A Markov Chain Analysis of the Size of Hog Production Firms in the United States

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ABSTRACT

The U.S. hog industry expanded rapidly during the 1980s and 1990s. Along with this expansion, hog farms have become larger, partly due to economies of size and new business arrangements. Using markov chain analysis, this study analyzes the movement of hog farms among three different size categories. Results indicate that the hog–corn price ratio has continued to affect the entry and exit of small hog farms, and has influenced the movement of hog farms among size categories. Interest rates, processing capacity, and agglomeration economies have impacted new entry of hog farms in the United States [L110, L230]. © 2001 John Wiley & Sons, Inc.

1. INTRODUCTION

The pork industry is among the fastest evolving major agricultural sectors in North America today. The introduction of large-scale integrated facilities owned by a single integrated investor or group of investors has dramatically changed the industry. Due to such technologies as split-sex feeding, all-in, all-out stocking, and medicated early feeding, large-scale integrated facilities enjoy significantly lower costs of production than the traditional family farm1 operation that has been common in the Midwest (Schrader & Boehlje, 1996). These cost differences are leaving people wondering about the future of the family farm with respect to raising hogs (Lawrence, Rhodes, Grimes, & Hayenga, 1997; Schrader & Boehlje, 1996).

Change in the size of hog farms is occurring at different rates across the United States. Figures 1 and 2 illustrate the changes in hog production and farm numbers that have occurred in the United States, North Carolina, and Iowa over the past decade. In 1988, over 90 million hogs were marketed in the United States on 322,600 farms. By 1999, over 121 million hogs were marketed from only 98,460 farms. However, along with these

1The family farm is defined by Cramer, Jensen, and Southgate (1997) as, “a farm in which the family provides most of the labor required in its operation.”

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changes in size, changes in location of production also occurred. In Iowa, a traditional hog producing state, hog marketings changed from 22.5 million to 26.5 million hogs; however, North Carolina increased from 4.5 million to 17.8 million hogs. Numbers of hog farms decreased in both states. The largest decreases in production came from small hog operations.

Figure 1 Hog Farms and Marketings in the United States, 1988–1999

Figure 2 Hog Farms and Marketings in Iowa and North Carolina, 1988–1999
Although economies of size explain some of the increase in size, changes in location are not as easily explained. Some states are encouraging the entry of large-scale, integrated hog operations. They recognize the advantages of increased employment and, in regions where corn or other feed grains are produced, an opportunity to establish value-added agribusiness. However, other states have viewed these changes negatively, and have adopted legislation governing the existence of corporate farming with the hope of maintaining the family farm structure. This has curbed opportunities for large integrated hog facilities to start up business and, as Hurt (1994) points out, “areas that do not allow change could see their region’s industry wither and even perish” (p. 13). Thus, some debate has arisen as to whether smaller, family-run hog farms can remain viable in the future and, if so, under what conditions.

It is essential that we understand what is happening in the hog industry, and gain insight regarding the factors associated with these changes. First, we need to understand how economic forces are influencing investment and operating decisions for hog producers by size category. Second, we need to understand the effect that anticorporate farm legislation is having and will continue to have on traditional hog producing regions. Some researchers have described the changing nature of the industry (e.g., Fulton & Gillespie, 1995; Hurt, 1994; Karantininis, Lambert, & St. Louis, 1995; Kliebenstein & Lawrence, 1995; Rhodes, 1995) and trends influencing the structure of animal agricultural industries in general (e.g., Abdalla, Lanyon, & Hallberg, 1995). However, given that the changes are so recent and ongoing, little work has been done to quantify the changes. Boehlje (1999) points out that, despite data limitations, there is a need to move beyond the descriptive works and obtain empirical estimates of factors contributing to the changes.

The objective of this article is to estimate, using Markov chain analysis, the relative importance of input and output prices and other factors in the determination of the size distribution of hog operations in the United States in recent years. The following section briefly reviews the literature on Markov Chain analysis as it applies to agricultural sub-sectors. Then, a model is presented for estimation. Empirical results are presented in the fourth section. The final section of the paper contains conclusions and implications.

