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Exit of Meat Slaughter Plants During Implementation of the PR/HACCP Regulations

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Implementation of the Pathogen Reduction and Hazard Analysis and Critical Control Points (PR/HACCP) regulations has occurred across all U.S. meat and poultry plants. A probit model is estimated to determine which factors have affected the probability of red meat slaughter plant exit during implementation of the regulations. While controlling for plant-level, company-level, regional-level, and supply conditions that may affect the probability of plant exit, smaller plants are found to exhibit a much greater probability of exit than larger plants. Other factors affecting plant exit include plant age, market share relative to the degree of market concentration, regional entry rates, and state-level wage rates.

Key words: HACCP, meat slaughter, plant exit, PR/HACCP, probit model

Introduction

From January 1997 to January 2000, the U.S. Department of Agriculture (USDA) phased in new food safety requirements for all meat and poultry plants in the United States and for foreign meat and poultry plants that export to the United States. This regulation, referred to as PR/HACCP for Pathogen Reduction and Hazard Analysis and Critical Control Points, includes requirements for Sanitation Standard Operating Procedures (SSOPs), pathogen testing for *Salmonella* on selected raw products and generic *E. coli* on all carcasses, and development of and adherence to a HACCP plan. Although the SSOPs and generic *E. coli* testing were required for all plants as of January 1997, HACCP and *Salmonella* testing were phased in from January 1998 to January 2000, depending on plant size.[1]

Because PR/HACCP increases the costs of producing meat and poultry products, researchers have suggested USDA's regulations may cause meat and poultry plants to exit at faster rates or enter at slower rates than in the past. In addition, many of the public comments on the proposed rule suggested small plants in particular would be

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[1] The largest plants, with 500 or more employees, were required to implement HACCP by January 1998. Small plants with 10 to 500 employees were required to implement HACCP by January 1999. Very small plants with fewer than 10 employees (or less than $2.5 million in annual sales) were required to implement HACCP by January 2000.

driven out of the industry because their costs per unit of output would be higher than for large plants (MacDonald et al.). Using databases of plants under federal inspection, we found the rates of *exit* of meat slaughter plants did increase during PR/HACCP implementation compared to the period immediately prior to implementation, particularly for very small meat slaughter plants.[2] However, the rate of *entry* of very small meat slaughter plants also increased, most likely because of the strength of the domestic economy during implementation of the regulations.

The objective of this study is to determine which characteristics of meat slaughter plants contributed most to the probability that a plant exited the industry during PR/HACCP implementation.[3] This analysis focuses on the federal plants that slaughter red meat species and may or may not also further process these products. We extend the methodology used by Anderson et al., who analyzed beef slaughter plants which exited from 1991 to 1993. Using this methodology, we estimate parameters to determine whether very small and small plants were more likely than large plants to exit the industry, while controlling for other plant characteristics which may affect the probability of exit. The results of the analysis may be useful for policy makers in determining whether, how, and to whom to provide assistance in mitigating the economic effects of the regulations.

Effect of PR/HACCP Regulations on Costs of Production

After conducting a hazard analysis to identify the hazards in their production processes, meat and poultry plants developed their own individual HACCP plans for controlling these hazards in each type of product they produce. Thus, each plant implemented PR/HACCP differently. Consequently, each had and continues to have different cost effects due to PR/HACCP. Furthermore, plants have implemented different pathogen testing procedures, including implementing their own voluntary testing.

To obtain qualitative descriptions of the kinds of changes plants have made that affect their costs of production and to identify how these changes differ across types of plants, we conducted 27 interviews during fall 2000 and spring 2001. Interview participants included a combination of trade association representatives, university food science faculty, Food Safety and Inspection Service (FSIS) district managers, FSIS Technical Service Center staff, and plant managers or HACCP coordinators. Based on the findings of our interviews, the types of costs associated with PR/HACCP are different for large plants compared to those for small plants because the types of changes made varied by plant size.[4]

The costs associated with implementing PR/HACCP include both the one-time start-up costs of PR/HACCP and the annual costs for equipment maintenance, labor, materials, and pathogen testing. All plants incurred the one-time costs of conducting a hazard analysis and developing a HACCP plan, but larger plants were more likely to have made

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[2] The term "meat slaughter plants" refers to plants in which red meat species are slaughtered. This is the term used in the PR/HACCP regulations.

[3] Another interesting analysis one could consider would be to determine which factors have contributed to plant entry during PR/HACCP implementation. However, the data set to perform such an analysis would need to include information not only on plants that entered, but also on plants that considered entering but did not.

[4] Using an econometric approach, Antle found the cost per pound for broadly defined food safety regulations was similar across plant sizes. However, his analysis using U.S. Census data included only the largest 175 meat plants.

large capital equipment purchases because of PR/HACCP. For example, larger red meat slaughter plants have installed systems for reducing pathogens on carcasses, including steam pasteurization systems and lactic acid and hot water rinse cabinets. Also, many larger plants made changes in the layout of the facility to reduce the possibility of cross-contamination between raw and cooked products by eliminating foot traffic between the separate production areas and changing airflow patterns. Larger plants were also likely to have made more changes affecting variable costs.

While larger plants have added more quality control staff (as many as 20 additional employees for two shifts) and have added PR/HACCP to their routine training programs, the smallest plants have more likely added approximately one hour per day of PR/HACCP duties to an existing employee (often the owner), and they conduct intermittent on-the-job training for PR/HACCP. Larger plants were also more likely to have increased the use of antimicrobials and sanitizers, including using different compounds, than before HACCP. Finally, many larger plants conduct their own voluntary programs for pathogen testing.

