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Abstract

Rapid change in the size and ownership structure of U.S. hog production has created new and varied challenges for the industry. This report describes an industry becoming increasingly concentrated among fewer and larger farms, and becoming more economically efficient. These changes have not come without problems. The increasing market control and power concentrated among packers and large hog operations, and the manure management problem posed by an increasing concentration of hog manure on fewer operations, are paramount concerns. Addressing these concerns through regulations would likely impose economic costs that could be passed on to consumers. In addition, the relative mobility of the hog industry means that regulations could result in significant changes in the location of hog production facilities, with ripple effects in local economies. Balancing environmental and economic interests will challenge policymakers dealing with the implications of structural change in U.S. hog production.

Keywords: Hog production, industry structure, structural change, production costs, contract production, manure management.

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Executive Summary

Rapid change in the size and ownership structure of U.S. hog production has created new and varied challenges for the industry. Once dominated by many small operations as part of traditional crop-hog farms, hog production has become highly concentrated on large operations with production on several different sites. As of 2002, nearly half of the U.S. hog inventory was owned by operations with more than 50,000 head.

This report assesses key economic and structural issues affecting U.S. hog production. Much of the report uses information from previous research on economic and structural issues in hog production to establish a context within which to present information obtained from a national survey of U.S. hog producers. This report presents detail about indicators, contributing factors, and implications of structural change in hog production, and addresses some of the economic and policy issues important to agriculture.

The main findings of this report are:

- *The rapid and widespread growth of contract hog production has substantially raised productivity in the industry.* On average, contracting raises total productivity by 20-23 percent and by as much as 50 percent for some inputs. The increase in productivity may result because contracts facilitate the exchange of information between contractors and growers. This information exchange may involve knowledge about feed mixtures or feed timing that results in higher feed productivity and lower labor costs. It is also possible that the goods and services provided by contractors, such as veterinary care, feed, and, especially, the genetic quality of the animals, may be superior to those typically used by independent producers, resulting in healthier animals and more efficient weight gain.

- *The higher level of productivity associated with contracting implies that responding to concerns about contracting with policies that regulate or restrict contracting would likely impose economic costs on the hog industry and could cause pork prices to rise*. However, negative producer welfare effects (e.g., loss of autonomy) or costs to contracting (e.g., increased transaction costs) could offset the potential on-farm efficiency gains from contracting. Off-farm or non-market costs, such as the environmental impact of an increased concentration of animal waste, may also result because of contracting. Available information is not adequate to quantify the overall benefits and costs to society of policies that restrict contracting.

- *The returns to contracting for contractors and contract growers have been largely determined by factors that affect the efficiency of the hog operation, but the size of contracts has not significantly impacted the returns of either party.* Production capacity utilization and feed efficiency have had a significant impact on the returns of both contractors and growers. The organization of the contractor's business and the education of the grower have also been important determinants of the returns to contracting. However, the evidence does not suggest that contractors have offered more favorable terms to larger versus smaller grower operations.

- *The potential for excess nutrients resulting from the concentration of hogs on the land is much higher in Southern States than in traditional hog-producing States of the Corn Belt, and among larger versus smaller operations.* It is likely that nutrient loading rates from manure match or exceed the utilization capability of the crops grown on many large farms and on many farms in the South.

- *Many hog producers could comply with more stringent regulations on manure management by spreading manure on more of their crop acreage.* On average, manure was spread on less than 30 percent of the crop acreage on hog farms. However, the technology used to handle manure on most operations in the South limits the ability to spread manure over more acreage at the same cost. Also, more than half of large operations in the South would still be loading nitrogen at the upper limit of crop utilization if manure were spread over all available acreage.

- *If alternative or innovative manure management technologies are required to comply with more stringent regulation, large and independent operations are in a much better position than small and contract grower operations to make the necessary capital investments.* Economies of size in hog production allow large operations to spread the fixed investment for manure management facilities over more units of output. Contract growers, with lower net farm income and less equity than independent producers of the same size, are less able to afford additional capital investments for manure management. Thus, contractors may need to become more involved with manure management or growers may need to locate other sources of capital.

- *The trend toward fewer, larger, and more productive hog operations will likely continue into the foreseeable future.* Many of the highest cost hog operations are small, independent operations, operated by older producers who plan to soon exit the hog industry. The lowest cost operations are mostly large, produce under contract, and are operated by younger producers with newer facilities.

- *The managerial ability of individual hog producers is probably as important as size economies in lowering the costs of hog production.* There is substantial variation in production costs that cannot be attributed to size of operation. The distribution of costs by size of operation indicates that, despite higher average costs among small- and medium-sized operations, many of these operations can produce hogs at a cost that is competitive with larger operations.

- *The comparative disadvantages that an area may have in producing hogs can be overcome with innovative technologies and business arrangements, making the hog industry highly mobile and able to locate where market and/or regulatory conditions are more favorable*. Despite higher feed prices in the South and West, cost advantages associated with improved productivity and size economies offset this disadvantage and have spurred growth of the industry in these areas. This mobility also means that hog production could locate to other areas of the Nation or out of the country should market and/or regulatory conditions warrant.

These findings paint a picture of an industry increasingly concentrated among fewer and larger farms, and becoming more economically efficient. However, these changes have not come without problems. Concerns about the increasing market control and power concentrated among packers and large hog operations, and from the manure management problem posed by the increasing concentration of hog manure on fewer operations, are paramount. Addressing these concerns through regulation would likely impose economic costs that could be passed on to consumers. In addition, the relative mobility of the hog industry means that regulations could result in changes in the location of hog production facilities, with ripple effects in local economies. Balancing environmental and economic interests appears to be a major challenge for policymakers dealing with the implications of structural change in U.S. hog production.

Economic and Structural Relationships in U.S. Hog Production

William D. McBride and Nigel Key

Introduction

The U.S. swine industry is undergoing significant and unprecedented changes in its size and ownership structure. These changes are having profound effects on industry performance and on the appropriate strategies for dealing with change by virtually all associated with the industry. Even those not associated with the industry are affected by this change due to environmental risks, nuisance impacts, social implications for rural communities, and as consumers of pork products. As a result, information about structural characteristics and economic relationships in hog production and what these suggest for the future of hog farms has a broad appeal.

During the 1980s and 1990s, considerable attention was given to the notion that U.S. hog production had become more industrialized. Industrialization in this context generally refers to increases in farm size and specialization in production, and the increased coordination of production and marketing with the plans of food processors and retail firms. Rhodes chronicled transition in hog production over the last quarter century, focusing on changes in firm size, organization, and location, and concluded that the primary forces contributing to industrialization are innovational profits and economies of size. He argued that the prospect of significant profits obtainable by those who utilize new technologies and practices has been the driving force behind the trend toward greater industrialization. Technological innovation in hog production has been particularly rapid during the last decade in the areas of nutrition, health, breeding and genetics, reproductive management, housing, and environmental management (Boehlje). Organizational innovation in hog production has taken the form of contract arrangements that have enhanced the ability of firms to access the capital necessary to adopt these new technologies and to achieve economies of size.

Important indicators of structural change in U.S. hog production have been the increasing size and specialization of operations. The traditional approach of farrow-to-finish production, where gestation, farrowing, nursery, and growing-finishing phases (see Glossary, p. 43) of production are performed on one operation, has given way to large operations that specialize in only one or two phases (see “A Primer on U.S. Hog Production,” p. 2). The coordinated production approach, where large integrators contract out production with many growers, has allowed individual producers in the system to grow to unprecedented size by specializing in one phase of production (Kliebenstein and Lawrence).

Factors Contributing to Structural Change

Production cost variation among U.S. hog producers has had important implications for industry structure. High-cost operations are vulnerable to declining hog prices, and are among the first to exit the industry when faced with a prolonged period of low hog prices. Government statistics show that more than 15,000 operations (about 14 percent) quit producing hogs between 1998 and 1999 (USDA, NASS, *Hogs and Pigs*), corresponding to a prolonged period of hog prices that were likely below the production costs of many operations. On the other hand, low-cost operations are in a better position to survive periods of low hog prices and to thrive when prices improve.

Economies of size are a form of cost variation among farms based on the premise that larger farms have lower per unit costs than smaller farms.[1] Therefore, farms will become larger over time as smaller farms exit the industry or expand to take advantage of the lower costs. The existence of economies of size is supported by empirical evidence that indicates an L-shaped relationship between costs and output (Hallam), and by the industry trend toward fewer and larger hog farms. However, economies of size are not the only explanation for structural change. Another view suggests that the existence of superior management and the desire to increase net income or wealth creates the opportunity for operations to expand in size (Seckler and Young).

Costs of production can also vary among farms due to factors that create a comparative advantage for one loca-

[1] Economies of size in hog production may exist because costs for capital items such as buildings and equipment can be spread over more units of production on larger operations, or because larger operations are able to negotiate price discounts from buying inputs in volume, among other reasons.

A Primer on U.S. Hog Production

The production of hogs to be slaughtered for pork is a process involving four phases: 1) breeding and gestation (breeding females and their maintenance during the gestation period); 2) farrowing (birth of baby pigs until weaning); 3) nursery (care of pigs immediately after weaning until about 30-80 pounds), and; 4) finishing (feeding hogs from 30-80 pounds to a slaughter weight of 225-300 pounds). Hog producers are commonly classified into type categories according to the number of production phases conducted on the operation into either: 1) farrow-to-finish (all 4 phases); 2) farrow-to-feeder pig (phases 1, 2, and 3); 3) feeder-pig-to-finish (phase 4); 4) weanling-to-feeder pig (phase 3), and; 5) farrow-to-weanling (phases 1 and 2).

The majority of U.S. hog production has historically occurred on farrow-to-finish operations located in areas with an abundant supply of corn. Hog farmers typically fed corn produced on their operation as a relatively inexpensive source of hog feed, and then sold their hogs at local markets. The industrialization of hog production began in the 1970s with the rapid transition of hog production into partial or total confinement. Since then, a continuing series of advancements in technology and management have made a science of hog production in large factory-like units staffed with specialized labor (Rhodes). As part of the industrialization of hog production, operations became more specialized, typically conducting only one or two of the production phases.

The evolution of contract production has had a significant role in the industrialization of U.S. hog production. Contract production is an arrangement between a pig owner (the contractor) who engages a producer (the grower) to take custody of the pigs and care for them in the producer's facilities. The producer is paid a fee for the service provided. The type of contractor most responsible for the rapid growth in contracting is often referred to as an integrator, characterized as a large conglomerate or corporate organization that contracts with many growers to produce hogs. Integrators typically furnish inputs for growers, provide technical assistance, and assemble the commodity to pass on for final processing or marketing. Integrators typically market hogs through marketing contracts or other arrangements with slaughter plants. Input suppliers and packers are other distinct types of contractors that use contract production to vertically integrate business activities, such as feed or hog processing. Farmers can also be contractors that employ other farmers as growers in order to expand or specialize their hog operation.

tion over another. For example, hog production has historically been concentrated in Corn Belt States where an abundant supply of corn has provided a relatively low-cost source of hog feed. However, more recent expansion in hog production has occurred in other regions. Rapid growth in North Carolina has been attributed to the development and widespread use of contract production arrangements by a few large integrators. Contract production is believed to have aided the expansion of hog operations by facilitating the accumulation of capital necessary for operations to adopt new technologies and achieve unprecedented economies of size. An emphasis on product quality and the proximity of North Carolina to a large market for pork products have also been cited as important to the developing hog industry. The cost and other advantages allowed producers in the South to overcome the comparative advantage of producers in Corn Belt States.

Implications of Structural Change

Rapid structural change in the hog industry has raised issues that are a source of concern for many associated with the industry and those affected outside the industry. A concern about the growing use of contracts in U.S. hog production stems from a perception that market control and power is increasingly concentrated among packers and large hog operations. Issues associated with contract complexity, information and grower education, and grower risk of significant losses if a particular contractor decides not to renew a contract are of particular concern (Hayenga, Harl, and Lawrence). As contracts become more prevalent and as the hog industry becomes increasingly concentrated, it is possible that large operations may be able to use their relatively stronger bargaining position to extract more of the economic surplus from contract growers.

Because of these and other concerns with the rapid growth in contracting, efforts at various levels of government have been made to regulate contract production. These regulations may have significant social welfare costs or benefits. Production contracts offer several potential advantages over independent production that could explain their growing prevalence. Contracts may lower transaction costs associated with search, negotiation, and transfer; reduce differences in the information that growers and processors have about product quality; improve coordination of product delivery; and lower income risk for growers. In addition, contracting may raise farm productivity by improving the quality of managerial inputs, by speeding the transfer of technical information to growers, or by facilitating growers' access to credit, thereby permitting the adoption of newer, more efficient technologies.

Another concern with the rapid restructuring of U.S. hog production is the waste management problem posed by concentrating a larger number of animals on a limited land base. Expansion and consolidation in hog production has meant that the responsibility for managing hog manure has become more concentrated among fewer operations, and some of the risks of mismanaging manure are magnified. Among the risks involved with managing hog manure is the potential movement of nutrients into ground and surface water supplies due to leakage, seepage, and/or breakage of storage facilities and the misapplication of effluent to fields. Growing concerns over these risks has brought calls for additional regulations to protect the environment. However, little is known about how the environmental risks from hog manure vary across the sector, or about the ability of various farm operations to pay the costs associated with additional regulations.

A Roadmap

The objective of this report is to provide an assessment of economic and structural issues that are affecting U.S. hog production. Much of this report uses information from previous research on economic and structural issues in hog production to establish a context within which to present information obtained from a recent national survey of U.S. hog producers. Hog producers were surveyed in 1998 as part of USDA's annual Agricultural Resource Management Survey (ARMS) to provide updated information on size, production costs, business arrangements, production facilities and practices, and farm operator and financial characteristics (see "The 1998 Agricultural Resource Management Survey," below).

The scope of this report is limited to an analysis of structural change in U.S. hog production. Change has occurred in many other segments of the U.S. pork industry, including considerable consolidation in the meatpacking and retailer segments. These changes are briefly mentioned throughout the report within the context of how they have affected U.S. hog production. Readers interested in a broader perspective on the structure of the U.S. pork industry are encouraged to see Martinez, and those seeking information on structural change in meatpacking should see MacDonald et al.

The report is divided into three main sections. The first section presents background material on structural change in U.S. hog production, focusing on the issues associated with industrialization and survey indications of structural change. In the second section, several factors contributing to structural change are explored. The importance of pro-

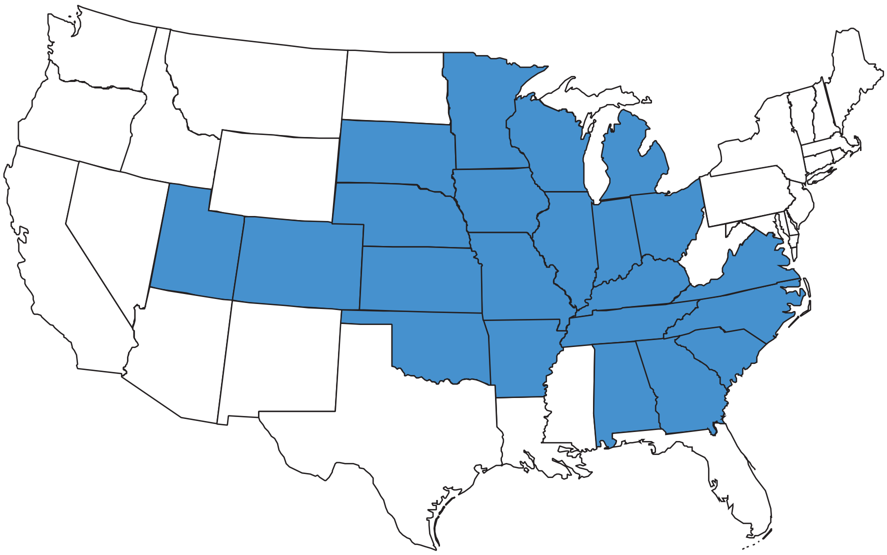
The 1998 Agricultural Resource Management Survey

A detailed survey of U.S. hog producers was conducted in 1998 as part of USDA's annual Agricultural Resource Management Survey (ARMS). The survey collected information from a cross section of U.S. hog operations, including measures of size, production costs, business arrangements, production facilities and practices, and farm operator and financial characteristics. The sampling resulted in 1,633 responses from 22 States (fig. 1). Hog producers in Northeast and Far West States were not surveyed because of their minor share of hog production and because of limited survey funds.

Hog farms surveyed in the 1998 ARMS were chosen from a list of farm operations maintained by the National Agricultural Statistics Service (NASS). Farmers were contacted during the summer of 1998 to determine how many hogs were on the operation in 1998. The ARMS target population was farms with 25 or more hogs on the operation at any time during 1998. A primary purpose of the hog producer survey was to collect the information necessary to estimate the average cost of production for hog operations. Screening out farms with a hog inventory below 25 head was done to exclude farms with only a few hogs for on-farm consumption or those with hogs for other noncommercial activities such as youth projects. The sample included operations with hogs located on the acres operated, regardless of who owned the hogs, and thus included independent hog operations and growers who produced hogs under contract (i.e., contractees). Therefore, results of the survey are not directly comparable with surveys of hog owners (for example, see Lawrence, Grimes, and Hayenga; Lawrence and Grimes). The survey was administered during March and April of 1999.

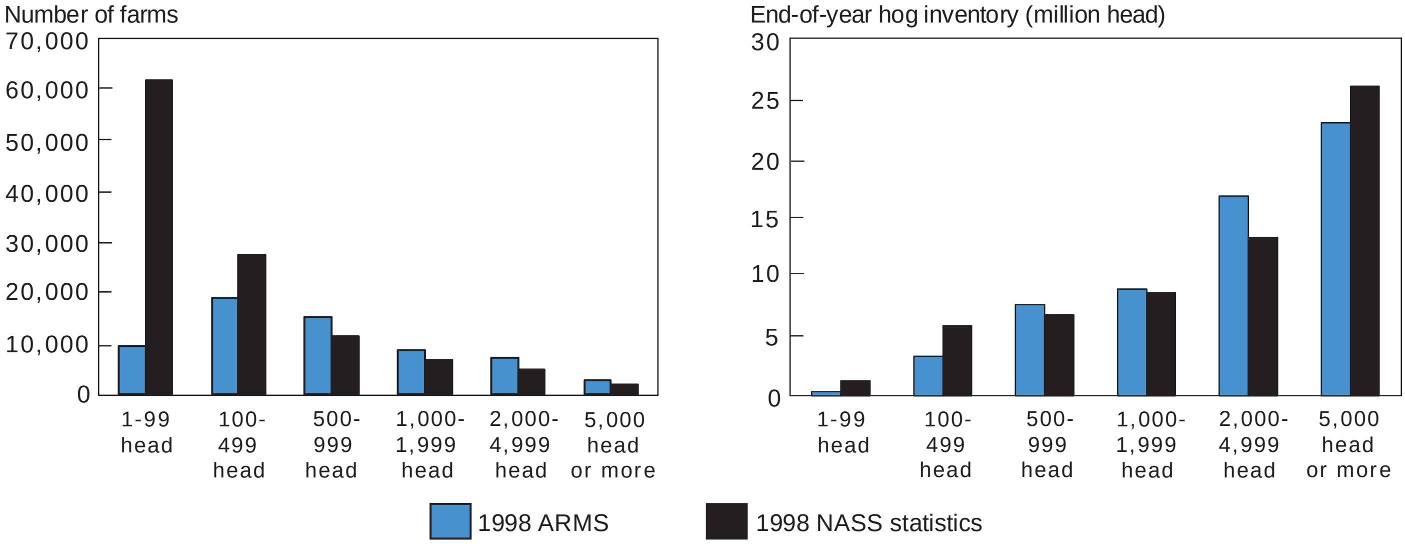
Each surveyed farm represents a number of similar farms in the population as indicated by its expansion factor. The expansion factor, or survey weight, was determined from the selection probability of each farm and thereby expands the sample to represent the target population. The sample represents approximately 97 percent of the hog inventory on U.S. farms at the end of 1998 (USDA, NASS, *Meat Animals Production, Disposition, and Income*). However, the hog sample expands to represent only about 54 percent of farm operations that had any hogs or pigs during 1998 (USDA, NASS, *Hogs and Pigs*) due largely to the 25-head threshold. A comparison of hog farms and inventory by size group from the 1998 ARMS and 1998 NASS hog and pig statistics is shown in figure 2. Because farms with only a few hogs are screened out of the ARMS, the number of farms and the hog inventory on farms with fewer than 100 head is significantly lower in the ARMS. While these small hog operations represent over half of U.S. hog farms, they include only 2 percent of the hog inventory. Among the other size groups, the ARMS sample of hog farms and inventory is distributed much like that in the NASS statistics (fig. 2).

Figure 1
States surveyed in the 1998 ARMS of hog producers
Producers in the surveyed States (shaded) accounted for about 97 percent of the hog and pig inventory on U.S. farms at the end of 1998.



Source: 1998 Agricultural Resource Management Survey.

Figure 2
U.S. hog farms and inventory by size of operation, 1998
Because of screening, the ARMS represented a small portion of farms with fewer than 100 head.
However, ARMS and NASS statistics are similar for hog inventories in most size groups.



Source: USDA, NASS, *Hogs and Pigs*, 1999; 1998 Agricultural Resource Management Survey.
Note: Both the ARMS and NASS estimates are based on surveys of farms with hogs on the operation. Thus, differences between the estimates are primarily due to the screening out of farms with less than 25 head of hogs in the ARMS, and the sampling and nonsampling error in each survey. The NASS estimates are based on a sample of about 14,200 operations, while the ARMS is based on a sample of 1,633 operations.

duction cost variation, economies of size, regional diversity, and contract production is developed. The third section looks at the implications of structural change for industry performance and the environment. Research examining what the expanded use of production contracts in hog production has meant for industry productivity and the returns to production is presented. Also discussed are structural and economic dimensions of the problems associated with managing hog manure in an increasingly concentrated industry.

