What Role Does Specialization Play in Farm Size in the U.S. Hog Industry?

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Abstract

An ordered probit analysis is used to determine the influence that specialized phases, other farm enterprises, production contracts, locations, management practices, risk preference and producer's age have on the size of U.S. hog operations. Results reveal that specialized phases along with other factors mentioned affect the size of hog operations.

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What Role Does Specialization Play in Farm Size in the U.S. Hog Industry?

U.S. hog farms have become fewer in number, larger in size and more specialized. A more vivid picture of how the hog industry has changed structurally can be seen in the distribution of hog operations by various size categories. Particularly, there are two size categories, 1 to 99 head and 5,000 or more head, showing the greatest change. The number of farms having 1 to 99 head decreased 64 percent from 1993 to 2000, while farms having 5,000 or more head increased by 112 percent over the same time period (NASS, 1994 – 2001). A similar trend can also be seen with respect to marketing. In 1997, 145 firms marketing 50,000 hogs or more a year marketed approximately 33.1 million hogs, 37 percent of the total (Lawrence et. al, 1998). In comparison, in 1994, only 16 million head were marketed by 66 firms in that size category.

As the average size of hog operations increases, traditional hog raising methods have given way to more specialized operations. The number of farrow-to-finish operations has declined, while the number of specialized operations has increased. According to McBride and Key (2003), from 1992 to 1998, the average size of independent hog operations doubled, while contract finishing operations tripled in size. During the same period, the number of farrow-to-finishing operations declined from 65 to 38 percent, while specialized operations increased from 22 to 58 percent.

Vertically coordinated (VC) and vertically integrated (VI) firms have used production contracts mostly for specialized operations. The question this study setout to answer is "what effect specialized hog operations have on the size of the operations." Several economists (Lawrence et al., 2001 and 1998; Grimes and Rhodes, 1992; and

others) have analyzed structural change and the ratification of the change as it relates to production and marketing of U.S. hogs. However, these studies fail to use empirical analyses to show the impacts of specialization and industrialization factors on farm size. A more recent study by Key and McBride compares factors that affect the choice of independent production and contract production. Although variables like size, production inputs, regional characteristics, and operator characteristics were considered, they did not examine size as an endogenous variable or analyze exogenous variables such as transaction costs, and risk into consideration in their analyses.

The uniqueness of this study is in the endogenous and exogenous variables examined. There is no known research that has examined the influences of factors such as specialized hog operations, risk, social capital, farm demographics, and socioeconomic characteristics on the hog producers' choice of size. Therefore, the objective of this study is to uncover some of the factors influencing the size of hog operations in the U.S.

The remainder of the article is structured as follows. A description of the data is then given along with a discussion of the econometric model. We then discuss the exogenous variables and their expected signs, which is followed by the results. The final section is a discussion of the results and conclusions.

Data and Analytical Framework

In 2000, 4,986 surveys were mailed to U.S. hog obtained from a stratified random sample of hog producers who were National Hog Farmer magazine subscribers. Dillman was used as a guide in conducting the survey. Initially, a survey was sent, followed by a postcard reminder two weeks later. A third mailing followed, which included a second copy of the survey. Eight hundred and thirty-one producers in each of the following hog

inventory size categories were surveyed: 200-999 head (SIZE1), 1,000-1,999 head (SIZE2), 2,000-2,999 head (SIZE3), 3,000-4,999 head (SIZE4), 5,000-9,999 head (SIZE5), and 10,000 or more head (SIZE6). Weighting variables are used to account for sample stratification as specified in Greene (2002). Information collected from the questionnaire included farm and financial characteristics, transaction costs, farmer attitudes toward risk, autonomy, and social capital. A total of 1,031 usable responses were received, a response rate of 21 percent.

To determine factors affecting the size of hog operations, an ordered probit model was used. Assume that we have the equation $y^* = \beta` x_i + \varepsilon_i$, where y^* is one of the six production size categories mentioned above, x_i is a vector of explanatory variables, β is a vector of coefficients, and ε_i is an error term. The following information is observed:

$y =$ if $y^* \leq 0$,

$y = 1$ if $0 < y^* \leq \mu_1$

$y = 2$ if $\mu_1 < y^* \leq \mu_2$

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$y = J$ if $\mu_{J-1} < y^*$.