In general, the interviews suggest the smallest plants have interpreted the PR/HACCP regulations to require fewer changes than those deemed necessary by larger plants. In particular, smaller plants are less likely to have installed new capital equipment, added more employees, changed their sanitizing and antimicrobial solutions, or conducted voluntary pathogen testing. With fewer changes but also lower output volumes, the net effect on per unit costs of production is unknown. However, even if per unit costs of production are less for smaller plants, these plants may have exited at faster rates because their managers lacked the expertise to implement PR/HACCP, or because their revenues decreased to the extent the business was no longer profitable. Although most of the effects of PR/HACCP have been on costs, many smaller plants stopped producing specialty, seasonal, and ethnic products rather than develop separate plans for these products, so their revenues may have declined.

Patterns of Entry and Exit in the Meat Slaughter Industry

The meat and poultry industries historically have been characterized by frequent plant entry and exit. Thus, as MacDonald et al. note, if the PR/HACCP regulations "drive small producers out of business, the observed pattern should be increases in exit and reductions in entry over normal flows" (p. 784). Because PR/HACCP has been implemented across all meat and poultry plants, rates of entry and exit from the period immediately prior to implementation of the regulations (1993 to 1996) to the period of implementation (1996 to 2000) may be compared using a database of plants under federal inspection. The Enhanced Facilities Database (EFD) combines data from the USDA/FSIS Performance-Based Inspection System (PBIS), Animal Disposition Reporting System (ADRS), Common On-line Reference for Establishments (CORE), and Field Automation and Information Management (FAIM). The combined EFD database contains approximately 6,000 plants which actively slaughter and/or process federally inspected meat and poultry products.[5]

[5] Approximately 2,500 state-inspected plants also slaughter and/or process meat and poultry products. These plants, which can ship products intrastate only, tend to be smaller volume plants.

Table 1. U.S. Federally Inspected Meat Slaughter Plant Inventories and Numbers of Plants Entering and Exiting, 1993, 1996, and 2000

	Number of Plants			Entry Numbers		Exit Numbers	
HACCP Size	1993	1996	2000	1993–1996	1996–2000	1993–1996	1996–2000
Very Small Plants: (<10 employees or < $2.5 mil. in sales)	639	609	567	50	79	80	121
Small Plants: (10 to 500 employees)	274	247	221	18	16	45	42
Large Plants: (> 500 employees)	59	64	63	7	0	2	1
Total Plants	972	920	851	75	95	127	164

Notes: Only plants which slaughter at least 50 animals per year are included. In addition to slaughtering, some plants also conduct processing activities. Note that plants appearing to have entered may potentially have switched from state to federal inspection. However, this analysis excluded plants in Florida which switched from state to federal inspection when the state discontinued its inspection program in 1997. Note also that plants apparently having exited may have switched from federal to state inspection.

Table 2. Percentage Rates of Entry and Exit of U.S. Federally Inspected Meat Slaughter Plants, 1993–1996 and 1996–2000

	Entry Rates (%)		Exit Rates (%)	
HACCP Size	1993–1996	1996–2000	1993–1996	1996–2000
Very Small Plants: (<10 employees or < $2.5 mil. in sales)	7.8	13.0	12.5	19.9
Small Plants: (10 to 500 employees)	6.6	6.4	16.4	17.0
Large Plants: (> 500 employees)	11.9	0.0	3.4	1.6
Total Plants	7.7	10.3	13.1	17.8

Note: Refer to footnote to table 1.

Table 1 presents the numbers of red meat slaughter plants by HACCP size in 1993, 1996, and early 2000, and the numbers of plants entering and exiting between those years. In developing these inventories, plants slaughtering on average at least one red meat species animal per week were included. Thus, if a plant dropped below one animal per week, stopped slaughtering entirely, or closed, the plant was considered to have exited from the red meat slaughter industry.[6] Similarly, if a plant opened or had only been processing but then began to slaughter at least one animal per week, the plant was considered an entrant to the red meat slaughter industry.[7] In total, the numbers of plants in the red meat slaughter industry have been declining because the number of plants exiting has exceeded the number entering.

[6] Because our analysis data set includes only federally inspected plants, we note that some plants which appear to have exited may actually have switched to state inspection. However, we were unable to determine if this occurred, and if it did, how many plants it affected.

[7] Likewise, some plants which appear to have entered may have switched from state to federal inspection.

Table 2 reports the percentages of entry and exit rates over the 1993–1996 and 1996–early 2000 time periods. As observed in table 2, the overall rate of plant entry increased from 7.7% to 10.3%, while the rate of plant exit increased from 13.1% to 17.8%. The highest rates of entry and exit occurred for the smallest plants with fewer than 10 employees or $2.5 million in sales. In comparison, after several entries by large plants (greater than 500 employees) from 1993 to 1996 (11.9%), this size category has had few subsequent entrants or exits.

Previous Studies of Entry and Exit

Most studies of industry entry and exit have compared the characteristics of plants across Standard Industrial Classification (SIC) code-level industries rather than across plants within a single industry. In these models, the rates or gross numbers of entry or exit, and sometimes both, are regressed on a set of explanatory variables (Agarwal; Audretsch 1991, 1995; Flynn; MacDonald; Mayer and Chappell; Rosenbaum and Lamort). The set of explanatory variables includes, for example, measures of scale economies, growth rates, concentration ratios, capacity rates, price-cost margins, and advertising-to-sales ratios. Although these studies help in guiding the types of variables to include in a plant-level analysis, the unit of analysis is different, and the results do not provide information on a particular industry of interest.

