PLANT ENTRY AND EXIT FROM THE MEATPACKING INDUSTRY DURING PATHOGEN REDUCTION AND HACCP IMPLEMENTATION

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ABSTRACT

Implementation of the Pathogen Reduction and Hazard Analysis and Critical Control Points (PR/HACCP) regulations has now occurred across all U.S. meat and poultry plants. Using databases of plants under federal inspection, we estimate a probit model to determine which factors have affected the probability of exit of meat slaughtering plants during implementation of the regulations.

PLANT ENTRY AND EXIT FROM THE MEATPACKING INDUSTRY DURING PATHOGEN REDUCTION AND HACCP IMPLEMENTATION

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. These requirements, referred to as PR/HACCP, for Pathogen Reduction and Hazard Analysis and Critical Control Points, include requirements for Sanitation Standard Operating Procedures (SSOPs), pathogen testing for *Salmonella* on selected raw products and generic *E. coli* on all carcasses, and for developing and following a HACCP plan. While 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 that the rule may cause meat and poultry plants to exit at faster rates or enter at slower rates than they have in the past. In addition, many of the public comments on the proposed rule suggested that small plants in particular would be driven out of the industry because their costs per unit of output would be higher than for large plants (MacDonald et al., 1996). Using databases of plants under federal inspection, we have found that the rates of *exit* of meat slaughtering plants did increase during PR/HACCP implementation compared to the period immediately prior to implementation, particularly for very small meat slaughtering plants. However, the rate of *entry* of very small meat slaughtering plants also increased, most likely because of the strength of the domestic economy during implementation of the regulations.

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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.

The purpose of this paper is to determine which characteristics of meat slaughtering plants, in addition to size, have most contributed to the probability that a plant exits the industry during PR/HACCP implementation.[2] While this paper focuses on the federal plants that slaughter red meat species (and which may or may not also further process these products), we will later be conducting analyses of plants that slaughter poultry and of plants that only process meat and poultry products. The methodology we use is an extension of Anderson et al. (1998) in which they analyzed beef slaughtering plants that exited from 1991 to 1993. The results of the analysis are useful for policy makers in determining how and to whom to provide assistance in mitigating the economic effects of the regulation.

EFFECT OF PR/HACCP REGULATIONS ON COSTS OF PRODUCTION

After having conducted 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 HACCP differently and therefore had and continues to have different cost effects due to HACCP. Furthermore, plants have implemented different pathogen testing procedures including implementing their own voluntary testing. To obtain in-depth information on the kinds of changes that plants have made that affect their costs of production and how the changes differ across types of plants, we conducted 27 interviews in fall 2000 and spring 2001. We conducted these interviews with a combination of trade association representatives, university food science faculty, FSIS district managers, FSIS Technical Service Center staff, and plant managers or HACCP coordinators. Based on these interviews, we found that the costs of HACCP are

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[2]Another interesting analysis that one could postulate is to determine which factors have contributed to plant entry during PR/HACCP implementation. However, the data set needed to do this analysis would have to include information not only on plants that entered but also on plants that considered entering but did not.

different for large plants than for small plants because they have made different types of changes than small plants.

The costs associated with implementing PR/HACCP include both the one-time start-up costs of 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 large capital equipment purchases due to HACCP. For example, larger red meat slaughtering plants have installed systems for reducing pathogens on carcasses, including steam pasteurization systems, lactic acid rinse cabinets, 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. On the variable cost side, larger plants are also likely to have made more changes. While larger plants have added additional quality control staff (as many as 20 additional employees for two shifts) and added HACCP to their routine training programs, the smallest plants have more likely added approximately 1 hour per day of HACCP duties to an existing employee (often the owner) and conduct intermittent on-the-job training for HACCP. Larger plants are also more likely to have increased the use of antimicrobials and sanitizers, including using different compounds than before HACCP, and to conduct their own voluntary pathogen testing programs.