In this case, the μ's are unknown parameters to be estimated with β. Using a normal distribution for the error term with a mean and variance of 0 and 1, probabilities for ordered probit model can be expressed as (Greene, 1997):

$Pr(y = 0) = \lambda(- \beta` x)$,

$Pr(y = 1) = \lambda(\mu_1 - \beta` x)$, - $\lambda(\mu - \beta` x)$,

$Pr(y = 2) = \lambda(\mu_2 - \beta` x)$, - $\lambda(\mu_1 - \beta` x)$,

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$\Pr(y = J) = 1 - \lambda(\mu_{J-1} - \beta`x)$.

The λ symbol represents the standard normal cumulative distribution function. All probabilities are positives and must add up to one. Computations of the log-likelihood function and coefficient estimates are derived straightforward. The marginal effects of the regressors are calculated using the following:

$\partial \Pr(y = 0) / \partial x$

$\partial \Pr(y = 1) / \partial x$

$\partial \Pr(y = 2) / \partial x$.

In cases where the regressor is a continuous variable, the marginal effects sum to zero. When the regressor variable is a dummy variable and the ordered probit consist of three or more choices, the dummy variable is analyzed by comparing the probabilities when the variable takes on two different values with those that occur with the other variables held at their sample mean (Greene, 1997).

Model Specification

Related to the number of different farm enterprises, *farm diversification* has traditionally been associated with small family farms. Diversified farms are small, in general, due to the constraints or limitations of the farm operator's ability to efficiently supervise and/or manage several enterprises and achieve economies of size for the hog enterprise. A large hog operation is not likely to be diversified. It is thus hypothesized that diversified farms will more likely be run by SIZE1 and SIZE2 operations.

Production specialization as it relates to farm size has changed greatly during the reorganization of the hog industry. Specialized operations may consist of farrowing,

feeder pig, a finishing, or any combination of the three. Farrowing operations provide breeding care for pigs from the time they are farrowed until they are weaned. Feeder pig operations focus on raising weaned pigs until they are ready to be finished, when they weigh approximately 40 to 60 pounds. Finishing operations involve raising pigs from approximately 40 to 60 pounds to a market weight of approximately 200 to 300 pounds. Growth in the average size of hog operations has been more pronounced among specialized operations (McBride and Key, 2003).

One of the reasons for this prediction is single task phases of production are easier to master and more programmable than multiple task operations. All things equal, it is probable that growers become more proficient at single tasks than multiple. Hog operations involving all phases of hog production are not likely to be as efficient as specialized operations. This inefficiency affects per unit costs. Highly task programmable (a concept discussed by Mahoney with respect to agency theory) production processes reduce transaction costs for specialized operations by decreasing monitoring costs and managerial supervisions. Thus, this study hypothesizes that *farrowing only, feeder pig only, finishing only*, and *semi-specialized* (two of the three specialized operations mentioned) will more likely be large hog operations, particularly SIZE5 and SIZE6 hog farms.

Production contracts, particularly of the resource-providing kind, have increased over the past two decades. Vertically integrated and coordinated firms have established agreements with farmers requiring some run breeding, gestation, and farrowing operations, feeder pig operations, finishing operations or a combination of the three. Most of these agreements are based on an incentive payment plan where farmers are

given a fixed salary (or fixed fee per pig) plus a bonus for efficient use of feed, low mortality rates, weight gain, efficiency relative to other competing producers, and/or lean value. We hypothesize that *incentive payment contracts* will likely be held by SIZE6 operations. The justification for this hypothesis is reduced transaction costs, one of the ways vertically integrated and coordinated firms achieve economies of scale. Having fewer large operations minimizes contractors' costs of supervising and monitoring production sites, which reduces transaction costs through direct movement. Further reductions in total costs are also realized through lower costs of transporting animals from fewer production sites.