In comparison, Anderson et al. developed a model to explain the probability that plants in the beef packing industry exited the industry from 1991 to 1993 based on variables representing plant-level characteristics, market structure, and supply and demand shifters. They found plant and market structure characteristics were significant in explaining the probability of plant exit, but supply and demand shifters were not. In particular, plant capacity, age, horizontal integration (a dummy variable for other species slaughtered in addition to beef), and vertical integration (a dummy variable for processing) were significant. In addition, the rate of entry of beef slaughter plants and a competitive fringe index (CFI) for plant procurement areas were statistically significant.

The analysis presented here updates Anderson et al.'s research to include the 1996–early 2000 period, thereby allowing examination of changes during the PR/HACCP implementation period. This analysis also expands the data set to include all plants engaged in the slaughter of any red meat species.

A Theoretical Model of the Plant Exit Decision

In modeling the decision to exit, the approach of Anderson et al. is followed. They define the decision to stay or exit the industry based on the relationship between profits (π_t) and the difference between the value of the firm from exiting (V_{Lt}) and the discounted value of the firm from remaining in the market at the end of the period ($e^{-rt}V_{t+1}$). Because the net payoff to remaining in the market through the period is calculated as $\Pi_t = \pi_t + e^{-rt}V_{t+1} - V_{Lt}$, the "exit" threshold for profits is defined as follows:

$$\pi_t < V_{Lt} - e^{-rt}V_{t+1}.$$

That is, whenever profits from continuing to operate plus the discounted future value of future profits are less than the value of the firm from exiting, it is in the firm's best interest to exit the industry. Per period profits, or quasi-rents to fixed factors, are defined as:

(1) $$\pi_t = P_t Q_t - P_{mt} M_t - W_t L_t - P_{et} E_t,$$

where (ignoring time subscripts) P, P_m, W, and P_e are output price, price of the raw material (i.e., animal slaughtered), wage rate, and price of energy. Q, M, L, and E are the corresponding output and input quantities.

As Anderson et al. suggest, profits as defined by equation (1) indicate slaughter revenues and variable factor costs are endogenous to the output and input decisions. Thus, the decision to exit is conditional on the plant or firm first deciding the level of production in each period, given the capacity constraint and expected output and input prices. In other words, the exit decision should be specified more specifically as to exit when

$$\pi_t^* < V_{Lt} - e^{-rt} V_{t+1},$$

where

(2) $$\pi_t^* = \pi\left(P_t, P_{mt}, W_t, P_{et}, \mathbf{K}_t\right)$$

denotes maximum profits computed from equation (1) given (expected) output and input prices and the levels of fixed factors (**K**). Two important properties of the profit function are that it is nondecreasing in output price and nonincreasing in input prices (Varian). These properties are useful in developing expected signs of the variables in the empirical model.

In the empirical analysis, not all of the variables in equation (2) are observed at the plant level. In particular, wholesale beef and pork prices are available only at the national level; therefore, we cannot disaggregate different output price levels for plants in different regions of the country.[8] One way around this problem is to replace output price with a reduced-form equation for output price, $P = P(P_m, W, P_e, \mathbf{Y}, \mathbf{K})$, where **Y** represents demand shifters for the output (e.g., income). Substituting into equation (2) and ignoring time subscripts yields the (partially) reduced-form profit function:

(3) $$\begin{aligned}\pi_t^* &= \pi\left[P\left(P_m, W, P_e, \mathbf{Y}, \mathbf{K}\right), P_m, W, P_e, \mathbf{K}\right] \\ &= \pi^*\left(P_m, W, P_e, \mathbf{Y}, \mathbf{K}\right).\end{aligned}$$

The profit function becomes a function of input prices, fixed factors specific to the individual plant, and factors influencing demand for the output. Note the impact of the input prices and fixed factors in equation (3) represents the combined effects of direct effects on profits and indirect effects through induced effects on output price. For example, the impact of the wage rate on profits can be characterized as follows:

(4) $$\frac{\partial \pi^*}{\partial W} = \frac{\partial \pi^*}{\partial P}\frac{\partial P}{\partial W} + \frac{\partial \pi^*}{\partial W} = Q\frac{\partial P}{\partial W} - L,$$

where the results $\partial\pi^*/\partial P = Q$, $\partial\pi^*/\partial W = -L$ follow from Hotelling's lemma (Varian, pp. 43–44). From the relationship between output price, marginal cost, and output demand, we expect $\partial P/\partial W > 0$. Thus,

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[8] In practice, beef and pork can be shipped long distances for relatively low cost, so regional price variation is generally not considered to be large.

$$\frac{\partial \pi^*}{\partial W} < 0 \text{ if } \frac{\partial P}{\partial W} < \frac{L}{Q}, \text{ or } \frac{\partial \pi^*}{\partial W} > 0 \text{ if } \frac{\partial P}{\partial W} > \frac{L}{Q}.$$

The sign of a change in wage rate on profits, and therefore its effect on the decision to exit, is ambiguous, depending on the relationship between the impact of the wage rate on output price and the labor-output ratio.[9] In other words, if the impact on output price from a change in wage rate is large enough to offset the impact of a change in wage on costs, then profits could rise and reduce the chances the plant would exit. In general, similar ambiguous effects exist for the other input prices and capacity variables in the model.

Plant- and Company-Level Factors

A number of factors could influence plant exit. In addition to the impact of HACCP, several observable plant-level characteristics are thought to be good indicators of profitability influencing the rate of exit from the industry. These observable plant-level characteristics can be grouped as factors influencing plant capacity, plant productivity, and degree of horizontal and vertical integration of the plant and of the company.