Overall, based on these interviews, we found that the smallest plants have interpreted the PR/HACCP regulations to require fewer changes than larger plants. In particular, smaller plants are less likely to have installed new capital equipment, added additional 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, they may have exited at faster rates because their managers lacked the expertise to implement PR/HACCP or their revenues decreased such that the business was no longer profitable. While most of the effects of PR/HACCP have been on the cost side, we found that many smaller plants stopped producing specialty, seasonal, and ethnic products rather than develop separate plans for these products, and thus their revenues may have declined.

PATTERNS OF ENTRY AND EXIT IN THE MEATPACKING INDUSTRY

The meat and poultry industries have historically been characterized by frequent plant entry and exit. Thus, as MacDonald et al. (1996) 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, we can now compare whether the rates of entry and exit have changed from the period immediately prior to implementation of the regulations (1993 to 1996) to the period of implementation (1996 to 2000) using a database of plants under federal inspection.[3] The Enhanced Facilities Database (EFD), which Research Triangle Institute maintains for FSIS, combines data from FSIS's 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 that actively slaughter and/or process federally-inspected meat and poultry products.[4]

Table 1 presents the numbers of red meat slaughtering plants in the EFD by HACCP size in 1993, 1996, and early 2000 and the numbers of plants that entered and exited between years.

[3] In 2002, we will update this database again and therefore will also be able to calculate rates of entry and exit in the post-PR/HACCP implementation period.

In developing these inventories, we included plants that slaughtered on average at least one red meat species animal per week. Thus, if a plant dropped below one animal per week, stopped slaughtering entirely, or closed, we considered the plant an exit from the red meat slaughtering industry.[5] Similarly, if a plant opened or had only been processing but then began to slaughter at least one animal per week, we considered the plant an entrant to the red meat slaughtering industry.[6] In total, the numbers of plants in the red meat slaughtering industry have been declining because the number of plants exiting has exceeded the number entering. As indicated in Table 2, the overall rate of plant entry increased from 7.7 percent to 10.3 percent, while the rate of plant exit increased from 13.1 to 17.8 percent. 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 large plant entries from 1993 to 1996, the largest size category with greater than 500 employees has had few 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, 1997; Audretsch, 1991, 1995; Flynn, 1991; MacDonald, 1986; Mayer and Chappell, 1992; Rosenbaum and Lamort, 1992). 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. While

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[4]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.

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

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

these studies are helpful 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. (1998) developed a model to explain the probability that plants in the beef packing industry exited the industry from 1991 to 1993 based on a set of plant characteristics. The set of characteristics included variables representing plant-level characteristics, market structure characteristics, and supply and demand shifters. They found that plant and market structure characteristics were significant in explaining the probability of plant exit but that 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 slaughtering plants and a competitive fringe index for plant procurement areas were statistically significant. The analysis presented in this paper updates Anderson et al.'s analysis to the 1996 to 2000 time period, which allows us to analyze changes during the PR/HACCP implementation period, and expands the data set to also include all plants that slaughter any meat species.

A THEORETICAL MODEL OF THE PLANT EXIT DECISION

In modeling the decision to exit, we follow Anderson et al.'s (1998) approach. 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 present value of profits equals $\Pi_t = \pi_t + e^{-rt}V_{t+1} - V_{Lt}$, the "exit" threshold for profits is defined as follows:

$$\pi_t < V_{Lt} - e^{-rt}V_{t+1} \quad (1)$$

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

$$\pi_t = P_tQ_t - P_{mt}M_t - W_tL_t - P_{et}E_t \quad (2)$$

where 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; and Q, M, L, and E are the corresponding output and input quantities sold and purchased.

As Anderson et al. (1998) suggest, profits as defined by Equation (2) indicate that 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 at what level of production to operate 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

$$\pi_t^* < V_{Lt} - e^{-rt}V_{t+1} \quad (3)$$

where

$$\pi_t^* = \pi(P_t, P_{mt}, W_t, P_{et}, K_t) \quad (4)$$

are maximum profits (computed from Equation 2) given (expected) output and input prices and the level of fixed factors (K). Two important properties of the profit function are that it is increasing in output price and decreasing in input prices (Varian, 1992). These properties are useful in developing sign expectations of the variables in the empirical model.