Management practices is a dummy variable that identifies techniques used by some hog operations. There were four *management practices* identified in the survey: all-in/ all-out production, split-sex feeding, high-density fat-added diets, and computer usage. For the purpose of this study, we are interested in the operations that adopted two or more *management practices*. It is expected that the larger operations (SIZE6) will likely adopt two or more *management practices*.

Although *North Carolina* (NC) is located in the *Southeast* region, we thought it would be interesting to analyze it separately due to the tremendous growth experienced in that state. Within the last decade, *North Carolina* has become the second largest hog producing state in the nation, behind Iowa. The geographical concentration of hogs per farm in *North Carolina* surpasses that of any other state. Thus, it is hypothesized that SIZE6 operations are more likely to be located in the *North Carolina* where contract production is growing.

Excluding *North Carolina*, the *Southeast* region has experienced some growth in hog production over past two decades. *Southeast* is a dummy variable indicating farm location in one of the following 10 states: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, South Carolina, Tennessee, Texas, and Virginia. The growth of hog production in Southeastern states has been partly attributed to relatively inexpensive labor and land, particularly in Arkansas, Mississippi, and Georgia. It is hypothesized that operations of SIZE5 and SIZE6 are likely to be found in the *Southeast*.

Risk is another factor to consider when raising hogs and increasing their size of operation. Different farm operations may: (a) "take on substantial levels of risk when making investment decisions", (b) " avoid risk when making investment decisions", or (c) "seek nor avoid risk when making investment decisions". Farmers could select only one answer to describe their preference. A similar elicitation method was examined by Fausti and Gillespie and was found to perform relatively well in mail surveys of risk preference. It is hypothesized that the SIZE5 and SIZE6 operations are likely to be run by risk prone producers. SIZE5 and SIZE6 operations are more likely to have large investments in capital equipment to improve production efficiency and obtain economies of scale.

Lender was used to identify relationships between farm size and lending institutions. The importance of relationships between lenders and farm operations could vary from "not important at all", "not very important", "somewhat important" to "very important". It is hypothesized that operations having greater social relations with loan officers are likely to be SIZE5 and SIZE6 operations. In order for hog operations to expand, capital equipment, including state-of-the-art facilities must be obtained to

increase productivity. The average cost of such equipment and/or facilities can sometimes exceed the cash flows of most farm operations, an expense that becomes an investment for many. Thus, it becomes important for large operations to have favorable relationships with lending institutions to acquire loans to purchase capital equipment.

It is expected that younger (*Age*) or beginning producers are more apt to expand and become large by acquiring the financial loans to purchase necessary capital. Older producers are less likely to increase liability and are apt to use aging capital equipment that can not provide the production efficiency needed to expand or achieve economies to scale. This also implies that SIZE5 and SIZE6 operations are likely to be run by young producers. Large operations are likely to be more appealing to young, beginning producers who are more willing to take on challenges and exert the necessary energy needed to run such operations. Given their longer business life expectancy, young producers also are more likely to benefit from and/or overcome certain financial liabilities incurred through the purchase of capital equipment used to improve productivity. Older producers are less likely to be concerned with expanding production and are likely to be producers who run SIZE1, SIZE2, SIZE3 or SIZE4 operations because they are adjusting and downsizing their production and management responsibilities in preparation to exit the industry. Boehlje identifies this as the third stage in the farm family life cycle, where producers exit and intergenerational transfer of property takes place.

The other socioeconomic variable, *Bachelor Degree* identifies individuals who have completed a four or five year degree at a college or university. A college education is expected to improve the farmers' skills and ability to manage people and large hog

operations. We hypothesize that SIZE5 and SIZE6 operations will have operators with *Bachelor Degrees.*

Empirical Results

Results from this study are derived using the survey data collected in 2000. There are many factors that could perhaps affect the size of hog operation in the U.S. Based on an Ordered Probit analysis, all of the variables hypothesized to affect operation size were significant at the 10%, 5% or 1% level for at least one farm size, except *relationships with lending institutions*, *Bachelor Degree*, and *Southeast*. The Pearson Correlation coefficient was used to detect multicollinearity, and no serious problems were found. Endogenous explanatory variables where identified and instrumental variables were used for *diversified* farms and *contract* production. Heteroskedasticity was corrected for using the Multiplicative Heteroskedasticity. The percentage correctly predicted using the Ordered Probit analysis was 86.81, while the McFadden's likelihood ratio index (or Pseudo` R^2) was 0.7835.