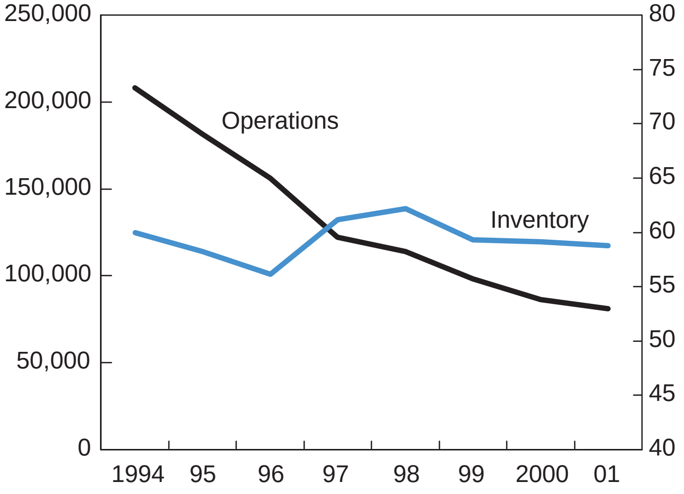
Background

Structural Change

The number of farms in the U.S. remained fairly constant at about 2.2 million throughout the 1990s (USDA, NASS, *Farms and Land in Farms*). However, between 1994 and 1999, the number of hog farms fell by more than 50 percent, from over 200,000 to less than 100,000, and fell to just over 80,000 by 2001 (fig. 3). Despite fewer hog farms, the hog inventory remained relatively stable, averaging about 60 million head with cyclical fluctuations between 56 and 63 million head (USDA, NASS, *Hogs and Pigs*). Considerable consolidation occurred in hog production during the 1990s. Since 1994, the percent of the hog and pig inventory on farms with 2,000 head or more increased from 37 percent to nearly 75 percent (fig. 4). Also, just over half of hogs and pigs were on farms with 5,000 head or more in 2001, compared with about a third in 1996.

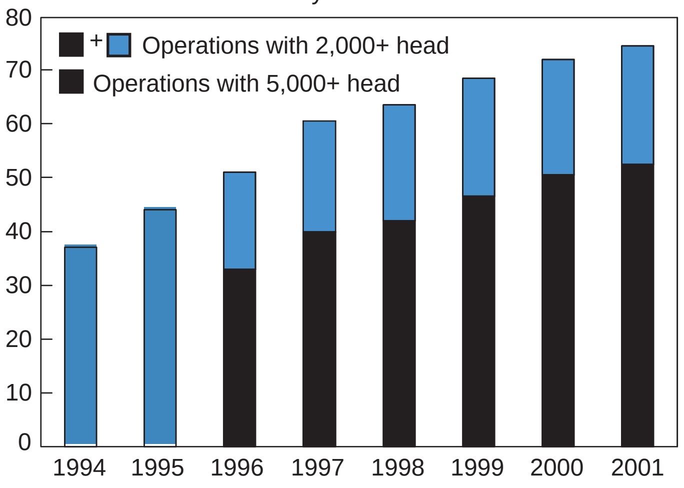
Much has been written about this rapid structural change in U.S. hog production. VanArsdall and Nelson were among the first to predict that "hog production will eventually be industrialized, breaking away from the traditional crop-livestock farm setting, as have fed beef and poultry..." Rhodes chronicled transition in the industry over the last quarter century, focusing on changes in firm size, organization, and location. Several forces driving structural change in hog production were identified, but Rhodes concluded that the primary forces are the same as those that have affected most sectors of agriculture, namely innovational profits and economies of size. He argued that the prospect of significant profits obtainable by those who utilize new technologies and practices has been the driving force. Technological change in hog production has been particularly rapid during the last decade in such areas as nutrition, health, breeding and genetics, reproductive management, housing, and environmental management (Boehlje).

Figure 3
Number of U.S hog operations and hog inventory
Since 1994, the number of hog operations has fallen by more than 50 percent, while the hog inventory has varied between 56 and 63 million head.



An operation is any place having one or more hogs on hand at any time during the year.
Source: USDA, NASS, *Hogs and Pigs*, various issues.

Figure 4
U.S. hog and pig inventory on largest operations
In 2001, farms with 2,000 head or more accounted for nearly 75 percent of total U.S. hog and pig inventory, double their 1994 share.



Operations with 5,000+ head were not reported prior to 1996.
Source: USDA, NASS, *Hogs and Pigs*, various issues.

While technological innovation during the 1990s created profit opportunities, organizational innovation enhanced the ability of firms to access the capital necessary to adopt these new technologies and to achieve economies of size. Production contract arrangements between contractors, often referred to as integrators, and individual producers, along with marketing contract arrangements between these integrators and packers, have been the major vehicle of organizational change in hog production. These arrangements allowed hog operations to achieve unprecedented size. The portion of hogs marketed by producers marketing 50,000 head or more increased from 18 percent in 1994 to 52 percent in 2000, while the portion of hogs marketed by operations marketing 500,000 head or more increased from 10 to 35 percent (Lawrence, Grimes, and Hayenga; Lawrence and Grimes). Marketing contracts between packers and integrators help ensure a large and stable volume of uniform hogs for packers and may reduce the market price risk for integrators. To deliver the volume of hogs desired by packers, integrators typically have many grower operations producing hogs under production contracts.

The growth of contract hog production has also been a major force behind the changing location of hog production. The rapid increase in hog production in the Southeast, particularly in North Carolina, is due in part to the increase in contracting. Hog production in North Carolina developed around the need to find alternative sources of economic activity to replace the declining importance of tobacco production (Kliebenstein and Lawrence). A concerted effort was made by the State government, land-grant university faculty, and entrepreneurs to focus on hog production as one area for economic growth and to develop a pork industry that could compete on a national level (Jones). Given the lack of industry infrastructure, the model of large integrated producers contracting with many farmers came to the forefront for industry development. This model was easier to introduce in this area because of producer experience with poultry contracting (Martinez), and due to the willingness of lending institutions to provide financing for hog production units since much of the price risk was managed by large contractors. Also, environmental, zoning, and corporate farming regulations did not present insurmountable barriers to siting and building production units and processing plants in the region.

Public Policy Concerns: Market Conduct

In late 1998, producer prices received for hogs fell to the lowest level since 1972 and, when adjusted for inflation, were at the lowest level this century (Gants). Retail pork prices did not decline accordingly, resulting in a farm-to-retail price spread large enough to prompt a group of U.S. senators to urge the Secretary of Agriculture to investigate. The senators argued that "Enough evidence exists to raise strong suspicions that more that just the invisible hand is at work" (Gants). With a growing share of market transactions occurring through marketing contracts between large producers and packers, many hog producers were concerned that the cash market was being reduced to a residual market, to the financial detriment of producers trading on the cash market. The resulting public and legislative attention to the lack of market information from hog contract sales, and strong margins in the hog packing sector, were important reasons for approval of the Livestock Mandatory Price Reporting (MPR) Act of 1999.

Prior to the MPR Act, USDA had been reporting market price information through its Market News system, but MPR differs in several important ways. For one, participation in the Market News system was voluntary whereas MPR participation is not. MPR also requires the reporting of price and quantity information in much greater detail. Packers must report the specific terms of formula and contract purchases, thereby revealing information previously treated as proprietary. Goals of the legislation are to increase transparency in livestock and meat sales, facilitate more informed marketing decisions, and promote competition in slaughter industries (Haley).

More recently, concerns about increasing packer control of the market for hogs and cattle through packer ownership and marketing contracts have brought calls for legislation to limit packer ownership and control of livestock (i.e., captive supplies) prior to slaughter. A concern is that the higher the percentage of livestock that is held in captive supplies by packers, the less incentive packers have to bid aggressively on livestock offered through cash markets. Packers argue that some control of livestock supplies is needed in order to secure a consistent supply of high-quality animals, to assure food safety, and to achieve operational efficiency (Lawrence, Schroeder, and Hayenga). Despite the concerns of packers and others who evaluated the proposals, an amendment that prohibits packer ownership of livestock for more than 14 days prior to slaughter was being considered as part of the 2002 Farm Bill (Fuez et al.). However, the amendment was deemed too controversial and was stripped in the final version.

A concern about contracting in hog production is the matter of a disparity of market power, and hence bargaining power, between the parties in the contract arrangement. Contracting between parties of approximately equal or somewhat unequal bargaining power can work satisfactorily. However, contracting between parties of vastly unequal power, with one party more economically vulnerable, can potentially pose serious problems if the more powerful party uses market power to extract concessions from the weaker party (Hayenga, Harl, and Lawrence). If the weaker party (e.g., a grower) cannot shift to other enterprises without added costs or loss of income, the weaker party is economically vulnerable and has a potential problem. For example, a contract relationship between the only large producer or packer offering contracts in an area and growers with a substantial fixed investment in production facilities may lead to a pattern of concessions by growers when contracts are up for renewal.

These concerns about the implications of consolidation and the expanding use of production contracts in the hog industry have generated calls for legislation to protect producers from unfair business practices. During May of 2001, a U.S. Senate Subcommittee on Agriculture heard testimony about the "risks of contracting" in agriculture that outlined the following concerns: 1) the disparity in bargaining power in contract arrangements, with contracts that are complicated, unclear, and offered on a "take it or leave it" basis; 2) the shifting of economic risks to growers who are required to make substantial capital investments; and 3) the loss of market transparency due to strict confidentiality clauses that restrict the ability to compare and negotiate contracts (Iowa Department of Justice). Despite the concerns of policymakers, producer survey results suggest that both hog contractors and growers have been generally satisfied with contracting (Lawrence and Grimes). However, an amendment to the Packers and Stockyards Act was passed as part of the 2002 Farm Bill that prohibits certain activities of swine contractors, requires swine contractors to maintain certain records, and holds them responsible for the acts of their employees, officers, and agents (USDA, GIPSA). In addition, it gives swine production contract growers the right to sue contractors in Federal District Court.

Public Policy Concerns: The Environment

Another concern with the industrialization of hog production is the environmental impact posed by the large volume of hog manure concentrated on fewer operations. It is widely believed that a major reason for the hog manure problem is that adequate land for proper manure application is often not available near the manure source or under the control of the hog producer. The increasing size and consolidation of hog production has meant that operations are more specialized, separating animal production from the cropland. Gollehon et al. found the 2 percent of hog farms with more than 1,000 animal units had 35 percent of the national hog inventory, but controlled only 2 percent of the cropland and pastureland on hog farms.[2] In contrast, the 36 percent of small farms with 50-300 animal units had 32 percent of the hog inventory and 45 percent of the land on hog farms. Also, the regional distribution of production indicated a much greater separation of hogs and cropland in the Southeast than in traditional production areas of the Corn Belt.

Manure management on hog operations is addressed in the Clean Water Act, under which the National Pollutant Discharge Elimination System (NPDES) program covers certain animal feeding operations (AFOs). NPDES permits are required by point sources (operations that discharge manure directly into water resources through a pipe or ditch) before they can discharge into navigable waters. AFOs may be considered a point source in the NPDES program and designated as concentrated animal feeding operations (CAFOs) if they meet certain criteria pertaining to size and other characteristics.[3] In addition, total maximum daily load (TMDL) provisions of the Clean Water Act could affect animal feeding operations by limiting wasteload allocations for point sources within a watershed.

In 1999, USDA and the Environmental Protection Agency (EPA) announced the Unified National Strategy for Animal Feeding Operations (USDA, EPA), setting forth a framework for minimizing impacts to water quality and public health from AFOs and establishing a national performance expectation for AFOs. This coordinated effort grew from the perception that the Clean Water Act was inadequate for dealing with problems posed by the changing structure of livestock production. For example, the land disposal of manure is unregulated by the Clean Water Act because it is not considered as a discharge from the facility. Also, effluent discharge guidelines of the Clean Water Act were developed when facilities were a lot smaller (the 1970s) and are considered to be no longer adequate for addressing the current large operations.

The Unified Strategy outlines approaches to be taken by USDA and EPA to address the environmental concerns with AFOs, and presents a goal for all AFOs to have a nutrient management plan. To carry out the strategy, EPA is focusing on the large operations (CAFOs) that require a NPDES permit. EPA has proposed changing the effluent discharge guidelines, and is expecting CAFOs to develop comprehensive nutrient management plans (CNMPs) for properly managing animal waste, including onfarm application and off-farm uses. Inclusion of the CNMP as part of the NPDES permit means that, for the first time, the land application of manure will be part of a required Federal permit. USDA is using voluntary approaches to get CNMPs on AFOs not under EPA regulation. Therefore,

[2] Gollehon et al. defined an animal unit as 1,000 pounds of live animal weight.

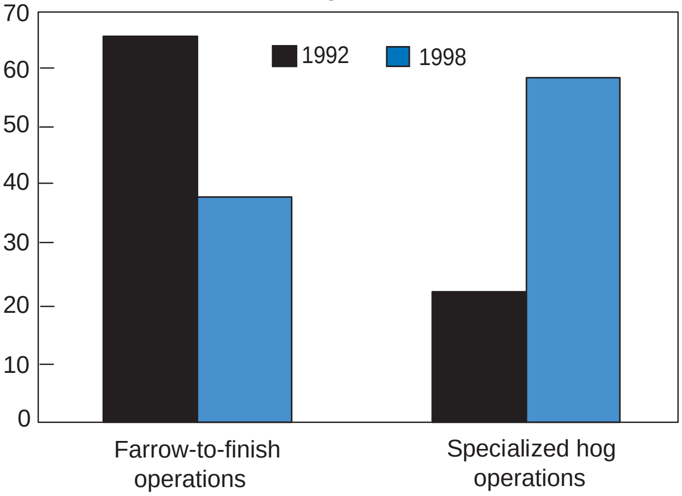
[3] Swine CAFOs are operations with a capacity of 2,500 head or more or operations with 750-2,500 head that discharge pollutants directly into navigable waters. An animal feeding operation of any size may also be designated as a CAFO if the permitting authority determines it to be a source of impairment.

the Unified Strategy outlines a general goal for all animal feeding operations to have a nutrient manure management plan, and the proposed EPA CAFO regulations and the USDA manure management strategy are the means by which the Unified Strategy goal is to be met.[4]

Indicators of Structural Change

In addition to the rapid growth in the size of U.S. hog operations, another important indicator of structural change has been the increasing degree of specialization. The traditional approach of farrow-to-finish production, where gestation, farrowing, nursery, and growing-finishing phases of production (see Glossary, p. 43) are performed on one operation, has given way to large operations that specialize in only one or two phases. The coordinated production approach, where large integrators contract out production with many growers, has allowed individual producers in the system to grow to unprecedented size by specializing in one area of production (Kliebenstein and Lawrence). Increasing specialization in U.S. hog production is illustrated in table 1 and figure 5. The proportion of total hog operations using the farrow-to-finish approach declined 5 percent (54 to 49 percent) between 1992 and 1998, but the proportion of total market hogs produced from these operations declined from 65 to 38 percent (fig. 5). The number of operations that specialized in finishing hogs increased from 19 to 31 percent of hog farms, and production increased from 22 to 58 percent of all market hogs sold or removed under contract.[5]

Figure 5
U.S. hog and pig production by producer type, 1992 and 1998
The proportion of total market hogs produced from farrow-to-finish operations fell from 65 to 38 percent between 1992 and 1998, while production from specialized hog operations increased from 22 to 58 percent.



Source: 1992 Farm Costs and Returns Survey; 1998 Agricultural Resource Management Survey.

The 1992 Farm Costs and Returns Survey

Changes in hog production during the 1990s are identified by comparing hog production and cost data from the 1998 Agricultural Resource Management Survey (ARMS) to similar data collected in the 1992 Farm Costs and Returns Survey (FCRS). USDA conducted the 1992 FCRS of hog producers in 20 States, mainly in the North Central and Southeast, representing 94 percent of 1992 U.S. hog and pig sales. Estimates from the 1992 FCRS are particularly useful for comparing to estimates from the 1998 ARMS because both surveys: (1) had a broad national coverage; (2) represented the same target population (i.e., operations with 25 head or more); (3) involved a complex sampling scheme designed to represent the target population; (4) were conducted with an identical approach (i.e., hand enumerated) by the same organization (i.e., NASS), and; (5) collected much the same information in a similar format. Also, the definitions of various types of hog producers were identical in 1992 and 1998. Detail on the 1992 FCRS of hog producers, along with the estimates used to compare with 1998, can be found in McBride.

As discussed in the previous section, technological and organizational innovations were important forces behind structural change in hog production during the 1990s. This section looks at key indicators of organizational and technological innovation in hog production, and how they changed between 1992 and 1998 (see "The 1992 Farm Costs and Returns Survey," above).

Organizational Innovation

Evidence of significant reorganization in hog production during the 1990s is indicated by the change in average production per farm. Hog sales and contract removals per farm nearly tripled between 1992 and 1998, from 945 to 2,589 (table 1). Growth in the average size of hog operations (see Glossary, p. 43) was most dramatic on specialized operations, where sales/removals from feeder pig operations grew by an average of about 400 percent and

[4] For more detail on Federal law pertaining to manure management see Gollehon et al.

[5] Farrow-to-feeder pig and weanling-to-feeder pig operations provide the feeder pigs that are finished to a market hog weight on feeder pig-to-finish operations. Hog finishing operations may also have obtained feeder pigs from other countries. The number of hogs imported for finishing from Canada has grown significantly in recent years (USDA, ERS).

Table 1—Characteristics and performance by type of hog producer, 1992 and 1998

Item	Farrow -to- finish	Farrow -to- feeder pig	Feeder pig -to- finish	Weanling -to- feeder pig	All hog and pig producers
Characteristics:					
Hog operations[1]					
1992 (percent)	54	8	19	nr	100
1998 (percent)	49	6	31	1	100
Market hogs sold/removed[1]					
1992 (percent)	65	-	22	-	100
1998 (percent)	38	-	55	-	100
All sales/contract removals					
1992 (head)	886	1,440	804	nr	945
1998 (head)	1,239	7,272	2,756	23,758	2,589
Contract operations					
1992 removals (percent)	id	8	22	nr	5
1998 removals (percent)	3	83	62	100	40
Land area					
1992 (acres operated)	634	291	556	nr	548
1998 (acres operated)	464	199	496	536	443
Performance:					
Farrowing					
1992 (litters per sow)	1.75	1.92	na	na	1.76
1998 (litters per sow)	2.08	2.18	na	na	2.12
1992 (pigs per litter)	8.72	9.08	na	na	8.85
1998 (pigs per litter)	9.25	10.71	na	na	9.59
Weaning					
1992 (pigs per litter)	7.54	8.07	na	na	7.70
1998 (pigs per litter)	8.32	9.59	na	na	8.65
1992 (pigs per sow)	13.22	15.48	na	na	13.59
1998 (pigs per sow)	17.33	20.92	na	na	18.36
Feed efficiency					
1992 (lbs per cwt gain)	416	527	383	nr	419
1998 (lbs per cwt gain)	374	318	282	229	325
Labor efficiency					
1992 (hrs per cwt gain)	1.13	1.81	0.89	nr	1.21
1998 (hrs per cwt gain)	0.72	0.83	0.24	0.27	0.50
Production costs [2,3]					
1992 (1992 $ per cwt gain)	46.78	90.82	55.59	nr	51.56
1992 (1998 $ per cwt gain)	52.21	101.36	62.04	nr	57.54
1998 (1998 $ per cwt gain)	43.56	79.00	46.93	62.54	48.54

Notes: id indicates insufficient data for legal disclosure; nr indicates not reported in 1992 data; na indicates not applicable.
Source: 1992 estimates from McBride, 1998 estimates from the ARMS survey of hog producers.
[1]The sum of operations and sales/removals for the specific producer types will not equal 100 percent because some producers could not be classified into one of the categories.
[2]Operating and ownership costs, where 1992 costs are deflated to 1998 dollars using the national GDP implicit price deflator (Bureau of Economic Analysis).
[3]A comparison of costs across producer types is not recommended because of differences in the methods used to compute costs. For example, the price used to value feeder pigs has a significant impact on hog finishing costs, but not on the costs for other types of producers. Also, differences in the size and ownership structure of farms would also affect their relative costs.

hog finishing operations grew about 240 percent. Off-site nurseries (weanling-to-feeder pig) were substantial operations in 1998, averaging more the 20,000 head of pigs. In contrast, average sales/removals from farrow-to-finish operations grew about 40 percent between 1992 and 1998, but by 1998 the average unit size was much smaller than that on specialized hog operations.

The reorganization of hog operations is also evident by substantial growth in coordinated production through the use of contracts. In 1992, only 5 percent of total hog production was through contracts. By 1998, contract removals accounted for 40 percent of total production (table 1). Expanded use of contract production occurred almost exclusively on specialized hog operations. Production contracts on specialized feeder pig operations grew from 8 to 83 percent, and from 22 to 62 percent on specialized hog feeding operations. All of the production from off-site nurseries surveyed in 1998 was removed under contract. However, very little production on farrow-to-finish operations was removed under contract in either 1992 or 1998.

Hog production also became more separated from the land base during the 1992-1998 period. Average acres operated by hog producers dropped by 100 acres, nearly 20 percent, from 1992 to 1998 with a similar trend across producer types. This means that less acreage was available on hog operations in 1998 to produce hog feed and thus more was acquired from off-farm sources, common among coordinated operations. Also, less acreage was available for manure disposal.

Technological Innovation

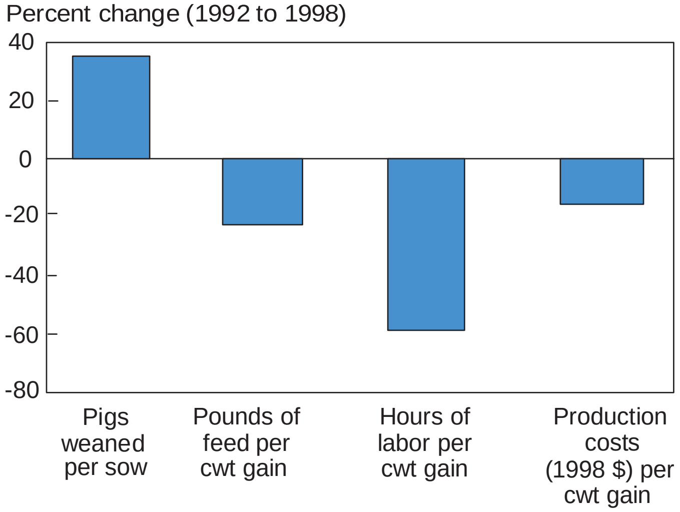
Technical change in hog production includes such advances as improved genetics, nutrition, housing and handling equipment, veterinary and medical services, and management that improves the performance of hogs and the efficiency of the operation, and/or reduces production risk. Evidence of technical change between 1992 and 1998 is indicated by significant improvements in farrowing and weaning performance (table 1). Pigs farrowed and weaned per litter increased by 8 and 12 percent, respectively, over the 1992-98 period. Average litters farrowed per sow rose 20 percent to 2.12 in 1998, while pigs weaned per sow improved 35 percent from less than 14 to more than 18 (fig. 6). Productivity gains were similar among the producer types, but specialized feeder pig operations continued to outperform farrow-to-finish operations, weaning three more pigs per sow in 1998.