In the empirical analysis, not all of the variables indicated in Equation (4) are observable at the plant level. In particular, output prices of beef, pork, and poultry are reported only for regions. One way around this problem is to replace output price with a reduced form equation for output price, $P = P(P_m, W, P_e, Y, K)$, where Y represents demand shifters for the output (e.g., income). Substituting into Equation (4) (ignoring for the moment time subscripts) yields the (partially) reduced-form profit function

$$\pi_t^* = \pi[P(P_m, W, P_e, Y, K), P_m, W, P_e, K] = \pi^*(P_m, W, P_e, Y, K) \qquad (5)$$

Therefore, we are able to express the profit function as a function of input prices, fixed factors specific to the individual plant, and factors influencing demand for the output. But now we need to be careful to note that the impact of the input prices and fixed factors in Equation (5) represent 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:

$$\frac{\partial \pi^*}{\partial W} = \frac{\partial \pi^*}{\partial P}\frac{\partial P}{\partial W} + \frac{\partial \pi^*}{\partial W} = Q\frac{\partial P}{\partial W} - L \qquad (6)$$

where the results $\partial \pi^* / \partial P = Q, \partial \pi^* / \partial W = -L$ follow from Hotelling's lemma (Varian, 1992, pp. 43-44). From the relationship between output price and marginal cost, we expect $\partial P / \partial W > 0$.

Thus,

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

or

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

Hence, we see that the sign of a change in wage rate on profits, and therefore 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. 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 that the plant would exit.   In general, similar ambiguous effects exist for the other input prices and capacity variables in the model.

Plant-Level 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 that influence 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 (1982) and Ward (1993) report that long-run average costs tend to decline as volume increases and to flatten out at higher output levels. If scale economies are present, we would expect to see an inverse relationship between plant capacity and the exit rate (Anderson et al., 1998).

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. We follow past studies and use plant age as a proxy for this effect. Because new capital is expected to be more productive than older capital and because age is likely positively correlated with operator experience, the relationship between the age effect on profitability and probability of exit is likely nonlinear.

Anderson et al. (1998) argue that firms that slaughter both beef and pork may receive higher prices for convenience provided to buyers, thus enhancing profits. Multiple species may also provide economies of scope. That is, a plant that provides both beef and pork slaughter 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 that integrate vertically might also be expected to increase profits over plants that do not integrate vertically. This can be accomplished through achieving efficiencies by combining different labor activities and by producing higher value-added products.

Regional-Level Factors

Market structure may also influence the decision to exit. Regional livestock markets are often populated by a few large producers and many small producers. If the markets are imperfectly competitive, then producers may earn profits in proportion to their market shares so higher share firms would be less likely to exit. In more highly concentrated markets we would expect there to be a lower probability of exit.

In this context, the concept of competitive fringe becomes important. As discussed by Anderson et al. (1998), this phenomenon is related to the concern that large producers might be pushing smaller firms out of the market. Forward contracting between meat processors and livestock producers (cattle or hogs) can be a source of this problem. We often observe a negative relationship between the proportion of sales forward contracted and open market price (Azzam, 1998). This may be due to either anti-competitive behavior or simply reflect scale economies through purchasing arrangements. At any rate, the competitive fringe is intended to capture the effect that firms on the competitive fringe are more likely to exit, other things being equal.

Another measure of market structure is the level of entry. In past studies (Dunne, Roberts, and Samuelson, 1988), a high positive correlation has been found between industry-level entry rates and exit rates. The line of causality is that higher entry rates may raise input prices (most notably P_m and W). Thus, we might expect a higher entry rate to increase the incidence of plants exiting.