Plant capacity is expected to have an impact on profitability because of plant scale economies. In the case of meat, Ball and Chambers, and Ward report long-run average costs tend to decline as volume increases, and then flatten out at higher output levels. If scale economies are present, an inverse relationship between plant capacity and the exit rate would be expected (Anderson et al.).

The productivity of the plant's capital can also affect profitability. As capital ages, it becomes less productive, either in absolute terms or relative to other newer plants. As the capital becomes less productive, the firm's profitability is lowered and the firm is faced with the decision either to exit the industry or replace the capital. As in past studies, plant age is used as a proxy for declining productivity. Because new capital is expected to be more productive than older capital, and because age of capital is likely positively correlated with plant management experience, the relationship between the age effect on profitability and probability of exit is likely nonlinear.

Anderson et al. argue that firms slaughtering both beef and pork may receive higher prices for convenience provided to buyers, thus enhancing profits. Multiple species may also provide economies of scope—i.e., a plant providing both beef and pork can produce both at a lower unit cost than it could if it produced each product separately. Either way, within-plant horizontal integration would be expected to reduce the probability of exit. Similarly, plants which integrate vertically might also be expected to increase profits over plants that do not integrate vertically. High profits may result from achieving efficiencies by combining different labor activities and by producing higher value-added products.

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[9] As pointed out by a referee, existence of market power in the market for the output can lead to the condition that the effect of a wage change on output price is larger than the labor-output ratio (see, e.g., McCorriston, Morgan, and Raynor). A similar result can occur under competitive conditions; for an isolated firm, the impact of a wage change on marginal cost can be larger than the impact on average cost which equals the labor-output ratio (Silberberg, pp. 265–67). In general, the relative magnitude of this price effect is indeterminate, especially in the short run (Wohlgenant). Finally, for a change in one of the livestock prices, (external) economies of scale to the processing industry can lead to a larger impact of the livestock price on output price than indicated by the input-output ratio (Gardner).

Regional-Level Factors

The characteristics and market structure of the procurement region in which the plant is located may also influence the decision to exit. Following Anderson et al., a procurement region is defined as an area within a 150-mile radius of each individual plant.[10] Livestock procurement regions are often populated by a few large producers and many small producers. If the regional markets are imperfectly competitive, then producers may earn profits in proportion to their market shares; thus, higher share firms would be less likely to exit. In more highly concentrated regional markets a lower probability of exit would be expected.

In this context, the concept of the competitive fringe index (CFI) becomes important. Following Anderson et al., the CFI is defined as H_j/C_{ij}, where H_j is the Herfindahl index ($0 \leq H_j \leq 1$) of region j, and C_{ij} is plant i's capacity share in region j. Thus, the CFI provides a measure of the effect of the plant's regional market share relative to its regional market concentration. As discussed by Anderson et al., there is concern that large producers might be pushing smaller firms out of the market. Forward contracting between meat processors and livestock (cattle or hog) producers can be a source of market power. A negative relationship between the proportion of sales forward contracted and the open market prices of livestock has been observed (Azzam). This may be due to anticompetitive behavior, or it may simply reflect scale economies for buyers through purchasing arrangements. In either case, the CFI is intended to capture the effect that firms on the competitive fringe are more likely to exit.

Another measure of market structure is the rate of entry in the prior period. Past studies have found that industries with higher than average entry tend to have higher than average exit in other years (Dunne, Roberts, and Samuelson). The line of causality is that higher entry rates may raise input prices, most notably raw product prices and wages. Thus, a higher entry rate in the pre-HACCP period might increase the incidence of plants exiting in later periods.

Supply and Demand Factors

Input prices, particularly livestock prices (beef and pork prices), wage rates, and energy prices, can vary from one plant to another. The higher the input price, the greater the likelihood of exit if the effect of higher input prices is to increase plant costs. However, as discussed above, the input prices may reflect the combined effect of changes in plant costs and the indirect effect of induced changes in output price. So, for example, a higher wage rate may actually increase profits and lower the probability of exit because it raises output price proportionately more than it raises plant costs.

Demand-side variables enter through the reduced-form price equation, as shown by equation (3). For example, higher per capita income in the state in which the plant is located might be expected to decrease the probability of exit because it raises output price, thereby increasing profit. Economic theory indicates such variables could be potentially important determinants of exit. Yet, because the markets for beef and pork are highly integrated, changes in per capita income, while shifting aggregate demand, may have little effect on differences in output prices between plants.

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[10] Anderson et al. based their assumption on a Grain Inspection, Packers and Stockyards Administration (USDA) report that found 82% of cattle were procured within 150 miles of the plant.

Empirical Specification

For purposes of this analysis, a meat plant was considered to be active if it was in the PBIS system, indicating FSIS inspectors currently inspect the plant, and if it had reported slaughter volumes for at least one red meat species. However, if the slaughter volume was less than one animal per week on average, its primary line of business was considered to be something other than slaughter, and so it was excluded from the data set. A plant was considered to have exited if it was no longer included in the PBIS system and thus no longer under active inspection, or if its slaughter volume fell below one animal per week.