Feed and labor efficiency (see Glossary, p. 43) gains were also substantial during the 1992-98 period. The feed efficiency of U.S. hog production improved by more than 20 percent between 1992 and 1998, an average annual gain of 3.7 percent. Labor efficiency on hog farms was nearly 60 percent higher in 1998 than in 1992, averaging a 9.8-percent annual gain. Both feed and labor efficiency improved the most on specialized hog operations.

Figure 6

Change in performance on U.S. hog operations, 1992 to 1998

The weaning, feed, labor, and cost efficiency of U.S. hog operations improved dramatically between 1992 and 1998.



Source: 1998 Agricultural Resource Management Survey.

Gains from technological innovation in hog production also contributed to a decline in real production costs during the 1992-98 period. Average operating and ownership costs (see Appendix I, p. 49) per hundredweight (cwt) of gain, expressed in 1998 dollars, were about 16 percent lower in 1998 than in 1992 among all U.S. producers. This amounts to a 2.6-percent annual rate of reduction (fig. 6). Real costs declined the most for the specialized producers, more than 20 percent, compared with 17 percent among farrow-to-finish operations.

Factors Contributing to Structural Change

Variation in Production Costs

Average hog production cost estimates reveal limited information about the economic performance of U.S hog producers. Considerable production cost variability exists among hog producers. Lawrence reports total production costs that were about $10 per cwt lower, or more than 20 percent, for the highest profit one-third of Iowa producers, compared with the lowest profit one-third. Similarly, total costs among farrow-to-finish producers in Kansas were $14 per cwt less for the top one-third of producers relative to the bottom one-third, a difference of nearly 30 percent (Langemeier and Schroeder). Such cost differences are important to the structure of hog production. In a survey of former hog producers in Iowa, economic factors, including costs of production, were the top four reasons that producers exited the hog industry between 1991 and 1997 (Lawrence and Wang). Government statistics on the number of hog farms show that more than 15,000 operations (about 14 percent) quit producing hogs between 1998 and 1999 (NASS, *Hogs and Pigs*), corresponding to a prolonged period of hog prices that were likely below the production costs of many operations.

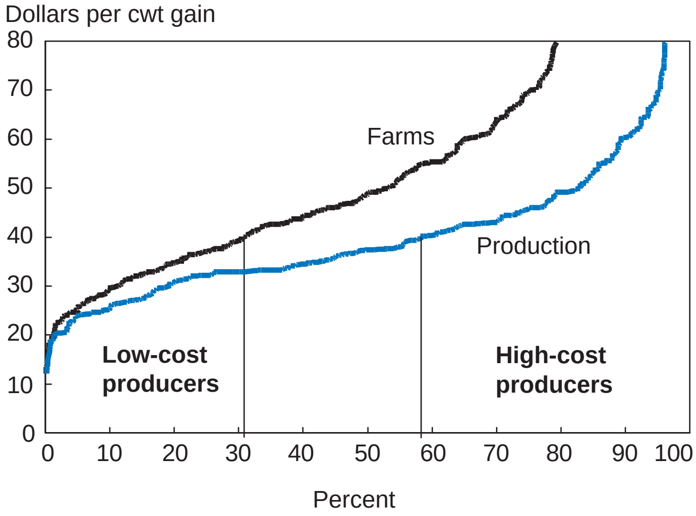
This report examines cost variation among U.S. hog producers by dissecting the distribution of costs for the different types of producers. Estimated production costs per cwt gain (see Glossary, p. 43) for each producer type were ranked from lowest to highest to form a weighted cumulative distribution. The cost estimates were expressed per unit of the primary product of each type of operation, either market hogs or feeder pigs, by deducting the value of secondary products, mainly cull or breeding stock, from costs.[6] Thus, production costs can be directly compared with market hog or feeder pig prices. Figure 7 illustrates the cumulative distribution of farrow-to-finish production costs. At a market price of $40 per cwt, only about 30 percent of farrow-to-finish producers were able to cover costs in 1998. However, these producers accounted for nearly 60 percent of total production from farrow-to-finish operations.

The cumulative distribution was divided into quartiles, with the bottom quartile representing hog producers with the lowest costs, and the top quartile representing hog producers with the highest costs (fig. 7). Factors that may

Figure 7

Cumulative distribution of farrow-to-finish production costs per cwt gain, 1998

At a market price of $40/cwt for hogs, only about 30 percent of producers covered costs, but they produced nearly 60 percent of total production.



Source: 1998 Agricultural Resource Management Survey.

have contributed to the relative costs of low- and high-cost producers were identified by comparing the structural and performance characteristics of each group.

Structural Characteristics by Cost Group

Low-cost operations were significantly larger than high-cost operations among all producer types. The 25 percent of operations with the lowest costs accounted for more than 40 percent of production (71 percent of feeder pig production), while the 25 percent of producers with the highest costs comprised less than 10 percent of production among the producer types (table 2). Low-cost farrow-to-finish operations produced more than 2,000 head of market hogs per farm, compared with 370 head on high-cost operations. The difference was even greater among specialized producer types where low-cost feeder pig operations produced more than 16,000 head per farm and low-cost hog finishers produced about 4,300 head. This compares to 754 feeder pigs and 615 finished hogs on the high-cost operations. Also, more of the hogs produced by low-cost producers on specialized operations were removed under contract than on high-cost operations. Over 90 percent of the pigs were removed under contract from low-cost feeder pig operations, while 56 percent of hogs were removed under contract from low-cost hog finishing operations. Farms with low-cost hog operations were also organized to be more highly specialized in hog production compared with high-cost operations. Almost

[6] This method of presenting the unit-cost of production has been referred to as the Residual Claimant method (Frank).

Table 2—Characteristics by cost group for hog producer types, 1998

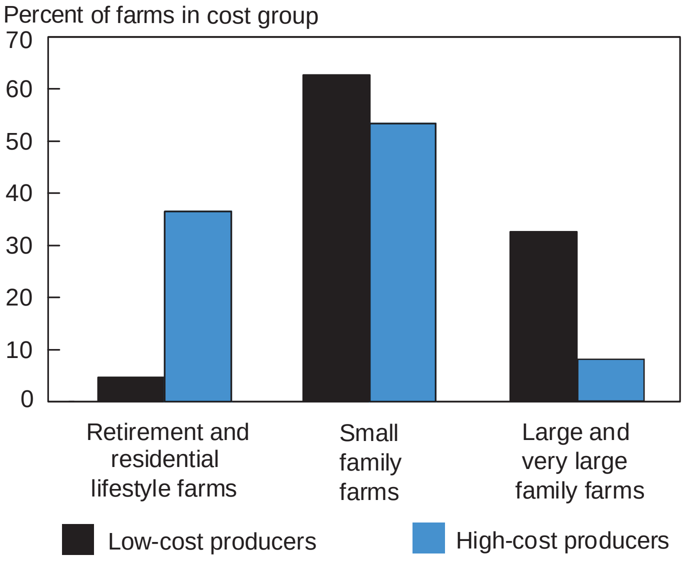
Item	Low-cost producers	High-cost producers
Farrow-to-finish		
Percent of farms/sales and removals	25/46	25/8
Hogs and pigs sold or removed (head)	2,180	370*
Head removed under contract (percent)	1**	id
Farm production value from hogs (percent)	58	26
Farm typology (percent of farms):		
Retirement	id	14**
Residential lifestyle	4*	22*
Farming occupation-lower sales	18*	25*
Farming occupation-higher sales	44	28*
Large family farm	18*	9**
Very large family farm	15	1**
Farm debt-to-assets ratio	0.18	0.18
Operator age (years)	48	56
Exiting industry in 1 year or less (percent)	20	40
Farrow-to-feeder pig		
Percent of farms/sales and removals	25/71	25/3
Hogs and pigs sold or removed (head)	16,618**	754**
Head removed under contract (percent)	92	70**
Farm production value from hogs (percent)	93	54*
Farm typology (percent of farms):		
Retirement	0	id
Residential lifestyle	11**	37
Farming occupation-lower sales	26*	48*
Farming occupation-higher sales	21*	5**
Large family farm	9**	id
Very large family farm	34**	3**
Farm debt-to-assets ratio	0.48*	0.17*
Operator age (years)	47	55
Exiting industry in 1 year or less (percent)	17**	52
Feeder pig-to-finish		
Percent of farms/sales and removals	25/41	25/6
Hogs and pigs sold or removed (head)	4,301	615
Head removed under contract (percent)	56	34*
Farm production value from hogs (percent)	64	24
Farm typology (percent of farms):		
Retirement	id	id
Residential lifestyle	16*	19*
Farming occupation-lower sales	id	15*
Farming occupation-higher sales	26*	42*
Large family farm	22*	16*
Very large family farm	30	8*
Farm debt-to-assets ratio	0.35	0.21
Operator age (years)	49	50
Exiting industry in 1 year or less (percent)	21*	36*

Notes: id indicates insufficient data for legal disclosure; single (*) and double asterisks (**) indicate a coefficient of variation between 25 and 50, and greater than 50, respectively. The definition of low- and high-cost producers can be found in the Glossary, p. 43.

60 percent of the total farm production value on low-cost farrow-to-finish and finishing operations was from the hog enterprise, while more than 90 percent was from the hog enterprise on low-cost feeder pig operations.

The relative diversity of low- and high-cost hog operations is illustrated from the distribution by farm typology (see Glossary, p. 43). Differences in typology are a reflection of operators' expectations and goals from farming, stage in the life cycle, and dependence on agriculture, as well as size of operation (Hoppe, Perry, and Banker). Significantly more of the high-cost producers were retirement and residential lifestyle farms, comprising more than a third of farrow-to-finish (fig. 8) and feeder pig opera-

Figure 8
Distribution of farrow-to-finish producers by farm typology, 1998
Retirement and residential lifestyle farms were mostly high-cost producers, while large and very large family farms were mostly low-cost producers.



Source: 1998 Agricultural Resource Management Survey.

tions. Because operations of these types depend relatively less on farming for income, they likely have less time for farming and different goals for the farm operation. Also, retirement operations have a shorter planning horizon and are likely to be using production technologies (e.g., buildings and equipment) closer to the end of their useful life, which may contribute to lower performance. Low-cost operations were more often large or very large farms that have a considerable time and financial investment in farming. Thirty percent or more of the low-cost feeder pig and hog finishing operations were very large farms, and these producers had a considerably greater financial investment in farming as indicated by a higher debt-to-asset ratio than among the high-cost producers (table 2).

Many low-cost producers were also significantly younger than were the high-cost producers. The average age on farrow-to-finish and feeder pig operations was about 8 years less among low-cost producers. With more retirement farms and older farm operators, many more high-cost producers reported plans to exit hog production in 1 year or less. Also, market hog prices during 1998 reached record lows in December (USDA, NASS, *Agricultural Prices*). Declining hog prices mean that more of the high-cost operations would have produced at a loss, providing an incentive for these producers to consider leaving the hog business.

Performance by Cost Group

Most indicators of physical and economic performance were significantly better on low-cost than on high-cost hog operations (table 3). A major difference between the groups was that low-cost producers were able to generate much greater output from the capital invested (breeding stock and facilities) in the hog operation. Low-cost farrow-to-finish and feeder pig producers farrowed more litters per sow, and produced about four times more litters per sow capacity of the farrowing facilities. This may have been achieved by weaning pigs at a younger age and lower weight, freeing up facility space for more litters. Also, many high-cost producers were likely operating well below total capacity.

Feed and labor efficiency on low-cost operations was also significantly greater than on high-cost operations. Less feed per unit resulted in considerable cost savings for low-cost operations of all producer types. Better feed efficiency also meant that low-cost producers could have finished hogs in fewer days, thus freeing up space to move more hogs through the finishing facilities.[7] Low-cost farrow-to-finsh and finishing operations produced nearly twice the hogs per head of finishing capacity than on high-cost operations. Because the farrowing and finishing facilities were used much more efficiently on low-cost operations, asset ownership costs were lower as fixed costs were spread over more units of production.

Greater productivity on low-cost operations was made possible by, among other factors, newer technologies. The average age of farrowing facilities was less on low-cost operations, particularly among feeder pig producers where the facilities were about half as old as those on high-cost operations (fig. 9). Likewise, finishing barns were newer by an average of 7 years on farrow-to-finish operations and 11 years on hog finishing operations. Technical advances make possible the improved care of baby pigs (thus lowering death losses and allowing pigs to be weaned younger), reduce labor requirements per unit of production, and increase feed efficiency by lowering feed losses and improving herd health. These are many of the advantages of low-cost compared with high-cost operations (table 3).

[7] This was more likely on the farrow-to-finish and feeder pig operations where final hog weights for the low- and high-cost producers were not significantly different. However, low-cost hog finishing operations fed hogs to a heavier weight than high-cost operations (254 versus 246 pounds), and thus may have achieved the added weight gain in about the same number of days on feed.

Table 3—Performance by cost group for hog producer types, 1998

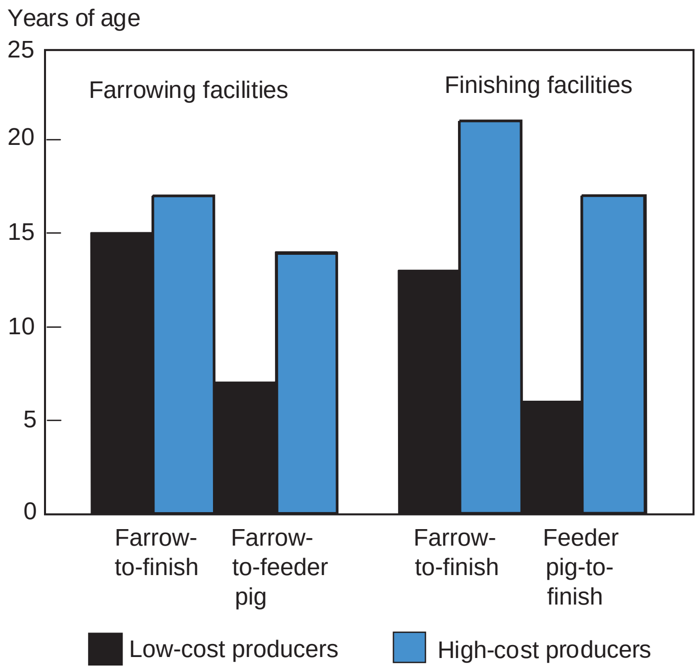
Item	Low-cost producers	High-cost producers
Farrow-to-finish		
Litters farrowed per sow (number)	2.20	2.02
Pigs weaned per litter (head)	8.71	7.18
Pigs weaned per sow (head)	19.19	14.48
Weaning age (days)	29	40
Weaning weight (pounds)	19	28
Feed efficiency (pounds fed per cwt gain)	299	626
Labor efficiency (hours per cwt gain)	0.50	1.92
Litters farrowed per sow capacity	6.53	1.50*
Farrowing facility age (years)	15	17
Hogs finished per head capacity	2.91	1.64*
Finishing facility age (years)	13	21
Production costs (dollars per cwt gain):		
Feed costs	19.27	40.71
Operating costs	25.67	51.33
Ownership costs	8.60	35.65
Total operating and ownership costs	34.26	86.98
Farrow-to-feeder pig		
Litters farrowed per sow (number)	2.33	2.20
Pigs weaned per litter (head)	9.69	7.80
Pigs weaned per sow (head)	22.58	17.18*
Weaning age (days)	25	33
Weaning weight (pounds)	17	22
Feed efficiency (pounds fed per cwt gain)	251	949
Labor efficiency (hours per cwt gain)	0.56**	4.05
Litters farrowed per sow capacity	10.47*	2.54*
Farrowing facility age (years)	7	14*
Production costs (dollars per cwt gain):		
Feed costs	26.18	77.19
Operating costs	47.23	134.11
Ownership costs	20.07*	84.95
Total operating and ownership costs	67.30	219.06
Feeder pig-to-finish		
Feed efficiency (pounds fed per cwt gain)	240	575
Labor efficiency (hours per cwt gain)	0.16	0.78
Hogs finished per head capacity	2.36	1.30
Finishing facility age (years)	6	17
Production costs (dollars per cwt gain):		
Feed costs	15.83	35.98
Operating costs	34.34	66.92
Ownership costs	5.68	14.15
Total operating and ownership costs	40.02	81.08

Notes: Single (*) and double asterisks (**) indicate a coefficient of variation between 25 and 50, and greater than 50, respectively.
The definition of low- and high-cost producers can be found in the Glossary, p. 43.

The much higher asset ownership costs estimated for high-cost operations are probably not considered by many of these producers in their production decisions. As previously mentioned, these operators are older than low-cost producers, have older production facilities, and likely have paid for the investment in hog buildings and equipment. At their stage in the life cycle, many high-cost producers will not replace the facilities once their useful life has ended. Annual production decisions for these producers are more likely to be based on operating costs. The much greater operating costs on high-cost operations is likely an important reason why a significant number of the high-cost producers of each producer type reported plans to exit the industry in 1 year or less (see table 2).[8]

[8] Feed costs for homegrown grain were estimated by valuing the grain at the market price (i.e., its opportunity cost as hog feed). Many of the high-cost producers fed corn produced on the farm and this method for valuing the corn may overstate their actual cost of producing hog feed.

Figure 9
Farrowing and finishing facility age by type of producer, 1998
The facilities used by low-cost producers were significantly newer than those used by high-cost producers, especially among the specialized producer types.



Source: 1998 Agricultural Resource Management Survey.

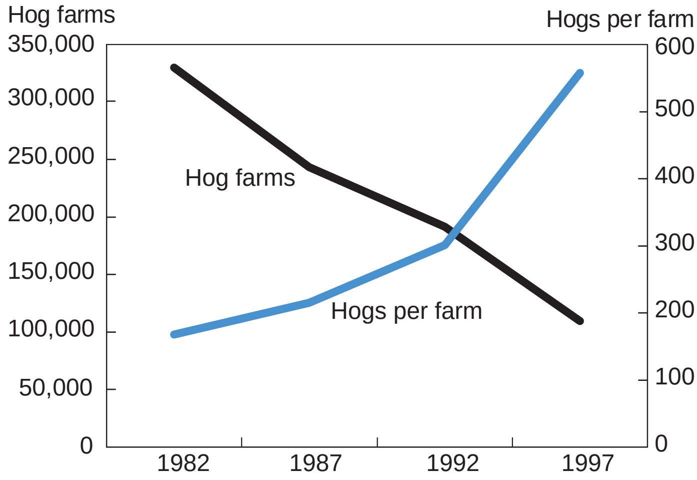
Economies of Size

This report also examines cost variation among U.S. hog producers by focusing on the cost-size relationship. A commonly held notion is that economies of size exist in U.S. agriculture and that these economies are perhaps the most significant factor in explaining structure (Ahearn, Whittaker, and El-Osta; Boehlje). More specifically, the view is that the most economically efficient size of farms will prosper and other farms will tend to exit or gravitate to that farm size. This view is supported by empirical evidence that indicates an L-shaped relationship between costs and output (Hallam). The trend in farm structure toward fewer and larger hog farms also supports the existence of economies of size in hog production. Census of Agriculture statistics show that the number of hog farms in 1997 dropped by about two thirds from 1982, while the number of hogs produced per farm more than tripled (fig. 10). Expansion in the number of hogs per farm was particularly rapid during the 1990s, increasing from about 300 head per farm in 1992 to more than 550 head in 1997.

Seckler and Young have offered an alternative explanation for the L-shaped relationship found between average costs and production levels and the increase in farm size over time, other than the existence of economies of size. Their explanation relates to the existence of superior management abilities and the desire to increase net income or wealth. Superior managers, as indicated by profitability, will have the ability and incentive to expand and leave the high-cost producers among the smaller sizes of farms. Boehlje also notes that enhanced managerial ability from investments in human capital increase the "span of control," allowing farmers to more effectively manage larger scale specialized units. Research by Mueller into Illinois hog production lends support for this view. This research found that size of the hog enterprise alone contributed very little to the profitability per unit of production, as measured by returns above feed costs per litter. The authors concluded that the managerial talent of the producer was much more important to profitability than was size of operation. More recent research examining swine operations in Iowa also suggests that size of operation is not the dominant factor to remaining competitive in hog production (Kliebenstein, Lawrence, and Duffy). Likewise, a comparison of efficiency across farrow-to-finish swine operations in Kansas suggests that small, efficient producers are able to compete on a cost basis with much larger operations (Rowland et al.).

To evaluate the relationship between hog costs of production and size of operation, surveyed producers were divided into discrete size groups and differences in hog

Figure 10
Farms and hogs per farm, 1982-97
The number of hog farms in 1997 was about one-third of that in 1982, while the number of hogs produced per farm more than tripled.



Source: Census of Agriculture, various years.

Table 4–Number of hog operations by size of operation, 1998 and 1999
More than 13,000 small hog operations went out of business between 1998 and 1999.

	Number of operations		
Size of operation (head)	1998	1999	Change
Small (1-499)	88,985	75,690	-13,295
Medium (500-1,999)	18,175	15,755	-2,420
Large (2,000-4,999)	4,765	5,110	+345
Industrial-scale (5,000+)	1,905	2,055	+150

Source: USDA, NASS, *Hog and Pigs*, 1999.

production costs, and farm structural and performance characteristics were examined. The size groups were assigned according to the reported peak hog inventory on the operation during 1998 into: 1) small operations (1-499 head); 2) medium operations (500-1,999 head); 3) large operations (2,000-4,999 head), and: 4) industrial-scale operations (5,000 head or more). Government statistics (USDA, NASS, *Hogs and Pigs*) indicate that more than 13,000 small hog operations went out of business between 1998 and 1999, while the number of large and industrial-scale operations increased, despite low hog prices during this period (table 4).

Structural Characteristics by Size Group

Small- and medium-sized hog operations far outnumbered large and industrial-scale operations during 1998, but produced a disproportionately small share of total hog production. About half of all farrow-to-finish and feeder pig operations were small, but these small operations produced only 8 percent of farrow-to-finish production and 2 percent of feeder pigs (table 5). Only 3 percent of farrow-to-finish and 5 percent of hog finishing operations were industrial-scale, but these operations accounted for about one-third of production. Nearly 70 percent of feeder pig production was from the 11 percent of industrial-scale farms, with an average production of about 48,000 feeder pigs. Among the specialized hog producer types, contract production was more common on larger operations, but was also used by smaller producers. Nearly all industrial-scale feeder pig production was under contract, while nearly 60 percent of production on medium-sized operations was also under contract. On hog finishing operations, about 40 percent of production from small- and medium-sized operations was under contract, compared with about 70 percent of production from the large and industrial-scale operations.