2. MARKOV CHAIN ANALYSIS

The use of Markov chain analysis has been justified by many previous researchers examining the changing nature of agricultural production in the United States. Padberg (1962), as well as Judge and Swanson (1962), and Alexander and Williams (1965), were pioneers in using Markov chain analysis to explain the changing size and structure of animal agriculture. These early analyses assumed stationarity, which meant that the probability of a firm moving from one size category to another was constant over time. Hallberg (1969) later projected size distributions of firms using nonstationary transition probabilities.

Stavins and Stanton (1980) used Markov chain analysis to predict the size distribution of dairy farms in New York State. They compared alternative applications of Markov analysis and found that a multinomial logit model utilizing microlevel data yielded the most accurate results. Microlevel data trace the sizes of individual farms through time, while macrodata, such as census data, provide only numbers of firms in each size category through time. The multinomial logit formulation is different from Hallberg’s (1969) model in that transition probabilities are constrained to be greater than or equal to zero and less than or equal to 1. The stationary microdata model yields the second best predictions, and the macrodata model is the least accurate approach. They discussed trade-
offs associated with choosing between the models. However, in many cases, it is not feasible to obtain microlevel data and, instead, macrolevel data must be used.

Markov chain analysis has been applied in many studies where the objective was to determine the causes of movement of firms between different size categories. Two analyses in hog production are Disney, Duffy, and Hardy (1988), and von Massow, Weersink, and Turvey (1992). Disney et al. (1988) used macrodata to examine the changing structure of the southeastern U.S. hog industry during the 1970s and early 1980s using the hog–corn price ratio as the explanatory variable. They used U.S. agricultural census data for 4 years (1969, 1974, 1978, and 1982). Their results indicate that higher hog–corn price ratios result in less exit of small farms and lower transition probabilities associated with the movement to larger size categories. von Massow et al. (1992) examined changes in the Ontario hog industry during the 1970s and early 1980s using the Minimization of Median Absolute Deviations nonparametric method. Explanatory variables included the hog–corn price ratio, interest rate, and labor/capital price ratio. Results indicated that a higher hog–corn price ratio made exit less likely and that numbers in the smaller size classes would remain higher. They found that high interest rates increased exit in the smallest size classes, and that an increase in the wage rate relative to the cost of capital had a negative influence on the share of small farms.


3. THE MODEL

A nonstationary, macrodata Markov chain model, similar in structure to Chavas and Magand (1988), and Zepeda (1995), is used to model changes in the size and location of firms in the U.S. hog industry. The model is structured such that the number of firms, \( n \), in size category, \( j \), time period, \( t \), at location, \( l \), is a function of the number of first time entrants, \( r \), exits, \( x \), and firms that transfer from another size category or remain within the same size category [Eq. (1)].

\[
n_{ijtl} = r_{ijtl} - x_{ijtl} + \sum_{i=1}^{j} P_{ijtl} n_{ij(t-1)l} \tag{1}
\]

where \( P_{ijtl} \) refers to the probability that a firm will move from size category \( i \) to \( j \) in time \( t \) at location \( l \); \( s \) is the number of size categories. Net new entrants \( a_{ij} \) are the subtraction of exits from entrants; thus, \( a_{ij} = r_{ij} - x_{ij} \). Net new entrants and transition probabilities may vary over time. They are assumed to be functions of factors \( X \) such that \( a_{ij} = f(X_{t-1}) \) and factors \( Z \) such that \( P_{ij} = f(Z_{t-1}) \). Factors \( X \) and \( Z \) may differ, because it is possible that the factors that affect entry and exit are different from those that affect movement among size categories. These variables are lagged 1 year because decisions for entry, exit, expansion, or contraction of a firm are likely dependent upon information available during the previous period. As well, there is a lag between the period when an expansion or
entry/exit decision is made and the period when more animals are actually in place, especially when expansion of facilities is required.

