SPCPs variable for further processing was significant. Neither the vertical nor horizontal integration terms were significant and were dropped.

## Summary

This chapter examined the effect of plant technology, market effects, company effects, and market structure effects on plant exits in the meat and poultry slaughter and processing industries. Results suggest that plant technology variables and market effects variables in both industries significantly affect plant survival rates. Of particular interest was the effect of percent-deficient SPCPs on the likelihood of plant exits. Results suggest that large slaughter plants and all processing plants with a high percentage of deficient SPCPs (the 90th percentile of percent-deficient SPCPs) have a higher likelihood of exiting than other plants, despite any cost savings that their competitors may realize from reducing their sanitation and process control effort (and costs). Why might this be so? Large slaughter plants produce very large volumes of meat products; thus, the likelihood of any single consumer's becoming sick is a lot greater, all else equal. Moreover, large plant output constitutes a larger share of the product stocked by a retailer, making detection more likely. Processors, on the other hand, produce unique products that are often branded, so they have an even stronger incentive to produce wholesome products because their identity is much more easily revealed, regardless of size.

The second major finding is that the discontinuous nature of the relationship between exits and percent-deficient SPCPs means that only plants severely lax in their sanitation and process control effort would likely exit the industry due to food safety process control performance. Thus, plants have considerable flexibility in producing products with various degrees of food safety quality without being penalized. This finding has important regulatory implications. If enforcement of SPCPs were strictly practiced and directed mainly at the most serious violators, there would be little regulatory effect on most plants, and regulatory actions would provide a strong incentive for plants to avoid deviating substantially from the median level of SPCP performance. Regulatory policy would, no doubt, still encourage plant exits, but those plants would be the ones with the poorest process control performance and least willing to undertake additional process control effort. In terms of regulation under the Pathogen Reduction/ Hazard Analysis and Critical Control Point rule, this means that any increase in regulatory stringency would increase exit rates, particularly among the most poorly performing plants. However, those plants that do exit would be the ones that would be more likely to exit anyway.

**Table 5.1— Percentage of slaughter plant exits by plant size and percentile of percent-deficient SPCPs, 1992-96**

| Percent-deficient SPCP category | Plant size | | | All sizes |
|---|---|---|---|---|
| | Less than one-half mean size | One-half to twice mean size | More than twice mean size | |
| | | *Percent exits, 1992-96* | | |
| **Slaughter plants:** | | | | |
| Less than 10th percentile | 8.3 | 0.0 | 0.0 | 8.2 |
| 10-90th percentile | 9.6 | 7.4 | 2.9 | 8.5 |
| More than 90th percentile | 4.0 | 15.0 | 7.1 | 7.1 |
| All percent-deficient levels | 8.9 | 8.6 | 4.1 | 8.3 |
| **Processing plants:** | | | | |
| Less than 10th percentile | 11.8 | 0.0 | 0.0 | 11.4 |
| 10-90th percentile | 10.0 | 8.7 | 4.8 | 9.2 |
| More than 90th percentile | 15.0 | 14.8 | 7.3 | 12.8 |
| All percent-deficient levels | 10.7 | 9.3 | 5.4 | 9.9 |
| | | *Number of plants in 1992* | | |
| **Slaughter plants:** | | | | |
| Less than 10th percentile | 144 | 1 | 1 | 146 |
| 10-90th percentile | 459 | 108 | 69 | 636 |
| More than 90th percentile | 50 | 20 | 28 | 98 |
| All deficiency levels | 653 | 129 | 98 | 880 |
| **Processing plants:** | | | | |
| Less than 10th percentile | 220 | 6 | 2 | 228 |
| 10-90th percentile | 789 | 172 | 124 | 1,085 |
| More than 90th percentile | 80 | 27 | 41 | 148 |
| All deficiency levels | 1,089 | 205 | 167 | 1461 |

