Structural Change in the Meat and Poultry Industry and the Pathogen Reduction Hazard Analysis Critical Control Point Rule

By

Michael Ollinger

Economic Research Service, United States Department of Agriculture

For presentation at the American Agricultural Economics Association Meetings, 2008

The judgments and conclusions herein are those of the authors and do not necessarily reflect those of the U.S. Department of Agriculture. The authors are responsible for all errors.

Abstract

By

Michael Ollinger

Structural Change in the Meat and Poultry Industry and the Pathogen Reduction Hazard Analysis Critical Control Point Rule

Some researchers, such as Antle (2000), have provided preliminary evidence suggesting that the Pathogen Reduction Hazard Analysis Critical Control Point rule would favor large plants over small ones and raise production costs, but others, such as the Food Safety Inspection Service, assert that the regulation would little effect. This paper uses plant-level micro-data covering the 1987-2002 from the U.S. Bureau of the Census and a translog cost function to estimate long-run costs in the meat and poultry industry in order to evaluate these conflicting arguments. Five distinct industries are considered: cattle, hog and chicken slaughter and prepared pork products and sausage-making. Results suggest that costs rose in the cattle and hog slaughter and prepared pork products industries and the cost shares of meat declined and of labor and capital rose. However, there is little evidence that events over the period favored large or small plants.

Structural Change in the Meat and Poultry Industry and the Pathogen Reduction Hazard Analysis Critical Control Point Rule

The cost of food safety regulation under the Pathogen Reduction Hazard Analysis Critical Control Point (PR/HACCP) rule has been controversial. Some experts contend that costs are too high and that it favors large plants over small ones. Others believe that costs are minimal and equitably distributed. This debate has generated considerable interest.

Prior to promulgation of the PR/HACCP rule, a Federal Register announcement by the Food Safety Inspection Service (FSIS) projected costs of 0.12 cents per pound. A separate study (Knutsen et al.) anticipated much higher costs. Later, econometric analyses (Antle; Nganje and Mazzocco; Ollinger and Mueller) estimated costs of 1.3, 0.04 to 43.5, and 0.9 cents per pound, and estimates based on post-PR/HACCP data from a national survey (Ollinger, Moore, and Chandran) and regional surveys (Boland, Peterson-Hoffman, and Fox.; Hooker, Nayga, and Siebert) indicated costs of 0.7, 0.9, and 2 to 20 cents per pound, respectively. Antle, Ollinger and Mueller, and Hooker, Nayga, and Siebert also showed that regulation favored large plants over small ones and Antle indicated that regulation favored poultry over beef.

The econometric studies are based on data existing prior to enactment of the PR/HACCP rule and the survey data provide short-run accounting cost information. The purpose of this paper is to evaluate the impact of the PR/HACCP rule on long-run costs and industry structure in five meat and poultry industries. In the analysis, pre- and post-PR/HACCP data from the 1987, 1992, 1997, and 2002 Censuses are used to estimate long-run costs for five separate meat and poultry industries. By comparing cost changes over 1987-2002, it should be possible to see whether long-run costs were significantly affected by the PR/HACCP rule of 1996. Additionally, a comparison of costs of different types of plants over time enables one to determine whether some groups, e.g. large plants or poultry producers, were favored over others, e.g. small plants and meat producers.

To capture changes in costs over time and across different groups, it is necessary to use a model that is flexible enough to account for plant-level differences in input and output mixes, type of plant ownership, and changes over time. For this reason, the paper uses a translog cost function similar to that used by MacDonald et al. (1999) and Ollinger, MacDonald, and Madison (2000) who examined technological changes over 1962-92. Other researchers who examined long-run costs include Morrison-Paul (1999a, 1999b), Melton and Huffman (1995), and Ball and Chambers (1982). These other researchers used aggregated data and none examined regulatory changes or the time period that is examined here.

The Census year of 1987 was chosen as the reference year because the first food safety regulation was enacted in 1989 and was followed by another regulation in 1993. FSIS, then, promulgated the PR/HACCP rule of 1996 – a regulatory framework that FSIS has been using for subsequent regulatory changes. The PR/HACCP rule was phased in over several years to give plants time to prepare to meet its provisions, becoming fully effective until January 31, 2000. This final deadline to meet the requirements of the PR/HACCP rule and the first food safety regulation of 1989 provide bookends representing the beginning and ending of major food safety initiatives and around which a test showing the effects of the food safety legislation must be crafted. Since the last Census year prior to the beginning of the major food safety regulations was 1987, the last Census year before the PR/HACCP rule of 1996 was 1992, and the first Census year after the phase-in of the PR/HACCP rule was 2002, costs in 2002 are compared to those in 1987 and 1992.

The Regulatory Environment: 1987-2002.

As reported in Ollinger and Mueller (2003), food safety as a public health threat became increasingly apparent in the 1980s as outbreaks of E coli: 0157H7 and *Listeria monocytogenes* made the news. For example, Farber and Peterkin (1991) reported that *Listeria monocytogenes* caused the most deaths ever recorded for a foodborne illness in Chicago when 142 known cases resulted in 48 deaths in 1985. In the aftermath of this and other deadly outbreaks, FSIS declared L*isteria monocytongenes* to be an adulterant in cooked meat or poultry and assigned it a zero tolerance in 1989 (Peter Perl, Magazine, January 16, 2000). Similarly, FSIS established a zero tolerance level in ground hamburger in 1994 after an outbreak of foodborne illnesses caused by

E coli: 0157H7 at a Jack-in-the-Box resulted in 4 deaths and 500 illnesses. To support these policies, FSIS conducted surveillance testing of cooked meat and raw hamburger in the marketplace.