Equation (2) represents the probability that a firm will move between size category \(i\) and all but one of the other size categories, where the size categories range from 1 to \(s\).

\[
P_{ijl} = \frac{e^{\sum_{k=1}^{s-1} \beta_{ik}}}{1 + \sum_{k=1}^{s-1} e^{\sum_{k=1}^{s-1} \beta_{ik}}} \quad i = 1, \ldots, s; j = 1, \ldots, s - 1
\]  

(2)

Equation (3) represents the probability that the firm will move between size category \(i\) and all but the last size category.

\[
P_{isl} = \frac{1}{1 + \sum_{k=1}^{s} e^{\sum_{k=1}^{s} \beta_{ik}}} \quad i = 1, \ldots, s
\]  

(3)

Multinomial logit would be used to estimate the parameters \(\beta\) if the data were firm specific. Because aggregate data are used, the parameters are estimated with nonlinear seemingly unrelated regression (SUR).

The panel dataset utilized in the analysis includes fifteen states for the years 1988–1997, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Carolina, Ohio, Pennsylvania, South Dakota, and Wisconsin. Data were used for Tennessee for 1988–1995, and for Arkansas and Oklahoma for 1996–1997. These are the 18 largest hog-producing states from which the National Agricultural Statistics Service (NASS) reported annual hog farm size data over the period analyzed. We also used NASS size categories.

Three farm-size categories are considered in the analysis. The small category includes farms of 1 to 499 pigs in inventory. These farms are typical of the family farm operation that has been common in the Midwest, but is rapidly decreasing. The medium category includes farms with 500 to 999 pigs in inventory. The medium category might be considered by many in the industry to also be a small operation, translating to a farrow-to-finish operation of between 50 to 150 sows, depending on sow efficiency. However, some contracting occurs in this size category, especially with finishing operations. The large size category includes farms of 1,000 or more pigs in inventory. Given the rapidly changing hog industry, 1,000 pigs and over includes a variety of operation types, especially in the latter years of the data period. Data limitations over the period prevent a further breakdown of this category.

3.1. Factors that Affect Entry and Exit and Movement between Size Categories

The factors discussed in the following paragraphs are considered important in the entry/exit decision of firms into or out of hog production. Of these factors, only the hog–corn price ratio (HC) was included in the transition probability portion of the equations. Estimation problems are persistent when more than one or two variables are included in the transition probability portion of the equation, so we focused on the variables expected to have the greatest effect on year-to-year movement among farm sizes. Output and input prices have been shown from previous research to be important factors in short-term
(year-to-year) decisions by hog producers (Disney et al., 1988; von Massow et al., 1992). As argued earlier in this article, this is expected to be true, especially among farmers who own production facilities with little or no debt. Interest rate (IR) was also considered in the transition probability portion of the equations. It was never statistically significant, so it is not included in the final analysis.

The hog–corn price ratio (HC) has traditionally been very important in hog producers’ decisions, as shown by Disney et al. (1988), and von Massow et al. (1992). When relatively high hog prices have occurred along with relatively low corn prices, hog farmers have raised more hogs than in the reverse situation. Traditionally, it has been less difficult for small producers to enter and exit because hog facilities have been less capital intensive and little debt was held on the facilities. Thus, the lost income from not producing in a year with lower hog and higher feed prices did not present the possibility of high losses to the bottom line of the farm operation. Many smaller Midwestern hog farms continue to own facilities that can be used for raising hogs when hog prices are high. It is expected, however, that the price ratio will not have as great an impact on the entry and exit of large farms, where considerable debt is incurred for expensive, state-of-the-art facilities. It is also expected that the hog–corn price ratio affects movement among the different size categories. The hog–corn price ratio used was calculated from NASS hog and corn prices. As with the other independent variables in the analysis, HC is lagged 1 year; thus, changes in HC in Year 0 affect entry, exit, or movement between size categories in Year 0 + 1.

The prime interest rate is hypothesized to be important in entry decisions. Under high interest rates, investment in facilities and/or breeding stock would be less attractive. Thus, we expect that higher interest rates will negatively affect net new entry, consistent with results from von Massow et al. (1992). The prime interest rate is used.

The presence of anticorporate farming laws CL in some states is considered important in entry decisions, especially in the large size category. Large, vertically integrated firms frequently locate in less traditional production areas. One of the purported reasons is the business environment. The presence of an anticorporate farming law disallows certain types of business arrangements to be considered. Of the states examined, those having significant anticorporate farming laws during all or part of the period include Iowa, Kansas, Minnesota, Nebraska, South Dakota, and Wisconsin (Hamilton & Andrews, 1992). “Significant” anticorporate farming laws are those that prohibit or restrict farming and/or ownership of agricultural land by corporations, and do not exempt hogs. All states that have adopted corporate farming laws have done so with somewhat different provisions. Analysis of the differences in those provisions is beyond the scope of this study. States that have adopted these laws have done so in an attempt to maintain the family farm structure. Thus, CL is also incorporated into the small and medium-sized categories. A dummy variable is used in the model for CL, for those states and years in which anticorporate farming laws are present.