**Table 5.2—Effect of percent-deficient SPCPs on slaughter plant exits, 1992-96**

| Variable[1] | Likelihood effect | | Marginal effect | | Mean |
|---|---|---|---|---|---|
| | Estimate | Standard error | Estimate | Standard error | |
| **Plant technology:** | | $\chi^2$ (10)=27.7*** | | | |
| INTERCEPT | 4.718 | 3.108 | 0.607 | (0.400) | - |
| Log OUTPUT | -0.784* | 0.418 | -0.100* | (0.054) | 15.30 |
| Log OUTPUT *Log OUTPUT | *0.026* | 0.014 | 0.0033* | (0.0018) | 241.20 |
| Log PLANTAGE | -0.483 | 0.540 | -0.062 | 0.070 | 2.632 |
| Log PLANTAGE* Log PLANTAGE | -0.047 | 0.100 | -0.006 | 0.013 | 7.386 |
| Log PLANTAGE* Log OUTPUT | 0.032 | 0.035 | 0.004 | 0.005 | 40.38 |
| MULTSPECIE | 0.418* | 0.252 | 0.054* | 0.032 | 0.621 |
| PROCESSES | 1.363* | 0.831 | 0.175* | 0.106 | 0.536 |
| PROCESSES* Log OUTPUT | -0.104* | 0.057 | -0.013* | 0.007 | 8.332 |
| Log (SHSLAUTER) | -1.558* | 0.833 | -0.200** | 0.105 | -0.596 |
| Log (SHSLAUTER) *Log OUTPUT | 0.114* | 0.061 | 0.015** | 0.008 | -9.037 |
| DEF90 | -2.713* | 1.469 | -0.350** | 0.185 | 0.112 |
| DEF90* Log OUTPUT | 0.174** | 0.088 | 0.022** | 0.011 | 1.874 |
| **Markets:** | | $\chi^2$ (10)=7.0** | | | |
| BEEF | -0.267 | 0.271 | -0.034 | 0.035 | 0.728 |
| CHICKEN | -0.510* | 0.324 | -0.066* | 0.041 | 0.10 |
| TURKEY | 0.055* | 0.313 | 0.071* | 0.040 | 0.057 |
| **Company:** | | $\chi^2$ (2) = 2.8 | | | |
| MULTFOOD | 5.823* | 3.372 | 0.749* | 0.430 | 0.165 |
| MULTFOOD* Log OUTPUT | -0.319* | 0.183 | -0.041* | 0.023 | 3.183 |
| **Market structure:** | | $\chi^2$ (3) = 2.2 | | | |
| SHREGION | -3.305 | 3.594 | -0.426 | 0.452 | 0.016 |
| HERFREGION | 0.341 | 1.103 | 0.044 | 0.142 | 0.117 |
| HERFREGION/ SHREGION | $-0.372*10^{-5}$ | $0.596*10^{-5}$ | $-0.478*10^{-6}$ | $0.764*10^{-6}$ | 1970 |
| Log Likelihood | -234.2** | | | | |
| Pseudo $R^2$ | 0.07 | | | | |
| Observations | 879 | | | | |

Notes: *Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.

[1] The symbol * used in some variable definitions represents the multiplication function, so Log Output*Log Output is Log Output times Log Output.