Farm specialization in hog production increased with size across all producer types, with the value from hogs ranging from around 10 percent of total farm value of production on small operations to around 90 percent on industrial-scale operations. Greater diversity among small operations is also apparent in typology classes that show significantly more producers generating the majority of household income from off-farm income sources. Operators of small hog enterprises were also generally older and carried less debt than larger operations. More than 60 percent of small farms also reported intentions of exiting hog production within the next 5 years, compared with very few of the industrial-scale operations. Production intentions reported in the 1998 ARMS support other data (USDA, NASS, *Hogs and Pigs*) that indicate more than 15,000 small- and medium-sized operations exited the industry between 1998 and 1999 (table 4). The data also suggest that many more small- and medium-sized operations will cease production in the next few years. The most striking illustration of this trend is in feeder pig production, where about 75 percent of small producers plan to be out of business by 2003, while 98 percent of industrial-scale operations plan to remain in business.

Performance by Size Group

Nearly all indicators of physical and economic performance improved as size of operation increased (table 6). Feed, labor, and capital, the three major inputs in hog production, were all used more efficiently on larger operations. Industrial-scale farrow-to-finish and hog finishing operations were nearly 40 percent more feed efficient on average than small operations, while industrial-scale feeder pig producers were about 65 percent more feed efficient than small feeder pig operations. Likewise, the labor requirement on the largest operations was only a fraction of that used by the smallest operations for all producer types. Differences in capital efficiency by size, as indicated by pigs weaned per sow and by production per unit of facility capacity, were also significant. Industrial-scale operations farrowed about five to seven more pigs per litter, and obtained about three times more litters per sow capacity and twice the market hogs per unit of finishing capacity than the small operations.

Table 5—Characteristics by size of operation for hog producer types, 1998

Item	Small	Medium	Large	Industrial-scale
Farrow-to-finish				
Percent of farms/sales and removals	49/8	41/39	7/21	3/32
Hogs and pigs sold or removed (head)	203	1,128	3,712	13,468
Head removed under contract (percent)	0	1**	id	7**
Farm production value from hogs (percent)	7	34	61	80
Farm typology (percent of farms):				
Retirement	9*	0	0	0
Residential lifestyle	28	1**	0	0
Operator age (percent less than 50 years)	44	51	76	44*
Farm debt-to-assets ratio	0.14	0.20	0.22	0.25
Exiting industry in 1 year or less (percent)	24*	34	9*	7*
Exiting industry in 5 years or less (percent)	62	51	16**	17**
Farrow-to-feeder pig				
Percent of farms/sales and removals	56/2	17/12	nr	11/69
Hogs and pigs sold or removed (head)	236	4,915	nr	47,999
Head removed under contract (percent)	0	59*	nr	98
Farm production value from hogs (percent)	11	58	nr	99
Farm typology (percent of farms):				
Retirement	3**	0	nr	0
Residential lifestyle	33*	id	nr	0
Operator age (percent less than 50 years)	26	62	nr	86*
Farm debt-to-assets ratio	0.12	0.28	nr	0.61*
Exiting industry in 1 year or less (percent)	51	20**	nr	0
Exiting industry in 5 years or less (percent)	73	31**	nr	id
Feeder pig-to-finish				
Percent of farms/sales and removals	39/5	39/25	18/35	5/36
Hogs and pigs sold/removed (head)	346	1,754	5,503	19,408
Head removed under contract (percent)	38**	45	74	66
Farm production value from hogs (percent)	14	40	73	90
Farm typology (percent of farms):				
Retirement	id	id	0	0
Residential lifestyle	17*	17*	2**	0
Operator age (percent less than 50 years)	40*	63	61	40*
Farm debt-to-assets ratio	0.20	0.27	0.37	0.39*
Exiting industry in 1 year or less (percent)	39*	13*	17*	id
Exiting industry in 5 years or less (percent)	65	29	32*	3**

Notes: id indicates insufficient data for legal disclosure; nr indicates not reported due to a limited sample size and a high coefficient of variation (CV); single (*) and double asterisks (**) indicate a CV between 25 and 50, and greater than 50, respectively.

Improvements in performance from the small to the industrial-scale operations were not linear, but rather were incrementally less with each size group (fig. 11). The largest efficiency gains on farrow-to-finish and feeder pig operations were made between the small and medium groups. Average costs on medium-sized farrow-to-finish operations were about 20 percent less than on small operations, while the average costs of feeder pig production fell 37 percent between the small and medium farms. Nearly all of the cost reduction by size for feeder pig production was achieved on medium-sized operations. However, the average cost of producing market hogs fell about 11-12 percent between medium and large farrow-to-finish and hog finishing operations. Average costs on these farms fell another 2-5 percent between large and industrial-scale operations (fig. 11). These data suggest that production costs are reduced significantly by increasing the size of operations from relatively small sizes, but that there are still cost-reducing incentives for operations to grow to the industrial-scale size.

While average costs by size of operation reveal information about the relative competitiveness of various sized operations, they mask the underlying variation in costs. Cost variation among the farrow-to-finish operations in each size group is illustrated in figure 12 (p. 20). The variation in cost was greatest among the small hog operations, and least among the large and industrial-scale operations.

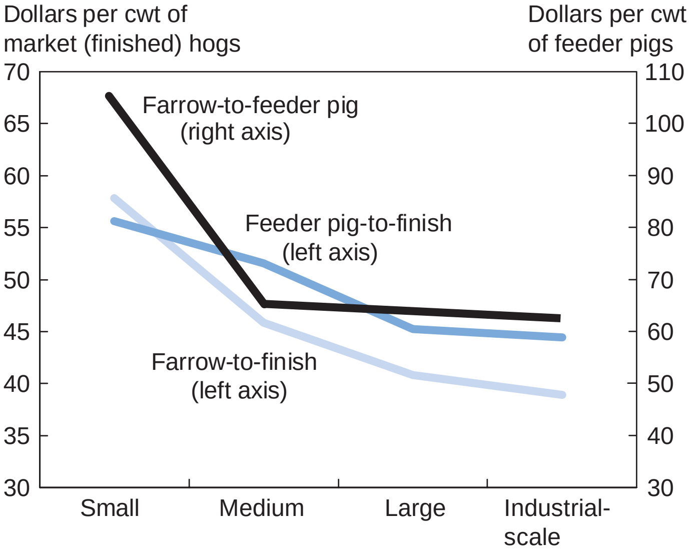
Table 6—Performance by size of operation for hog producer types, 1998

Item	Small	Medium	Large	Industrial-scale
Farrow-to-finish				
Litters farrowed per sow (number)	1.88	2.15	2.04	2.09
Pigs weaned per litter (head)	7.24	8.05	8.68	8.77
Pigs weaned per sow (head)	13.64	17.34	17.74	18.30
Weaning age (days)	40	28	22	18
Weaning weight (pounds)	29	18	14	12
Feed efficiency (pounds fed per cwt gain)	498	403	379	300
Labor efficiency (hours per cwt gain)	1.82	0.98	0.49	0.27
Litters farrowed per sow capacity	1.40	3.09*	5.75	6.24*
Farrowing facility age (years)	18	14	16	10
Hogs finished per head capacity	1.38	2.16	2.57	3.26
Finishing facility age	20	17	12	8
Production costs (dollars per cwt gain):				
Feed costs	26.29	25.14	22.82	21.20
Operating costs	32.94	32.18	30.75	30.02
Ownership costs	24.87	13.66	10.05	8.92
Total operating and ownership costs	57.81	45.85	40.80	38.94
Farrow-to-feeder pig				
Litters farrowed per sow (number)	2.09	2.05	nr	2.19
Pigs weaned per litter (head)	7.09	8.68	nr	10.01
Pigs weaned per sow (head)	14.80	17.77	nr	21.92
Weaning age (days)	33	21	nr	19
Weaning weight (pounds)	24	14	nr	13*
Feed efficiency (pounds fed per cwt gain)	777*	349	nr	260*
Labor efficiency (hours per cwt gain)	4.14	1.82	nr	0.30*
Litters farrowed per sow capacity	2.65*	4.32*	nr	7.71**
Farrowing facility age (years)	19	9	nr	5
Production costs (dollars per cwt gain):				
Feed costs	45.55	29.62	nr	29.34
Operating costs	64.36	45.09	nr	52.11
Ownership costs	47.87	27.45	nr	21.75
Total operating and ownership costs	104.81	66.01	nr	62.97
Feeder pig-to-finish				
Feed efficiency (pounds fed per cwt gain)	389	342	265	247
Labor efficiency (hours per cwt gain)	0.86	0.39	0.19	0.12
Hogs finished per head capacity	1.30	1.73	2.14	2.45*
Finishing facility age	20	13	6	4
Production costs (dollars per cwt gain):				
Feed costs	23.27	22.52	19.40	18.26
Operating costs	43.24	43.08	38.80	38.80
Ownership costs	12.35	8.51	6.41	5.65
Total operating and ownership costs	55.60	51.59	45.21	44.45

Notes: id indicates insufficient data for legal disclosure; nr indicates not reported due to a limited sample size and a high coefficient of variation (CV); single (*) and double asterisks (**) indicate a CV between 25 and 50, and greater than 50, respectively.

This result coincides with the greater diversity among small producers relative to other producers. The cost distributions also show that despite higher average costs among the small- and medium-sized groups, many of these operations produce at a cost that is competitive with larger operations. For example, at a hog price of $40 per cwt, 19 percent of small producers covered production costs in 1998, compared with over 50 percent of the large and industrial-scale producers (fig. 12). However, this 19 percent corresponded to about 17,000 small operations, compared with about 4,000 large and industrial-scale operations (see table 4 for 1998 farm numbers). Therefore, there is substantial variation in production costs that cannot be attributed to size of operation. This suggests that the managerial ability of individual hog producers is likely to be as important as size economies to lowering the costs of hog production.

Figure 11
Production costs by size of operation for hog producer types, 1998
Average production costs declined as size of operation increased, with most of the reduction occurring between small to medium and medium to large operations.



Source: 1998 Agricultural Resource Management Survey.

Regional Diversity

As the structure of the hog industry has changed, so has its geography. Hog production has historically been concentrated in Corn Belt States where an abundant supply of corn provided a relatively cheap source of hog feed. However, during the 1980s and 90s, the growth and concentration of hog production was the most dramatic in nontraditional areas (Hubbell and Welsh). In North Carolina, the inventory of hogs and pigs more than doubled between 1987 and 92, as the State went from 6th to rank 2nd in total hog inventory. The hog inventory in North Carolina nearly doubled again between 1992 and 1997 (fig. 13).[9] Recently, the hog industry has moved aggressively into Western States, most notably in Oklahoma where the hog inventory increased more than 500 percent between 1992 and 1997.

Rapid growth and concentration in the North Carolina hog industry has been attributed to the development of "supply chains" that more closely link producers, packers, and consumers (Drabenstott).[10] The prominent feature of supply chains is contracting. Hog production in North Carolina expanded almost exclusively from the use of contracting by a few large integrators who developed pork supply chains. Recent expansion into Western States cannot be attributed to traditional factors, such as the availability of low-cost feed grains, or to the development of supply chains. A possible reason for growth of the hog industry in Western States is the presence of open space and a relatively low population density, features that provide flexibility in managing animal waste (Drabenstott). Growing concerns over waste management and odor in North Carolina and eastern Corn Belt States, areas with much higher population densities, have resulted in tighter state environmental regulations.[11] In many of these areas, the State and local governments have become more actively involved with regulating hog farming, creating a more uncertain regulatory environment. Research by Abdalla and Mo suggests that this uncertainty has likely encouraged investment in the hog industry to look elsewhere. Recent evidence suggests that Western States have attracted hog production using traditional business recruitment and retention tools such as tax breaks and less stringent environmental regulation (Roe, Irwin, and Sharp). However, other research finds no evidence that increasing environmental regulation in a State has had a detrimental effect on hog production in that State (Metcalfe). Whatever has caused the current geographic dispersion of hog production, it is likely that some interplay between economic conditions and environmental regulations will determine future geographic movements in the industry.

This report explores regional diversity in hog production by comparing characteristics of different producer types in the major production regions. Other studies have suggested that operations in the traditional Corn Belt production areas have a natural competitive advantage, but that the advantage has been overcome in other areas through investment in new technologies and from economies of size (Onal, Unnevehr, and Bekric). ERS Farm Resource Regions (Heimlich) will be used as the basis for the regional delineation (fig. 14). Among these regions, the Heartland is the region where hog production has traditionally been concentrated, including the Corn Belt, while the Southern Seaboard includes the areas of rapid growth during the 1980s and 1990s. The Western Region, defined to include the Prairie Gateway, Northern Great Plains, and

[9] In 1999, the total pig crop (i.e., pigs farrowed) in North Carolina exceeded Iowa's.

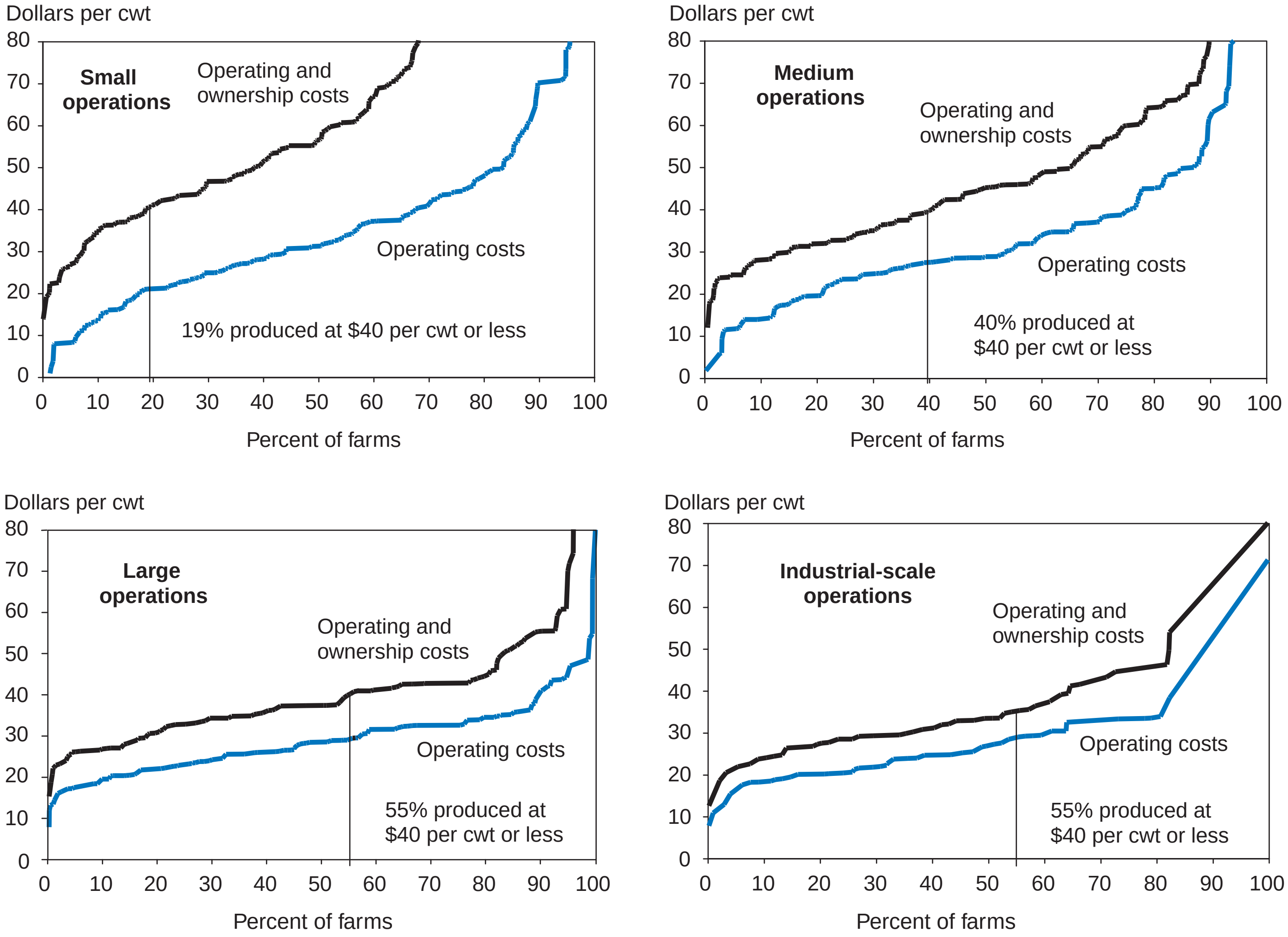
[10] A supply chain represents the many components of production, processing, distribution, and marketing aligned into a single system for the purpose of meeting consumer demand. A major advantage of supply chains is that they provide for a more rapid response to changes in consumer demand

[11] Growing environmental concerns in North Carolina resulted in a moratorium on the construction of new facilities in 1997 (Feitshans), causing the rapid growth in hog production during much of the 1990s to plateau in recent years.

Figure 12

Farrow-to-finish production cost distributions by size of operation, 1998

The variation in costs among small hog operations was much greater than among other operations, with the least variation in costs among the large and industrial-scale operations.



Source: 1998 Agricultural Resource Management Survey.

the Basin and Range, is where expansion in hog production has been most recent.

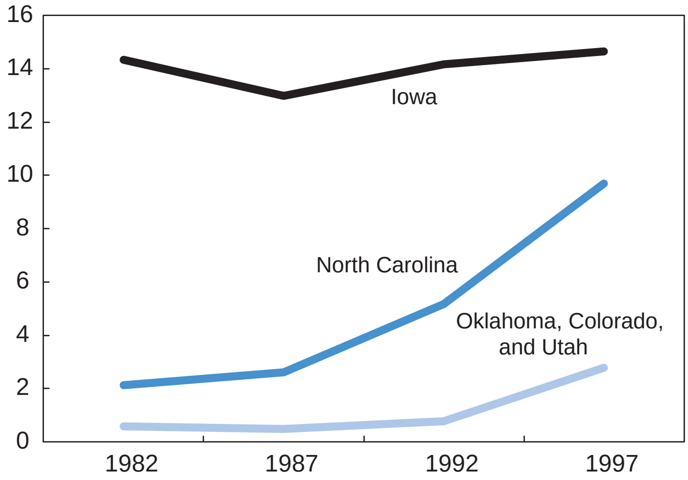
Structural Characteristics by Region

Farrow-to-finish hog production in 1998 was highly concentrated in the Heartland, with about three-fourths of the farms and production, compared with less than 10 percent in the other regions (table 7). Farrow-to-finish operations were about the same size in each region, with little contract activity in any of the regions. More than 80 percent of these operations had been in business more than 10 years and most had operators that were more than 50 years of age. The main differences between farrow-to-finish growers in each region was that they operated much larger farms in the Western regions and the Heartland than in the Southern Seaboard, and that significantly more Heartland producers grew their own corn.

Regional differences were more apparent among the specialized feeder pig and finished hog producers. Feeder pig producers in the Southern Seaboard were significantly larger than those in the Heartland (13,753 vs. 8,960 head), while nearly all feeder pigs in both regions were removed under contract from highly specialized feeder pig operations. Despite the large average size of feeder pig operations, a majority of feeder pig producers in both regions had small hog operations (fig. 15) that had been in business more than 10 years. This means that there was considerable variation in the size distribution of feeder pig

Figure 13
Hog inventories in selected States, 1982-97

Hog numbers remained stable in Iowa during 1982-97, but grew rapidly in North Carolina and have been growing in Western States since 1992.



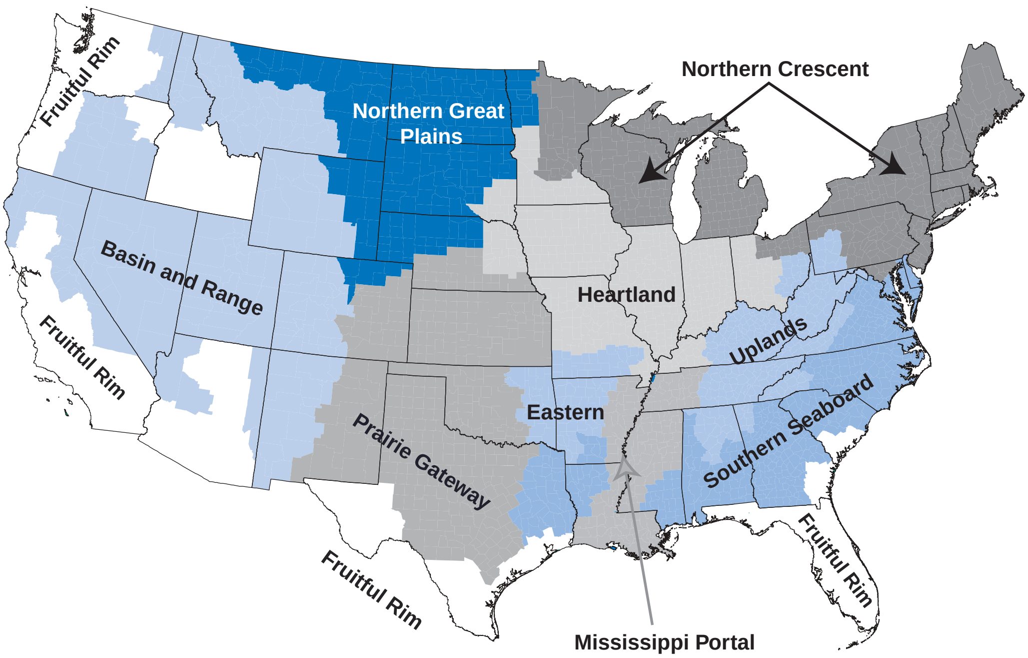
Source: Census of Agriculture, various years.

farms, with a few "mega-operations" responsible for inflating the per farm average. The relatively large proportion of Heartland producers under 50 years of age and the higher debt-to-assets ratio suggests that the investment in large-scale feeder pig production in this region has been more recent than in the Southern Seaboard. The farrow-to-feeder pig farms in both regions were highly concentrated on a relatively small land area compared with that on farms producing finished hogs.