FSIS also began to seriously consider the use of a Hazard Analysis 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 (Ollinger and Mueller, 2003). After a well-scrutinized regulatory process, FSIS promulgated the final PR/HACCP rule on July 25, 1996 and completely phased it in by January 31, 2000. The rule mandated that (1) all meat and poultry slaughter and processing plants had to develop, implement, and take responsibility for standard sanitation operating procedures (SSOPs) and a HACCP process control program, (2) all slaughter plants must conduct generic *E. coli* microbial tests to verify control over fecal matter, and (3) all slaughter and ground meat plants comply with *Salmonella* standards under a program established and conducted by FSIS. Large plants (more than 500 workers) had to comply with the regulation by January 31 of 1998; small and very small plants (10-500 and fewer than 10 employees with sales less than $2.5) had until January 31 in 1999 and 2000 to comply.

The SSOPs mandated under PR/HACCP were in addition to the SSOPs mandated by FSIS under the former regulatory regime. Plants still had to meet these and other previously mandated requirements. SSOPs are cleaning and sanitizing tasks that enhance pathogen control; facility control tasks require plants to monitor and control rodent infestations, dripping condensation, and other sources of harmful contaminants. See Ollinger and Mueller (2003) for a complete description of the regulatory regime prior to the PR/HACCP rule.

HACCP controls differ markedly from SSOPs in that plants design and implement their own HACCP plans under the guidance of FSIS. More importantly, HACCP systems serve as monitoring devices that call for action if food safety deviates from acceptable limits. Plants correct deviations from acceptable food safety limits in any manner that they choose.

The PR/HACCP rule did not explicitly require any new equipment or investment. However, plants did have to bring their food safety process control technologies up to FSIS standards and may have had to make additional investments in labor and capital equipment to adhere to their HACCP plan and comply with the generic *E coli* and *Salmonella* standards. For example, plants may have invested in steam vacuum equipment to remove fecal matter.

A Model of Plant Costs

Of central interest of this paper are the effects of food safety regulation on long-run plant costs. These costs are derived from investment decisions and permanent changes in operating practices in response to regulatory changes and should be reflected in a long-run shift in plant costs. In this type of analysis, it would be ideal if the costs of plants affected by regulation could be compared against a control group of plants that was not affected. However, meat and poultry food safety regulation affected all plants, making it necessary to use an alternative approach.

The analysis proceeds with a temporal comparison of total costs before and after promulgation of the PR/HACCP rule. One potential problem is deciding when the regulatory period actually begins and when it is completely effective. Plants know that regulation is imminent before it is mandated and many would be expected to begin making adjustments prior to actual promulgation of the regulation. Since FSIS released a preliminary HACCP rule in 1995, many plants likely began making adjustments in 1994 in anticipation of the regulation. Other plants would wait until the last possible day to become completely compliant with the new regulation. That last day was January 31, 2000 when all very small plants had to comply with PR/HACCP. Thus, it is appropriate to compare cost in 2002 to those in 1992 to ascertain the impact of the PR/HACCP rule. Further, since a major pathogen-related food safety regulation was mandated in 1989 when FSIS established a zero tolerance *for Lysteria monocytogenes* , it is necessary to compare the cost in 2002 to the cost in 1987 to evaluate the impact of all food safety regulations.

The analysis links the cost of production (C) to meat or poultry, labor, and capital input prices (**P**), pounds of output (LB) and controls for key differences in inputs and outputs across plants. These control variables include a continuous output mix variable (Q), a vector of dummy-variable meat input and output characteristics **(K)**, and a dummy variable for plants owned by firms that own multiple plants (M). A vector of time dummy variables (**T**) is also included to account for temporal changes.

C = C (**P**, LB, Q, **K**, M, **T**)

In the analysis, competitive factor markets are assumed and a translog cost function is used. In a translog cost function, all of the continuous variables -- C, P, LB, and Q -- are transformed to natural logarithms. Additionally, following standard practice, symmetry and homogeneity of degree one was imposed on the model, and factor demand (cost share) equations, which are the derivatives of the cost function with respect to each factor price, are estimated together with the cost function in a Seemingly Unrelated Regression (SUR) technique. Note that is necessary to drop one factor demand equation, in this case capital, because its coefficients are implied by the other two and there is a requirement that cost shares sum to one. Finally, all variables are normalized by their sample means, so the first order factor price coefficients (β_i) can be interpreted as cost shares at sample means.

The model is expressed as follows:

$$(2)\ln C = \alpha_0 + \sum_i \beta_i \ln P_i + \tfrac{1}{2}\sum_i \sum_j \beta_{ij} \ln P_i * \ln P_j + \gamma_{lb} \ln LB_{LB} + \tfrac{1}{2}\gamma_{LBLB}(\ln LB)^2$$

$$+ \sum_i \gamma_{LBi} \ln LB * \ln P_i + \delta_Q \ln Q + \frac{1}{2}\delta_{QQ}(\ln Q)^2 + \sum_i \delta_{Qi} \ln Q * \ln P_i + \delta_{QLB} \ln Q * \ln LB$$

$$+ \sum_i \eta_i K_i + \sum_i \sum_j \eta_{ij} K_i * \ln P_j + \sum_i \eta_{iLB} K_i * LB + \sum_i K_i * Q + \delta_M M + \sum_i \delta_{Mi} M * \ln P_i$$

$$+ \delta_{MLB} M * LB + \sum_j \eta_j T_j + \sum_j \sum_i \eta_{ij} T_j * P_i + \sum_j \eta_{LBi} T_j * LB + \varepsilon$$

where total cost (C) is the sum of labor, meat, and capital input expenses. The price of labor (P_{labor}) is total employee wages and benefits divided by total employees. The meat input price (P_{meat}) is the cost of the live-weight of animals for slaughter plus any packed fresh or frozen meat or poultry. For slaughter plants, fresh or frozen meat may be zero; for processing plants, live-weight is zero. The price of capital ($P_{capital}$) follows Allen and Liu and has two components. The first is the weighted sum of machinery and structures rental values, where the weights are their respective book values. Annual capital rental prices are calculated by the Bureau of Labor Statistics separately for buildings and for machinery in the two-digit Food and Kindred Products Industry Group, using methods described in chapter 10 of the BLS Handbook of Methods, Bulletin 2490 and on the Multifactor Productivity Website (stats.bls.gov/mprhome.htm). The measures include components for depreciation, changes in asset prices, and taxes. Since the weights (book values of structures and equipment) differ across plants, capital prices are plant-specific. The second component adds the ratio of new investment to beginning of year assets, as a way to capture costs of adjustment.