Supply and Demand Factors

Input prices can vary from one plant to another, particularly livestock prices (beef and pork prices), wage rates, and energy prices. 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 in the model section, because output price is not included in the model, the input prices may reflect the combined effect of changes in plant costs and the indirect effect from 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 lowers plant costs.

Demand-side variables are not included in the model because of previous results by Anderson et al. (1998) indicating that variables to represent these effects were individually and collectively insignificant. A major reason for this is that the markets for beef and pork tend to be national in scope, indicating that plants across the country face similar demand conditions. Indeed, preliminary statistical analysis with per capita income included as a separate variable confirmed this expectation.

EMPIRICAL SPECIFICATION

We considered a meat plant to be active if it was in the PBIS system, which indicates that it is currently being inspected by FSIS inspectors, and 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, we considered its primary line of business to be something other than slaughtering, and thus we excluded it from our data set. We considered a plant to have exited if it was no longer included in the PBIS system and thus no longer under active inspection or its slaughter volume fell below one animal per week.

Following Anderson et al. (1998), we use a probit model to parameterize the empirical model. Let 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). 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 that are unobservable to us, the payoff function can be written as follows:

$$\Pi_i = \beta' \mathbf{X}_i + \varepsilon_i \qquad (7)$$

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

$$\text{Prob}\ (Y_i = 1) = \text{prob}\ (\Pi_i < 0)$$

$$= \text{prob}(\varepsilon_i < -\ \beta' \mathrm{X}_i)$$

$$= 1 - F(\beta' \mathrm{X}_i)$$

where $F(\bullet)$ is the cumulative distribution function.

Assuming the error term is normally distributed, the estimation problem becomes to maximize the following log likelihood function:

$$\ln L = \sum_{i=1}^{N} \{Y_i \ln[1 - F(\beta' \mathbf{X}_i)] + (1 - \mathrm{Y}_i) \ln[F(\beta' \mathbf{X}_i)]\} \qquad (8)$$

where N is the number of observed plants.

DATA

The data used in the model are 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. While the plant, company, and regional characteristics come directly from or are derived from plant-level USDA/FSIS databases, the supply condition variables are from published Bureau of Labor Statistics (BLS) and National Agricultural Statistics Service (NASS) data sets.

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 that 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 (less 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 indicate which species (cattle, hogs) the plant slaughters and whether the plant also conducts processing activities.

The company characteristics variables are included to indicate evidence of economies of scope in meat slaughtering. 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, we used information from "The Top 100" issue of *Meat and Poultry: The Business Journal of the Meat and Poultry Industry* in addition to matching plant names across the data set. We then combined the plant information for each company to create the company variables.

The regional characteristics are similar to those used by Anderson et al. (1998) and are based on an assumed livestock procurement area within a 150-mile radius around the plant. For each plant's procurement area, we calculated the rate of meat slaughtering plant entry, the plant's share of the meat slaughtering volume, the Hirshmann–Herfindahl index (HHI), and a competitive fringe index defined as the HHI divided by the share. The competitive fringe index provides a measure of the level of market concentration relative to the size of the plant within its procurement area.

Finally, the supply condition variables include indicators of the costs of inputs for the area in which the plant is located. These include processing wage rates, an energy index, live cattle prices, and live hog prices. Demand-side variables are not included because packaged meat products can be transported throughout the United States, and the markets for meat products have been found to be national in scope. Thus, plants across the country face similar demand-side conditions.

The final data set includes 920 federally-inspected plants that slaughtered at least one animal per week on average in 1996. As noted in Table 1, 164 (17.8 percent) 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 listed in Table 4. The average plant in the data set slaughtered 147,000 animals, was 17 years old, was owned by a company that also owned two other federally-inspected meat and/or poultry plants, and slaughtered 5 percent of the volume in its procurement area.

In comparing plants that exited to those that remained, plants that exited 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. In terms of company ownership, plants that exited were owned by companies that owned fewer plants, had lower total slaughter volumes, and were less likely to also conduct processing activities. While most of the regional characteristics are similar for plants that exited and those that remained, the competitive fringe index was nearly three times greater for exit plants, meaning that 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 plants that exited and those that remained.