As expected, more *diversified farms* are likely to be smaller (SIZE1 and SIZE2), while more specialized operations are likely to be larger. Specialized hog operations are less likely to be run by smaller operations. The significance and negative signs for *farrowing, feeder pig, finishing* and *semi-specialized* operations of SIZE1 and SIZE2 indicate that these farms are not likely to be small in size. Our findings also show that *semi-specialized* and *finishing* variables operations of SIZE3 are significant and positive for SIZE3 operations, which implies there are some specialized operations that have 2,000 – 2,999 head.

Production *contracts*, particularly incentive payment arrangements, are less likely to be associated with farm operations of SIZE1 and SIZE2. A significant, yet positive sign in the SIZE6 category implies that production contracts and farms in *North Carolina* are likely to be large hog operations of 10,000 or more head. *Investment risk,* particular risk-prone attitudes toward investing are less likely to be exhibited by the smaller operations (SIZE1, SIZE2, and SIZE3), while the opposite is true for SIZE6 hog operations.

Different *management practices* incorporated into the production of hogs are more likely to be adopted by producers who run operations with 10,000 or more head, and older producers are less likely to undertake large hog operations.

Discussion and Conclusions

Results of this study provide insights on some of the different farm characteristics, preferences and demographics of hog farms that may influence the size of hog operations. Specifically, it reveals that specialization in specific phases of hog production operations may influence the size U.S. hog farms.

One of the factors likely to influence the operations with 200 – 1,999 head (SIZE1 and SIZE2) is farm diversification. Smaller farms in the U.S. have traditionally consisted of several enterprises. Farms of these sizes face fewer managerial constraints and are more likely to have other enterprises as well as off-farm employment, which increases the competition for labor. In contrast, larger operations are not as likely to have several farm enterprises. Operations with 10,000 or more head require greater time and energy, thus leaving less time for other farm activities or off-farm work. Managers of large operations

are further persuaded by some vertically integrated and coordinated firms to limit other farm enterprises to minimize the threat of disease outbreaks.

There is a direct link between the size of hog operations and specialized phases of production. Our findings indicate that specialized phases of production are positively linked to the large operations (SIZE6), which is also validated by McBride and Key. Such large operations may be specialized either in a farrowing operation, feeder pig operation, finishing operation or a combination of the three. Single task operations are more programmable, and they enhance production efficiency by reducing production errors. According to Mahoney, task programmable jobs reduce transaction costs by minimizing the monitoring costs attributed to management surveillance. Semi-specialized operations are less programmable than single task operations and time is allocated to perform each task. Two disadvantages of multiple task operations are the loss of productivity and efficiency. Aside from these disadvantages, our findings reveal that semi-specialized and specialized operations are a positively linked to large operations.

Specialized phases of production are not as likely to be found on farms with 200 – 1,999 head. One reason for this is management constraints. The management constraint shared by all producers limits time and attention given to each phase of the production process. A producer who decides to diversify over multiple enterprises does not have the management capability or resources to run very large operations with every enterprise.

Recent studies (McBride and Key, 2003; Lawrence et al, 2001 and 1998) indicate that size and specialization are two of the distinctive characteristics associated with production contracts. Results from our study also indicate that contracts, particularly

incentive payment contracts, are likely to be common among large operations. Contract production has been a method used by vertically integrated and coordinated firms to achieve economies of scale through reductions in transaction costs and more efficient animal production. As the grower utilizes inputs and management expertise supplied by the contractors plus the capital and/or state-of-the-art facilities purchased, the average variable cost of the operation decreases. With increases in output, at some point the hog operation achieves economies of scale. Smaller operations are likely to be run by independently owned farms comprised of fully integrated systems such as farrow-to-finish operations. Vertically integrated and coordinated firms are not as likely to take interest in smaller diversified farms.