**Table 5.3—Effect of percent-deficient SPCPs on processing plant exits, 1992-96[1]**

| Variable[2] | Likelihood effect | | Marginal effect | | Mean |
|---|---|---|---|---|---|
| | Estimate | Standard error | Estimate | Standard error | |
| **Plant technology:** | | $\chi^2$ (7)=40.0*** | | | |
| INTERCEPT | 1.631 | 1.104 | 0.262 | 0.178 | - |
| Log OUTPUT | -0.305** | 0.155 | -0.049** | 0.025 | 14.00 |
| Log OUTPUT* Log OUTPUT | 0.006 | 0.006 | 0.001 | 0.001 | 202.00 |
| Log PLANTAGE | 0.009 | 0.384 | 0.0014 | 0.061 | 2.560 |
| Log PLANTAGE* Log PLANTAGE | -0.114 | 0.072 | -0.018 | 0.012 | 7.128 |
| Log PLANTAGE* Log OUTPUT | 0.027 | 0.027 | 0.004 | 0.004 | 36.26 |
| PROCESS | 0.501** | 0.207 | 0.081** | 0.033 | 0.247 |
| DEF90 | 0.321** | 0.147 | 0.051** | 0.023 | 0.101 |
| **Markets:** | | $\chi^2$ (6)=14.4** | | | |
| SAUSAGE | -0.193 | 0.155 | -0.031 | 0.025 | 0.144 |
| READY-TO-EAT | -0.127 | 0.131 | 0.020 | 0.021 | 0.389 |
| CURED | -0.220* | 0.136 | -0.035* | 0.022 | 0.529 |
| COOKED and UNCURED | -0.389*** | 0.140 | -0.062*** | 0.022 | 0.215 |
| CURED and UNCOOKED | -0.017 | 0.140 | -0.003 | 0.022 | 0.697 |
| DRYCURED | 0.036 | 0.199 | 0.006 | 0.032 | 0.062 |
| **Company:** | | $\chi^2$ (1) =0.6 | | | |
| MULTMEAT | 0.163 | 0.192 | 0.026 | 0.031 | 0.079 |
| Log Likelihood | | -448.5*** | | | |
| Pseudo $R^2$ | | 0.05 | | | |
| Observations | | 1461 | | | |

Notes: *Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.
[1] Interactions with output were insignificant and were dropped.
[2] The symbol * used in some variable definitions represents the multiplication function, so Log Output*Log Output is Log Output times Log Output.

*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.

[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.

## 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 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:

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

[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 $H_i^* \leq 0$,

$H_i$ (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.

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, $\sigma_i$.

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

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 | | $\chi^2$ (5) = 36** | | | $\chi^2$ (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 | | $\chi^2$ (4) = 6.6 | | | $\chi^2$ (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 | | $\chi^2$ (2) = 2.8 | | | $\chi^2$ (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) | |
| $\sigma$ | | 108.6*** | | | | 0.002 |
| Model likelihood | $\chi^2$ (11) = 144*** | | | $\chi^2$ (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 | | $\chi^2$ (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 | | $\chi^2$ (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 | | $\chi^2$ (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) | $(0.14*10^{-3})$ | |
| $\sigma$ | 3.06*** | | |
| Model likelihood | $\chi^2$ (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.

*Chapter 7*

# Projecting the Costs of HACCP from the Costs of SPCPs

To our knowledge, there have been four previous cost estimates of PR/HACCP: the FSIS cost-benefit analysis published in the *Federal Register* prior to promulgation of PR/HACCP, Knutsen et al. (1995), and academic reports by Antle (2000) and Boland et al. (2001). These estimates suggested that costs would vary from less than 1 cent per pound (FSIS) to a maximum of about 17 cents per pound for beef, and 5 cents per pound for chicken (Antle, 2000).[1] Boland et al. (2001) provide the only post-HACCP survey evidence of HACCP costs. However, their results are not nationally representative since they include 50 small plants in the Great Plains. The FSIS and Knutsen et al. (1995) cost analyses are *ex-ante* analyses based on estimated costs of the effort required to perform mandated tasks and ignore unexpected downtime and production costs for addressing food safety problems. Antle's (2000) estimate provides an upper bound under which HACCP costs likely fall. His cost function approach accounts for food safety-related costs, such as product condemnations and production downtime, but also includes the costs of producing products with nonfood safety quality attributes.

Ideally, there would be a lower bound cost estimate of PR/HACCP regulation because that lower bound combined with Antle's (2000) upper bound estimate would provide a window within which we would expect the costs of PR/HACCP to fall. In this chapter, making several strong assumptions and using a weighting factor to adjust our cost estimates to those costs that exist under PR/HACCP, we provide that lower bound cost estimate.