When one questions why the hog industry has not grown significantly in a particular region, an answer commonly provided is lack of sufficient processing capacity. This argument has frequently been used in the past, when most hogs were produced by small, independent producers. Increased distance of farms from slaughterers increases average cost per unit transported, making raising hogs distant from slaughterers cost prohibitive. However, it is uncertain whether existing processing capacity is as important as it once was in affecting hog production expansion. Today, vertical coordinating firms sometimes build processing capacity while also expanding hog production. Thus, with significant capital investment, agglomeration economies along each phase of production from rais-
ing pigs to processing may arise simultaneously. We utilize the variable, laborers employed in meat processing, PC, as a proxy for meat processing capacity. The alternative hypothesis is that increased hog production occurs in states where increased meat processing occurs.

The percentage of land in farms, LF, is included in the model. It is hypothesized that traditional farming states have more net new entry of hog farms than those with fewer farms, due to greater agglomeration economies. Alternatively, the opposite could be argued. A number of operations have recently moved into regions with sparse population densities and large amounts of forest, rangeland, and minor cover/use. Although these areas typically have higher associated feed costs, they are not traditional hog production regions. Thus, the introduction of large, vertically integrated hog production does not pose a perceived threat to existing producers. As well, with large amounts of forest and rangeland, operations are further from neighbors and, in some cases, less visible. Thus, the potential for future complaints over odor and water quality are reduced, reducing future costs and possible shutdown. This variable is measured as the number of acres of land in farms divided by the total number of acres of land in the state. Although the total acres in the state includes developed land including cities and towns, the developed land accounts for a fairly minor portion of total land in each of the examined states, with South Dakota having the lowest percentage, 2.5%, and Pennsylvania having the highest, at 12.3%. Because land in farms was collected by the National Agricultural Statistics Service annually, but developed land was collected by the U.S. Census, which occurs every 5 years, no attempt was made to adjust for developed acres.

The model to be estimated is presented in Equations (4a) through (4c). All independent variables are lagged 1 year. The small size category is represented by category 1, the medium size category by category 2, and the large size category by category 3. It is assumed that, in a single period, firms change by only the closest size category. In other words, large farms could not move to the small category in 1 year and, likewise, small farms could not move to the large category in 1 year. The variable, SD, represents 17 dummy variables, one representing each state analyzed, with Indiana as the base.