Of all the states in the Southeast region and the nation, North Carolina has shown the greatest increase in the number of hogs per farm over the past fifteen years (NASS, 1989-2003). As the second largest hog producing state nationally, North Carolina has more operations with 5,000 or more hogs than any other state. Results from this study indicate that North Carolina is more likely to have operations with 10,000 or more head. USDA's National Agricultural Statistics Service shows that operation's with 5,000 or more head grew by over 120% from 1994 to 2001. Some possible reasons for the enormous growth in North Carolina are soft corporate farming laws, favorable production contracts, and relatively inexpensive labor.

Perhaps one of the most common characteristics found among large operations is state-of-the-art capital equipment. Our findings reveal that risk-prone investors are highly probable among operations with 10,000 or more head, while the converse is true for smaller operations (SIZE1, SIZE2 and SIZE3). Initial investment for production

facilities such as farrowing, nursery and finishing units, may cost more than $1 million (Hurt, Boehlje, and Hale, 1995). This common denominator is not as prevalent among small operations mostly run by independent decision-makers that do not share their production, management, and marketing decisions with integrators or contractors.

Certain management practices are more likely to be adopted on the large operations with 10,000 or more head. The four identified practices, all-in/ all-out production, split-sex feeding, high-density fat-added diets, and computer usage, are ways to improve productivity. For example, split-sex feeding is used to ensure that gilts are not deprived of proper nutrition by barrows, enabling both sexes to grow equally. Also, computers become more of a necessity when performing administrative responsibilities such as record keeping of pedigrees, rations, estrus cycles of sows, farrowing dates, inventories, etc. Small operation (SIZE1 and SIZE2) managers may not consider these management practices as essential given the work load associated with their sizes, which is not as likely to be as stringent and demanding as it is for large operations.

Older producers are less likely to be concerned with expanding production and are not as likely to run large operations, a point identified as the third stage in the farm family life cycle when producers exit and intergenerational transfer of property takes place (Boehlje, 1992). Retirement/exit and transfer property may be correlated with economic losses, disinvestments, production inefficiencies, reduction in size economies, and health failures experienced by older producers.

Although the theory of industrial organization has guided economists in understanding some of the factors responsible for structural change in the hog industry, there is still more empirical evidence to be uncovered. Risk, management practices,

production contracts, age and specialized operations are found to influence large operations. Economies of size have given rise to continued reorganization leading to fewer, larger and more specialized hog operations (Van Arsdall and Nelson, 1985). Specialized operations used along with production contracts have produced greater potential for production efficiency through task programmable phases of hog production. Feed costs, ownership costs, and hours per cwt gain are all lower for large specialized operations than they are for large farrow-to-finish operations (McBride and Key, 2003). Specialized operations within the last decade have increased in size (McBride and Key, 2003), and this trend is expected to continue in years to come. One of the shortcoming to this study is not much information is offered concerning the factors that influence operations with 2,000 to 9,999 head (SIZE4 and SIZE5), which may be due to the low response rate in those size categories.

Interestingly, education and favorable relationships with lending institutions were not found to be significant in our analysis. Education was expected to improve producers' ability to manage large sized operations, while better relations with the lender were expected to lead to greater access capital, allowing for expansion of facilities. (However, it is possible that the producers' education and financial support were obtained through internal sources, which were not measured by our survey instrument.) Van Arsdall and Nelson postulated in the mid-1980's that substantial economies of size and increases in size of hog operations would be the result of technology used in the hog industry, and this is very much a reality today. Young producers are more apt to adopt technology and have large operations (Boehlje, 1992). The technology employed in specialized operations has helped give rise to efficient, productive, and large hog farms in

North Carolina and in other states. Thus, it is clear that the hog industry has undergone structural change but whether or not it will resemble the poultry industry is a question that requires more research.

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Table 1. Exogenous Variables Mean and Standard Deviation Estimates.