Output (LB) is defined as pounds of meat products (all categories in SIC 201). The continuous output mix variable (Q) is defined only for cattle, hog, and chicken slaughter. For cattle slaughter, Q equals 1 - share of boxed beef; for hog slaughter Q is 1-share of further processed pork products; for chicken Q is 1 - share of luncheon meats and other processed poultry - share of roasters. The characteristics vector (K) also varies by industry. Hog slaughter has none of these characteristics variables and cattle slaughter has only one. The variable K_1 for cattle is defined as one if share of input cattle is less than 0.75 and 0 otherwise; for chicken slaughter, K_1 is one if share packed meat greater than 0 and zero otherwise; for pork processing, K_1 is one if 1 - share of sausages - share of cooked/boiled ham > 0 and zero otherwise; for sausage-making, K_1 is one if more than 90 percent of output is a product other than cooked or fresh sausage and zero otherwise. The variable K_2 for chicken slaughter equals one if non-chicken input > 0 and zero otherwise; for processed pork, K_2 is one if the plant used any processed meat inputs and zero otherwise; for sausage-making, K_2 is one if more than 80 percent of inputs comes from fresh or frozen meat and zero otherwise. Note, fresh or frozen meat and processed meat inputs are primary ingredients for pork processors and sausage-makers.

The remaining variables are defined as follows. The dummy variable for plants owned by multi-plant firms (M) equals one if the plant is owned by a multi-plant firm and zero otherwise. The time variable NINE2 is one if the year equals 1992 and zero otherwise; the time variable NINE7 is one if the year equals 1997 and zero otherwise; the time variable TWO02 is one if the year equals 2002 and zero otherwise.

Scale Economies

Major cost reductions have occurred in the meat and poultry slaughter industries through the realization of economies of scale (MacDonald et al., 1999; Ollinger, MacDonald, and Madison, 2000). Scale economies are measured at the plant level by estimating the elasticity of total cost with respect to changes in output—the derivative of the cost function with respect to output (equation 3):

$$3) \qquad \varepsilon_{CM} = \frac{\partial lnC}{\partial lnLB} = \gamma_{LB} + \gamma_{LB}\gamma_{LB}\ln LB + \sum_i \gamma_{LBi}\ln P_i + \delta_{QLB}\ln Q + \sum_i \eta_{iLB}K_i + \delta_{MLB}M + \sum_J \eta_{LBi}T_j$$

where values of the cost elasticity, ε_{CM}, that are less than 1 show scale economies and values above 1 show scale diseconomies. For example, a value of .90 indicates that costs increase by 0.9 percent for every 1.0-percent increase in pounds of meat produced (average costs fall as the pounds of output rises). Because the variables are all divided by their sample means before estimation, the first-order term, $\gamma_{LB,}$ can be interpreted as estimated scale economies for plants at the sample mean size.

Equation 3 allows the estimated cost elasticity to vary with time, plants owned by multi-plant firms, factor prices, and characteristics. The parameter, γ_{LB} , shows how the elasticity varies with plant output; the parameters on the factor price terms (γ_{LBi}) show how scale economies vary with factor prices. The other coefficients illustrate how scale economies vary with time, plants owned by multi-plant firms, and characteristics.

Of particular interest is how economies of scale changed over time. In this case, multi-plant and characteristics variables are set equal to zero and factor prices are set equal to sample mean prices. If η_{LBj} T_j is greater than zero, then the economies of scale parameter rises over 1987 levels, suggesting a decline in scale economies, and vice versa for η_{LBj} T_j less than zero. Similarly, if η_{LBj} T_j (j=1992) is greater than η_{LBj} T_j (j=2002), then the scale parameter rises over 1992 levels, suggesting a decline in scale economies, and vice versa for η_{LBj} T_j (j=1992) less than $\eta_{LBj}T_j$ (j=2002).

Data

All variables, except capital rental prices are derived from the Longitudinal Research Database (LRD) maintained at the Center for Economic Studies of the U.S. Census Bureau. Only data from Census years, starting in 1987 and occurring every five years through 2002, were used, yielding a dataset that includes all plants producing meat or poultry products (SIC 201) over 1987-2002. Plants within this broad dataset were then grouped into five industries with similar technologies: cattle, hog, and chicken slaughter and prepared pork products, and sausage-making. The Census year of 1987 is the starting point because this is the last Census before FSIS mandated a zero tolerance for *Listeria monocytogenes* in 1989, the first of a series of important food safety regulations imposed by FSIS. The Census year of 2002 is the last year because it is the first Census year after the final phase-in of the PR/HACCP rule.

The LRD covers all plants with more than 20 employees and a sample of those with less than 20. There were 449 cattle slaughter, 354 hog slaughter, 521 chicken slaughter and processing, 312 prepared products, and 630 sausage-making plant observations that have the complete complement of data.

LRD notes each plant's ownership and location, and provides detailed information on employment, wages and benefits, building and machinery asset values, new capital expenditures, energy use and costs, the physical quantities and dollar sales of seven digit SIC code products, and the physical quantities and dollar expenses of detailed materials purchases. Because the file contains data on individual plants over several Censuses, researchers can make comparisons for different plants during the same year, and can also trace changes in product and input mixes, costs, and concentration over time.

Estimation and Model Selection

The model outlined in equation (2) is quite general, so a Gallant-Jorgenson (G-J) likelihood ratio test (a chi-square test) is used to choose the specific model best able to explain plant production costs from among a set of restrictive models. Table 1 summarizes the model number and description, model tests, test variable, and the relevant statistical data for cattle and hog slaughter, chicken slaughter and processing, prepared pork, and sausage-making. The statistical data include the G-J value, the number of parameters estimated in the cost function, the number of restrictions, and the model chi-square.