Following Anderson et al., we use a probit model to parameterize the empirical model. Let $Y_i = 1$ if plant i slaughtered in 1996 but not in early 2000 (exit), and $Y_i = 0$ if plant i slaughtered in both 1996 and early 2000 (stay). Let $\mathbf{X}_i$ be the vector of parameters influencing the present value of profit (Π_i). Then adding a random error term to capture factors affecting profits unobservable to us, the payoff function can be written as follows:

$$\Pi_i = \beta'\mathbf{X}_i + \varepsilon_i .$$

Because the payoff function is stochastic, the exit/stay decision is viewed in a probabilistic sense:

$$\text{prob}(\Pi_i < 0) = \text{prob}(Y_i = 1|\mathbf{X}_i) = F(\beta'\mathbf{X}_i), \tag{5}$$

where $F(\cdot)$ is the cumulative normal distribution function, $Y_i = 1$ if plant i slaughtered in 1996 (exit) but not in early 2000, and $Y_i = 0$ if plant i slaughtered in both 1996 and early 2000 (stay). The $\mathbf{X}_i$ vector includes plant-, company-, and regional-level characteristics, and local supply and demand conditions for each plant.

Data Description

The data used in the model are derived from several USDA/FSIS databases and published sources. Table 3 lists each variable by the following categories: plant characteristics, company characteristics, regional characteristics, and supply conditions. The plant, company, and regional characteristics come directly from or are derived from plant-level USDA/FSIS databases, and the supply condition variables are taken from published Bureau of Labor Statistics (BLS) and National Agricultural Statistics Service (NASS) sources. For helpfulness to the interested reader, these sources are detailed in footnotes to table 3.

The plant characteristics variables include slaughter volume, plant age, HACCP size dummy variables, species dummy variables, and a processing dummy variable. Slaughter volume and slaughter volume squared are included as proxies for plant capacity; however, they tend to understate true capacity for plants which also process products using purchased meat inputs. Age and age squared are measured relative to 1996. The HACCP size dummy variables correspond to very small (fewer than 10 employees), small (10 to 500 employees), and large (greater than 500 employees) categories, as specified in the PR/HACCP regulations. Finally, as indicators of horizontal and vertical integration, dummy variables identify which species (cattle, hogs) the plant slaughters and whether the plant also conducts processing activities.

Table 3. Meat Slaughter Plant Exit Model: Definitions of Variables

Variable	Definition
PLANT CHARACTERISTICS:	
▸ Slaughter Volume	Plant's slaughter volume for all red meat species, 1996 [a]
▸ Slaughter Volume Squared	Plant's slaughter volume squared
▸ Age	Plant's age in 1996 based on year of grant of inspection or grant status data, whichever is earlier [b]
▸ Age Squared	Plant's age squared
▸ Very Small Size	Plant is designated as HACCP size very small (binary) [c]
▸ Small Size	Plant is designated as HACCP size small (binary) [c]
▸ Large Size	Plant is designated as HACCP size large (binary) [c]
▸ Slaughters Cattle	Plant slaughters cattle (binary)
▸ Slaughters Hogs	Plant slaughters hogs (binary)
▸ Processing at Plant	Plant also conducts processing activities (binary) [d]
COMPANY CHARACTERISTICS:	
▸ Number of Plants	Number of meat and poultry plants owned by the company
▸ Meat Slaughter Volume	Total company meat slaughter volume
▸ Poultry Slaughter Volume	Total company poultry slaughter volume
▸ Processing	Company conducts processing activities in at least one plant (binary)
REGIONAL CHARACTERISTICS:	
▸ Entry Rate	Rate of plant entry for red meat slaughter from 1993–1996 for the region in which the plant is located
▸ Slaughter Volume Share	Plant's share of the region's volume of red meat slaughter
▸ HHI	Hirschmann-Herfindahl index based on red meat slaughter volumes for the region in which the plant is located
▸ Competitive Fringe Index	HHI divided by the slaughter volume share
SUPPLY CONDITIONS:	
▸ Wage Rates	Hourly wages for SIC 20 Food and Kindred Products in 1996 for the plant's state or area [e]
▸ Energy Index	Energy price index in 1996 for the plant's area, 1982–1984 = 100 [f]
▸ Live Cattle Price	Live cattle price ($/100 lbs.) for the plant's state or area, average of 1995, 1996, and 1997 [g]
▸ Live Hog Price	Live hog price ($/100 lbs.) for the plant's state or area, average of 1995, 1996, and 1997 [g]

Sources:

[a] USDA's Animal Disposition Reporting System (ADRS).

[b] USDA's Common On-line Reference for Establishments (CORE).

[c] USDA's Field Automation and Information Management (FAIM), and *info*USA (formerly American Business Lists).

[d] USDA's Performance-Based Inspection System (PBIS).

[e] U.S. Department of Labor/Bureau of Labor Statistics, "State and Area Employment, Hours, and Earnings" (available by state except for AK, CO, NV, NM, SD, and WY, which are based on average wages for surrounding states).

[f] U.S. Department of Labor/Bureau of Labor Statistics, "Consumer Price Index: Energy" (available for Northeast, Midwest, South, and West).

[g] USDA's National Agricultural Statistics Service (NASS), "Meat Animals Production, Disposition, and Income" (annual summaries, available by state).

The variables for company characteristics measure possible economies of scope in meat slaughter. These variables include number of meat and poultry plants owned by the company, total meat and poultry slaughter volumes for the company, and a dummy variable indicating whether at least one plant owned by the company conducts processing activities. To identify company ownership of plants, information from "The Top 100" issue of *Meat and Poultry: The Business Journal of the Meat and Poultry Industry* was used in addition to matching plant names across the data set. The plant information for each company was then combined to create the company variables.