We use the cost estimates from chapter 4 to project the cost of PR/HACCP regulation. Although these cost estimates pertain to the cost of SPCPs, the arguments in chapter 3 and empirical linkage between HACCP tasks and SPCPs in chapter 6 suggest that food safety regulation under WMA and WPPA is correlated with food safety regulation under PR/HACCP. Thus, the implications and cost estimates derived in chapter 4 should be related to the costs of regulation under PR/HACCP. It is important to understand the nature of these costs because PR/HACCP is the foundation of Federal food safety process control and future regulations are likely to be derived from the current PR/HACCP rules.

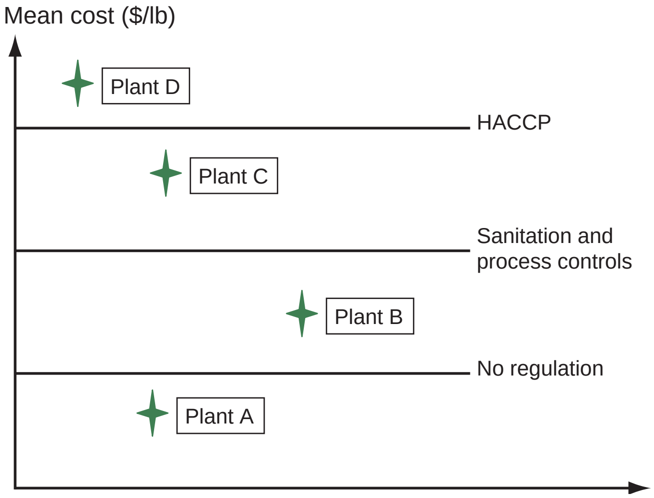
## Previously Estimated Costs of SPCPs and the PR/HACCP Rule

Most plants would perform some SPCPs and some HACCP tasks in the absence of FSIS regulation because the markets that they serve demand process controls. The precise number and comprehensiveness of the tasks may or may not exceed the number and detail required by FSIS under the 1996 PR/HACCP rule. We illustrate three industry-average, cost-per-pound levels for quality control effort in figure 7.1: no regulation, mandatory sanitation and process control standards, and PR/HACCP rule. The cost levels are arbitrarily drawn but do illustrate that mean regulated costs are likely to be higher than the no-regulation case because regulation may require some tasks that a plant may not otherwise perform. We assume that plants would continue to perform tasks that they deem essential but are not required under regulation. PR/HACCP costs are greater than SPCP costs because sanitation and process control tasks are components of HACCP plans, which also include monitoring critical control points.

[1] Antle (2000) provides several estimates depending on the level of food safety when HACCP was promulgated. A lower level of food safety at the time of HACCP enactment leads to higher cost estimates. He also assumes a level of improvement due to the regulation. Based on a previous study, he uses a 20-percent level. For his upper bound estimate, he uses a 20-percent level of improvement and a 50-percent level of food safety at the time of HACCP implementation. Cost estimates range from 2.3 to 17 cents per pound for hog, cattle, and poultry slaughter. Lower bound HACCP cost estimates, based on a 90-percent level of safety at HACCP enactment and a 20-percent level of improvement, vary from 0.3 to 1.9 cents per pound for hog, cattle, and poultry slaughter. Antle also reports average costs of about $1.15 per pound for cattle slaughter, $0.79 per pound for hogs (large plants), and $0.60 per pound for poultry (large plants).

Figure 7:1

**Hypothetical mean cost per pound expended for food safety process control under PR/HACCP, SPCPs, and no regulation**




The stars in figure 7.1 represent individual plant costs of process control effort per pound and are hypothetical points that are used only to illustrate that different plants will choose to expend different levels of process control effort. For example, plant A expends less effort than the mean level of expenditures that would exist without regulation, and plants A and B put forth less effort than the mean level of expenditures put forth by the industry under the WMA and WPPA, while plants C and D expend more effort than the mean expenditure level. Only plant D incurs greater process control expenses than the mean level of expenditures under the PR/HACCP rule. Thus, plants A and B would incur regulatory costs to raise their performance to a level compatible with SPCPs, and plants A, B, and C would incur costs to meet the amount of effort required under PR/HACCP. Plant D never incurs regulatory costs.