Hypotheses are tested by comparing a reference model (the least restrictive model --- model II in the first comparison) to a test model in which that variable is excluded (models I, III, IV, and V in table 1). If the difference in the G-J statistic exceeds the value at which the difference becomes significant, then the hypothesis that the test variable does not affect costs is rejected and the variable is retained in the model.

In the tests shown in table 1, one variable other than price or output was removed from the least restrictive model II. Those tests showed that the multi-plant dummy variable (M) is not significant for cattle slaughter and the time dummy variable (T) is not significant for hog slaughter and prepared pork products. Both of these variables are included in the reported results, however, because they do contribute to model fit and they are essential for subsequent simulations. A number of other model tests were also conducted but not reported here. None of these model tests contradicted our findings for the best fitting models. Those best models are: P,LB,Q,K,M,T for cattle slaughter, P,LB,Q,M,T for hog slaughter, P,LB,Q,K,T for chicken slaughter and processing, and P,LB,K,M,T for prepared pork and sausage-making.

Results

Cost function results for all industries are given in table 2. R^2 values given at the bottom of the table are comparable to those in other cost studies. Tests for monotonicity indicated no violations of that condition.

Notice that the cost function has no measure for the costs of materials. We dropped this term because it proved to be unreliable. Census data give a value for total materials and supplies (this includes meat inputs) separate values for only supplies and packing materials and meat. For years prior to 1996, the value for total materials equaled that for meat and supply and packing material inputs, but, for years after 1996, the same identity did not always hold. Since supplies and packing materials were missing from some plants in all industries, the inaccuracy of the identity was likely due to reporting errors, so the materials term was dropped, leaving a three factor cost model similar to that by Antle (2001).

The parameters on the first order price variables give the share of costs comprised of that factor in 1987 at the sample mean size plant, meaning that the labor cost share for cattle slaughter is 4.3 percent; the range of labor cost shares for all industries vary from that for cattle to 17.6 percent for sausages. Conversely, the meat share declines from 94.4 for cattle slaughter to 75.8 percent for sausage-making. The capital cost share is quite small, equaling one minus the meat and labor cost shares.

The labor shares for cattle and hog slaughter are about half the size of those reported in MacDonald et al. (1999) et al. while the meat shares for these two industries are correspondingly larger. Factor shares for chicken slaughter are comparable to shares reported in Ollinger, MacDonald, and Madison (2000). The differences in cattle and hogs may be due to a larger percentage of small plants in this study than in MacDonald et al. (1999). Recall that the dataset used here contains more small plants than was possible in MacDonald et al. (1999) because FSIS provided meat input and production output data for several plants that lacked those data.

The interaction terms show how elasticities and cost shares vary with movement away from sample means. The interaction of the price of labor with output shows that the labor shares decline by 1.2 to 3.1 percent and the meat shares rise by 0.9 to 3.6 percent with each 100 percent change in output in all five industries. Since output mix is held constant, these changes suggest better use of labor as meat output rises. Of particular importance to this study are the interactions of the price of labor and output with the time dummy variables. The price interactions show how the labor and meat shares varied over time and the output interaction terms shows how economies of scale might have changed.

Labor, capital, and meat cost shares changed dramatically over time. Table 2c shows the net change in labor share of costs for cattle, hog, and chicken slaughter and sausages. Hog slaughter had the smallest change in the labor share from 1992 levels. The change from 1987 to 1992 was 2.8 (the parameter on $NINE2*P_{Labor}$) and to 2002 was 4.6 (the parameter on $TWO02*P_{Labor}$), giving a net change of 1.8 percent over 1992-2002. Sausage-making had the largest change in labor share. The change to 1992 was 1.8 percent and to 2002 was 5.8 percent in 2002, giving a net change of 4.0 percent. The net changes for the cattle and chicken slaughter were 3.1 and 2.1 percents. There was little change for prepared pork products.

Net changes over 1992-2002, for capital shares were larger than for labor shares, varying from a minimum increase of 3.3 percent in hog slaughter (0.024 to 0.057) to a maximum of 6.9 percent in sausages (0.025 to 0.094). Meat shares fell substantially in all industries, ranging from a minimum decline of 5.1 percent in hog slaughter (-0.052 to -0.103) to a maximum decline of 10.9 percent in sausages (-0.043 to -0.152) over 1992-2002.

The changes in factor shares could have two sources. First, there has been a long-term trend in the meat and poultry industries from the production of carcasses and other low-value products to higher-value items requiring more processing, such as processed meats, ready-tocook boneless meat cuts, etc. More processing typically means more labor and capital inputs and fewer meat inputs.

The other force affecting factor shares was the PR/HACCP rule of 1996 and the increased public scrutiny of food safety issues that started in the early 1990s and continues to this day. That focus on food safety led to a government-mandated increase in industry effort devoted to food safety and greater demands from major meat buyers that suppliers provide safe meat products. These demands are met with greater cleaning intensity and production precautions that require additional labor and capital inputs.

Policy-makers have a strong interest in knowing whether changes affecting the industry in 1990s favored large or small plants. Recall that the coefficient on the output terms indicates economies of scale at sample mean prices and output, i.e. whether costs were declining for plants at the sample mean size. Since the first order coefficient for output varies from 0.692 to 0.890, there are sizeable economies of scale at sample mean prices. The coefficients for cattle and hog slaughter reported here (0.890 and 0.857) are somewhat smaller than those reported in MacDonald et al. (1999) -- 0.932 and 0.926 for cattle and hogs. The chicken slaughter coefficient reported here is similar in value to the coefficient provided by Ollinger, MacDonald, and Madison (2000).