RESULTS

Results of the probit model of meat slaughtering plant exit are presented in Table 5, including the tests of joint significance of the plant, company, regional, and supply condition variables. Because of the low pseudo-R^2, the model is not suited for predicting if an individual plant will close based on its characteristics. However, the model is useful for providing information on the general characteristics that increase the probability of plant exit.

The variables that appear to explain the probability of plant exit during PR/HACCP implementation include plant characteristics, regional characteristics, and supply conditions. Within the variables representing plant characteristics, age of the plant and the HACCP size designation for the plant affected the probability of exit. The age and age-squared variables are jointly significant at the 0.04 level and indicate that the probability of plant exit decreases by 0.5 percent 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. The binary variables for very small and small HACCP sizes were also significant and indicate that a very small plant was 35 percent more likely and a small plant was 55 percent more likely to exit than a large plant.[7] We expected the relative sizes of these coefficients to be reversed; however, we could not reject a test of the null hypothesis that these coefficients are in fact equal ($p = 0.25$).

In contrast to Anderson et al., we did not find slaughter volume or slaughter volume squared to be significant explanatory variables. This result could be because the slaughter volume does not represent the total product volume for the plant if it also produces processed

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

products using boxed beef or pork inputs or because the HACCP size binary variables capture the effects of plant capacity on the plant exit decision. However, when we reran the model without the HACCP size variables, we could not reject the null hypothesis that the coefficients on slaughter volume and slaughter volume squared are zero (p = 0.35). Because economies of scale in meat slaughtering have been well documented, and thus higher volume plants should be less likely to exit, we believe our result is due to the former effect that the slaughter volume variables are imperfect measures of plant capacity.

We also did not find a significant effect of horizontal and vertical integration within the plant. We believe this result occurs either because the HACCP size variable is also picking up some of the effects of these variables or because the fact that we combined all meat slaughtering plants in the data set obscures some of these effects.

It is likely that we find no evidence of the effects of economies of scope on the plant's exit decision, as evidenced by the insignificance of the company variables, because most of the plants (83.7 percent) 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, in the data set. We also estimated the model 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 signs.

Within the set of regional characteristics, the entry rate and competitive fringe index both have significant estimated effects on plant exit. Surprisingly, the coefficient on the entry rate variable is negative, indicating that a plant in a region with higher rates of entry has a lower probability of exit. One explanation for this result may be that favorable supply or demand conditions within the region cause more plants to enter and fewer plants to exit. The coefficient on the competitive fringe index is positive, as expected, and significant, indicating that a low market-share plant in a concentrated region is more likely to exit. An increase in the competitive fringe index by one standard deviation (3,839) increases the probability of plant exit by 4.3 percent.

Finally, within the set of supply condition variables, only the wage index is significant. The positive sign results from the fact that, as described above, an increase in the wage rate has both a direct effect on profits and an indirect effect on profits through induced effects on output price. Thus, a plant in an area with higher wages is likely also obtaining a higher price for its output such that 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 likely insignificant because the published state-level data correspond imprecisely to the input prices faced by the plant.

SUMMARY AND POLICY IMPLICATIONS

Using a plant-level database of meat slaughtering plants under federal inspections, we compare rates of plant entry and exit prior to and during PR/HACCP implementation and analyze the factors contributing to plant exit during PR/HACCP implementation. The effects of PR/HACCP occur primarily through its effects on costs of production and thus its effects on profitability. Some plants, particularly smaller plants, may also have lacked the expertise to implement PR/HACCP and thus closed.