The regional characteristics are similar to those used by Anderson et al. and are based on an assumed livestock procurement area within a 150-mile radius around the plant. For each plant's procurement area, the rate of meat slaughter plant entry in the prior period (1993–1996), the plant's share of the meat slaughter volume, the Herfindahl index (HHI), and the CFI (defined as the regional HHI divided by the plant's regional market share) were calculated. As described previously, the CFI provides a measure of the level of market concentration relative to the size of the plant within its procurement area. Meat slaughter plants that exited had an average CFI value three times the average CFI value for plants not exiting (refer to table 4). For the 25 plants with the highest CFI values, seven of which exited the industry, the CFI ranged from 12,500 to 42,900. For the 25 plants with the lowest CFI values, none of which exited the industry, the CFI values ranged from 0.4 to 0.7. In all but one case, the plants with the highest CFI values were very small plants, but the plants with the lowest CFI values were all different sizes.

Finally, the supply and demand condition variables include indicators of the direct costs of inputs for the area in which the plant is located. These variables, which also have induced effects on output prices, include processing wage rates, an energy index, live cattle prices, live hog prices, and per capita disposable income.[11] State-level processing wage rates for 1996 were obtained from the Bureau of Labor Statistics, "State and Area Employment, Hours, and Earnings" for SIC 20 Food and Kindred Products. These wage rates were assigned to individual plants based on the state in which they were located. For six of the states, state-level processing wage rates were not available, so an average value for the surrounding states was assigned. Energy price indexes for 1996 were obtained from the Bureau of Labor Statistics, "Consumer Price Index: Energy," available for the Northeast, Midwest, South, and West. These energy indexes were assigned to individual plants based on the region in which they were located. State-level live cattle and live hog prices for 1995, 1996, and 1997 were obtained from the USDA/National Agricultural Statistics Service annual publication, "Meat Animals Production, Disposition, and Income." The average values for these three years were calculated and assigned to plants based on the state in which they were located. The live cattle price variable was included for plants that slaughtered cattle, as was the live hog price variable for those plants slaughtering hogs. Finally, state-level per capita disposable income values were obtained from the Bureau of Labor Statistics.

The final cross-sectional data set includes the characteristics in 1996 of 920 federally inspected plants reporting the slaughter of at least one animal per week on average in 1996. As noted in tables 1 and 2, 164 (17.8%) of these plants exited or stopped slaughtering red meat species by early 2000, the final year of HACCP implementation. Means and standard deviations for each of the variables are provided in table 4. The average plant

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[11] The per capita disposable income variable is excluded from tables 3, 4, and 5 because, as explained in the model results section, it was not included in the final model specification.

Table 4. Meat Slaughter Plant Exit Model: Means and Standard Deviations, 1996

	Mean / (Standard Deviation)		
Variable	All Plants (n = 920)	Exit Plants (n = 164)	Non-Exit Plants (n = 756)
PLANT CHARACTERISTICS:			
▸ Slaughter Volume (mil. head)	0.148	0.063	0.166
	(0.532)	(0.332)	(0.565)
▸ Slaughter Volume Squared (mil. head)	0.305	0.113	0.347
	(1.838)	(1.041)	(1.967)
▸ Age (years)	16.95	15.53	17.26
	(9.097)	(8.835)	(9.13)
▸ Age Squared (years)	370.12	318.8	381.3
	(393.65)	(285.9)	(412.6)
▸ Very Small Size (binary)	0.662	0.738	0.646
	(0.473)	(0.441)	(0.479)
▸ Small Size (binary)	0.268	0.256	0.271
	(0.443)	(0.438)	(0.445)
▸ Large Size (binary)	0.070	0.006	0.083
	(0.255)	(0.078)	(0.277)
▸ Slaughters Cattle (binary)	0.839	0.860	0.835
	(0.368)	(0.348)	(0.372)
▸ Slaughters Hogs (binary)	0.768	0.768	0.768
	(0.422)	(0.423)	(0.422)
▸ Processing at Plant (binary)	0.695	0.640	0.706
	(0.461)	(0.481)	(0.456)
COMPANY CHARACTERISTICS:			
▸ Number of Plants	2.934	1.652	3.212
	(8.911)	(2.978)	(9.711)
▸ Meat Slaughter Volume (mil. head)	1.117	0.503	1.251
	(4.739)	(3.326)	(4.985)
▸ Poultry Slaughter Volume (mil. head)	6.984	1.069	8.267
	(52.93)	(9.084)	(58.17)
▸ Processing (binary)	0.717	0.652	0.732
	(0.450)	(0.478)	(0.444)
REGIONAL CHARACTERISTICS:			
▸ Entry Rate (1993–1996)	0.105	0.076	0.111
	(0.335)	(0.181)	(0.360)
▸ Slaughter Volume Share	0.052	0.031	0.056
	(0.139)	(0.124)	(0.142)
▸ HHI	0.293	0.290	0.293
	(0.197)	(0.195)	(0.197)
▸ Competitive Fringe Index (CFI)	1,275	2,752	954.1
	(3,839)	(6,257)	(2,985)
SUPPLY CONDITIONS:			
▸ Wage Rates ($/hour)	11.54	11.39	11.58
	(1.41)	(1.50)	(1.38)
▸ Energy Index (1982–1984 = 100)	109.9	109.8	109.9
	(2.44)	(2.34)	(2.46)
▸ Live Cattle Price ($/100 lbs.)	53.11	53.33	53.06
	(8.09)	(7.85)	(8.14)
▸ Live Hog Price ($/100 lbs.)	46.95	46.76	46.99
	(4.69)	(2.55)	(5.03)

in the data set slaughtered 148,000 animals, was approximately 17 years old, was owned by a company also owning two other federally inspected meat and/or poultry plants, and slaughtered 5% of the volume in its procurement area.