Consider how economies of scale changed over time. The coefficients on the interaction of the time dummy variables and output indicate changes in economies of scale since 1987 and differences between the interaction term for 2002 and 1992 illustrate changes over that time span. The interaction of output and the time dummy variable for 2002 is negative in all cases but significant only for hog slaughter, suggesting modestly greater economies of scale relative to 1987. However, the difference between 1992 and 2002 is positive in all cases except hog slaughter, suggesting weaker economies of scale for four industries for that period. Weaker economies of scale mean that small plants are at less of a cost disadvantage relative to their larger competitors.

The multi-plant dummy variable (MULTI in table 2) is significant and positive in all industries except chicken slaughter, which is comprise of mainly of plants owned by multi-plant firms. Of particular interest is the coefficient on the interaction of the multi-plant dummy variable on output. This interaction term shows that plants owned by multi-plant firms had significantly weaker economies of scale since the coefficient on the multi-plant variable interacted with output is positive, ranging from 0.069 to 0.162 for hog slaughter, prepared pork products, and sausages.

The continuous output mix term (Q) and Characteristics 1 and 2 (K) are control variables that account for differences in input and output mixes. Past research had suggests that comparable variables significantly affected costs. Q equals one minus the share of boxed beef for cattle, one minus the share of processed pork for hog slaughter, and one minus share of processed poultry minus roasters for chicken slaughter. Each of these variables are shares of output requiring less effort, thus, as reported in table 2a, their coefficients should be and are negative. Characteristics 1 and 2 are control variables to which we have no prior expectations.

Changes in Costs over Time and for Different Scale Plants

Changes in economies of scale give some indication how cost structure may have changed over the 1987-2002 period. To get a slightly different view, we examine price changes over time for plants with sizes equal to one-half and twice the sample means.

Antle (2001) separated slaughter plants into large and small categories and then examined cost effects. In our case, we separate plants into those owned by multi-plant firms and those owned by single-plant firms because our cost model shows a significant difference between the two in all cases except cattle slaughter. One noticeable difference is that plants owned by single-plant firms were smaller than those plants owned by multi-plant firms. There also appeared to be differences in product mixes. Additionally, parameter estimates showed substantial differences in initial conditions (the intercept) and the economies of scale parameter.

The analysis proceeded in the following way. First, two different size plants were chosen to provide a comparison between a relatively small and a relatively large plant. Although any two sizes could be used, sizes at one-half and twice the sample mean were used. The same sizes were used for plants owned by either single- or multi-plant firms. Second, costs were estimated for each year – 1987, 1992, 1997, and 2002 – for plants owned by both single and multi-plant firms. Prices and continuous output mix variable were set equal to sample mean values and the characteristics dummy variables were set equal to zero. Third, all costs for plants owned by single- or multi-plant firms were normalized relative to costs of plants owned by single- or multi-plant firms at one-half the sample mean size in 1987. Thus, for plants owned by single-plant firms, the estimated costs for all plants owned by single-plant firms at one-half or twice the sample mean size for all years were divided by the estimated cost of a 1987 plant with a size equal to one-half the sample mean size. The resulting number is an index that shows how costs change over time and by size relative to a plant with a size equal to one-half the sample mean in 1987. Values that are greater than one indicate a cost greater than the cost in 1987 for a plant at one-half the sample mean size and owned single-plant firm. Values less than one suggest costs are less than those of a plant at one-half the sample mean size and owned by single-plant firm in 1987. The same procedure was followed for plants owned by multi-plant firms.

Table 3 shows that costs were higher in 2002 than in 1987 in all four cases for all industries except sausage-making. There was little change in costs in sausage-making. The picture changes when comparing costs in 2002 to those in 1992. For cattle and hog slaughter, costs in 2002 were higher than those in 1992 in three of four cases and for chicken slaughter and sausage-making costs in 1992 were higher than 2002. For prepared pork, costs in 1992 were lower than those in 2002 for all cases. Taken together, the trends suggest no change in costs over time for chicken slaughter and sausage-making plants, but substantial changes for prepared pork. The trends are less certain for cattle and hog slaughter but did rise modestly.

To see whether the PR/HACCP rule affected small plants more than large ones, the cost index for large plants (twice sample mean) was divided by the index for small plants (one-half sample mean) for both plants owned by single and multi-plant firms and then examined changes over 1987-2002. If economies of scale favored large plants, then there should be a progressive decline in the ratios. Results (table 4) show very little change. A comparison of 1987 to 2002 shows very slight or no declines in the large plant to small plant ratio in all industries except hog slaughter. A comparison of 1992 to 2002, however, shows declines only in cattle slaughter. All other industries had increases in their ratios.

Conclusions

Combined, these results suggest that the PR/HACCP rule caused increases in the labor and capital shares of costs, a decline in the meat share of costs, and increased long-run costs in three industries -- cattle and hog slaughter and prepared pork products. Except for cattle slaughter, however, there was little favoritism shown toward large plants. Taken together, these results suggest only a modest impact of the PR/HACCP rule on plant costs and long-run industry structure.

References

References

Antle, John M. “No Such Thing as a Free Lunch: The Cost of Food Safety Regulation in the Meat Industry,” *American Journal of Agricultural Economics* 82 (2000): 310-22.

Ball, V.E., and R. Chambers. "An Economic Analysis of Technology in the Meat Products Industry." *American Journal of Agricultural Economics* 62 (1982): 699-709.

Boland, Michael, Dana Peterson-Hoffman, and J.A. (Sean) Fox. “Postimplementation Costs of HACCP and SPCPs in Great Plains Meat Plants,” *Journal of Food Safety* 21 (2001):195-204.

Bureau of the Census. *Longitudinal Research Database*. (Washington, D.C.: U.S. Bureau of the Census, 1997).

Farber, J.M. and P. I. Perterkin. “*Listeria monocytogenes*, a Food-Borne Pathogen,” *Microbiological Reviews.* (September 1991) pp. 476-511.

Hooker N.H., R. M. Nayga Jr, and J. W. Siebert. “The Impact of HACCP on Costs and Product Exit.” J. Agr. Appl. Econ. 34 (2002):165-174.