Over the pre-HACCP period (1993 to 1996) and the implementation period (1996 to 2000), the total number of meat slaughtering plants has declined steadily. However, while the number of very small and small plants decreased, the total number of large plants increased slightly. We also compared the rates of plant entry and exit that underlie these total plant numbers. 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 effects, 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 our probit model of plant exit, the factors contributing to plant exit during PR/HACCP implementation include plant age, plant size, local competition, local plant entry rate, and local 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, and plants in regions with low wages had a higher probability of exit. While most results are expected, the result that plants in regions with higher rates of entry were actually less likely to exit was not. However, we speculate that this result occurs because high rates of entry correspond to favorable economic conditions for the region, as do higher wage rates. Thus, to help alleviate the economic effects of PR/HACCP, our results suggest that policy interventions should be directed toward the youngest plants that 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.

In addition to the analysis presented here, we will also be conducting similar analyses of poultry plant slaughtering exit and processing plant exit. We expect the results to differ from those presented here because of the high degree of vertical coordination within the poultry industry. Relatively few poultry slaughtering plants are very small or owned by single-plant companies as in the meat slaughtering industry. However, the processing industry, which is made up of plants that do no slaughtering, has a substantial number of these types of firms.

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Table 1. U.S. Federally-Inspected Meat Slaughtering Plant Inventories and Numbers of Plants Entering and Exiting, 1993, 1996, and 2000[a]

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

[a]Includes only plants that slaughter at least 50 animals per year. In addition to slaughtering, some plants also conduct processing activities. Note that plants that appear to have entered may potentially have switched from state to federal inspection. However, we excluded from the analysis plants in Florida that switched from state to federal inspection when the state discontinued its inspection program in 1997. Note also that plants that appear to have exited may have switched from federal to state inspection.

Table 2. Rates of Entry and Exit of U.S. Federally-Inspected Meat Slaughtering Plants, 1993 to 1996 and 1996 to 2000[a]

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

[a]Includes only plants that slaughter at least 50 animals per year. In addition to slaughtering, some plants also conduct processing activities. Note that plants that appear to have entered may potentially have switched from state to federal inspection. However, we excluded from the analysis plants in Florida that switched from state to federal inspection when the state discontinued its inspection program in 1997. Note also that plants that appear to have exited may have switched from federal to state inspection.

Table 3. Meat Slaughtering Plant Exit Model: Variable Definitions

Variables	Definitions
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 earliest[b]
Age squared	Plant's age squared
Very small size	
Small size	Plant's HACCP size designation (binary)[c]
Large size	
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 red meat slaughtering plant entry from 1996 to 2000 for the region in which the plant is located
Slaughter volume share	Plant's share of the region's red meat slaughtering volume
HHI	Hirschmann–Herfindahl index based on red meat slaughtering 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[e]
Live cattle price	Live cattle price for the plant's state or area, average of 1995, 1996, and 1997[f]
Live hog price	Live hog price for the plant's state or area, average of 1995, 1996, and 1997[f]

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

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

[c]Source: USDA's Field Automation and Information Management (FAIM) and infoUSA (formerly American Business Lists)

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

[e]Source: Bureau of Labor Statistics

[f]Source: USDA's National Agricultural Statistics Service

Table 4. Meat Slaughtering Plant Exit Model: Means and Standard Deviations

Variables	All Plants (n = 920)	Exit Plants (n = 164)	Non-Exit Plants (n = 756)
Plant characteristics			
Slaughter volume (mil pds)	0.1478	0.0633	0.1662
	(0.5324)	(0.3316)	(0.5651)
Slaughter volume squared (mil pds)	0.3050	0.1133	0.3466
	(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)	0.6620	0.7378	0.6455
	(0.4733)	(0.4412)	(0.4787)
Small size (binary)	0.2685	0.2561	0.2712
	(0.4434)	(0.4378)	(0.4449)
Large size (binary)	0.0696	0.0061	0.0833
	(0.2546)	(0.0781)	(0.2766)
Slaughters cattle (binary)	0.8391	0.8598	0.8347
	(0.3676)	(0.3483)	(0.3717)
Slaughters hogs (binary)	0.7685	0.7683	0.7685
	(0.4220)	(0.4232)	(0.4221)
Processing at plant (binary)	0.6946	0.6402	0.7063
	(0.4608)	(0.4814)	(0.4557)
Company characteristics			
Number of plants	2.934	1.652	3.212
	(8.911)	(2.978)	(9.711)
Meat slaughter volume (mil pds)	1.117	0.5029	1.251
	(4.739)	(3.326)	(4.985)
Poultry slaughter volume (mil pds)	6.984	1.069	8.267
	(52.93)	(9.084)	(58.17)
Processing (binary)	0.7174	0.6524	0.7315
	(0.4505)	(0.4777)	(0.4435)

