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:

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

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:

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

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[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, α_{1k} measures the value of producing a particular attribute, α_{2k} indicates how a value attribute changes with changes in that attribute, α_{3kj} indicates how value changes with interactions with other types of value attributes, and α_{4ik} and α_{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 (β_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:

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

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, α_{1k}, gives the cost elasticity with respect to value attribute k at the sample mean. The coefficient on the second-order output term, α_{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 α_{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 α_{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-

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[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.

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[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

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[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.

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[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** (0.150)	0.050*** (0.015)	0.060*** (0.020)	0.013 (0.013)	-0.030 (0.020)	0.024 (0.041)	0.025 (0.020)	0.080** (0.038)
PLAB	0.105*** (0.016)	0.056*** (0.001)	0.056*** (0.003)	0.020*** (0.006)	-0.020** (0.009)	0.001 (0.003)	0.001 (0.002)	0.022*** (0.003)
PMEAT	0.797*** (0.200)		0.089*** (0.010)	0.063*** (0.005)	0.030*** (0.008)	0.001 (0.004)	-0.002 (0.002)	0.023*** (0.003)
PMAT	0.062*** (0.013)			0.053*** (0.005)	-0.011 (0.007)	0.001 (0.003)	-0.0002 (0.001)	0.004* (0.002)
PK	0.036* (0.020)				0.001 (n.a.)	-0.003 (0.004)	0.0012 (0.002)	-0.005 (0.003)
MIX	-0.051 (0.060)					-0.110 (0.010)	0.012* (0.007)	0.006 (0.010)
DEF	0.006 (0.030)						0.001 (0.004)	-0.001 (0.004)
Q (lbs)	0.857*** (0.050)							0.002 (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*** (0.011)	0.031*** (0.010)	0.029*** (0.008)	0.008* (0.005)	0.010 (0.010)	0.012** (0.006)	0.005** (0.002)	0.015*** (0.002)
PMEAT	0.700*** (0.012)		0.106*** (0.008)	0.098*** (0.005)	0.021*** (0.005)	-0.015** (0.007)	-0.005** (0.002)	0.009*** (0.003)
PMAT	0.120*** (0.009)			0.086*** (0.005)	0.004 (0.007)	-0.003 (0.005)	-0.001 (0.002)	0.003* (0.002)
PK	0.050* (0.014)				-0.015 (n.a.)	0.006 (0.008)	0.001 (0.003)	(0.003) (0.003)
MIX	0.009 (0.085)					-0.018 (0.020)	0.010* (0.007)	0.010 (0.017)
DEF	-0.032 (0.028)						-0.005 (0.006)	-0.005 (0.004)
Q (lbs)	0.962*** (0.021)							0.006 (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*** (0.008)	0.068*** (0.014)	0.071*** (0.009)	0.009 (0.006)	-0.006 (0.012)	0.003 (0.002)	0.006* (0.003)	0.029*** (0.004)
PMEAT	0.634*** (0.010)		0.155*** (0.011)	0.082*** (0.007)	-0.002 (0.007)	-0.004* (0.003)	-0.005 (0.004)	0.029*** (0.005)
PMAT	0.124*** (0.007)			0.081*** (0.006)	-0.008 (0.006)	-0.002 (0.002)	0.001 (0.003)	0.005 (0.003)
PK	0.047*** (0.007)				0.016 (n.a.)	0.003 (0.002)	-0.002 (0.003)	-0.005 (0.004)
MIX	0.046 (0.047)					0.007 (0.011)	0.007 (0.007)	0.002 (0.007)