Knutson, Ronald D., H. Russell Cross, Gary R. Acuff, Leon H. Russell, Fred O. Boadu, John P. Nichols, Suojin Wang, Larry J. Ringer, Asa B. Childers, Jr., and Jeff W. Savell. *Reforming Meat and Poultry Inspection: Impacts of Policy Options.* IFSE Working Paper 95-1, AFPC Working Paper 95-9; Institute for Food Science and Engineering, Agricultural and Food Policy Center, Center for Food Safety, Texas A&M University System, April, 1995.

MacDonald, J. M., Ollinger, M., Nelson, K., and Handy C. Consolidation in U.S. Meat Packing. AER- 785. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service, 2000.

Melton, B. E. and W. E. Huffman. “Beef and Pork Packing Costs and Input Demands: Effects of Unionization and Technology. American Journal of Agricultural Economics 77 (1995): 471-485.

Morrison-Paul, C. J. Cost Structure and the Measurement of Economic Performance: *Productivity, Utilization, Cost Economics, and Related Performance Indicators* Boston, MA: Kluwer Academic Publishers, 1999a.

Morrison-Paul, C. J. "Scale Effects and Mark-Ups in the U.S. Food and Fibre Industries: Capital Investment and Import Penetration Impacts." *The Journal of Agricultural Economics* 55 (1999b): 64-82.

Muth, M., Wohlgenant, M., and Karns, S.A., "Did the Pathogen Reduction and Hazard Analysis and Critical Control Points Regulation Cause Slaughter Plants to Exit," *Review of Agricultural Economics* 29, 3 (2007): 596-611.

Nganje, William and Michael A. Mazzocco. "Economic Efficiency Analysis of HACCP in the U.S. Red Meat Industry." *Economics of HACCP: Costs and Benefits*. L. J. Unnevehr, ed., pp. 241-66. St. Paul, MN: Eagan Press, 2000.

Ollinger, Michael, Danna Moore, and Ram Chandran. *Meat and Poultry Plants' Food Safety Investments: Survey Findings.* Washington, DC: U.S. Department of Agriculture, Economic Research Service, Technical Bulletin 1911, 2004.

Ollinger, Michael and Valerie Mueller. *Managing for Safer Food: The Economics of Sanitation and Process Controls in Meat and Poultry Plants.* Washington, DC: U.S. Department of Agriculture, Economic Research Service, Agricultural Economic Report 817, 2003.

Ollinger, M., MacDonald, J. M., and Madison, M, *Structural Change in U.S. Chicken and Turkey Slaughter*, AER- 787. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service, 2000.

Perl, Peter. "Outbreak: Poisoned Package," *Washington Post Magazine.* January 16, 2000, pp, 7-27.

Table 1: Likelihood Tests comparing significance of plant characteristics.

Industry	Model	Description	G-J Value	Parameters Estimated	Test	Restric-tions	Test Variable	Model Chi-Square
Cattle Slaughter	I	P,LB[1]	979	10	-	-		-
	II	(P,LB,Q,K,M,T)[2]	913	37	I vs II	27	All	66^{***}
	III	(P,LB,Q,K,M)[3]	935	25	II vs. III	12	Time	22^{**}
	IV	(P,LB,Q,K,T)[4]	922	32	II vs. IV	5	Multi	9
	V	(P,LB,M,T)[5]	961	26	II vs. V	11	Char.[6]	48^{***}
Hog Slaughter	I	P,LB[1]	800	10	-	-		-
	II	(P,LB,Q,M,T)[2]	739	31	I vs II	26	All	61^{**}
	III	(P,LB,Q,M)[3]	748	19	II vs. III	12	Time	9
	IV	(P,LB,Q,T)[4]	763	27	II vs. IV	4	Multi	24^{***}
	V	(P,LB,M,T)[5]	756	26	II vs V	5	Char.[6]	17^{***}
Chicken Slaughter	I	P,LB[1]	1443	10	-	-		-
	II	(P,LB,Q,K,T)[2]	1344	35	I vs II	25	All	99^{***}
	III	(P,LB,Q,K)[3]	1378	23	II vs. III	12	Time	65^{***}
	IV	(P,LB,T)[4]	1415	22	II vs. IV	13	Char.[6]	28^{**}
Prepared Pork	I	P,LB[1]	788	10	-	-		-
	II	(P,LB,K,M,T)[2]	657	34	I vs II	24	All	131^{***}
	III	(P,LB,K,M)[3]	677	22	II vs. III	12	Time	20
	IV	(P,LB,K,T)[4]	693	30	II vs. IV	4	Multi	36^{***}
	V	(P,LB,M,T)[5]	710	26	II vs. V	8	Char.[6]	53^{***}
Sausage	I	P,LB[1]	1760	10	-	-		
	II	(P,LB,K,M,T)[2]	1633	34	I vs II	24	All	127^{***}
	III	(P,LB,K,M)[3]	1691	22	II vs. III	12	Time	69^{***}
	IV	(P,LB,K,T)[4]	1643	30	II vs. IV	4	Multi	117^{***}
	V	(P,LB,M,T)[5]	1686	26	II vs. V	8	Char.[6]	74^{***}

1 Model I: base model consisting of prices (P) and pounds of output (LB) and denoted (P,LB).

[2] Model II: Adds time (T), multi-plant (M), and continuous and discrete characteristics (Q and K) to (P,LB) to make (P,LB,Q,K,M,T for cattle slaughter). Others may add K or Q. Chicken does not add M.

[3] Model III: Removes T from II to make (P,LB,Q,K.M for cattle slaughter). Others may vary.

[4] Model IV; Removes M from II to make (P,LB,Q,K,T for cattle slaughter). Others may vary.

[5] Model V; Removes Q and K from II to make (P,LB,M,T). Other may vary.

[6] Characteristics (Char) vary by industry.

Table 2a: First-order parameter estimates of the costs of producing meat and poultry products in five meat and poultry industries.