In table 4.3, we showed how average costs relative to industry mean costs vary with differences in percent-deficient SPCPs. We did not and could not estimate the costs of complying with sanitation and process control standards because regulation exists for all plants, making an estimate of costs under no regulation impossible. However, we can estimate the potential costs that a plant with above the mean percent-deficient SPCP performance would incur to reach the sample mean level (a benchmark used by FSIS regulators). We can also estimate the potential costs savings that a plant with below the mean percent-deficient SPCP level would realize by performing at the sample mean.

Table 7.1 (columns 5, 6, and 7) contains the estimated costs of performing SPCPs at various performance levels relative to the sample mean, as outlined in chapter 4 and described in table 4.4. The first two columns in the table show the industry and the associated mean percent-deficient SPCPs, column 3 indicates the number of plants in the industry, and column four shows mean plant costs (animal and meat, materials, and labor costs) as published by the Census Bureau. We express SPCP costs as costs relative to the mean percent-deficient SPCPs at various percent-deficient SPCP levels.

Table 7.1 shows that plants with higher-than-average percent-deficient SPCPs have lower costs in all industries except cattle slaughter and cured/cooked pork products. On average, plants with twice the mean percent-deficient SPCPs (column 6, last row) would need roughly $263,000 to improve to the sample mean of percent-deficient SPCPs. Alternatively, plants above the sample mean level of percent-deficient SPCPs could reduce costs by performing only at the sample mean level.[2] For example, a plant at one-half the mean level of percent-deficient SPCPs (column 5, last row) could reduce effort to a level compatible with the industry mean and lower its costs by about $240,000. Note that only about 10 percent of all plants have more than twice the mean percentage of deficiencies and less than 2 percent of plants have more than four times the mean percentage of deficiencies, suggesting that few plants actually reduce process control effort to these levels.

## Projecting the Cost of Performing at the Mean HACCP Level

The costs of PR/HACCP can be projected from SPCP costs since the nature of the tasks and enforcement appear to be similar. Employees perform cleaning and process control tasks and record information to comply with SPCP standards and record information and adjust process controls for critical control points under PR/HACCP. Similarities also exist for enforcement. Under both systems, inspectors observe an operation being performed, a particular site, or a record to verify

[2] Chapter 5 showed that plants in the 90th percentile of percent-deficient SPCPs were more likely to exit the industry than other plants, suggesting that plants would benefit little by reducing process control effort above the 90th percentile. So, we assume that the 90th percentile (twice the sample mean of deficiencies) is the level at which no or minimal process controls exist.

compliance with a required task. If a plant improperly performs a task, the inspector marks the task as either a deficient SPCP (pre-HACCP) or a HACCP noncompliance record (post-HACCP) and asks the plant to address the failure. Moreover, under both systems, an excessive number of serious noncompliances could cause FSIS to temporarily shut down the plant by refusing inspector services.

To accurately project the costs of HACCP based on our SPCP cost estimates, we need comparable estimates of costs under the two regulatory regimes. These costs need not be precise in absolute value but should capture cost components associated with compliance. If cost estimates are comprehensive, then a ratio of the two estimates can be used to illustrate the relative change in regulatory requirements. For example, Ollinger and Cornejo (1999) estimated regulatory stringency based on ratios of the estimated regulatory costs announced in the *Federal Register* by the Environmental Protection Agency (EPA) for one regulatory regime relative to the estimated costs under a former regulatory regime. This ratio provided a gauge of the relative change in costs of the two regimes. The individual cost estimates from the EPA did not reflect actual costs, but since the regulatory cost estimates did capture all aspects of the regulatory change, the ratio of cost estimates across different regulatory regimes did measure relative stringency.

Working under contract for FSIS, the Research Triangle Institute (RTI) assessed the regulatory costs of SPCP performance standards in 1994. It suggested that costs amounted to about $12,500 per plant. Our cost estimates are sharply higher than this estimate because the RTI estimate considered only the supervisory costs of maintaining SPCPs and dealing with the FSIS inspector, while our estimates are based on the actual performance of SPCPs and resulting outcomes. Poorly performing plants may incur production shutdowns, meat condemnations, and other costs due to failure to perform SPCPs but will also avoid the costs of performing and monitoring SPCPs. Highly performing plants will incur the labor and supervisory costs of performing SPCPs and the costs of voluntarily shutting down production when there is a threat to product safety.