\[
\begin{align*}
    n_{1\ell} &= \gamma_{01} + \gamma_{11} HC + \gamma_{21} IR + \gamma_{31} CL + \gamma_{41} PC + \gamma_{51} LF + \gamma_{61} SD \\
    &+ \frac{e^{\beta_{011} + \beta_{111} HC}}{1 + e^{\beta_{011} + \beta_{111} HC}} n_{1(t-1)\ell} + \frac{e^{\beta_{021} + \beta_{121} HC}}{1 + e^{\beta_{021} + \beta_{121} HC}} n_{2(t-1)\ell} \\
    n_{2\ell} &= \gamma_{02} + \gamma_{12} HC + \gamma_{22} IR + \gamma_{32} CL + \gamma_{42} PC + \gamma_{52} LF + \gamma_{62} SD \\
    &+ \frac{1}{1 + e^{\beta_{011} + \beta_{111} HC}} n_{1(t-1)\ell} + \frac{e^{\beta_{022} + \beta_{122} HC}}{1 + e^{\beta_{022} + \beta_{122} HC}} n_{2(t-1)\ell} \\
    &+ \frac{e^{\beta_{032} + \beta_{132} HC}}{1 + e^{\beta_{032} + \beta_{132} HC}} n_{3(t-1)\ell} \\
    n_{3\ell} &= \gamma_{03} + \gamma_{13} HC + \gamma_{23} IR + \gamma_{33} CL + \gamma_{43} PC + \gamma_{53} LF + \gamma_{63} SD \\
    &+ \frac{1}{1 + e^{\beta_{021} + \beta_{121} HC} + e^{\beta_{022} + \beta_{122} HC}} n_{2(t-1)\ell} + \frac{1}{1 + e^{\beta_{032} + \beta_{132} HC}} n_{3(t-1)\ell}
\end{align*}
\]
Table 1: Results of the Seemingly Unrelated Regression Analysis: Entry/Exit Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Small Size</th>
<th>Medium Size</th>
<th>Large Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>Std Error</td>
<td>Estimate</td>
</tr>
<tr>
<td>Intercept</td>
<td>−10321.08*</td>
<td>5464.20</td>
<td>−999.03</td>
</tr>
<tr>
<td>H-C Price Ratio</td>
<td>101.28**</td>
<td>22.57</td>
<td>−23.52</td>
</tr>
<tr>
<td>Interest Rate</td>
<td>−100.63**</td>
<td>44.89</td>
<td>11.53</td>
</tr>
<tr>
<td>Corp Farm Law</td>
<td>19.92</td>
<td>405.27</td>
<td>−189.63</td>
</tr>
<tr>
<td>Process Labor</td>
<td>−70.15</td>
<td>47.13</td>
<td>56.67**</td>
</tr>
<tr>
<td>% Land in Farms</td>
<td>13210.32*</td>
<td>7933.90</td>
<td>1117.29</td>
</tr>
<tr>
<td>Arkansas</td>
<td>5472.46**</td>
<td>1882.80</td>
<td>−1373.80</td>
</tr>
<tr>
<td>Georgia</td>
<td>6382.48**</td>
<td>2763.10</td>
<td>−665.57</td>
</tr>
<tr>
<td>Illinois</td>
<td>−796.05</td>
<td>1039.40</td>
<td>−391.35</td>
</tr>
<tr>
<td>Iowa</td>
<td>−3159.24</td>
<td>2231.20</td>
<td>−635.32</td>
</tr>
<tr>
<td>Kansas</td>
<td>−2004.55</td>
<td>1906.70</td>
<td>−425.08</td>
</tr>
<tr>
<td>Kentucky</td>
<td>1846.08</td>
<td>1228.80</td>
<td>307.95</td>
</tr>
<tr>
<td>Michigan</td>
<td>7233.75*</td>
<td>4097.20</td>
<td>565.35</td>
</tr>
<tr>
<td>Minnesota</td>
<td>2362.84*</td>
<td>1290.50</td>
<td>68.35</td>
</tr>
<tr>
<td>Missouri</td>
<td>156.08</td>
<td>408.89</td>
<td>−281.19</td>
</tr>
<tr>
<td>Nebraska</td>
<td>−2623.96</td>
<td>2274.60</td>
<td>−1070.77</td>
</tr>
<tr>
<td>North Carolina</td>
<td>6637.37***</td>
<td>3155.60</td>
<td>−621.95</td>
</tr>
<tr>
<td>Ohio</td>
<td>2313.83*</td>
<td>1257.90</td>
<td>30.50</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>−49.39</td>
<td>834.21</td>
<td>41.99</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>6425.23**</td>
<td>3256.60</td>
<td>5.48</td>
</tr>
<tr>
<td>South Dakota</td>
<td>−2900.34*</td>
<td>1659.60</td>
<td>248.14</td>
</tr>
<tr>
<td>Tennessee</td>
<td>2604.68</td>
<td>1840.00</td>
<td>140.76</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>4310.41**</td>
<td>2182.80</td>
<td>−19.11</td>
</tr>
</tbody>
</table>

*Indicates significance at the 0.10 probability level.
**Indicates significance at the 0.05 probability level.

4. RESULTS

The SUR estimation was performed using SAS. Results of the Markov chain analysis are presented in Tables 1 and 2. The adjusted $R^2$ values are 0.9727, 0.8929, and 0.7544 for the small, medium, and large equations, respectively. Thus, the best fit was found with the small size equation. It is not surprising that goodness-of-fit is better for small and medium-sized operations than for the large category, given that the large category includes a heterogeneous distribution of farms, from larger family farms to very large corporate and contract farms. Table 1 reports results of the net new entry variables, while Table 2 reports results of the transition probability estimates.