(continued)

Table 4. Meat Slaughtering Plant Exit Model: Means and Standard Deviations (continued)

Variables	All Plants (n = 920)	Exit Plants (n = 164)	Non-Exit Plants (n = 756)
Regional characteristics			
Entry rate	0.1048	0.0755	0.1112
	(0.3350)	(0.1813)	(0.3595)
Slaughter volume share	0.0518	0.0308	0.0563
	(0.1391)	(0.1235)	(0.1419)
HHI	0.2927	0.2896	0.2934
	(0.1967)	(0.1951)	(0.1972)
Competitive fringe index	1,275	2,752	954.1
	(3,839)	(6,257)	(2,985)
Supply conditions			
Wage rates ($/hr)	11.54	11.39	11.58
	(1.41)	(1.50)	(1.38)
Energy index (1982–1984 = 100)	109.9	109.8	109.9
	(2.44)	(2.34)	(2.46)
Live cattle price ($/100 pds)	53.11	53.33	53.06
	(8.09)	(7.85)	(8.14)
Live hog price ($/100 pds)	46.95	46.76	46.99
	(4.69)	(2.55)	(5.03)

Note: Standard deviations are in parentheses below the means.

Table 5. Meat Slaughtering Plant Exit Model: Probit Results

Explanatory Variables	(dF/dx) (Marginal Effect)	Standard Error	χ^2 Test of Joint Significance	Elasticity
Plant characteristics			$\chi^2(9) = 15.34$*	
Slaughter volume (mil pds)	0.044115	0.1282		0.04238
Slaughter volume squared (mil pds)	0.004293	0.0290		0.00851
Age (years)	–0.005605*	0.0034		–0.61770
Age squared (years)	0.000059	0.0001		0.14086
Very small size (binary)[a]	0.350270***	0.0902		2.00069
Small size (binary)[a]	0.551093***	0.1951		0.74591
Large size (binary)				
Slaughters cattle (binary)[a]	–0.033217	0.1186		–0.17316
laughters hogs (binary)[a]	–0.149534	0.3075		–0.65150
Processing at plant (binary)[a]	0.034534	0.0976		0.16067
Company characteristics			$\chi^2(4) = 1.85$	
Number of plants	0.011105	0.0115		0.21175
Meat slaughter volume (mil pds)	–0.005846	0.0089		–0.04246
Poultry slaughter volume (mil pds)	–0.001749	0.0015		–0.07940
Processing (binary)[a]	–0.073195	0.1188		–0.32077
Regional characteristics			$\chi^2(4) = 23.00$***	
Entry rate	–0.132276**	0.0636		–0.09387
Slaughter volume share	–0.027919	0.1203		–0.00940
HHI	–0.086201	0.0677		–0.16402
Competitive fringe index	0.000011***	2.86E-06		0.09305
Supply conditions			$\chi^2(4) = 6.22$	
Wage rates ($/hr)	–0.021954**	0.0093		–1.64737
Energy index (1982–1984 = 100)	–0.000696	0.0056		–0.49703
Live cattle price ($/100 pds)	0.000436	0.0019		0.12554
Live hog price ($/100 pds)	0.001763	0.0051		0.41234

Notes: Log likelihood = –400.35768
Psuedo $R^2 = 0.0716$
N = 920

Notes: *Significant at the 0.10 level.
**Significant at the 0.05 level.
***Significant at the 0.01 level.

[a]Marginal effect is for a discrete change of the binary variable from 0 to 1.