Under another contract with FSIS, Anderson et al. (1994) of RTI estimated the costs of HACCP regulation for nine plants. As with the SPCP study, costs included all supervisory costs, the cost of dealing with FSIS inspectors, and recordkeeping tasks (a prime component of HACCP plans) but did not include the costs of corrective actions, carcass condemnations, or plant shutdowns for corrective actions.

The ratio of cost estimates of the two RTI studies should indicate the relative change in stringency of the costs of PR/HACCP relative to the costs of SPCP standards. This ratio shows HACCP costs to be about 90 percent higher than the costs plants incur for SPCPs. Table 7.2 (columns 4, 5, 6, and 7) contains the estimated relative changes in HACCP costs at various levels of percentage of HACCP noncompliance records.

Table 7.2 shows that PR/HACCP sharply increases food safety process control costs relative to SPCPs. Plants that have two times the industry mean percentage of HACCP noncompliance records realize about $500,000 in lower costs—about 2.6 percent of its costs—than they would if they performed at the industry mean level. Alternatively, plants with one-half the mean percentage of HACCP noncompliance records incur about $450,000 more in costs than plants at the sample mean.

## Cost Estimates of Complying With the PR/HACCP Rule

It is possible to estimate the costs of HACCP compliance based on our estimate of SPCP costs and the RTI estimates. However, we must make several strong assumptions. First, we assume that plants at two times the mean level of percent-deficient SPCPs (table 7.1) completely ignore sanitation and process control requirements to the point that product quality is noticeably affected and likewise ignore PR/HACCP requirements. This assumption appears to be plausible because plants with about twice the sample mean percent-deficient SPCPs (about the 90-percentile level of performance) increase their chances of failing to survive in their industry (see chapter 5). Second, we assume that RTI cost projections accurately reflect the relative change in regulatory compliance costs across regulatory regimes. Third, we assume that there are no private incentives to increase product quality during the transition from SPCPs to HACCP. This assumption means that all new costs incurred under PR/HACCP would not have taken place otherwise and appears to be conservative because it seems unlikely that consumer demand for greater safety has not changed given increased media coverage of food safety and a number of foodborne illness outbreaks since 1992. Finally, we assume that plants with below the industry-mean level of percent-deficient SPCPs would reduce their regulatory costs by redeploying resources such that they performed at the industry's mean percentage of HACCP noncompliance records after a regulatory change.

A plant would incur costs of about $500,000 to improve its performance to the mean of the percentage of HACCP noncompliance records if it performed HACCP tasks at twice the industry mean level of percentage of HACCP noncompliance records (table 7.2). This is about the same amount that a plant with a fourth the mean percent-deficient SPCPs could save by redeploying assets in order to comply with HACCP regulation. This means that all plants with more than the mean percent-deficient SPCPs (about a fourth of all plants) would incur an average cost of regulation of about $500,000. Additionally, plants with from a fourth the mean percent-deficient SPCPs to the mean percent-deficient SPCPs (about a third of all plants) would incur somewhere between zero and $500,000 in costs. Plants with less than a fourth the mean percent-deficient SPCPs would have no cost of compliance under PR/HACCP because they already make expenditures compatible with the requirements under PR/HACCP. The average cost per plant works out to about $208,300—about 1.1 percent of all costs—or, based on Antle's (2000) costs of production, about 1.2 cents per pound for beef, 0.7 cent per pound for pork, and 0.4 cent per pound for poultry. These costs are in line with Antle's (2000) average estimated cost of compliance of 1.39 cents per pound on a weighted-average basis and the Boland et al. (2001) estimate of about 0.9 cent per pound for small meat plants.[3] Estimated costs for processed meat and processed poultry are about 1.6 cents per pound.