Finished hog producers in the Southern Seaboard were more than 3 times larger than in the Western regions and nearly 6 times larger than in the Heartland. Over 70 percent of Southern Seaboard farms had large or industrial-scale operations (fig. 15) that were highly specialized, contract operations. In contrast, independent operations were predominant among finished hog producers in the Western regions. Producers in the Western regions were also younger and had a higher debt-to-assets ratio, suggesting a recent investment in production facilities. Half of the finished hogs in the Heartland were removed under contract, and nearly all Heartland operations also grew a substantial amount of corn (table 7). Finished hog production in the Southern Seaboard was much more concen-

Figure 14
Farm Resource Regions

Hog production has traditionally been concentrated in the Heartland, but during the 1980s and 90s expanded rapidly in the Southern Seaboard and more recently in Western regions, particularly in the Prairie Gateway and Basin and Range.



Source: Heimlich.

Table 7—Characteristics by region for hog producer types, 1998

Item	Heartland	Southern Seaboard	Western regions[1]
Farrow-to-finish			
Percent of farms/sales and removals	74/76	5/4	9/9
Hogs and pigs sold or removed (head)	1,245	1,145	1,272*
Head removed under contract (percent)	3*	3**	0
Farm production value from hogs (percent)	47	61	45*
In the hog business (percent of farms):			
Less than 10 years	6	15*	12**
10 years or more	94	85	88
Operator age (percent less than 50 years)	50	35	49
Farm debt-to-assets ratio	0.20	0.09	0.20
Farm land area (acres operated)	474	236	709*
Farms producing corn (percent of farms)	85	49	46
Corn harvested (acres per reporting farm)	213	55*	159*
Farrow-to-feeder pig			
Percent of farms/sales and removals	49/60	15/29	nr
Hogs and pigs sold or removed (head)	8,960**	13,753*	nr
Head removed under contract (percent)	80**	99	nr
Farm production value from hogs (percent)	91*	84	nr
In the hog business (percent of farms):			
Less than 10 years	21**	41	nr
10 years or more	79	59	nr
Operator age (percent less than 50 years)	70	28*	nr
Farm debt-to-assets ratio	0.51*	0.29	nr
Farm land area (acres operated)	191*	108*	nr
Farms producing corn (percent of farms)	35*	16*	nr
Corn harvested (acres per reporting farm)	78*	22**	nr
Feeder pig-to-finish			
Percent of farms/sales and removals	72/51	8/32	8/11
Hogs and pigs sold/removed (head)	1,959	10,691	3,492*
Head removed under contract (percent)	50	83	23**
Farm production value from hogs (percent)	46	74	52*
In the hog business (percent of farms):			
Less than 10 years	11*	59	26*
10 years or more	89	41	74
Operator age (percent less than 50 years)	51	47	65
Farm debt-to-assets ratio	0.29	0.23*	0.39*
Farm land area (acres operated)	524	193	725
Farms producing corn (percent of farms)	92	27	65
Corn harvested (acres per reporting farm)	253	34*	206*

[1]Includes the Prairie Gateway, Northern Great Plains, and the Basin and Range (see fig. 14).

Notes: nr indicates not reported due to a limited sample size and a high coefficient of variation (CV); single (*) and double asterisks (**) indicate a CV between 25 and 50, and greater than 50, respectively.

trated on a smaller land base than in the Heartland and Western regions.

Performance Characteristics by Region

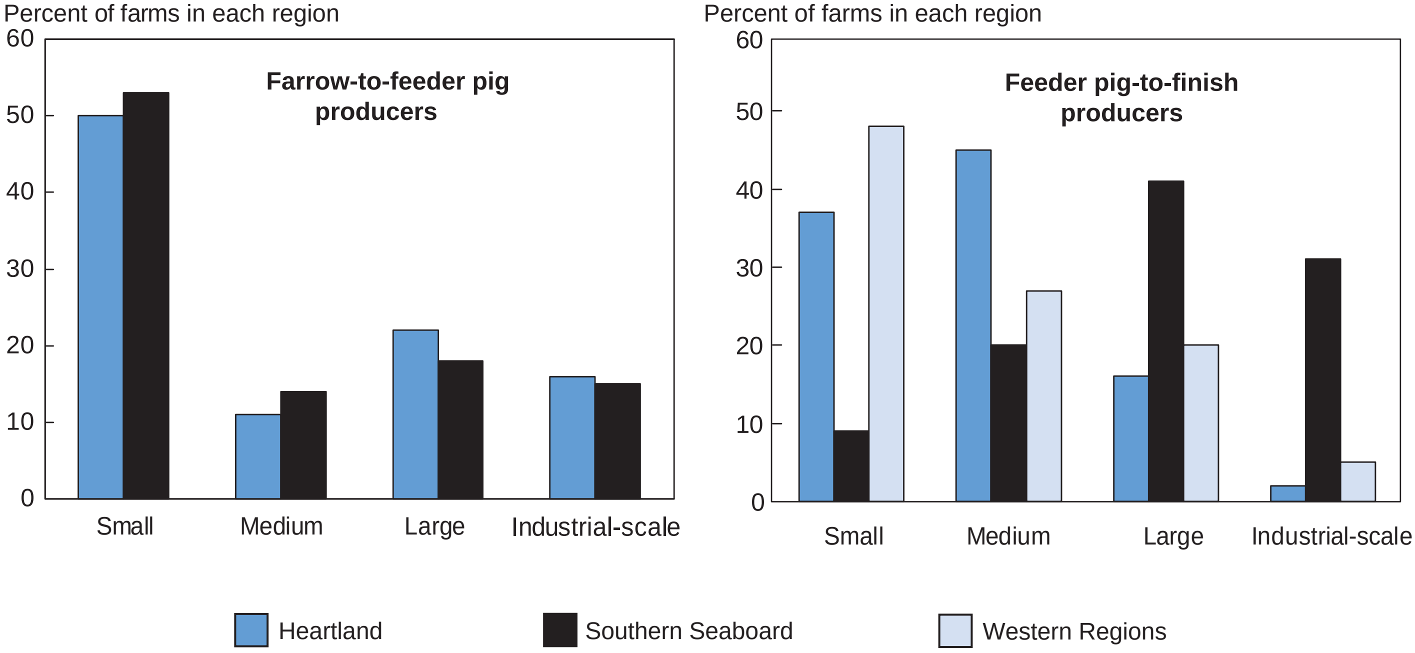
Most performance measures were not significantly different among the farrow-to-finish operations in each region, but Southern Seaboard and Western producers were more feed efficient than in the Heartland (table 8). Greater feed efficiency in the Southern Seaboard may be due to several factors, including the use of more technologically advanced facilities for both farrowing and finishing, and lighter sale/removal weights. Despite being more feed efficient, the average feed cost on Southern Seaboard operations was not significantly different than that in the Heartland. This can be attributed to corn prices that in 1998 were nearly 50 cents per bushel higher in North Carolina than in Iowa (fig. 16). In contrast, better feed efficiency on operations in the Western regions resulted in about $4 per cwt lower feed costs than in the Heartland because the regional difference in 1998 corn prices was not as substantial.

Figure 15

Regional distribution of hog farms by size of operation, 1998

A majority of feeder pig producers in the Heartland and Southern Seaboard were small producers.

Over 70 percent of hog finishers in the Southern Seaboard were large or industrial-scale operations.



Source: 1998 Agricultural Resource Management Survey.

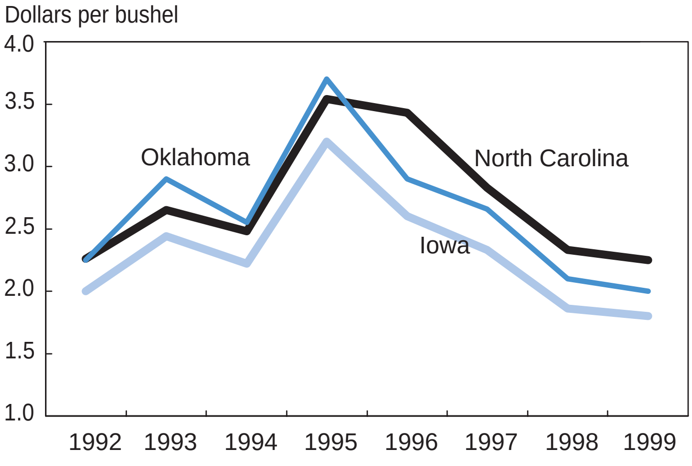
Several performance measures differed between feeder pig producers in the Heartland and Southern Seaboard. Heartland growers farrowed more litters per sow and weaned about two more pigs per sow than in the Southern Seaboard. These producers also weaned pigs earlier at lighter weights, enabling them to farrow more litters per unit of capacity. However, Southern Seaboard growers were more feed efficient than in the Heartland and produced hogs at a lower feed cost despite higher corn prices in the South (fig. 16). Southern Seaboard growers were significantly larger and almost exclusively contract operations that had feed provided by large integrators who purchased and/or processed feed in volume. Despite less intensive use of the production facilities, feeder pig producers in the Southern Seaboard had lower capital ownership costs that reflect greater size economies, but also reflect a difference between the types of facilities needed in the warmer Southern climate versus the colder Heartland.

Finished hog operations in the Southern Seaboard also had a significant competitive advantage over operations in the other regions because of lower feed and capital costs. Again, it appears that the cost advantages associated with large and industrial-scale operations in the South were able to overcome the inherent regional differences in feed prices. Hog finishing operations in the Southern Seaboard were about 25 percent more feed efficient than in the other regions, owing in part to more current production technologies and lighter sales/removals weights. Capital ownership costs were also significantly lower as the fixed

Figure 16

Corn prices in selected States, 1992-99

Average corn prices in Iowa were nearly 50 cents per bushel lower than in North Carolina, and about 25 cents lower than in Oklahoma during 1998.



Source: USDA, NASS, *Agricultural Prices*, various years.

Table 8—Performance by region for hog producer types, 1998

Item	Heartland	Southern Seaboard	Western regions[1]
Farrow-to-finish			
Litters farrowed per sow (number)	2.13	2.15	2.01
Pigs weaned per litter (head)	8.29	8.40	8.70
Pigs weaned per sow (head)	17.63	18.08	17.47
Weaning age (days)	32	42	34
Weaning weight (pounds)	22	28	23
Sale/removal weight (pounds)	252	242	249
Feed efficiency (pounds fed per cwt gain)	376	324	338
Labor efficiency (hours per cwt gain)	0.72	0.66	0.67*
Litters farrowed per sow capacity	3.99	3.94*	4.53*
Farrowing facility age (years)	16	10	13
Hogs finished per head capacity	2.37	1.74*	2.79*
Finishing facility age	15	10	13
Production costs (dollars per cwt gain):			
Feed costs	24.10	25.00	19.95
Operating costs	31.79	34.52	28.72
Ownership costs	12.11	15.81	11.68
Total operating and ownership costs	43.91	50.33	40.40
Farrow-to-feeder pig			
Litters farrowed per sow (number)	2.25	2.08	nr
Pigs weaned per litter (head)	9.74	9.56	nr
Pigs weaned per sow (head)	21.94	19.93	nr
Weaning age (days)	24	32	nr
Weaning weight (pounds)	17	26	nr
Feed efficiency (pounds fed per cwt gain)	317**	292	nr
Labor efficiency (hours per cwt gain)	0.73**	0.62*	nr
Litters farrowed per sow capacity	4.86**	3.31**	nr
Farrowing facility age (years)	5*	7*	nr
Production costs (dollars per cwt gain):			
Feed costs	32.30	25.96	nr
Operating costs	56.37	48.31	nr
Ownership costs	28.68*	20.13	nr
Total operating and ownership costs	85.05	68.44	nr
Feeder pig-to-finish			
Sale/removal weight (pounds)	254	246	250
Feed efficiency (pounds fed per cwt gain)	307	228	309
Labor efficiency (hours per cwt gain)	0.31	0.12	0.24*
Hogs finished per head capacity	1.93	2.41	1.70*
Finishing facility age	11	6	5**
Production costs (dollars per cwt gain):			
Feed costs	20.70	18.67	20.14
Operating costs	41.44	37.93	41.31
Ownership costs	7.27	5.38	8.94
Total operating and ownership costs	48.71	43.31	50.25

[1]Includes the Prairie Gateway, Northern Great Plains, and the Basin and Range (see fig. 14).
Notes: nr indicates not reported due to a limited sample size and a high coefficient of variation (CV); single (*) and double asterisks (**) indicate a CV between 25 and 50, and greater than 50, respectively.

capital investment was spread over many more units of production on operations in the Southern Seaboard.

These findings demonstrate that the comparative disadvantages an area may have in producing hogs can be overcome with innovative technologies and business arrangements, making the hog industry highly mobile and able to move to locations where market and/or regulatory conditions are more favorable. This mobility also means that hog production could easily locate in other areas of the U.S., or move out of the country should market and/or regulatory conditions warrant.

Contract Production

A widely held view is that rapid restructuring in U.S. hog production during the 1980s and 1990s came about, in large part, from the expanding use of contract production arrangements. Contract production is believed to have aided the expansion of hog operations by facilitating the accumulation of capital necessary for operations to achieve unprecedented size. Research by Barry et al. lends support to this view, indicating that lenders have responded to the risk-return tradeoff between independent and contract production by allowing greater borrowing capacity to producers under contracts. New entrants to hog production and producers contemplating expansion were, on average, found to have access to more financing with a production contract. Boehlje and Ray analyzed the impact of the availability of additional financing in contract production, and found that it enhanced a producer's return on equity sufficiently to justify entering into the contract arrangement.

Contractors have regarded contract production as an effective means to achieve economies of size in hog production, while requiring minimal capital and labor. In a survey of large hog contractors, the increased financial leverage resulting from substituting grower capital for contractor capital was the most frequently mentioned advantage of contract production arrangements (Lawrence, Grimes, and Hayenga). Other important advantages mentioned in the survey were the mitigation of environmental/regulatory problems and the sourcing of motivated labor. Handling and disposal of hog manure has most often been the responsibility of growers on contract operations. The loss of operational control was the leading disadvantage reported by contractors. Having to pay for grower assets and disagreements with growers were also cited by contractors as important disadvantages of contract production.

Growers have embraced contracting as a means of reducing risk, accessing capital, and stabilizing income. Survey results suggest that risk reduction is the leading reason that producers enter into contract arrangements, followed by a lack of capital and the need for more income (Wind-Norton and Kliebenstein). Several studies have demonstrated that risk-averse producers prefer contracting to independent production (Martin; Johnson and Foster; Parcell and Langemeier). However, there is a risk/expected-return tradeoff involved with hog production contracts as growers trade potentially higher returns for risk reduction. Another tradeoff contract growers experience is the loss of control over such aspects of their operation as management responsibilities. There is evidence showing that, for some hog producers, autonomy is more important than risk reduction in selecting between contract and independent business arrangements (Gillespie and Eidman). This may explain, in part, why the growth of contracting has varied among different areas of the country, and why new entrants to the hog industry have been more attracted to contracting than have established independent producers.

This report compares contract and independent feeder pig and hog finishing operations by examining their relative characteristics and performance.[12] It also examines the contractor-grower relationship by summarizing information on structural characteristics, contract terms, and incentive mechanisms for different types of contractors.

Structural Characteristics by Business Arrangement

About 19 percent of feeder pig producers and 34 percent of finished hog operations produced under contract in 1998, but these operations accounted for 82 percent of feeder pigs and 63 percent of finished hogs (table 9). Most contract feeder pig farms were highly specialized industrial-scale operations with an average size of more than 30,000 pigs removed (fig. 17). In contrast, nearly 70 percent of independent feeder pig farms were diversified small operations, with an average size of about 1,500 head sold in 1998. This difference is also reflected in the typology of farm operations. Among independent feeder pig producers, 23 percent were residential lifestyle farms and nearly half were farm occupation/lower sales (see Glossary, p. 43). Almost three-fourths of contract feeder pig operations were very large family farms. Contract feeder pig producers also had about 20 times the number of pigs concentrated on about a third of the land area held by independent operations, making manure management a much greater issue for contract feeder pig producers.

This size differential between contract and independent operations was also apparent, but not as pronounced, among hog finishing operations. Contract hog finishing operations had an average of more than 5,000 hogs removed in 1998, compared with about 1,500 head sold from independent operations (table 9). The distribution of hog finishing farms by typology shows that 67 percent of contract operations were among the large farm groups, while 64 percent of independent operations were in the small farm categories. Also, the average size of hog finishing operations increased much more among

[12] The characteristics and performance of contract and independent farrow-to-finish operations were not compared because of limited data on contract operations. Less than 1 percent of farrow-to-finish operations produced hogs under contract and these contract operations accounted for only about 3 percent of total hog sales and contract removals from farrow-to-finish operations.

Table 9—Characteristics by business arrangement for hog producer types, 1998

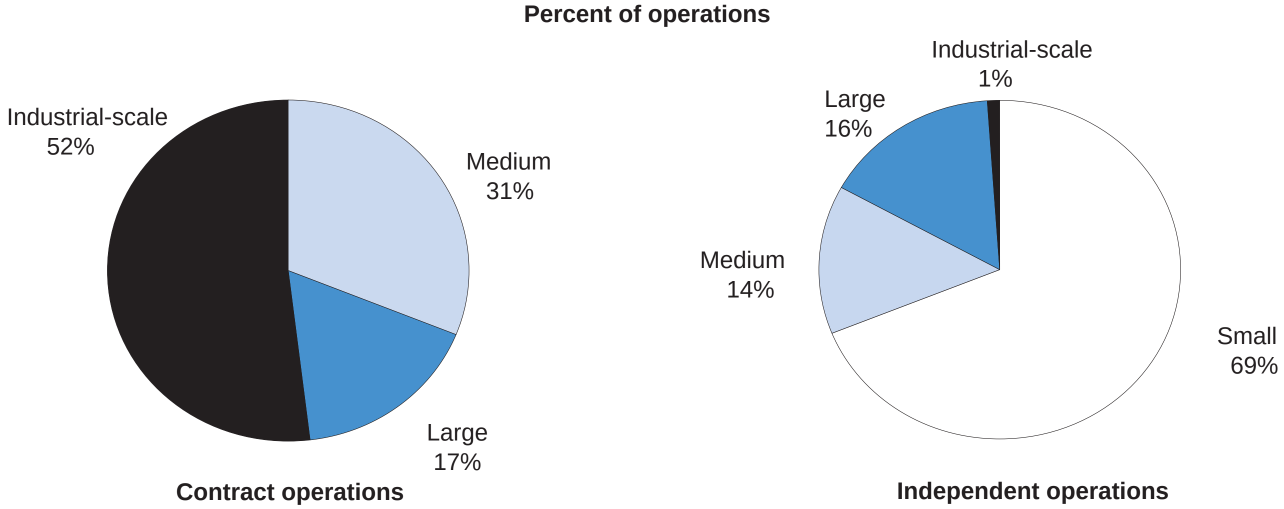
Item	Contract operations	Independent operations
Farrow-to-feeder pig		
Percent of farms/sales and removals	19/82	81/28
Hogs and pigs sold or removed (head)	31,237*	1,531*
Farm production value from hogs (percent)	96	50
Farm land area (acres operated)	71**	229
Farm typology (percent of farms):		
Retirement	0	2**
Residential lifestyle	id	23*
Farming occupation-lower sales	0	48
Farming occupation-higher sales	8**	17*
Large family farm	16**	6**
Very large family farm	74	3*
In the hog business (percent of farms):		
Less than 10 years	72	8*
10 years or more	28**	92
Operator age (percent less than 50 years)	68*	44*
Farm debt-to-assets ratio	0.54*	0.19
Exiting industry in 1 year or less (percent)	10**	48
Exiting industry in 5 years or less (percent)	14**	65
Feeder pig-to-finish		
Percent of farms/sales and removals	34/63	66/37
Hogs and pigs sold or removed (head)	5,154	1,452
Farm production value from hogs (percent)	66	44
Farm land area (acres operated)	403	545
Farm typology (percent of farms):		
Retirement	id	id
Residential lifestyle	15*	13*
Farming occupation-lower sales	5**	14*
Farming occupation-higher sales	13*	37
Large family farm	37	22*
Very large family farm	30	14
In the hog business (percent of farms):		
Less than 10 years	37	9
10 years or more	63	91
Operator age (percent less than 50 years)	65	47
Farm debt-to-assets ratio	0.33	0.25
Exiting industry in 1 year or less (percent)	3*	34
Exiting industry in 5 years or less (percent)	21*	54

Notes: id indicates insufficient data for legal disclosure; single (*) and double asterisks (**) indicate a coefficient of variation between 25 and 50, and greater than 50, respectively.

contract operations between 1992 and 1998 than among independent operations (fig. 18). Contract operations were about 3 times larger in 1998 than in 1992, increasing from an average of about 1,700 head to more than 5,000 head removed. The average size of independent operations doubled, but in absolute terms the average size was only 1,400 head in 1998.

Other structural characteristics of contract and independent operations suggest that contract arrangements have mainly appealed to recent and younger entrants to the hog industry. More than 70 percent of contract feeder pig producers had been producing hogs less than 10 years in 1998, while over 90 percent of independent producers had been in business 10 years or more. More than 65 percent of the contract producers were less than 50 years old, compared with less than 50 percent of independent producers. The higher average debt-to-assets ratio for contract operations suggests that the investment in hog production facilities has been more recent among these producers. Also, a significantly higher proportion of independent producers reported plans to exit hog production within the next 5 years than did the contract producers, indicating that the trend toward an increasing proportion of total hogs produced under contract is likely to continue.

Figure 17
Size distribution of feeder pig operations by business arrangement, 1998
More than half of contract feeder pig operations were industrial scale, while nearly 70 percent of independent operations were small in size.



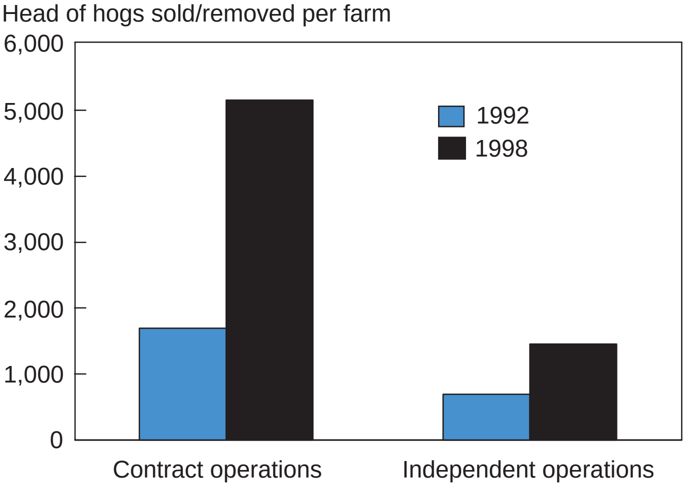
Source: 1998 Agricultural Resource Management Survey.