In comparing plants that exited to those that remained, exiting plants had lower slaughter volumes, were slightly younger, and were more likely to be very small. Indicators of horizontal and vertical integration (species slaughtered and whether the plant processes) were similar for both types of plants. Across company ownership characteristics, plants that exited were owned by companies who held fewer plants, had lower total slaughter volumes, and were less likely to also conduct processing activities. Although most of the regional characteristics are similar for exiting plants and those that remained, the CFI was nearly three times greater for exiting plants, meaning small plants in concentrated regions tended to exit more frequently than larger plants in less concentrated regions. Finally, on average, the supply conditions were similar for both exiting plants and those that remained.

Model Results

Initial results of the probit model of meat slaughter plant exit indicated that the measure of regional demand conditions, per capita disposable income variable, was insignificant. In addition, because per capita disposable income is highly correlated with processing wage rates, its inclusion caused the processing wage rate to be insignificant. As described previously, processing wage rates have a direct effect on production costs and an indirect effect on output prices. Thus, the disposable income variable was dropped from the final model specification.

Results of the final specification of meat slaughter plant exit are presented in table 5, including the χ^2 tests of joint significance of the plant, company, regional, and supply condition variables. The estimates of marginal effects ($\partial F/\partial X_i$) are evaluated at the sample means for continuous variables, and for a discrete change from 0 to 1 for the binary variables. Because of the low pseudo-R^2 (0.072), the model is not suited for predicting if an individual plant will close based on its characteristics. However, the model provides information on the general characteristics observed to increase the probability of plant exit.

The variables apparently explaining the probability of plant exit during PR/HACCP implementation include plant characteristics, regional characteristics, and supply conditions. Of the variables representing plant characteristics, age of the plant and the HACCP size designation for the plant had statistically significant effects on the probability of exit. The age and age-squared variables were jointly significant at the 0.04 level, and indicate the probability of plant exit decreases by 0.4% for each additional year of age up to 48 years of age, which is about half the age of the oldest plant in the data set.[12]

The binary variables for very small and small HACCP plant sizes were also significant and suggest a very small plant was 35% more likely and a small plant was 55% more likely to exit than a large plant.[13] Thus, even after controlling for other plant characteristics affecting plant exit, very small and small plants were more likely than large plants to exit during implementation of the regulations. This finding is in contrast to what might be expected based on Antle's results in which the costs per pound for

[12] The combined marginal effect of age is calculated as $-0.006 + 2(0.00006)(16.95)$, where 16.95 is the average age of plants in the data set.

[13] The dummy variable for large size was omitted from the estimation.

Table 5. Meat Slaughter Plant Exit Model: Probit Results, 1996–early 2000

Explanatory Variable	Marginal Effect[a] ($\partial F / \partial X_i$)	Standard Error	χ^2 Test of Joint Significance
PLANT CHARACTERISTICS:			$\chi^2_{[9]} = 15.34$*
▸ Slaughter Volume (mil. head)[b]	0.044	0.128	
▸ Slaughter Volume Squared (mil. head)[b]	0.004	0.029	
▸ Age (years)[c]	-0.006*	0.003	
▸ Age Squared (years)[c]	0.00006	0.0001	
▸ Very Small Size (binary)	0.350***	0.090	
▸ Small Size (binary)	0.551***	0.195	
▸ Large Size (binary)	—	—	
▸ Slaughters Cattle (binary)	-0.033	0.119	
▸ Slaughters Hogs (binary)	-0.150	0.308	
▸ Processing at Plant (binary)	0.034	0.098	
COMPANY CHARACTERISTICS:			$\chi^2_{[4]} = 1.85$
▸ Number of Plants	0.011	0.012	
▸ Meat Slaughter Volume (mil. head)	-0.006	0.009	
▸ Poultry Slaughter Volume (mil. head)	-0.002	0.002	
▸ Processing (binary)[a]	-0.073	0.119	
REGIONAL CHARACTERISTICS:			$\chi^2_{[4]} = 23.00$***
▸ Entry Rate (1993–1996)	-0.132**	0.064	
▸ Slaughter Volume Share	-0.028	0.120	
▸ HHI	-0.086	0.068	
▸ Competitive Fringe Index (CFI)	0.00001***	0.000003	
SUPPLY CONDITIONS:			$\chi^2_{[4]} = 6.22$
▸ Wage Rates ($/hour)	-0.022**	0.009	
▸ Energy Index (1982–1984 = 100)	-0.001	0.006	
▸ Live Cattle Price ($/100 lbs.)	0.000	0.002	
▸ Live Hog Price ($/100 lbs.)	0.002	0.005	

Log Likelihood = -400.358
Pseudo R^2 = 0.072
N = 920

Notes: Single, double, and triple asterisks (*) denote significance at the 0.10, 0.05, and 0.01 levels, respectively. The Large Size binary variable was omitted from the regression.

[a]The marginal effects, standard errors, and elasticities are evaluated at the sample means for continuous variables, and for a discrete change from 0 to 1 for the binary variables.

[b]The combined marginal effect of slaughter volume is 0.044 + 2(0.004)(0.148) = 0.045 with a standard error of 0.128 evaluated at the sample average slaughter volume of 0.148 million head.

[c]The combined effect of age is -0.006 + 2(0.00006)(16.95) = 0.004 with a standard error of 0.001 evaluated at the sample average plant age of 16.95 years.

safety are found to be similar across plant sizes. However, Antle's analysis considered only the largest size plants. We expected the relative sizes of the coefficients on the very small and small dummy variables to be reversed; nevertheless, we could not reject a test of the null hypothesis that these coefficients are in fact equal (p = 0.25).