4.1. Results of the Net New Entry Analysis

Results of the entry–exit component of the analysis suggest that the variable that has been traditionally important in determining entry and exit of hog farms, the hog–corn price

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**Note:** We define a contract farm as one in which the producer (contractee) contracts with a vertical coordinator (contractor) to raise the contractor’s hogs using the contractor’s feed and other variable inputs. The producer is paid according to a contracted price formula. The contractee provides facilities, labor, and specified fixed and variable inputs to the operation. There are many variations of this type of contract, as discussed by authors such as Kliebenstein and Lawrence, and Fulton and Gillespie.
ratio, HC, is more important in the small size category than in the medium and large sizes. In the small-size category, the coefficient for HC is positive and statistically significant. An increasing HC positively influences net new entry into the small size category, and vice versa. This is consistent with our expectations that smaller producers who have less capital investment in facilities will enter and exit with greater ease, depending upon prices. The failure of HC to be significant in the medium- and large-size categories could be partially due to the recent movement of new hog facilities to nontraditional regions where HC is actually lower. Although we attempt to account for variables that might be driving the growth in those regions, HC remains nonsignificant in the medium- and large-size equations.

A second variable that appears to influence entry and exit in the small-size category is the interest rate. The negative and statistically significant coefficient on this variable suggests that as the interest rate increases, producers are less likely to enter into small-scale hog production, which is as expected.

A third significant variable is the percentage of land in farms. This suggests that, in traditional farming states, more net new entry into the small size category has occurred than in states where less of the land is used for farming. Perhaps these states are more likely to have nearby supporting agribusinesses and agglomeration economies that allow smaller hog farmers to more efficiently access inputs and markets.

Several states were estimated to have greater net new entry in the small size category than Indiana. These states included Arkansas, Georgia, Michigan, Minnesota, North Carolina, Ohio, Pennsylvania, and Wisconsin. South Dakota was estimated to have less net new entry than Indiana.

The only statistically significant coefficient in the medium and large farm size entry/exit equations is the number of laborers involved in meat processing. This is not surprising, given the importance of processing facility availability in many large-scale hog operation decisions as to where to locate. Although some integrated operations, such as Seaboard in Oklahoma and Kansas, build packing facilities alongside hog production facilities, the proximity of existing packing facilities remains important for expanding hog production firms that do not own packing facilities.

Surprisingly, the anticorporate farming law variables were not significant in any of the equations. It is of interest to note that, in previous runs that did not include 1996 or 1997 data, anticorporate farming law was significant for the large size category, suggesting that states with significant anticorporate farming laws were not expanding in the large-size categories to the extent of nonanticorporate farming law states (Gillespie & Fulton, 1997). However, with 1996 and 1997 data included, CL was no longer significant. A possible explanation is that, early in the evolution of vertical coordination in the U.S. hog

### TABLE 2. Results of the Seemingly Unrelated Regression Analysis: Transition Estimates

<table>
<thead>
<tr>
<th>Variable</th>
<th>Small to Small</th>
<th>Medium to Small</th>
<th>Medium to Medium</th>
<th>Large to Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.31**</td>
<td>9.99**</td>
<td>5.31**</td>
<td>-12.77**</td>
</tr>
<tr>
<td></td>
<td>(1.04)</td>
<td>(1.91)</td>
<td>(0.90)</td>
<td>(2.27)</td>
</tr>
<tr>
<td>Hog–corn price ratio</td>
<td>0.01</td>
<td>-0.60**</td>
<td>-0.20**</td>
<td>0.53**</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.17)</td>
<td>(0.03)</td>
<td>(0.09)</td>
</tr>
</tbody>
</table>

**Indicates significance at the 0.05 probability level.
industry, anticorporate farming legislation significantly impacted farm size, with corporations desiring to feed hogs locating in regions where corporate feeding of hogs was legal. The rapid expansion of the North Carolina hog industry provides an example of a nonanticorporate farming law state expanding rapidly through the use of corporate feeding of hogs. More recently, however, hog farm sizes in the anticorporate farming law states of the Midwest, such as Iowa and Minnesota, have increased rapidly in response to pressures to become larger and more efficient. Producer networks have arisen such that producers can effectively market large numbers of quality hogs to packers without packer ownership of the hogs. It is possible that anticorporate farming legislation has had less of an impact on farm size than originally expected.