Variable Name	Variable	Cattle	Hog	Chicken	Prepared Pork	Sausages
Intercept		-0.114 (0.06)	0.010 (0.08)	0.056* (0.031)	-0.259*** (0.096)	-0.068 (0.072)
NINE2	T	0.047 (0.05)	0.123** (0.062)	0.100** (0.04)	-0.067 (0.091)	0.015 (0.042
NINE7	T	0.036 (0.056)	0.120** (0.072)	0.060 (0.042)	-0.006 (0.088)	-0.028 (0.047)
TWO02	T	0.123** (0.056)	0.188*** (0.069)	0.068* (0.042)	0.084 (0.096)	-0.006 (0.049)
MULTI	M	0.181*** (0.064)	0.237*** (0.083)	-	0.371*** (0.095)	0.257*** (0.052)
P_{labor}	P	0.043*** (0.006)	0.066*** (0.008)	0.167*** (0.005)	0.133*** (0.013)	0.176*** (0.011)
P_{meat}	P	0.944*** (0.01)	0.910*** (0.015)	0.784*** (0.008)	0.828*** (0.017)	0.758*** (0.017)
$P_{capital}$	P	0.013 (0.009)	0.028** (0.011)	0.049*** (0.005)	0.039*** (0.011)	0.066*** (0.011)
Output	LB	0.890*** (0.036)	0.878*** (0.044)	0.816*** (0.037)	0.692*** (0.067)	0.800*** (0.045)
Output Mix (continuous)	Q	-0.491*** (0.075)	-0.056 (0.042)	-0.096*** (0.023)	-	-
Characteristic2	K	0.023 (0.09)	-	0.043 (0.034)	0.081 (0.084)	-0.037 (0.056)
Characteristic3	K	-	-	-0.060 (0.054)	0.047 (0.066)	0.040 (0.034)
R^2		0.97	0.95	0.91	0.88	0.95
Observations		449	354	521	312	630

Table 2b: Second-order parameter estimates of the costs of producing meat and poultry products in five meat and poultry industries.

Industry	Cattle	Hog	Chicken	Prepared Pork	Sausages
P_{labor}* P_{labor}	-0.002 (0.008)	0.060*** (0.008)	0.057*** (0.007)	0.054*** (0.011)	0.057*** (0.007)
P_{labor}* P_{meat}	0.010* (0.006)	-0.034*** (0.004)	-0.033*** (0.007)	-0.032*** (0.010)	-0.036*** (0.006)
P_{labor}* $P_{capital}$	-0.007 (0.007)	-0.026*** (0.008)	-0.024*** (0.006)	-0.022** (0.009)	-0.021*** (0.006)
P_{labor}*Output	-0.017*** (0.002)	-0.028*** (0.002)	-0.012*** (0.003)	-0.024*** (0.004)	-0.031*** (0.002)
P_{meat}* P_{meat}	-0.010 (0.009)	0.027** (0.013)	0.038*** (0.011)	0.057*** (0.015)	0.047*** (0.009)
P_{meat}* $P_{capital}$	0.001 (0.008)	0.007 (0.010)	-0.004 (0.007)	-0.025*** (0.009)	-0.011* (0.006)
P_{meat}*Output	-0.024*** (0.003)	0.032*** (0.004)	0.009** (0.004)	0.036*** (0.005)	0.033*** (0.003)
$P_{capital}$*$P_{capital}$	0.006 (-)	0.019 (-)	0.028 (-)	0.047 (-)	0.032 (-)
$P_{capital}$*Output	-0.007*** (0.002)	-0.004 (0.003)	0.003 (0.003)	-0.012*** (0.003)	-0.003 (0.002)
Output*Output	0.014 (0.010)	0.009 (0.015)	0.084*** (0.016)	-0.016 (0.026)	-0.022* (0.012)
Output Mix * P_{labor}	-0.002 (0.002)	0.001 (0.001)	-0.0001 (0.001)	-	-
Output Mix * P_{meat}	0.001 (0.002)	0.002 (0.002)	0.0005 (0.001)	-	-
Output Mix *$P_{capital}$	0.001 (0.002)	-0.003** (0.001)	-0.0005 (0.001)	-	-
Output Mix *Output	-0.008 (0.007)	-0.003 (0.004)	-0.011** (0.005)	-	-
Output Mix* Output Mix	-0.045*** (0.008)	-0.004 (0.005)	-0.008*** (0.002)	-	-
Output Mix* Characteristic2	0.066*** (0.024)	-	-	-	-
Characteristic2	0.008	-	-0.001	-0.006	-0.004

* P_{labor}	(0.007)		(0.007)	(0.011)	(0.010)
Characteristic2 * P_{meat}	-0.014 (0.011)	-	0.006 (0.010)	0.005 (0.015)	0.003 (0.014)
Characteristic2 *$P_{capital}$	0.006 (0.010)	-	-0.005 (0.017)	0.001 (0.001)	0.001 (0.001)
Characteristic2 *Output	0.016 (0.030	-	-0.015 (0.029)	-0.023 (0.042)	0.020 (0.031)
Characteristic3 * P_{labor}	-	-	0.009 (0.009)	0.028*** (0.009)	-0.011* (0.006)
Characteristic3 * P_{meat}	-	-	-0.027** (0.014)	-0.055*** (0.012)	0.014 (0.009)
Characteristic3 *$P_{capital}$	-	-	0.017** (0.009)	0.027*** (0.008)	-0.003 (0.006)
Characteristic3 *Output	-	-	-0.046 (0.035)	-0.002 (0.036)	-0.003 (0.018)

Cattle slaughter: Output Mix=1 - share of boxed beef; Characteristic2= 1 if share of input cattle is less than 0.75 and 0 otherwise.
Hog slaughter: Output Mix=1-share of processed pork, sausage, and other processed products
Chicken slaughter: Output Mix = 1 - share of luncheon meats and other processed poultry - share of roasters; Characteristic2 = 1 if share packed meat greater than 0 and zero otherwise; Characteristic3 = one if non-chicken input > 0 and zero otherwise.
Pork processing: Characteristic2 = one if 1 - share of sausages - share of cooked/boiled ham>0 and zero otherwise; Characteristic3= one if plant used any processed meat inputs, zero otherwise.
Sausage-making: Characteristic2=one if more than 90 percent of output is a product other than cooked or fresh sausage and zero otherwise; Characteristic3 = one if more than 80 percent of inputs comes from fresh or frozen meat and zero otherwise. Note, fresh or frozen meat and processed meat inputs are primary ingredients for pork processors and sausage-makers.