In contrast to the findings of Anderson et al., slaughter volume and slaughter volume squared, both individually and jointly, were not statistically significant explanatory variables.[14] Economies of scale in meat slaughter have been well documented; thus, higher volume plants should be less likely to exit. Our result could have occurred for two reasons: (*a*) the slaughter volume does not represent the total product volume for the plant if it also produces processed products using boxed beef or pork inputs, and (*b*) the HACCP size binary variables capture the effects of plant capacity on the plant exit decision. When the model was rerun without the HACCP size variables, the null hypothesis that the coefficients on slaughter volume and slaughter volume squared are zero ($p = 0.35$) could not be rejected.[15] Thus, lack of statistical significance is likely due to the first effect—i.e., the slaughter volume variables are imperfect measures of plant capacity.

The effects of horizontal and vertical integration within the plant were not significant. This result possibly occurred because the HACCP size variable is also capturing some of the effects of these integration variables. The fact that all meat slaughter plants were combined in the data set may also obscure some of the effects of the integration variables.

As indicated by the insignificance of the company variables, there is no evidence linking the effects of economies of scope to the plant's exit decision. This is because most of the plants (83.7%) are the sole establishments of the company. Thus, the plant characteristics are identical to the company characteristics for most of the plants, particularly the smallest size plants. The model was also estimated without the company variables to determine whether some of the results are affected by collinearity between the plant and company variables. However, the level of significance of the remaining coefficients did not change, and only one (insignificant) coefficient changed sign.

Within the set of regional characteristics, the entry rate in the prior period and the CFI both have significant estimated effects on plant exit. The coefficient on the entry rate variable is negative, denoting a lower probability of exit for a plant in a region with a higher rate of entry in the prior period. One explanation for this result may be that favorable demand conditions within the region caused more plants to enter in the prior period and fewer plants to exit in the current period. The coefficient on the CFI is positive, as expected, and significant, revealing the greater likelihood of a low market-share plant in a concentrated region to exit. An increase in the CFI by one standard deviation (3,839) increases the probability of plant exit by 4.3%.

Finally, within the set of supply variables, only the wage index is significant. As explained above, the negative sign on the wage effect can be attributed to an increase in the wage rate having both a direct effect on profits and an indirect effect on profits through induced effects on output price. Thus, it is likely a plant in an area with higher wages is also obtaining a higher price for its output, and so its probability of exit is less than in an area with lower wages. The energy cost index has no effect on plant exit, most likely because energy costs are a small component of plant-level costs. The coefficients on the price of live cattle and live hogs have the correct signs but are insignificant, suggesting the published state-level data correspond imprecisely to the input prices faced by each plant.

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[14] The combined marginal effect of slaughter volume is calculated as $0.044 + 2(0.004)(0.148)$, where 0.148 is the average slaughter volume (million head) in the data set.

[15] We also ran the model without the HACCP size variables and with only slaughter volume (without slaughter volume squared), and still found the slaughter volume variable was not significant. To determine whether we should be considering the joint effect of HACCP size and slaughter volume, we calculated the standard errors associated first with the very small plant size variable, slaughter volume, and slaughter volume squared, and then with the small plant size variable, slaughter volume, and slaughter volume squared. For each of the marginal effects, we calculated the effect on exit of the differences in average slaughter volume for a very small plant relative to a large plant, and the effect of the differences in average slaughter volume for a small relative to a large plant. We did not find these combined effects to be significant in either case.

Summary and Policy Implications

Using a plant-level database of meat slaughter plants under federal inspection, rates of plant entry and exit prior to and during PR/HACCP implementation are compared and the factors contributing to plant exit during PR/HACCP implementation are analyzed. The effects of PR/HACCP implementation occur primarily through changes in costs of production and thus profitability. Some plants, particularly smaller plants, may also have lacked the management expertise to implement PR/HACCP and therefore closed.

Over the pre-HACCP period (1993–1996) and the implementation period (1996–2000), the total number of meat slaughter plants has declined steadily. However, while the number of very small and small plants decreased, the total number of large plants increased slightly. The rates of plant entry and exit underlying these total plant numbers were also compared. For very small plants, the entry rate increased, but the exit rate increased more, thus leading to a decline in the total number of very small plants. For small plants, the entry and exit rates were fairly similar between the two periods, but the exit rate increased enough to result in a decline in the number of small plants. Finally, for large plants, both the entry and exit rates declined substantially because only one plant exited and none entered during the implementation period. In describing these entry and exit rates, we note that some of the effects of PR/HACCP may have been attenuated by the strong domestic economy during implementation of the regulations.

Based on the probit model of plant exit, the factors contributing to plant exit during PR/HACCP implementation include plant age, plant size, regional competition, regional plant entry rates in the prior period, and state-level wage rates. In general, very young or very old plants, very small and small plants, plants with small market share in a concentrated region, plants in regions with lower rates of entry in the prior period, and plants in regions with low wages had a higher probability of exit. Thus, while controlling for other plant characteristics affecting plant exit, very small and small plants, as defined by the PR/HACCP regulations, were more likely to exit than large plants. Although most results are expected, the finding that plants in regions with higher rates of entry in the prior period were actually less likely to exit was not anticipated. However, we speculate this result occurs because high rates of entry in the prior period correspond to favorable economic conditions for the region, as do higher wage rates. Consequently, to help alleviate the economic effects of PR/HACCP, our results suggest policy interventions should be directed toward the youngest plants which may lack appropriate expertise, the oldest plants with aging capital equipment, plants in the very small and small size categories, plants in concentrated regions, and plants in economically depressed areas.

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