4.2. Results of the Transition Probability Analysis

All but one of the transition probability estimates are statistically significant. Results suggest that, with a more favorable hog–corn price ratio, fewer farms remain the same size. In the medium-size category, a higher hog–corn price ratio led to a decrease in the number of farms moving from the medium to the small category, fewer farms remaining in the medium-size category, and more farms moving from the medium- to the large-size category. On the other hand, fewer larger farms remained in the large-size category with a higher hog–corn price ratio; more moved from the large to the medium-size category. This suggests that higher hog prices relative to corn prices encourage the movement of firms between the medium- and large-size categories. This makes sense if the 1,000 hog inventory captures the major economies of size in hog production and debt is not held on the facilities. In such cases, producers are able to freely move among the categories according to financial needs. Under such conditions, it is likely that farmers expand under better economic conditions to reap the benefits of favorable prices. On the other hand, some farmers may be inclined to reduce operation size while continuing to maintain a similar standard of living. This is consistent with the tendency of large farms to decrease to the medium-sized category under more favorable hog–corn price ratios. Thus, these results indicate that more favorable hog–corn price ratios cause greater movement among size categories, while less favorable hog–corn price ratios tend to encourage remaining in the same size category.

The null hypothesis of stationarity of the transition probabilities was tested; in other words, we tested whether the transition probabilities change over time. The model was run with only a constant in the transition probabilities; i.e., $\beta_{1ik} = 0$. This assumes that HC has no effect on the transition probabilities and, thus, the transition probabilities are constant. The likelihood ratio test was used; the likelihood function of the restricted model was $-3344$, and that of the unrestricted model was $-3388$. The chi-square statistic is, thus, $2(-3388 + 3344) = 80$. With four restrictions, the null hypothesis of stationarity is rejected at $p = 0.001$. This is not surprising, given the significance of the parameters in the transition probability matrices.

5. CONCLUSIONS AND DISCUSSION

Some important conclusions can be derived from this study. First, let us emphasize that, although the fit of the model is very good for the small size category, it is not as good for the medium- and large-size categories. For this reason, we do not wish to emphasize the predictive capabilities of the model, but rather the implications of the importance of fac-
tors on structural change in the industry. Estimation of a Markov chain model with an exceptional fit under the current structural change of the industry presents a challenge, given that many “nontraditional” factors, such as environmental, political, and overall business environment factors are entering into producers’ entry and exit decisions.

We were at first surprised that the hog–corn price ratio was not significant for the medium and large producers, although it was significant for smaller producers. As expected, smaller producers continue to enter and exit production according to prices. Low-cost or established and debt-free operations have this freedom of entry and exit. As well, the hog–corn price ratio appears to be important in the producer’s decision as to whether to expand or contract the operation. However, our analysis does not suggest that the ratio significantly affects the entry/exit decision for larger operators. This is likely partially due to the increase in medium- and large-sized farms in nontraditional regions where hog–corn price ratios are low relative to the traditional regions. It could also be because the new, larger farms that hold high debt loads are reluctant to exit under unfavorable prices. As farms continue to increase in size, this result raises the important question of whether the hog cycle will continue to fluctuate as widely as it has in the past. If the hog–corn price ratio is less significant in the increasing number of large producers’ entry/exit decisions, it is likely that fluctuation will continue to decrease and the supply of hogs will become more constant over time. The latest downturn in hog prices during 1998 was relatively severe, partially because of the highly leveraged mega-farms’ inability to reduce or discontinue production in the face of lower prices. As previously shown in other studies, such as Disney et al. (1988), and von Massow et al. (1992), the hog–corn price ratio continues to be important in affecting expansion and contraction decisions of producers.