For the plant, regulatory costs are a much higher share of nonmeat and poultry costs because meat inputs account for anywhere from 79.7 percent of total costs for cattle slaughter to about 50 percent of total costs for sausage products. Thus, the costs of PR/HACCP relative to all nonmeat and poultry costs varies from about 5.5 percent of all costs for cattle slaughter to about 2.2 percent of all costs for sausages.

## Summary

Chapters 4, 5, and 6 show that an increase in percent-deficient SPCPs results in a decline in plant costs, leads to a greater likelihood of plant's exiting the industry, and is positively correlated with a relatively high percentage of HACCP noncompliance records. In this chapter, we used cost function results from chapter 4 to estimate the costs of HACCP. We found that the costs of maintaining a HACCP system is about 1.1 percent of costs, which amounts to costs ranging from about 0.4 cent per pound for poultry to 1.2 cents per pound for beef, or about 0.9 cent per pound on average for meat or poultry. This estimate is much higher than that proposed by FSIS in the *Federal Register* announcement, which placed the cost at about 0.12 cent per pound. However, the estimate is quite close to the weighted-average cost estimated by Antle (2000) of about 1.39 cents per pound and almost identical to the Boland et al. (2001) survey costs of about 0.9 cent per pound.[4]

The 1.1-percent increase in costs is much more substantial to the plant operator than it may appear. Meat and poultry plants have little control over the price of animals and inputs of raw meat and poultry; but these costs constitute anywhere from 50-80 percent of input costs. As a result, the costs of PR/HACCP amount to anywhere from about 2.2 to 5.5 percent of controllable costs.

The increased costs of PR/HACCP relative to the sanitation and process control standards under the WMA and WPPA give plants a stronger incentive to reduce compliance unless buyers increased their food safety demands. In the absence of increased buyer demand for greater food safety, FSIS regulators would have to increase enforcement stringency to maintain the same compliance level.[5]

[3] Antle (2000) reports average meat prices varying from $1.15 per pound for beef to $0.60 per pound for poultry. Recall that the SPCP cost of HACCP compliance is biased downward because there is not a perfect linkage between SPCPs and food safety, whereas Antle's (2000) estimate is biased upward due to quality aspects unrelated to food safety. The weighted-average-cost estimate for Antle (2000) comes from Boland et al. (2001).

[4] Cost estimates of HACCP reported in each publication can be criticized, but their consistency suggest that HACCP costs may approach about 1 cent per pound. The SPCP-based estimate provided here is biased because it measures effort rather than quality; Antle (2000) estimates total product quality and then controls for some observable quality attributes so the accuracy of the quality variable depends on the correlation of the instrument with safety; and Borland et al. (2001) estimate plant labor and materials costs but do not consider downtime.

[5] It appears likely that heightened media coverage of food safety and a number of foodborne illness outbreaks since 1992 have increased demand for food safety over the past 10 years.

The higher cost estimate provided here for PR/HACCP than estimated by FSIS does not suggest that PR/HACCP is not cost effective. Depending on the anticipated effectiveness of the regulation and methodology used, the ERS estimate of the benefits of PR/HACCP ranged from $1.9 billion - $171.8 billion annually. Even the lowest benefits estimate, which assumes 20-percent effectiveness and the most conservative benefits methodology, generates about twice as much in health cost savings as industry incurs in cost increases.

We did not address the issue of whether HACCP regulation favors large plants over small plants in this chapter. However, recall that we did examine this question in chapter 4 dealing with the costs of SPCPs. In that chapter, we found that large plants did not have lower costs of performing SPCPs than small plants. Since the two regulations are related, it appears likely that, in the long run, PR/HACCP does not favor large plants. In the short run, a different assessment may be reached because HACCP costs include many more fixed costs than the SPCP-based system. Large plants can more readily spread these fixed costs over their larger production volumes.