Performance by Business Arrangement

The differences in performance between the contract and independent feeder pig operations in 1998 were dramatic, and mirror differences in performance between small and industrial-scale operations (table 10). Contract operations farrowed more litters per sow and weaned about 1.2 more pigs per litter. This translated into nearly four more pigs per sow on average than on independent operations. This was possible because pigs were weaned earlier and at a lighter weight, allowing sows to be rebred sooner. This also meant that farrowing facilities were emptied and filled more often, so more litters were farrowed per crate. Feed efficiency was also much greater on contract operations, resulting in feed costs that were $8 per cwt less than on independent operations. Differences in feed efficiency can be attributed to the better reproductive performance that produced more pigs per sow and per pound of sow feed, and to significantly lower contract removal weights compared with the sale weights on independent operations. Ownership costs were significantly lower on contract feeder pig operations partly because capital assets (the breeding herd and facilities) were used more intensively, and due to the cost advantages of large-scale production. Total production costs were about 20 percent less on contract feeder pig operations than on independent operations.

Economic performance was also greater for contract hog finishers than for independent operations due again to better feed and capital use efficiency. Contract operations used about 30 percent less feed than independent operations, and produced about 20 percent more hogs per head of facility space. Newer production technologies and differences in management approach may be behind these efficiencies. As a result, total costs were more than $7 per

Figure 18
Size of hog finishing operations by business arrangement, 1992 and 1998
Average size of contract hog finishing operations more than tripled between 1992 and 1998, while size of independent operations only doubled.



Source: 1992 Farm Costs and Returns Survey; 1998 Agricultural Resource Management Survey.

Table 10—Performance by business arrangement for hog producer types, 1998

Item	Contract operations	Independent operations
Farrow-to-feeder pig		
Litters farrowed per sow (number)	2.21	2.06
Pigs weaned per litter (head)	9.80	8.63
Pigs weaned per sow (head)	21.68	17.76
Weaning age (days)	19	30
Weaning weight (pounds)	14	21
Sale/removal weight (pounds)	35	46
Feed efficiency (pounds fed per cwt gain)	266	491
Labor efficiency (hours per cwt gain)	0.47*	2.04
Litters farrowed per sow capacity	4.52**	1.82**
Farrowing facility age (years)	7	7**
Production costs (dollars per cwt gain):		
Feed costs	28.44	36.94
Operating costs	52.11	56.50
Ownership costs	22.94	35.68
Total operating and ownership costs	75.05	92.18
Feeder pig-to-finish		
Sale/removal weight (pounds)	250	254
Feed efficiency (pounds fed per cwt gain)	242	352
Labor efficiency (hours per cwt gain)	0.15	0.41
Hogs finished per head capacity	2.21	1.79
Finishing facility age	7	12
Production costs (dollars per cwt gain):		
Feed costs	19.48	22.65
Operating costs	38.31	42.98
Ownership costs	5.94	8.63
Total operating and ownership costs	44.25	51.60

Notes: Single (*) and double asterisks (**) indicate a coefficient of variation between 25 and 50, and greater than 50, respectively.

hundredweight lower on contract operations, a savings of about 14 percent compared with independent operations.

Contract Arrangements for Finishing Hogs

Details of the hog contract arrangement used on hog finishing operations by contractor type are shown in table 11. About a third of all farms finishing hogs under contract were with each type of contractor, but integrators were responsible for the majority of contract production (56 percent).[13] The average size among growers for integrators was more than 9,000 head, nearly triple that for the other contractor types. Integrators were also most active in the Southern Seaboard region, where 65 percent of their growers were located. Nearly 90 percent of growers for vertically integrated firms or other farmers were located in the Heartland region.

Integrators appeared to have exercised more influence over grower operations than did the other contractor types. Nearly 80 percent of integrators provided the facility specifications, compared with only about a quarter of the other contractors. Integrators also had a larger role in transporting hogs, monitoring herd health, and managing animal waste than the other contractors. Managing animal waste was likely a bigger issue among the growers for integrators because these large operations were located on much less acreage. While integrators provided more influence and production inputs, they also paid growers about 10 percent less in production fees than did the other contractors. The fee paid to growers by integrators depended mostly on performance bonuses, while vertically integrated firms used all types of fee systems and most other farmers paid a fixed fee.

Growers for integrators had been with their contractor the longest, but tended to be younger and in the hog business

[13] These data were collected in 1998 prior to considerable consolidation among the top hog contractors. During 1999 and 2000, Smithfield Foods acquired other large hog contractors including Carroll's Foods and Murphy Family Farms, previously the largest hog producer in the U.S. These acquisitions made Smithfield Foods the largest hog producer, with more than 3 times the sows as the next largest operation (Successful Farming). Smithfield Foods is also the largest pork processor and has increasingly combined hog production and processing in a vertical integration strategy (Smithfield Foods News Release).

Table 11—Contractor and grower characteristics by contractor type, 1998

Item	Integrators	Vertically integrated firms[1]	Other farmers
Feeder pig-to-finish			
Percent of farms/sales and removals	31/56	33/24	25/15
Hogs and pigs sold or removed (head)	9,245	3,680*	3,141
Farm production value from hogs (percent)	83	53*	55
Farm land area (acres operated)	285	504	416
Location (percent of farms):			
Heartland	22*	89	83
Southern Seaboard	65	1**	1**
Contract characteristics:			
Contractor services (percent of farms)			
Finances facility construction	10*	1**	7**
Provides facility specifications	79	25**	22*
Transports hogs to and from operation	99	72	94
Transports feed	100	99	93
Monitors herd health	90	61*	73
Assists with waste management	60	48*	18*
Fees paid by contractor ($ per head)	10.41	11.53	11.55
Fee payment basis (percent of farms):			
Fixed fee	41	30*	66
Fixed fee with bonus	57	43*	29*
Other	2*	27**	5**
Grower Characteristics:			
Years with current contractor	6	3	5*
In the hog business (percent of farms):			
Less than 10 years	62	32**	24*
10 years or more	38	68*	76
Operator age (percent less than 50 years)	53	75	75
Farm typology (percent of farms):			
Retirement	id	0	0
Residential lifestyle	5*	22**	22*
Farming occupation-lower sales	id	0	id
Farming occupation-higher sales	10*	6**	17*
Large family farm	29	45*	42*
Very large family farm	48	27**	14*

[1]Includes input suppliers (e.g., feed companies) and output processors (e.g., packers).
Notes: Statistics are the average across grower operations with each type of contractor; id indicates insufficient data for legal disclosure; single (*) and double asterisks (**) indicate a coefficient of variation between 25 and 50, and greater than 50, respectively.

a shorter time than other growers. This suggests that integrators more often attracted less experienced producers, while the other types of contractors likely appealed more to formerly independent producers. Also, growers for integrators tended to have very large, specialized operations. In contrast, more than 20 percent of the growers for vertically integrated firms and other farmers also had a primary occupation off the farm.

Implications of Structural Change

Contract Production and Industry Productivity

Production contracts offer several potential advantages over independent production that could explain their growing prevalence. Contracts may serve to lower transaction costs associated with search, negotiation, and transfer; reduce differences in the information that producers and processors have about product quality; improve coordination of product delivery; and lower income risk for growers. In addition, contracting may raise farm productivity by improving the quality of managerial inputs, by speeding the transfer of technical information to growers, or by facilitating growers' access to credit, thereby permitting the adoption of newer, more efficient technologies.

However, the recent growth in contracting does not necessarily imply that contracts are associated with higher farm productivity. The use of contracts could potentially lower onfarm productivity if they reduce incentives for growers to work efficiently or to invest fully in specific productive assets. In addition, because contractors and growers share the returns to hog production in contract arrangements, the most productive hog producers may choose not to contract because they can earn higher returns through independent production.

Understanding the link between contracts and farm productivity is crucial to an analysis of the distributive, efficiency, and environmental implications of the recent structural changes in the hog industry, and of policies to regulate contracting. Concerns about the rapid growth in contracting have led to efforts at various levels of government to regulate contract production. These regulations may have significant social welfare costs or benefits, depending in part on how contracting impacts hog farm productivity.

This section discusses potential impacts of contracting on industry productivity and presents research that attempts to identify and measure the farm-level productivity gains, if any, that can be attributed to contracting. To isolate the effect of contracting on farm productivity, differences between farmers who choose to contract and those that do not must be controlled. Contract growers may be more credit-constrained, more risk-averse, and may value autonomy less, or have less managerial or entrepreneurial ability, characteristics that could be correlated with farm productivity. The empirical model used in this research isolates the effect of contracting on farm productivity by controlling for other factors that could also be correlated with productivity. Data from feeder pig-to-finish operations are used to estimate the model. The impact of contracting is measured on 1) partial and total factor productivity and 2) the production technology. Details of the empirical procedure and model results are presented in Appendix II, p. 51. Empirical results identify the determinants of hog farmers' decisions to contract and the factors that influence productivity. Results also shed light on the implications of contracting for the scale of production.

Potential Impacts of Contracting on Productivity

Under the terms of a typical production contract to finish hogs, the contractor provides feed, feeder pigs, veterinary care, managerial assistance, and marketing services. Growers are paid a fee for raising the animals. The feed and other inputs supplied by the contractor represent over 80 percent of the total costs of production. Because contractors supply such a large share of the production costs, contracts drastically reduce the amount of production credit needed by growers. In addition, because a contract reduces price risk, a contract may make it easier for some farmers to obtain financing for setting up or expanding hog production (Boehlje and Ray). Contracting could therefore serve to relieve a binding credit constraint for some growers, freeing them to invest or apply inputs at a more efficient level. On the other hand, because hog production involves large investments in specific assets, contracting may make growers vulnerable to changes in contract terms. If greater investment in specific assets reduces the bargaining power of growers vis-à-vis the contractor, growers may draw back from socially optimal levels of investment, resulting in lower productivity (Shelanski and Klein).

Costs associated with measuring hog quality may result in a difference in the information that producers and purchasers of hogs have about product quality that can affect productivity. If there is asymmetric information about product quality, then farmers have less incentive to invest in raising quality because they may not be fully compensated for this investment by the purchaser (Hennessy). Production contracts that specify the genetic characteristics of the hogs reduce uncertainty about quality. Hence, these contracts can reduce quality measurement costs associated with asymmetric information and may encourage investment in quality (Martinez, Smith, and Zering).

Contractors may also have asymmetric information about the ability of potential growers, which could create a problem for the contractor in selecting among potential growers. Rhodes notes that "in the Corn Belt, their [commercial feed companies and packers] efforts to contract hog production largely subsided within a few years. The better producers were seldom interested in the quasi-employee status that did not provide access to the profits of the good years of the hog cycle." However, another view is that the grower's provision of productive assets (e.g., growing facilities) is an indicator of the grower's ability (Knoeber). Hence, the capital requirement may act as a screening device resulting in the self-selection of growers with greater ability, as these are the producers who are capable of securing the necessary capital.

Findings: Contracting and Productivity

Results showing the impact of contract production on partial and total factor productivity in the hog sector are summarized in figure 19. The impact of contracting was statistically significant for all measures of factor productivity. For an average hog farm, contracting raises feed, labor, capital, other input, and total factor productivity by 36, 44, 16, 52 and 23 percent, respectively. Results also indicate that the impact of contracting on productivity would have been underestimated had the selectivity bias[14] not been taken into account.

Similar results were found in the analysis of the impact of contracting on the production technology. Statistical testing indicates that contract and independent operations were using different levels of technology. An index of technical change constructed from production functions for the contract and independent operations indicates that contracting raises productivity, on average, by about 20 percent. More detail about the results from this analysis is presented in Appendix II, p. 51.

The primary conclusion from these results is that contracting appears to substantially increase the productivity of all inputs used in hog production and total factor productivity. In addition, contracting appears to represent a technological improvement over independent production resulting in significantly more output for an average farm, holding inputs constant. The magnitude of the productivity gains that can be attributed to contracting is striking, and is similar in each of the modeling approaches.

The increases in productivity that result from contracting may be due to an exchange of "know-how" between contractors and growers, which may be particularly important given the relative lack of hog production experience of the contract growers. This information exchange may involve knowledge about feed mixtures or feed timing that results in higher feed productivity and lower labor costs. In addition, it is possible that the goods and services provided by the contractor, such as veterinary care, feed, and especially the genetic quality of the animals, may be superior to those typically used by independent producers, resulting in healthier animals and a more efficient weight gain.

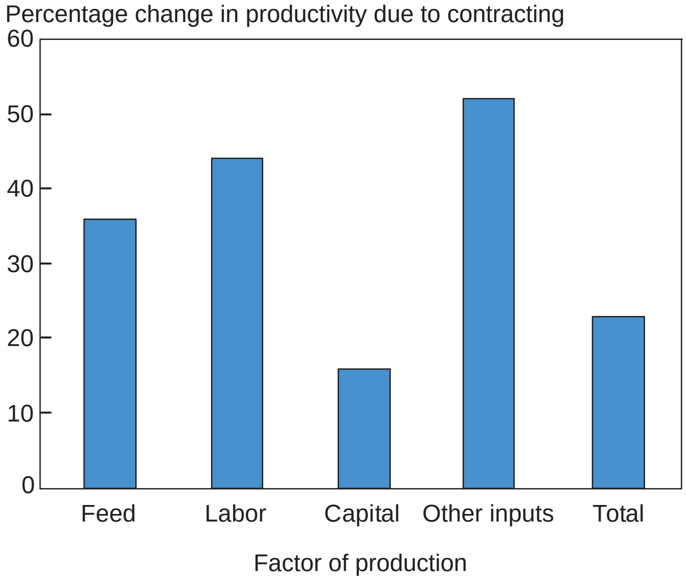
The magnitude of the estimated productivity gains attributable to contracting suggests that improved productivity was likely an important factor in the recent growth in contracting in the hog industry. In addition, contracting may have played a role in the recent increase in the average scale of production. Because contract operations are larger operations, on average, it will be larger operations that enjoy the productivity gains from contracting. Consequently, contracting may serve to enhance the competitive position of larger operations compared with smaller operations.

The higher level of farm productivity associated with contracting implies that policies to regulate or restrict contracting would likely impose economic costs on the industry that could be passed on to consumers. However, negative producer welfare effects (e.g., loss of autonomy) or upstream and downstream costs to contracting (e.g., increased transactions costs) could offset the potential on-

Figure 19

Estimated change in factor productivity from contracting, 1998

Contract hog finishing operations were estimated to have a total factor productivity that was 23 percent higher than independent operations in 1998.



Source: 1998 Agricultural Resource Management Survey.

[14] Selectivity bias occurs because contract growers may differ from independent growers in other ways that may also influence farm productivity. The research model attempts to account for these factors in order to reduce the bias.

farm efficiency gains from contracting. Off-farm or non-market costs, such as the environmental impact of an increased concentration of animal waste, may also result because of contracting. Hence, available information is not adequate to quantify the overall benefits and costs to society of policies that restrict contracting.

The Costs and Returns to Contracting

Concern about contract arrangements in the hog industry stems from a perception of increasing market control and power concentrated among packers and large hog operations (Hayenga, Harl, and Lawrence). There is a widespread perception that marketing contract arrangements between packers and large operations insulate large producers from some of the hog price variation in the cash market to which most small independent producers are subjected, and lead to limited market alternatives for independent producers.[15] Also, there are issues associated with contract complexity, grower information and education, and grower risk of significant losses if a particular contractor decides not to renew a contract (Hayenga, Harl, and Lawrence). As contracts become more prevalent and as the hog industry becomes increasingly concentrated, it is possible that large operations could use their stronger bargaining position to extract more of the economic surplus from contract growers. Concerns about the implications of consolidation and the expanded use of contracts in the hog industry have generated calls for legislation to limit packer ownership and control of livestock prior to slaughter, and legislation to protect producers from unfair business practices (Lawrence, Schroeder, and Hayenga; Iowa Department of Justice).

Understanding what impacts the returns to contracting is important for evaluating the policy issues associated with contracting in agriculture. In hog production contract arrangements, the net returns are shared between growers and contractors. Research in this section examines the factors that have affected the success of contractors and growers in these arrangements. Specific objectives of this research are to examine 1) what characteristics of hog contracts, hog operations, and contract participants are important determinants of the contract fees paid, and 2) what factors are associated with the net returns to producing hogs in contract arrangements and how these differ for the contractor and the grower. A better understanding of contract fees and the distribution of returns to contracting is useful for evaluating the impact that various contract design, economic, and human capital factors have had in the success of each party to contracts, and for evaluating the conduct of participants in these arrangements.

[15] However, most large producers sell hogs with marketing contracts that are often tied to the cash market through formula pricing (Lawrence and Grimes).

Distribution of Contracting Costs and Returns

Contract production is an arrangement between a pig owner (the contractor) who engages a producer (a grower) to take custody of the pigs and care for them in the grower's facilities. Each party to the contract provides specified resources used in production, and contractors pay growers a fee for the services they provide. A detailed breakdown of the average costs and returns of contractors and growers in hog finishing contracts, as estimated from the survey data, is shown in table 12. Contractors incurred nearly all the operating costs by providing the feed and feeder pigs, while growers paid for most of the fuel and electricity, repairs, and hired labor. Growers' main costs were the ownership costs associated with the production facilities and equipment, including housing and manure management structures. Gross returns of growers were the fees paid by contractors. Contractors are the residual claimant to the final product, and thus the gross returns of contractors were defined by the value of the finished hogs.

An empirical model of the returns to contracting was estimated in this research. The model was specified by relating several characteristics of contracts and contract participants to the contract fee payments and to the net returns earned by contractors and growers in hog finishing arrangements. The model was estimated using the method of seemingly unrelated regression (Zellner). Details of the model specification, empirical procedure, and model results are presented in Appendix III, p. 57.

Findings: Returns to Contracting

Design of the contract, grower characteristics, age of production facilities, and location of the operation were important determinants of the contract fee payment in hog finishing contracts. Bonus incentives paid as part of the contract resulted in higher contract fees. The monitoring and maintenance of herd health was also associated with higher contract fees and was likely part of the contract incentive structure as payment incentives are often based on performance factors tied to animal health, such as death loss. Greater education and experience by growers, factors likely to enhance the managerial ability and the opportunity cost of engaging in contract production, were also associated with higher contract fees. Location in the South, likely to be associated with lower facility costs and

Table 12—Estimated costs and returns for participants in contract hog finishing arrangements, 1998

Item	Grower	Contractror
	Dollars per cwt gain	
Gross returns:		
Market hogs	0	39.20
Contract fees	5.11	-
Inventory change	0	0.70
Total gross returns	5.11	39.90
Operating costs:		
Feed	0	19.44
Feeder pigs	0	14.87
Veterinary and medicine	0.01	0.20
Marketing	0	0.92
Custom services and supplies	0.08	0.32
Fuel, lubrication, and electricity	0.49	0.03
Repairs	0.26	0.01
Contract fees	--	5.11
Hired labor	0.34	0.00
Operating capital	0.03	0.86
Total operating costs	1.21	41.76
Ownership costs:		
Depreciation and interest[1]	5.53	0.00
Taxes and insurance	0.25	0.02
Total ownership costs	5.78	0.02
Total operating and ownership costs	6.99	41.78
Gross returns less operating and ownership costs	-1.88	-1.86

[1]Computed using the capital recovery method.

lower opportunity costs of contracting, was associated with lower contract fees.

The net returns of both growers and contractors in contract arrangements were largely determined by factors that affect the efficiency of the hog operation. However, these factors impact growers and contractors differently because of the types of inputs provided by each. Growers were responsible for financing and maintaining the investment in production equipment and facilities. Growers had economic incentives for increasing the intensity of facility use in order to spread the fixed facility costs over more units of production. Contractors owned the animals and primarily provided feed and other operating inputs, and sought to improve animal performance through higher quality genetics and other production technologies that maintain herd health and minimize feed and other operating costs. However, growers also benefit from more efficient input use as hogs reach market weight in less time, reducing labor requirements and freeing up facilities that can be utilized more intensely.

Both contractor and grower returns to hog contracting were invariant to size of contracts. This suggests that contractors have not offered large operations more favorable contract terms than smaller operations. In addition, contractors appear to have an incentive to offer contracts to producers with relatively less education. This may result because more highly educated producers have greater off-farm employment opportunities and thus demand a higher wage for contracting. Contractors can offer contracts to producers with less education because contractors provide much of the “how to” knowledge needed to be successful with contract hog production.

The greatest difference between grower and contractor returns from hog contracting arrangements was due to the type of contractor. Integrators had significantly higher returns than did other types of contractors, while growers under contract with integrators had significantly lower returns than did growers under contract with other types of contractors. This could have resulted for several reasons, such as differences in the efficiency of the operations with different contractors and the contract designed by different contractors. Also, the geographic dispersion of contractors and the competitiveness of local markets for contracts could have influenced the contract terms offered in different areas. Integrators provide more services to contract growers, including knowledge about various aspects of hog production. Therefore, integrators are able to provide employment opportunities to producers with relatively less education and experience with hog production, and thus a lower reservation wage for contracting.

An important caveat to this research is that the data used to estimate the empirical model included limited information about hog contractors. The survey sample was of contract growers, which limited the data that could be collected about contractors. Information on the type of contractor was used in the analysis, but information on the size of the contractor's operation, contractors' capital costs, and on the hog marketing methods and strategies used by contractors was not included in the data. These factors would also tend to affect contractors' net returns to hog production.

Manure Management and the Environment

A consequence of the rapid restructuring of U.S. hog production is the waste management challenge posed by concentrating a larger number of animals on a limited land base. The average adult hog produces three times the amount of waste as the average adult person. In Iowa and North Carolina alone, this translates into handling a hog waste volume roughly equal to the sewage from one-third of the U.S. human population (Innes). Rapid expansion and consolidation in U.S. hog production has meant that the responsibility for managing this volume of hog manure has become more concentrated among fewer operations, and the risks of mismanaging manure are magnified.