DEF	-0.018 (0.033)						-0.007 (0.010)	-0.0003 (0.010)
Q (lbs)	0.819*** (0.038)							-0.020 (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*** (0.011)	0.071*** (0.014)	0.081*** (0.011)	0.037*** (0.011)	-0.026* (0.014)	0.0014 (0.0010)	0.020*** (0.005)
PMEAT	0.776*** (0.010)		0.136*** (0.012)	0.088*** (0.011)	0.033*** (0.011)	-0.0008 (0.0010)	0.020*** (0.005)
PMAT	0.056*** (0.012)			0.033** (0.014)	0.018 (0.014)	-0.0010 (0.0010)	-0.0055 (0.0050)
PK	0.036*** (0.013)				-0.025 (n.a.)	0.0004 (0.0010)	0.0055 (0.0050)
DEF	-0.003 (0.026)					-0.0002 (0.0040)	-0.001 (0.004)
Q (lbs)	0.950*** (0.024)						0.021 (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 (0.036)							
PLAB	0.178*** (0.006)	0.018** (0.007)	0.029*** (0.006)	0.030*** (0.006)	0.019*** (0.007)	0.006*** (0.001)	0.00038 (0.00100)	0.0137*** (0.0020)
PMEAT	0.613*** (0.006)		0.140*** (0.010)	0.144*** (0.009)	0.033*** (0.006)	0.0065*** (0.0010)	-0.00016 (0.00100)	0.010*** (0.002)
PMAT	0.165*** (0.006)			0.129*** (0.010)	-0.015** (0.006)	0.003*** (0.001)	-0.00002 (0.00100)	-0.0003 (0.0020)
PK	0.044*** (0.006)				0.001 (n.a.)	0.0035*** (0.0010)	-0.0002 (0.0010)	0.004 (0.003)
MIX	0.009 (0.023)					0.002 (0.006)	0.016 (0.025)	-0.005 (0.003)
DEF	-0.024 (0.020)						-0.004 (0.003)	-0.003 (0.003)
Q (lbs)	0.926*** (0.019)							0.035*** (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 (0.039)							
INPUT	0.119 (0.126)	-0.0078 (0.0230)	0.0032 (0.0270)	0.0007 (0.0130)	0.0039 (0.0260)	0.053 (0.262)	-0.096 (0.096)	0.033 (0.059)
PLAB	0.176*** (0.008)	0.075*** (0.015)	0.049*** (0.012)	-0.003 (0.006)	-0.023* (0.014)	0.005*** (0.002)	0.00095 (0.00200)	0.029*** (0.004)
PMEAT	0.624*** (0.009)		0.122*** (0.017)	0.088*** (0.009)	0.015 (0.012)	0.0055*** (0.0020)	-0.00005 (0.00200)	0.030*** (0.005)
PMAT	0.141*** (0.004)			0.089*** (0.011)	0.002 (0.008)	-0.0013 (0.0020)	-0.0001 (0.0010)	0.006*** (0.002)
PK	0.059*** (0.009)				0.006 (n.a.)	0.0018 (0.0020)	-0.0008 (0.0020)	-0.007 (0.005)
MIX	-0.081 (0.063)					-0.010 (0.009)	-0.0004 (0.0020)	-0.003 (0.008)
DEF	0.029 (0.032)						0.002 (0.006)	-0.009 (0.008)
Q (lbs)	0.945*** (0.042)							0.029 (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 (0.039)							
PLAB	0.217*** (0.007)	0.045*** (0.012)	0.040*** (0.007)	0.016*** (0.005)	0.011 (0.001)	0.006*** (0.002)	0.0001 (0.0010)	0.039*** (0.004)
PMEAT	0.499*** (0.006)		0.1553* (0.0090)	0.124*** (0.007)	0.0087 (0.0060)	0.006*** (0.002)	-0.0003 (0.0010)	0.031*** (0.003)
PMAT	0.208*** (0.004)			0.1407*** (0.0070)	-0.0007 (0.001)	-0.002 (0.001)	-0.0002 (0.0010)	0.014*** (0.002)
PK	0.076*** (0.006)				-0.019 (n.a.)	0.002 (0.002)	0.0004 (0.0010)	-0.006** (0.003)
MIX	0.015 (0.051)					0.007 (0.011)	-0.003 (0.003)	0.015*** (0.005)
DEF	-0.009 (0.025)						-0.0006 (0.0040)	-0.002 (0.005)
Q (lbs)	0.858*** (0.024)							0.044** (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 (0.061)						
PLAB	0.236*** (0.015)	0.083*** (0.021)	0.107*** (0.016)	0.052*** (0.010)	-0.028* (0.016)	0.002 (0.002)	0.023*** (0.005)
PMEAT	0.522*** (0.016)		0.164*** (0.019)	0.116**** (0.010)	0.059*** 0.013)	-0.001*** (0.003)	0.010 (0.006)
PMAT	0.198*** (0.018)			0.085*** (0.009)	-0.021** (0.010)	0.001 (0.003)	-0.011** (0.005)
PK	0.044** (0.019)				-0.011 (n.a.)	-0.002 (0.003)	0.024*** (0.006)
DEF	-0.029 (0.045)					0.0002 (0.0070)	-0.014** (0.006)
Q (lbs)	1.013*** (0.042)						0.078*** (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.