In recent years, a number of integrated operations have expanded in nontraditional hog production regions. In such cases, processing facilities have been built alongside production facilities. However, the availability of processing capacity remains important in determining where hog production will locate, as evidenced by the processing labor estimates that are statistically significant. For example, in 1991, Prestage Farms located integrated hog facilities in Northeastern Mississippi, which was close to a processing plant capable of processing all of the hogs produced by the Northeastern Mississippi Prestage hog farms. The presence of processing capacity was an important factor in the firm’s decision to locate in Mississippi. Thus, while existing processing capacity is not a necessary condition for larger-scale hog production to locate in a particular region, it is an important factor for many firms with expansion plans.

Other significant factors influencing entry and exit include the interest rate, which was found to be significant by von Massow et al. (1992), and the percentage of land in farms. It is not surprising that more net new entry is likely to occur in the small size category in traditional farming states than in nontraditional farming states. Such states have significant agglomeration economies, including local agribusinesses, to support small-scale hog production. Such small-scale operations are less likely to enter in regions where input supply agribusinesses and markets are more distant.

Unexpectedly, corporate farming laws did not appear to have a significant influence on hog production. Currently, if a state has enacted significant anticorporate farming legislation, producers in that state who want to enter into large-scale production using a corporate arrangement must go elsewhere to produce. However, producers in states that have enacted corporate farming laws are finding ways to capture economies of size in hog production without resorting to corporate ownership of hogs, or packer feeding of hogs,
whichever is the constraining law. In the Midwest, for example, farms have increased in size and, in many cases established producer marketing networks to deliver large quantities of high-quality hogs to packers (see Koehler, Lazarus, & Buhr, 1996). The implication is that hog farms are likely to become larger to capture economies of size and scope, regardless of whether corporate farming legislation is present.

Overall, the lack of significance of variables in the medium and large entry/exit equations leads to the conclusion that there are important factors that are not included in our model. This model is traditional in approach, using similar variables as past research concerning farm entry and exit and changes in farm size. One may ask whether the structure of the hog industry has changed drastically enough such that traditional models no longer fully capture the dynamics of the industry. Investment in new, large-scale, asset-specific facilities is a long-run decision. Exiting during unfavorable prices is less likely to be perceived as an option if a note on the facilities is to be paid. Likewise, entry of expensive new, large-scale facilities is more likely to occur on the basis of a long-run outlook on economic viability, rather than a short-run consideration of prices. Modeling of the dynamics of entry and plant location of large, contracted mega-farms also provides challenges. For instance, sociological variables such as the general attitude of residents toward large-scale animal production is likely to be an important factor in such decisions. It appears that a traditional neoclassical view of the world does not fully capture the dynamics of what is driving change in the industry, and thus leads to important avenues of further research.

5.1. Opportunities for Further Research

Several opportunities for further research follow from this study. Until a few years ago, the largest size category of hog operation collected by NASS was the 1000 hog operation, thus constraining our analysis. NASS is now collecting data for larger size categories, as well as those used in this study. A few years down the road, once enough observations have been collected, it is expected that this type of analysis might better take into account the larger farm sizes. In addition, future research could incorporate more states if data became available. Some of the states, which have recently become involved in hog production, such as Colorado, and Utah, could be incorporated. It is expected that, if these states were included, more significant shifts in production would be seen. Additional analysis could examine the effect of independent variables on changes in the percentage of inventory in each of the size classes, instead of conducting the Markov chain analysis, as we have done.

Another area for further research involves examining the effect of environmental regulations on the changing structure of the hog industry. Environmental concerns have received some attention in the literature (e.g., Gillespie, Karantininis, & Storey, 1997; Mo & Abdalla, 1997) and are certainly an important factor with respect to public opinion as evidenced by the reaction to a 60 Minutes presentation that aired in December 1996. It has been argued that the recent movement of hogs into some of the western states (that are not included in this analysis due to data limitations) has been partially due to environmental constraints in recently expanded regions. Only recently have states such as North Carolina begun to face significant binding constraints on growth due to environmental concerns. We did examine the “green” index (Hall & Kerr, 1991–1992) as an explanatory variable in the analysis. However, it was not surprising that the corresponding coefficients were insignificant, given that it is a static measurement, and the most
aggressively expanding states continued to expand rapidly throughout the observed period. Future research could explore (1) the development of an environmental index that accounts for the dynamic effects of environmental legislation on hog farm structure, and (2) the effects of environmental constraints on hog farm structure.

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REFERENCES


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