Among the risks involved with managing hog manure is the potential movement of nutrients into ground and surface water supplies due to leakage, seepage, and/or breakage of storage facilities and the misapplication of effluent to fields. Although limited, evidence does support concerns about these risks. Results from a small sample of lagoons in North Carolina (Huffman) and Iowa (Libra, Quade, and Seigley) showed evidence of localized seepage around storage facilities. Other studies have shown higher nitrate levels in shallow groundwater where excess manure was applied, compared with where manure was applied according to crop requirements (Lorimor and Melvin; Sloan et al.). During the past several years, major lagoon spills or leaks have occurred in Illinois, North Carolina, Iowa, Kentucky, Minnesota, Missouri, Montana, South Dakota, Utah, Virginia, Washington, and Wisconsin (EPA). In June 1995, a lagoon broke in Jacksonville, North Carolina, spilling more than 20 million gallons of sewage into the New River, causing a massive fish kill. Subsequent inspection of more than 4,000 lagoons in North Carolina found 2.8 percent with illegal discharge devices, and another 10 percent with lesser problems (Martin and Zering). Also, a significant amount of public attention has been directed toward offensive odors released from hog barns and manure handling systems. Rural residents have complained that living close to large hog operations has adversely affected the quality of life, and there is some evidence that proximity to large hog operations has lowered surrounding property values (Palmquist, Roka, and Vukina).

It is widely believed that a major reason for the hog manure problem is a lack of adequate land for proper manure application available near the manure source or under the control of the hog producer. The increasing size and consolidation of hog production has meant that farms are more specialized, separating animal production from crop production and cropland. Gollehon et al. found the largest 2 percent of hog farms (those with more than 1,000 animal units) had 35 percent of the national hog production, but controlled only 2 percent of the cropland on hog farms. In contrast, the 36 percent of small farms (those with 50-300 animal units) had 32 percent of the hog production and 45 percent of the cropland. Also, the regional distribution of specialized animal production indicated a much greater separation of hogs and cropland in the Southeast than in traditional production areas of the Corn Belt.

While evidence suggests that many hog operations may not have adequate acreage on which to apply manure, basic economic considerations also suggest that producers may not have an incentive to apply manure properly. This is because transporting manure to distant fields can be costly (Westenberger and Letson), and thus producers can be expected to overapply manure nutrients on fields nearest to the hog production/manure storage facility. Because the additional costs of transporting manure are saved by applying manure close to the facility, producers can be expected to apply more manure nutrients to these fields than would otherwise be applied in chemical fertilizers (Innes). Thus, from an environmental perspective, current incentives for the use of manure can be expected to increase the risk of nutrient runoff and leaching from cropland in the proximity of hog production when compared with the use of commercial fertilizers. Also, manure nutrients have value for crop production only when the farm is growing crops for commercial purposes

Table 13—Characteristics of hog operations by size of operation and region, 1998

Item	50-299 AU	300-999 AU	1,000 AU or more
All hog producers			
Percent of farms	45	12	3
Percent of production	29	33	34
Animal units per farm	131	520	1,980
Percent of farms in AU group			
Heartland	81	66	49*
Southern Seaboard	2	17*	37*
Other regions	17	18*	14*
Percent of farms in region			
Heartland	52	11	2**
Southern Seaboard	15	27	18*
Other regions	32	9*	2**
Heartland			
Arrangement (percent of farms)			
Independent producer	86	64	54
Contract producer	14	36	46
Southern Seaboard			
Arrangement (percent of farms)			
Independent producer	54	6*	5*
Contract producer	46	94	95

Notes: Animal units (AU) are a measure of size used for livestock operations where 1 AU equals 1,000 pounds of live animal weight; percents will not add to 100 due to missing size group (under 50 AU); single (*) and double asterisks (**) indicate a coefficient of variation between 25 and 50, and greater than 50, respectively.

(i.e., for feed or sale). On farms not engaged in commercial crop production, such as on many specialized hog farms, manure management becomes a minimal-cost-disposal issue and spreading manure on nearby land is often the least-cost disposal alternative.

Another issue raised by the rapid structural change in hog production is the liability of managing the hog manure on contract operations. Contract growers have generally held the responsibility for manure management. Most production contracts have required growers to comply with all State, Federal, and local regulations in operating their facilities, while failure to comply can result in termination of the contract (Martin and Zering). Since contract growers have relatively large investments in facilities, they are highly motivated to avoid liability. However, if more stringent regulations increase the cost of manure management, growers may no longer be financially capable of paying the additional costs without assistance from contractors or other sources. Vukina discusses the issues involved with regulating some form of shared responsibility for manure management between contractors and growers.

This section examines relationships between structural characteristics and manure management practices in the U.S. hog industry, describes how potential environmental risks from hog manure vary across the sector, and evaluates the ability of various farm operations to pay for improved manure management. To address these issues, the surveyed hog operations were divided into size groups according to the estimated number of animal units (1 AU=1,000 pounds of liveweight) on each operation: (a) 50-299 AU, (b) 300-999 AU, and (c) 1,000 AU or more. The two largest size groups, operations with 300 AU or more, were specified to include those operations most likely regulated as Concentrated Animal Feeding Operations (CAFOs) by EPA (Lovell and Kuch; see Glossary, p. 43). Regional differences in manure management issues were examined by contrasting the situations in the Heartland and Southern Seaboard. Differences in manure management technologies, manure application and crop production, and farm financial performance were examined. The ability to pay for improved manure management was also contrasted by size of operation and for contract and independent operations. All surveyed hog operations, regardless of type, were included in this analysis.

Only 3 percent of hog operations had 1,000 AU or more in 1998, but these operations were responsible for about one-third of hog production (table 13). Another 12 percent of operations had 300-999 AU and provided another third of production. The largest facilities averaged nearly 2,000 AU, equivalent to about 8,000 head of finished (250-pound) hogs. More than 85 percent of farms with 1,000 AU or more were in the Heartland and Southern

Table 14—Manure management technologies by size of operation and region, 1998

Item	(a) 50-299 AU	(b) 300-999 AU	(c) 1,000 AU or more
Heartland			
Storage facilities (percent of farms)			
Lagoons	19*bc	35*ac	66*ab
Pits or tanks	60*c	62*c	34*ab
Manure handled (percent of manure)			
Solid	36*bc	8*a	2a
Percent incorporated	5	4*	24
Liquid	63*bc	91*a	98a
Percent incorporated	47*b	74*a	68*
Equipment used (percent of farms)			
Liquid spreader	73*c	81*c	47*ab
Sprinkler irrigation	8*bc	18*a	28*a
Manure tested (percent of farms)			
N content	14*bc	39*ac	68*ab
P content	14*bc	39*ac	68*ab
Other practices (percent of farms)			
Moved manure off operation	17bc	41*a	46*a
Manure given free of charge	16bc	30*a	43*a
Southern Seaboard			
Storage system (percent of farms)			
Lagoons	83bc	98a	98a
Pits or tanks	1	id	id
Manure handled (percent of manure)			
Solid	1	id	9
Percent incorporated	15bc	idac	idab
Liquid	93	99	91
Percent incorporated	14	15c	7b
Equipment used (percent of farms)			
Liquid spreader	8	6	5
Sprinkler irrigation	93	100	99
Manure tested (percent of farms)			
N content	69bc	96a	99a
P content	69bc	90a	96a
Other practices (percent of farms)			
Moved manure off operation	7	3	1
Manure given free of charge	7	2	1

Notes: * Indicates estimate is significantly different from Southern Seaboard estimate (90-percent level); *a,b,c* indicates estimate is significantly different from size group listed (90-percent level); id means insufficient data for legal disclosure.

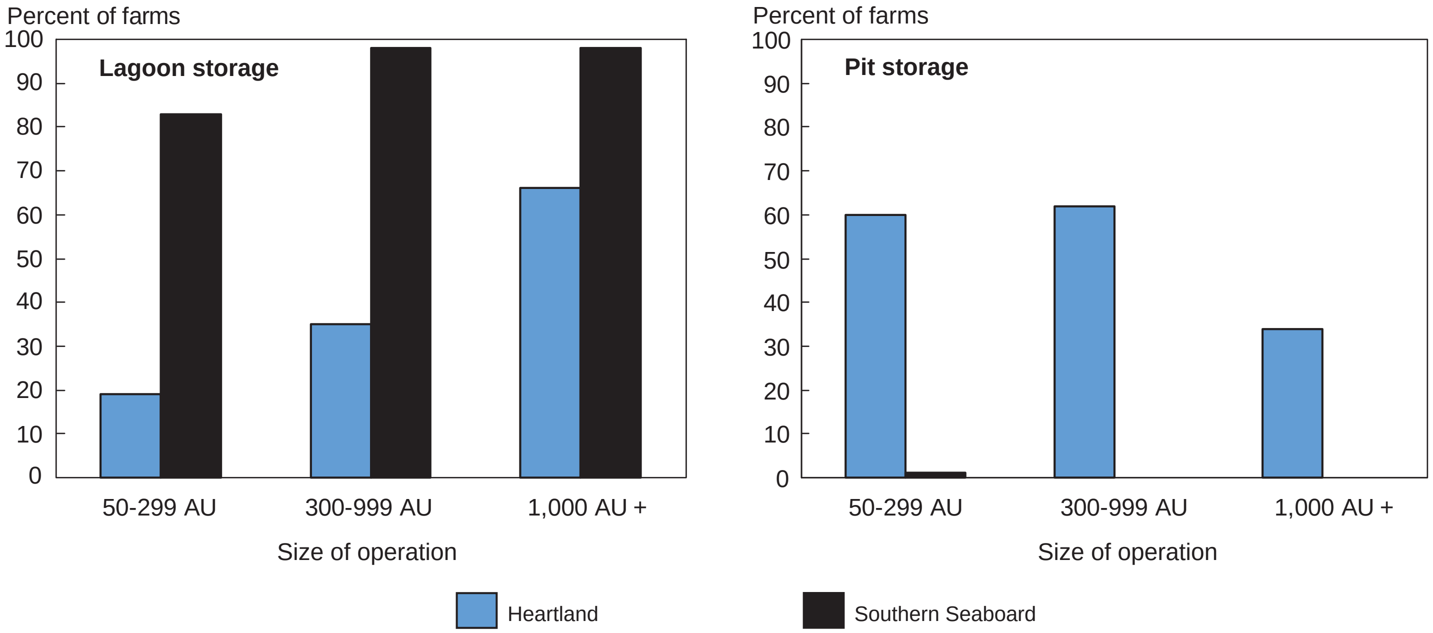
Seaboard regions. Within the Southern Seaboard, 18 percent of farms had 1,000 AU or more, and an additional 27 percent of farms had 300-999 AU. In contrast, only 2 percent of Heartland farms had 1,000 AU or more and another 11 percent had 300-999 AU.

Contract production arrangements were used significantly more often on farms with 300 AU or more in both regions and across all sizes on Southern Seaboard farms. More than 90 percent of operations with 300 AU or more were operating under contract business arrangements in the Southern Seaboard, compared with less than half of the operations in the Heartland.

Manure Management Technologies

Hog manure management technologies (facilities and practices) used on the different size of operations in each region are shown in table 14. The use of manure storage facilities differed substantially between the regions (fig. 20). Significantly more producers used pit storage in the Heartland than in the Southern Seaboard, where lagoons were used by more than 80 percent of operations in each size group. Also, lagoon storage was more common in the Heartland on operations with 1,000 AU or more than on smaller operations. Pit storage retains much more of the manure nutrient value than does lagoon storage. Lagoon storage is generally more cost effective on large opera-

Figure 20
Regional distribution of manure storage facilities by size of operation, 1998
Lagoons were used by more than 80 percent of Southern Seaboard operations in each size group, while pit storage was used more often on Heartland operations.



Source: 1998 Agricultural Resource Management Survey.

tions and serves as a treatment system when acreage for manure disposal is limited, because more of the nitrogen is volatilized into the atmosphere.

Most manure in both regions was handled in liquid form, but manure application systems differed sharply in each region. Most Heartland operations used a liquid spreader to transport manure from storage to the field. More than two-thirds of the liquid manure from operations with 300 AU or more in the Heartland was incorporated into the soil (either by injection or tillage operation) at application, compared with less than 15 percent of manure on those operations in the Southern Seaboard. Incorporating manure at application is a practice that reduces nutrient volatilization, making more nutrients available for plant uptake, and reduces the risk of nutrient runoff. Nearly all Southern Seaboard operations in each size group used sprinkler irrigation technology to move and apply lagoon liquid. Sprinkler application increases nitrogen volatilization, which reduces the nitrogen available for plant use relative to other manure application methods. The lagoon/sprinkler system is designed to allow producers to dispose of the manure from a given operation on fewer acres when a nitrogen criterion is used to determine appropriate application levels.

The larger operations in both regions were more likely than smaller operations to monitor the manure nutrient content through testing, a practice required as part of many State-mandated manure management plans, particularly among States in the Southern Seaboard (table 14). Heartland operations of 300 AU or more were more likely to dispose of manure by moving it off the operation for use on other operations. More than 40 percent of these operations reported that hog manure was removed from the operation, with the majority of these farms giving the manure away free of charge. This practice was rarely used in the Southern Seaboard and is likely influenced by differences in the manure handling technologies used in each region. Manure handled with the lagoon/sprinkler technology has much less applied nutrient value and the effluent is more difficult to move to outlying fields or neighboring farms than manure handled with the pit/spreader system. Heartland producers also may have had more crop farms nearby on which to apply the manure than did producers in the Southern Seaboard.

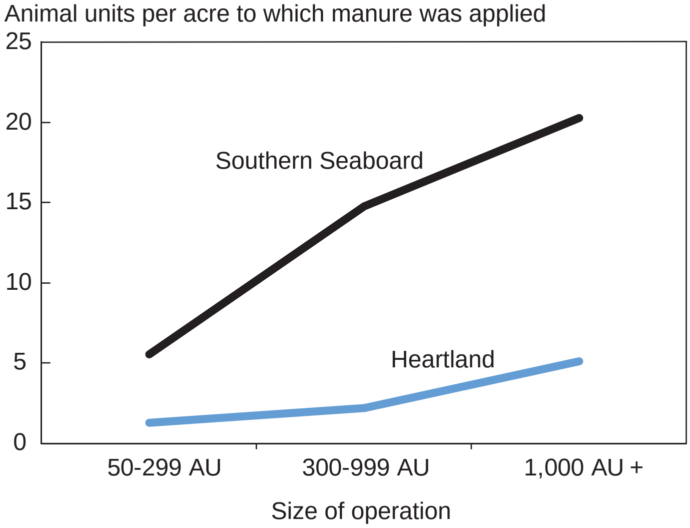
Manure Application and Crop Production

The acreage used for manure application and total crop production increased with operation size, but so did the concentration of animals on the land base (table 15). The actual intensity of manure application is the ratio of animal units to acres on which manure is applied.[16] This ratio provides a measure across size groups and regions of the relative difficulty that these farms would have in meeting policies that require agronomic rates of manure application.[17] In the Heartland, the ratio ranged from 1.28 AU per acre among operations with 50-299 AU to 5.14 AU per acre among operations with 1,000 AU or more. Producers in the Southern Seaboard applied manure to fewer acres and the actual intensity ratio was significantly higher than in the Heartland for all size groups, rising from 5.55 AU per acre to 20.30 AU per acre from the smallest to the largest operations (fig. 21).

Potential intensity of manure application, measured as the ratio of animal units per total crop acre, can be regarded as an indicator of the extent to which producers could alter practices to reduce manure application rates on the existing land base. This ratio was much lower than the actual application ratio, ranging across size groups from 0.24 to 1.20 AU per acre in the Heartland, and 0.62 to 4.73 AU per acre in the Southern Seaboard. The actual and potential intensity ratios likely differ because of factors such as cropping patterns, manure management technologies, and the distance from storage facilities to farm fields. The coverage ratio indicates the percent of total crop acres to which manure was applied, running 30 percent or less in all cases. This means that producers were not applying manure on 70 percent or more of their crop acreage. Liquid hog manure is expensive to transport, and it appears likely that producers minimized the distanced hauled by spreading mainly on fields close to manure storage. Also, the lagoon/sprinkler technology used on many operations limits the ability to move manure long distances without a significant additional investment.

Manure nutrients pose less environmental risk if applications are balanced by crop utilization. Crops grown on hog operations in the Heartland varied little across size groups and included mainly corn and soybeans, accounting for about 90 percent of the crop acreage in each group. The crop mix on Southern Seaboard farms also varied little by size, but the crop mix was more varied than in the Heartland with significantly more acreage in other field crops (e.g., cotton), small grains, and forage crops, and less acreage in corn and soybeans. Forage crops tend to have higher nutrient uptake rates than field or small grain crops.

Figure 21
Concentration of hogs on the land base by operation size, 1998
The concentration of hogs on the farmland area increased with size of operation, but was significantly greater in the Southern Seaboard than in the Heartland.



Source: 1998 Agricultural Resource Management Survey.

The animal and acreage data were also used to estimate actual and potential manure nitrogen loading rates by size of operation and region.[18] The distribution of farms by nitrogen loading levels, using both the actual and potential acreage levels, are presented in table 15. Most field crops utilize nitrogen in the range of 100-299 pounds per acre. Nitrogen rates of 300 pounds per acre or more are above the utilization rate of most field crops and are more in the range suitable for forage crops. Larger operations applied more nitrogen per acre than smaller operations in both regions. About one-third of Heartland producers with 300 AU or more applied manure nitrogen at a rate of 300 pounds or more per acre. In contrast, three-fourths of Southern Seaboard producers with 300-999 AU and more than 90 percent with 1,000 AU or more applied 300 pounds per acre or more of nitrogen. If manure was spread on all cropland (potential N rate), the percentage of large Heartland farms loading nitrogen at a rate of 300 pounds or more per acre falls to just above 10. However,

[16] In computing the production intensity ratios for farms that moved manure off the operation, the number of AU was reduced by the equivalent amount of manure removed. For example, if 50 percent of the manure was moved off a 1,000 AU operation, only 500 AU was used to compute the ratio. This gives a better estimate of the AU being supported by the land base.

[17] Agronomic nutrient rates depend on type of crop, crop yield, soil nutrients, and other factors. Gollehon et al. reported national average agronomic ratios of 1.1 AU per acre for nitrogen and 0.25 AU per acre for phosphorus, although these may not be comparable across all confined animal types.

[18] Per acre nutrient loading was estimated using secondary data on manure production and nutrient content, with appropriate adjustments for nutrient losses due to alternative storage, treatment, and application methods (Moore).

Table 15—Manure application and crops produced by size of operation and region, 1998

Item	(a) 50-299 AU	(b) 300-999 AU	(c) 1,000 AU or more
Heartland			
Acres to which manure was applied	96*[b]	186*[a]	194*[a]
Total crop acres	524*[b]	685*[a]	829*[a]
Coverage ratio (percent of crop acres)	18*	27	23
Production intensity:			
Actual intensity (AU/applied acre)	1.28*[c]	2.20*[c]	5.14*[ab]
Potential intensity (AU/crop acre)	0.24[bc]	0.60*[ac]	1.20*[ab]
Crops produced (percent of crop acres):			
Corn grain	48*	48*	45*
Soybeans	41	43*	42*
Other field crops	id*	1*	1*
Small grain crops	4*	4*	7*
Forage crops	7[c]	4*	4*[a]
Actual N loading (percent of farms)			
100-299 pounds per acre	42	30	27
300 pounds per acre or more	14*[bc]	31*[a]	36*[a]
Potential N loading (percent of farms):			
100-299 pounds per acre	3*[bc]	18[ab]	33[bc]
300 pounds per acre or more	id*[bc]	12*[a]	11*[a]
Southern Seaboard			
Acres to which manure was applied	31[c]	38[c]	96[a,b]
Total crop acres	281	128[c]	410[b]
Coverage ratio (percent of crop acres)	11[b]	30[a]	23
Production intensity:			
Actual intensity (AU/applied acre)	5.55[bc]	14.81[ac]	20.30[ab]
Potential intensity (AU/crop acre)	0.62[bc]	4.45[a]	4.73[a]
Crops produced (percent of crop acres):			
Corn grain	22	22	18
Soybeans	25	30	30
Other field crops	27	16	15
Small grain crops	13[c]	11[c]	20[ab]
Forage crops	11	19	17
Actual N loading (percent of farms):			
100-299 pounds per acre	39[bc]	21[ac]	7[ab]
300 pounds per acre or more	29[bc]	75[ac]	92[ab]
Potential N loading (percent of farms):			
100-299 pounds per acre	29	21	29
300 pounds per acre or more	18[bc]	58[a]	54[a]

Notes: * Indicates estimate is significantly different from Southern Seaboard estimate (90-percent level); *a,b,c* indicates estimate is significantly different from size group listed (90-percent level).

more than half of farms in Southern Seaboard with 300 AU or more would still be loading 300 pounds per acre or more of nitrogen.

Paying for Manure Management

The ability of operations of different sizes and types to pay for manure management is an indicator of what might happen if regulations increased the cost of manure management. Farm financial performance, including farm income statement and balance sheet information, is presented in table 16 by size of operation and region. Net cash and net farm incomes[19] increased by size of operation in each region, but were substantially greater for farms with 1,000 AU or more than for other farms. In the Heartland, net cash farm income was nearly $500,000 among the largest farms compared with less than $70,000 among the other farms, while net farm income was more than $300,000 versus only about $20,000. Similar differences were measured in the Southern Seaboard where net cash income was nearly $275,000 on farms with 1,000 AU or more compared with less than $70,000 on other farms.

[19] Net cash farm income is the difference between gross cash income and cash expenses. Net farm income is computed as net cash farm income less expenses for depreciation and noncash labor benefits, plus the value of inventory change and noncash income.

Table 16—Financial performance of hog farms by size of operation and region, 1998

Item	(a) 50-299 AU	(b) 300-999 AU	(c) 1,000 AU or more
Heartland			
Farm income statement (dollars/farm)			
Gross cash income	230,205[bc]	444,297*[ac]	1,760,599*[ab]
Cash expenses	180,344[bc]	375,393*[ac]	1,278,836*[ab]
Net cash farm income	49,861[c]	68,904[c]	481,763*[ab]
Net farm income	21,034[c]	14,489[c]	319,219*[ab]
Farm balance sheet (dollars/farm)			
Assets	764,220[bc]	1,252,370*[ac]	2,963,233*[ab]
Liabilities	176,508[bc]	393,733*[ac]	1,269,486*[ab]
Equity	587,711[bc]	858,637[ac]	1,693,747[ab]
Debt-to-asset ratio	0.23[bc]	0.31*[ac]	0.43[ab]
Return on equity (percent)	3.58[c]	1.69[c]	18.85[ab]
Southern Seaboard			
Farm income statement (dollars/farm)			
Gross cash income	204,227[c]	193,152[c]	729,275[ab]
Cash expenses	184,339[c]	123,746[c]	454,596[ab]
Net cash farm income	19,889[bc]	69,406[ac]	274,679[ab]
Net farm income	-15,299[c]	29,022[c]	155,864[ab]
Farm balance sheet (dollars/farm)			
Assets	801,474[c]	886,801[c]	2,000,288[ab]
Liabilities	122,530[c]	181,915[c]	589,423[ab]
Equity	678,945[c]	704,886[c]	1,410,866[ab]
Debt-to-asset ratio	0.15[c]	0.21	0.29[a]
Return on equity (percent)	-2.25[c]	4.12[c]	11.05[ab]

Notes: * Indicates estimate is significantly different from Southern Seaboard estimate (90 percent level); *a,b,c* indicates estimate is significantly different from size group listed (90 percent level).