Table 2c: Time and multi-plant estimates of the costs of producing meat and poultry products in five meat and poultry industries.

Variable Name	Cattle	Hog	Chicken	Prepared Pork	Sausages
NINE2* P_{labor}	0.008 (0.006)	0.028*** (0.008)	0.005 (0.007)	0.022* (0.013)	0.018*** (0.007)
NINE2*P_{meat}	-0.016 (0.010)	-0.052*** (0.014)	-0.028** (0.012)	-0.039** (0.017)	-0.043*** (0.010)
NINE2 *$P_{capital}$	0.007 (0.009)	0.024** (0.011)	0.023*** (0.008)	0.017 (0.011)	0.025*** (0.007)
NINE2*Output	0.029 (0.023)	-0.008 (0.026)	-0.056 (0.040)	-0.016 (0.051)	-0.024 (0.023)
NINE7* P_{labor}	0.043*** (0.007)	0.029*** (0.009)	0.005 (0.008)	0.023* (0.012)	0.023*** (0.008)
NINE7* P_{meat}	-0.070*** (0.011)	-0.060*** (0.016)	-0.031*** (0.012)	-0.061*** (0.016)	-0.077*** (0.011)
NINE7 *$P_{capital}$	0.027*** (0.010)	0.030*** (0.012)	0.027*** (0.008)	0.038*** (0.010)	0.054*** (0.008)
NINE7*Output	-0.010 (0.021)	0.039 (0.027)	0.0002 (0.042)	0.021 (0.048)	-0.030 (0.024)
TWO02* P_{labor}	0.039*** (0.007)	0.046*** (0.010)	0.026*** (0.008)	0.020 (0.014)	0.058*** (0.009)
TWO02 *P_{meat}	-0.084*** (0.011)	-0.103*** (0.018)	-0.096 (0.012)	-0.100*** (0.019)	-0.152*** (0.012)
TWO02 *$P_{capital}$	0.044*** (0.011)	0.057*** (0.014)	0.070*** (0.008)	0.080*** (0.012)	0.094*** (0.009)
TWO02*Output	-0.014 (0.025)	0.093*** (0.031)	-0.030 (0.040)	-0.004 (0.054)	-0.008 (0.027)
MULTI* P_{labor}	-0.007 (0.006)	0.021** (0.008)	-	0.011 (0.014)	-0.005 (0.007)
MULTI* P_{meat}	0.007 (0.010)	-0.029** (0.014)	-	-0.012 (0.011)	-0.007 (0.010)
MULTI *$P_{capital}$	0.0004 (0.010)	0.008 (0.011)	-	0.001 (0.010)	0.012* (0.007)
MULTI*Output	-0.020 (0.031)	0.071** (0.032)	-	0.162*** (0.057)	0.069** (0.029)
R^2	0.97	0.96	0.91	0.88	0.95
Observations	449	354	521	312	630

Table 3: The change in costs over time for large and small plants owned by single-plant and multi-plant firms.

	Ratio of plant size to mean size	Plant type	1987	1992	1997	2002		
			-------------cost index---------					
Cattle Slaughter								
	0.50	Single	1.00	1.03	1.03	1.14		
	2.00	Single	0.86	0.96	0.90	0.92		
	0.50	Multi	1.00	1.03	1.03	1.14		
	2.00	Multi	0.83	0.89	0.87	0.93		
Hog Slaughter								
	0.50	Single	1.00	1.11	1.14	1.14		
	2.00	Single	0.85	0.97	0.95	1.09		
	0.50	Multi	1.00	1.14	1.10	1.13		
	2.00	Multi	0.93	1.05	1.08	1.20		
Chicken Slaughter								
	0.50	Multi	1.00	1.15	1.06	1.09		
	2.00	Multi	0.77	0.82	0.82	0.81		
Prepared Pork								
	0.50	Single	1.00	0.95	0.97	1.09		
	2.00	Single	0.65	0.59	0.66	0.71		
	0.50	Multi	1.00	0.95	0.98	1.10		
	2.00	Multi	0.81	0.75	0.82	0.89		
Sausage Making								
	0.50	Single	1.00	1.04	0.99	1.00		
	2.00	Single	0.76	0.76	0.73	0.75		
	0.50	Multi	1.00	1.03	1.00	1.00		
	2.00	Multi	0.83	0.83	0.79	0.82		

Table 4: The cost of production of large relative to small plants.[1]

	Plant type	1987	1992	1997	2002		
		Ratio of cost indexes of twice mean size plants to those of half mean size plants					
Cattle Slaughter							
	Single	0.86	0.93	0.87	0.81		
	Multi	0.83	0.86	0.84	0.82		
Hog Slaughter							
	Single	0.85	0.87	0.83	0.96		
	Multi	0.93	0.92	0.98	1.06		
Chicken Slaughter							
	Multi	0.77	0.71	0.77	0.74		
Prepared Pork							
	Single	0.65	0.62	0.68	0.65		
	Multi	0.81	0.79	0.84	0.81		
Sausage Making							
	Single	0.76	0.73	0.74	0.75		
	Multi	0.83	0.81	0.79	0.82		

1. Cost of production of large relative to small plants equals the cost index of plants of twice the sample mean size divided by the cost index of plants of one-half the sample mean size for each year. For example, for cattle slaughter in 1987, we divide the cost index for plants that are twice the sample mean plant size in 1987 by the cost index for plants that are one-half the mean plant size in 1987. Ratios are computed for each year for plants owned by single-plant firms and also for multi-plant firms