**Table 7.1—Estimated costs of various percent-deficient SPCPs relative to the mean level of percent-deficient SPCPs[1]**

| Industry | Percent deficiency[2] | Plants | Plant costs[3] | Costs of SPCP tasks relative to the costs of a plant at the mean level of percent-deficient SPCPs | | | Average cost of performing SPCP tasks relative to industry mean level |
|---|---|---|---|---|---|---|---|
| | | | | ½*Mean | 2*Mean | 3*Mean | |
| | *Percent* | *Number* | *$ million* | *$1,000* | | | |
| Cattle slaughter | 3.70 | 230 | 32.3 | 89 | -101 | -261 | -66.5 |
| Hog slaughter | 9.16 | 307 | 32.3 | -957 | 1,041 | 1,810 | 597.4 |
| Poultry slaughter | 8.33 | 155 | 32.5 | -424 | 548 | 1,083 | 327.5 |
| Cured/ cooked pork | 5.53 | 117 | 12.5 | 257 | -273 | -460 | -155.2 |
| Sausage | 4.25 | 257 | 12.5 | -79 | 82 | 137 | 46.5 |
| Processed meat from animals | 2.17 | 288 | 12.5 | -27 | 28 | 47 | 15.9 |
| Processed meat from raw meat | 2.00 | 546 | 12.5 | -205 | 227 | 400 | 90.8 |
| Processed poultry | 3.95 | 129 | 12.5 | -254 | 247 | 390 | 137.8 |
| Average—all industries | 5.00 | | 19.3 | -237 | 263 | 510 | 156.2 |

[1] Negative numbers mean that costs are below the costs for plants at the industry mean level of percent-deficient SPCPs.
[2] Percent-deficiency is the industry average plant-level number of unperformed or poorly performed SPCPs divided by the total number of SPCPs.
[3] Mean plant cost is mean values published by Census of Manufacturers for all meat slaughter, meat processing, and poultry slaughter and processing plants. It is defined as value added plus meat and material input costs.

**Table 7.2—Projected HACCP costs based on estimated costs of various percent-deficient SPCP levels relative to the industry mean levels of percent-deficient SPCPs[1]**

| Industry | Average total plant costs[2] | HACCP non-compliance records[3] | Costs of HACCP tasks relative to the costs of a plant at the mean level of percent HACCP noncompliance records [4] | | | Average cost of performing HACCP tasks relative to industry mean level |
|---|---|---|---|---|---|---|
| | | | ½*Mean | 2*Mean | 3*Mean | |
| | *$ million* | *Percent* | *$1,000* | | | |
| Cattle slaughter | 32.3 | 2.38 | 170 | -193 | -496 | -126 |
| Hog slaughter | 32.3 | 1.90 | -1,827 | 1,977 | 3,439 | 1,135 |
| Poultry slaughter | 32.5 | 5.45 | -810 | 1,047 | 2,058 | 622 |
| Cured/cooked pork | 12.5 | 1.23 | 491 | -521 | -874 | -294 |
| Sausage | 12.5 | 1.39 | -151 | 157 | 260 | 88 |
| Processed meat from animals | 12.5 | 1.40 | -52 | 53 | 89 | 30 |
| Processed meat from raw meat | 12.5 | 1.40 | -392 | 434 | 760 | 172 |
| Processed poultry | 12.5 | 5.45 | -485 | 472 | 741 | 262 |
| Average—all industries | 19.3 | 2.13 | -450 | 500 | 969 | 297 |

[1] Negative numbers mean that costs are below the costs for plants at the industry mean level of percentage of HACCP noncompliance records tasks.
[2] Mean plant cost is mean values published by Census of Manufacturers for all meat and poultry slaughter and processing plants. It is defined as value added plus meat and material input costs.
[3] Percentage of HACCP noncompliance records is the average of the number of HACCP in noncompliance divided by the number of scheduled and performed tasks.
[4] Research Triangle Institute estimated the costs of compliance with HACCP tasks is about 1.90 times higher than the costs of complying with SPCP tasks. We multiplied this level of change in stringency times the estimated costs of SPCPs (table 7.1) to determine cost levels.

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# List of Tables

**Text tables**



**Appendix table**