Variable	Measurement	Mean	Standard Deviation
Size 1	(0-1)	0.16	0.36
Size 2	(0-1)	0.17	0.37
Size 3	(0-1)	0.16	0.36
Size 4	(0-1)	0.18	0.39
Size 5	(0-1)	0.21	0.40
Size 6	(0-1)	0.12	0.33
Diversified Farm	(1-22)	3.17	1.74
Farrower	(0-1)	0.07	0.25
Feeder Pig	(0-1)	0.03	0.17
Finisher	(0-1)	0.30	0.46
Semi-Specialize	(0-1)	0.12	0.32
Farrow to Finish	(0-1)	0.48	0.50
Contract Production	(0-1)	0.21	0.41
North Carolina	(0-1)	0.17	0.14
Production in Southeast	(0-1)	0.06	0.24
Risk Prone	(0-1)	0.23	0.42
Relations w/Lending Institutions	(1-4)	3.40	0.92
Management Practices	(0-1)	0.42	0.49
Producer Age	Continuous	47.03	12.76
Completed College	(0-1)	0.26	0.44

Table 2. The Ordered Probit's Marginal Effects for Hog Operational Size

Variable	200 - 999	1,000 – 1,999	2,000 – 2,999	3,000 - 4,999	5,000 – 9,999	10,000 or more
	----------Category, Number of Hogs----------					
Farm/Locational Characteristics						
DIVERSIFIED	0.045793**	0.051858**	0.008516	-0.005241	-0.027071	-0.073854**
	(.003143)	(.006089)	(.001756)	(.011204)	(.020647)	(.017065)
FARROWER	-0.100314**	-0.144370**	-0.039982	-0.004360	0.052690	0.236352**
	(.013425)	(.011939)	(.049246)	(.012979)	(.093920)	(.011854)
SEMISPECI	-0.045799**	-0.049075**	0.006976**	0.006128	0.026910	0.068812**
	(.010033)	(.008067)	(.002801)	(.013228)	(.057115)	(.009654)
FEEDPIG	-0.074089**	-0.096386**	-0.021722	0.003099	0.042691	0.146407**
	(.011553)	(.010017)	(.022892)	(.008152)	(.073360)	(.010458)
FINISHER	-0.026981**	-0.025983**	0.002391**	0.004558	0.015572	0.034939**
	(.009171)	(.007274)	(.000629)	(.009869)	(.050964)	(.009819)
CONTRACT	-0.067198**	-0.084384**	-0.017664	0.004269	0.039203	0.125774**
	(.011115)	(.009539)	(.017384)	(.009916)	(.068819)	(.010198)
NC	-0.074474**	-0.098004**	-0.022555	0.002617	0.042784	0.149632**
	(.011556)	(.010125)	(.024614)	(.007465)	(.074015)	(.010521)
SOUTHEAST	-0.003485	-0.003117	-0.00021	-0.000640	-0.001984	-0.004185
	(0.00742)	(0.00682)	(.005866)	(.002548)	(.043837)	(.011417)
Farm Financial Characteristics						
RISK1	-0.040316**	-0.040424**	-0.004644**	0.006229	0.023466	0.055689**
	(.009884)	(.007647)	(.000878)	(.013402)	(.054826)	(.009502)

Table 2. Continued --The Ordered Probit's Marginal Effects for Hog Operational Size

Variable	200 - 999	1,000 – 1,999	2,000 – 2,999	3,000 - 4,999	5,000 – 9,999	10,000 or more
	----------Category, Number of Hogs----------					
Social Capital						
LENDER	-0.000077	-0.000070	-0.000005	0.000014	0.000044	0.000094
	(.000052)	(.000047)	(.000029)	(.000031)	(.000033)	(.000065)
Producer Practices						
MANAGPRA	-0.127911**	-0.121748**	-0.013567	0.018833	0.070696	0.173696**
	(.015825)	(.007946)	(.021323)	(.040262)	(.077046)	(.011417)
Producer Characteristics						
AGE	0.000083	0.000075	0.000005	-0.000015	-0.000047	-0.000101**
	(.000071)	(.000064)	(.000031)	(.000035)	(.000043)	(.000011)
BACHELO	-0.006425	-0.005914	-0.000463	0.001141	0.003684	0.007977
	(.007941)	(.006972)	(.003741)	(.003103)	(.045853)	(.010874)

** and * show significance at 0.05 and 0.10 levels, respectively. % Corr Pred: 86.81; McFadden's R^2: 0.7835; X^2 =151.9