Net farm income was over $150,000 on the largest farms, about $30,000 on farms with 300-999 AU, but negative for farms with 50-299 AU.

The balance sheet data indicate much higher asset, debt, and equity levels on the largest farms in both regions. Farms with 1,000 AU or more had asset levels over $2 million in 1998 and about $1.5 million in farm equity. These farms were generally more highly leveraged than other farms with a debt-to-asset ratio of more than 0.4 in the Heartland and near 0.3 in the Southern Seaboard. However, the return on equity during 1998 was significantly higher on farms with 1,000 AU or more than on other farms, running at over 18 percent in the Heartland and over 11 percent in the Southern Seaboard.

Despite similar trends across the size groups in each region, there are significant differences between regions in terms of the income, asset, and debt levels for operations with 300-999 AU and 1,000 AU or more. These differences are due mainly to the type of business arrangements that predominate in each region, with more independent producers in the Heartland and more contract operations in the Southern Seaboard. The financial performance data for contract operations exclude contractor resources and income. Thus, the income from hog production is the contract fee paid to the contract grower, and the assets and debt are also the grower's. Table 17 includes a comparison of the financial performance data for contract and independent operations for the 1,000 AU or more and 300-999 AU size groups. In both size groups, the net farm income on contract operations is only about one-third of the net farm income on independent operations. Contract producers also have significantly less equity in the operation and are carrying significantly higher debt relative to assets.

Findings: Industry Structure and Manure Management

The data indicate that manure management technologies, potential environmental risks, and farm financial performance vary substantially with size and location of operation across the hog industry. Among manure management technologies, two systems predominate. One system handles liquid manure using pit storage, mostly under hog buildings, and uses slurry spreaders to move the manure from storage to fields and injects the manure into the soil. This system manages the manure for its potential nutrient value as fertilizer and is used more often on Heartland farms and on smaller operations. Because this system is

Table 17—Financial performance of hog farms by business arrangement and size of operation, 1998

Item	Contract operations	Independent operations
1,000 AU or more		
Farm income statement ($/farm)		
Gross cash income	597,833*	2,877,859
Cash expenses	364,791*	2,199,785
Net cash farm income	233,092*	678,074
Net farm income	140,677*	502,716
Farm balance sheet ($/farm)		
Assets	1,914,542*	3,676,888
Liabilities	876,259	1,306,058
Equity	1,038,284*	2,370,830
Debt-to-asset ratio	0.46*	0.36
Return on equity (percent)	13.55*	21.20
300-999 AU		
Farm income statement ($/farm)		
Gross cash income	221,348*	566,221
Cash expenses	165,431*	490,667
Net cash farm income	57,917	75,555
Net farm income	7,592*	25,328
Farm balance sheet ($/farm)		
Assets	883,836*	1,483,828
Liabilities	332,421	381,589
Equity	551,415*	1,102,239
Debt-to-asset ratio	0.38*	0.26
Return on equity (percent)	1.38	2.30

Notes: * Indicates estimate is significantly different from independent operation estimate (90-percent level).

designed to retain manure nutrients for subsequent crop use, more land is needed to apply manure. However, because the manure potentially has more value as a nutrient source and because it is transported in slurry spreaders, manure can be more readily moved off the operation. The other predominant system handles liquid manure in lagoon storage and uses a sprinkler irrigation system to spread manure. This system manages manure more for disposal than nutrient value and is used more often in the Southern Seaboard and on larger operations. Because the manure is treated to reduce nutrient content by increasing the volatilization of nitrogen into the atmosphere, less land is needed to apply manure. Sprinkler delivery directly from the lagoon also limits the distance the manure can be transported, thereby restricting manure spreading to fields close to the facility and restricting the ability to move manure off the operation.

Significant disparities in the land base concentration of hog operations were measured across size groups and regions. The data suggest that the potential for excess nutrients from hog operations is much higher in the Southern Seaboard than in the Heartland, and among larger versus smaller operations. Even though large Southern Seaboard operations used technologies to minimize manure nutrient content, about three-fourths of operations with 300-999 AU and nearly all operations with 1,000 AU or more had nitrogen loading rates from manure at 300 pounds per acre or more. About one-third of Heartland operations with 1,000 AU or more applied manure nitrogen at 300 pounds per acre or more. Given the crop mix on farms in these groups, it is likely that that nitrogen loading rates from manure applied on the farms' land matched or exceeded the utilization capability on many farms. This means that proposed guidelines to base manure applications on the most limiting of nitrogen and phosphorus would require significant changes in the way manure is managed on many farms, particularly large farms and farms in the Southern Seaboard.

One strategy for dealing with tighter regulations on manure management is to spread manure over more acreage. These data suggest that many hog producers have a significant potential for spreading manure over more crop acreage on their farms. In none of the cases examined was manure applied on more than 30 percent of available crop acreage, so nutrient loading could be significantly lowered by spreading on more farm acreage. However, the lagoon/sprinkler technology used to handle manure on many Southern Seaboard operations may restrict the ability to spread manure over more acreage. Also, more than half of Southern Seaboard operations with 300 AU or more would still be loading nitrogen at extreme levels of crop utilization if manure were spread over all available acreage. With the available acreage and manure management technologies used on Heartland farms, this strategy appears to be a much more feasible approach to dealing with any new restrictions. However, the additional costs of spreading manure over more farm acreage would reduce the economic performance of the hog operation.

An alternative for dealing with tighter regulations is to invest in alternative or innovative manure management technologies, such as new treatment facilities. Results of the financial analysis in this study indicate that operations with 1,000 AU or more have net income and equity levels that place them in a much better position than smaller operations to make the necessary capital investments required with these systems. Economies of size in hog production would allow these large operations to spread the fixed investment over more units of output. Farms with less than 1,000 AU had less than a fourth of the cash income and half the equity that the larger operations had. Also, the potential environmental risk from hog production was greatest in the Southern Seaboard region, where contract production is predominant. The relative financial position of contract growers indicates that they are less able than independent producers of the same size to afford additional capital investments. Manure management restrictions thus have the potential to influence the structure of hog production.

Glossary

Hog operations are represented by those selected in a special survey of hog farms as part of USDA's 1998 Agricultural Resource Management Survey (ARMS). Hog operations are defined as farms that had a hog inventory of 25 head or more on the acres operated at any time during 1998. This means that hog operations include independent hog producers and growers who produced hogs under contract.

Phase of production refers to one of four commonly used categories that describe stages of the hog production process: 1) breeding and gestation—the breeding of females and their maintenance during the gestation period; 2) farrowing—the birth of baby pigs until weaning; 3) nursery—the care of pigs immediately after weaning until about 30-80 pounds, and; 4) finishing—the feeding of hogs from 30-80 pounds to the slaughter weight of 225-300 pounds.

Type of hog producer is a classification that defines the hog operation according to the phases of production conducted on the operation and the type of product produced. Some operations in the survey could not be classified using the criteria shown below.

Farrow-to-finish operations are those on which pigs are farrowed and then finished to a slaughter weight of 225-300 pounds. Using the survey data, they were defined as farms on which during 1998 more than 75 percent of pigs came from onfarm farrowings and more than 75 percent of the value of hogs and pigs left the operation through market hog sales or contract removals.

Farrow-to-feeder pig operations are those on which pigs are farrowed and then sold or removed under contract at or after weaning at a weight of about 30-80 pounds. Using the survey data, they were defined as farms on which during 1998 more than 75 percent of pigs came from onfarm farrowings and more than 75 percent of the value of hogs and pigs left through feeder pig sales or contract removals.

Feeder pig-to-finish operations are those on which feeder pigs are obtained from outside the operation, either purchased or placed under contract, and then finished to a slaughter weight of 225-300 pounds. Using the survey data, they were defined as farms on which during 1998 more than 75 percent of pigs came from feeder pig purchases or contract placements and more than 75 percent of the value of hogs and pigs left through market hog sales or contract removals.

Weanling-to-feeder pig operations are those on which weanlings (10-20 pounds) are obtained from outside the operation, either purchased or placed under contract, and then fed to a feeder pig weight of about 30-80 pounds. This type of production is done almost exclusively under production contract arrangements. Using the survey data, they were defined as farms on which during 1998 more than 75 percent of pigs came from weanlings purchased or placed under contract and more than 75 percent of the value of hogs and pigs left through feeder pig sales or contract removals.

Farrow-to-weanling operations are those on which pigs are farrowed and then sold or removed under contract after an early weaning at a weight of about 10-20 pounds. This type of production is done almost exclusively under production contract arrangements. Using the survey data, they were defined as farms on which during 1998 more than 75 percent of pigs came from onfarm farrowings and more than 75 percent of the value of hogs and pigs left through weanling sales or contract removals. A summary of this producer type was not included in the report because of insufficient data from the survey.

Hundredweight gain equals hundredweight (cwt) of hogs sold or removed under contract less cwt of hogs purchased or placed under contract, plus cwt of inventory change during 1998, expressed as:

$$CWTGAIN=(CWTSR–CWTPP)+(CWTEINV–CWTBINV)$$

where CWTGAIN is cwt gain, CWTSR is cwt of sales and contract removals, CWTPP is cwt of purchases and contract placements, CWTEINV is cwt of inventory on December 31, 1998, and CWTBINV is cwt of inventory on January 1, 1998.

Feed efficiency is the total weight (in pounds) of all feed items fed, expressed per cwt of gain added to the animals during the year. Therefore, hog operations with lower values were more feed efficient than hog operations with higher values.

Labor efficiency is the hours of labor used in production, expressed per cwt of gain. Therefore, hog operations with lower values were more labor efficient than hog operations with higher values.

Operating costs are the costs for purchased and farm-raised input items that are consumed during one production period. These include feed; feeder pigs; veterinary and medical services; marketing; custom services and supplies; fuel, lubrication, and electricity; repairs; hired labor; and operating capital.

Ownership costs are the costs associated with the ownership of depreciable assets, such as farm tractors and hog production facilities. These include depreciation, interest, property taxes, and insurance.

Low-cost producers are the 25 percent of hog operations with the lowest total operating and ownership costs.

High-cost producers are the 25 percent of hog operations with the highest total operating and ownership costs.

Farm Typology is a classification that categorizes farms according to a measure of size, operators' expectations from farming, stage in the life cycle, and dependence on agriculture. The typology measure used in this study is:

> **Retirement** farms are those with sales less than $250,000 whose operators report that they are retired.
>
> **Residential /lifestyle** farms are those with sales less than $250,000 whose operators report a major occupation other than farming.
>
> **Farming occupation/lower sales** farms are those with sales less than $100,000 whose operators report farming as their major occupation.
>
> **Farming occupation/higher sales** farms are those with sales between $100,000 and $249,999 whose operators report farming as their major occupation.
>
> **Large** farms are those with sales between $250,000 and $499,999.
>
> **Very large** farms are those with sales of $500,000 or more.

Size of hog operation is defined by the largest number of hogs and pigs on the farm at anytime during 1998, and divided into:

> **Small** operations (1-499 head)
>
> **Medium** operations (500-1,999 head)
>
> **Large operations** (2,000-4,999 head)
>
> **Industrial-scale** operations (5,000 head or more)

Farm Resource Regions portray the geographic distribution of U.S. farm production by identifying areas where similar types of farms intersect with areas of similar physiographic, soil, and climatic traits (Heimlich).

Contract production is an arrangement through which a pig owner (contractor) engages a producer (grower) to take custody of the pigs and care for them in the producer's facilities with other inputs often furnished by the pigs' owner. The producer is paid a fee for the service provided.

Integrator is a type of contractor characterized as a large conglomerate or corporate organization that contracts with many growers to produce hogs. The integrator typically furnishes inputs for the growers, provides technical assistance, and assembles the commodity to pass on for final processing or marketing. The integrator typically markets hogs through marketing contracts or other arrangements with slaughter plants.

Vertically integrated firm is a type of contractor whose main business is the production of inputs used in hog production or the processing of hogs. Feed companies are the primary input suppliers who are vertically integrated in hog production, while packers are the primary output processors.

Concentrated animal feeding operation (CAFO) is a category of operations regulated by the Environmental Protection Agency under authority from the Clean Water Act. Swine CAFOs are operations with a capacity of 2,500 head or more, or operations with 750-2,500 head that discharge pollutants directly into navigable waters. An animal feeding operation of any size may also be designated as a CAFO if the permitting authority determines it to be a source of impairment

Animal units (AU) are a measure of size used for livestock operations where 1 AU equals 1,000 pounds of live animal weight.

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Appendix I: Measuring Hog Production Costs

Production costs are an important indicator of the potential financial success of hog enterprises. Business decisions, such as how much or whether or not to produce, are based on the relationship between production costs and expected product price, and the length of the planning period. In a short-term planning period where production decisions are made about the number of sows to breed or feeder pigs to purchase, decisions are based only on the level of operating costs. During this time, ownership costs are fixed regardless of these decisions. As the length of the planning period increases and production decisions about replacing capital assets are faced, both operating and asset ownership costs need to be considered. Because of the substantial investment required in replacing hog production facilities, this is when most hog producers must decide whether or not to stay in business. Most hog producers make shorter term business decisions several times per year, whereas they make longer term decisions every 10-20 years as facilities need to be replaced.

This report uses production costs to evaluate the relative success of hog operations in terms of their ability to meet short-term obligations and to replace capital assets as needed, and thus stay in business over time.[20] Therefore, both operating and ownership costs on hog operations are used in the analysis of costs (Appendix table I-1). Operating costs include costs for feed; feeder pigs; veterinary and medical services; bedding and litter; marketing; custom services; fuel, lubrication, and electricity; repairs; hired labor; other operating costs; and operating interest. Ownership costs include the annualized cost of maintaining the capital investment (depreciation and interest) in hog facilities and equipment, and costs for non-real estate property taxes and insurance. The costs incurred by all participants in the production process, including farm operators, landlords, contractors, and contractees, are included in the accounts. The 1998 ARMS survey of hog producers provides the primary data used to estimate the costs. All costs are computed using methods recommended by the American Agricultural Economics Association Task Force on commodity cost and return estimation (AAEA).

[20] In this report, production costs of producers of the same type (e.g., farrow-to-finish, farrow-to-feeder pig, feeder pig-to-finish) are compared. Because of differences in the methods used to compute costs, a comparison of costs across producer types is not recommended. For example, the price used to value feeder pigs has a significant impact on hog finishing costs, but not on the costs for other types of producers. Also, differences in the size and ownership structure among producer types would affect their relative costs.

The hog cost estimates are developed from measurements taken during the 1998 calendar year, and are presented on a per hundredweight (cwt) of gain basis. This gain is measured as the cwt of hogs sold or removed under contract, less cwt of inventory change during 1998 (see Glossary, p. 43). Gain is an indicator of the value added to the hogs during the calendar year and reflects the output achieved for the inputs used. In contrast, sales may be high or low during a year depending on whether the hog operation is reducing inventory, such as operations exiting the industry, or adding inventory, such as new entrants to the industry.

Operating Costs

Feed, comprised of feed grains, protein sources, complete mixes, and other feed items, is the largest component of total operating costs on hog operations. Costs of purchased feed items were taken directly from the survey data. Quantities of farm-raised feed grains were valued according to annual average feed grain prices in each State obtained from *Agricultural Prices* (USDA, NASS). Head of feeder pigs purchased were valued at the feeder pig purchase price on each surveyed farm, while those placed under contract were valued with State feeder pig prices obtained from *Agricultural Prices* (USDA, NASS).

Most other operating costs (including bedding and litter; marketing; custom services; fuel, lubrication, and electricity; repairs; hired labor; and other operating costs) were taken directly from the survey data. Other operating costs include odor control expenditures, and fees, permits, licenses, and other regulatory costs. The cost of operating capital is the cost of carrying the operating expenses from the time they are incurred until the time they are paid, assumed to be a 6-month period for hog operations. Operating capital cost was computed using the 6-month Treasury bill rate.

Ownership Costs

The capital recovery method (AAEA) for estimating asset ownership costs was used to specify annual depreciation and interest costs associated with hog operations. Information was collected in the survey to determine the capital assets used in hog production, including those for hog housing, feed storage and processing, manure storage and handling, and other livestock handling equipment. These data were combined with current price information

Appendix table I-1—Items included in the analysis of cost

Estimates of operating and ownership costs were used to evaluate the relative success of hog operations.

Operating Costs	Ownership Costs
Feed	Depreciation and interest[1]
Feeder pigs	Property taxes (excluding real estate)
Veterinary and medicine	Insurance
Bedding and litter	
Marketing	
Custom services	
Fuel, lubrication, and electricity	
Repairs	
Hired labor	
Other operating costs[2]	
Operating interest	

[1]Computed using the capital recovery method.

[2]Other operating costs include costs for odor control, and fees, permits, licenses, and other regulatory costs.

(Boeckh; USDA, NASS, *Agricultural Prices*) and engineering coefficients developed by the American Society of Agricultural Engineers. Capital costs were also estimated for purchased breeding stock, but not for replacement stock raised on the farm because costs of raising these replacements were included in the other cost items. The interest component of the capital recovery method was estimated using the longrun (10-year moving average) rate of return to agricultural production assets from current income.

Appendix II: Modeling the Impact of Contract Production on Productivity

Two approaches were used to evaluate the impact of contract production on productivity in the hog sector: 1) measurement of the impact on partial and total factor productivity, and 2) measurement of the impact on the production technology. A treatment-effects model was used with both approaches (Greene). Applying the treatment-effects model, the decision to contract versus independent production and marketing can be expressed with the latent variable C_i^* as:

$$(1)\ C_i^* = Z_i\gamma + u_i \text{ ; where } C_i = 1 \text{ if } C_i^* > 0, 0 \text{ otherwise,}$$

where Z_i is a vector of operator, farm, and regional characteristics. If the latent variable is positive, then the dummy variable indicating contracting C_i equals one, and equals zero otherwise. A measure of the impact of contract production on a measure of farm performance y_i can be expressed by:

$$(2)\ y_i = X_i\beta + C_i\delta + \varepsilon_i$$

where X_i is a vector of operator, farm, and regional characteristics. More generally, contracting can be allowed to interact with all the exogenous variables, in which case equation (2) becomes:

$$(3)\ y_i = X_i\beta + C_i X_i\delta + \varepsilon_i$$

where δ is now a vector of parameters associated with the interaction terms.

Equations (2) or (3) cannot be estimated directly because the decision to contract may be determined by unobservable variables (management ability, regional characteristics, etc.) that may also affect performance. If this is the case, the error terms in equations (1) and (2) will be correlated, leading to biased estimates of δ. This selection bias can be accounted for by assuming a joint normal error distribution with the following form:

$$\begin{bmatrix} u \\ \varepsilon \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & \sigma^2 \end{bmatrix} \right)$$

and by recognizing that the expected performance of contract growers is given by:

$$E\left[y_i | C_i = 1\right] = X_i\beta + \delta + \rho\sigma\lambda_i$$

where λ_i is the inverse Mills ratio. To derive an unbiased estimate of δ, a two-stage approach can be used starting with a probit estimation of equation (1). In the second stage, estimates of γ are used to compute the inverse Mills ratio, which is included as an additional term in an ordinary-least-squares estimation of equation (2). This two-stage Heckman procedure is consistent, albeit not efficient. Efficient maximum likelihood parameter estimates can be obtained by maximizing:

$$L(\gamma,\beta,\sigma,\rho) = \prod_{C_i=0} \int_{-\infty}^{0} \int_{-\infty}^{\infty} f\left(C_i^*, y_i, \gamma, \beta, \sigma, \rho\right) dy dC^* \cdot \prod_{C_i=1} \int_{0}^{\infty} \int_{-\infty}^{\infty} f\left(C_i^*, y_i, \gamma, \beta, \sigma, \rho\right) dy dC^*$$

where $f(C_i, y_i, \gamma, \beta, \sigma, \rho)$ is the joint normal density function, which is a function of the parameters. In practice, the negative of the log of the likelihood function is minimized using the estimates from the Heckman procedure as starting values. The solution gives estimates of the impact of contracting on partial and total factor productivity.

The second approach was to measure the impact of contracting on the hog production technology by estimating a production function that takes into account the selection process. In this approach, equation (3) was specified with a translog production function in the form:

$$\log q_i = \beta_0 + \sum_k \beta_k \log x_{ik} + \tfrac{1}{2} \sum_k \sum_l \beta_{kl} \log x_{ik} \log \log x_{il} + \delta_0 C_i + \sum_k \delta_k C_i \log x_{ik} + \tfrac{1}{2} \sum_k \sum_l \delta_{kl} C_i \log x_{ik} \log x_{il} + \sum_m \alpha_m z_{im} + \varepsilon_i$$

where $\beta_{ij} = \beta_{ji}$, x_{ik} are the inputs (i.e., feed, labor, capital, other), z_{im} are exogenous shifters, and C_i is a dummy variable equal to one if operation *i* uses a production contract, and equal to zero otherwise. Interacting the contract dummy with all the inputs allows the impact of contracting to vary non-linearly with the scale of production.

To evaluate the results of this model, a likelihood ratio test was used to test the joint null hypothesis of no technical difference between contract and independent producers, as in:

$$H_0 : \delta_0 = \delta_k = \delta_1 = \delta_m = 0 \text{ for all } k,l,m.$$

In addition, a discrete index of technical change (τ) was constructed using the estimated production function:

$$\tau = \frac{\hat{q}(\hat{\beta},\hat{\delta},\hat{\alpha}, \overline{x},\overline{z},C = 1)}{\hat{q}(\hat{\beta},\hat{\alpha}, \overline{x},\overline{z},C = 0)}$$

where $\hat{q}$ is the estimated production function evaluated at the input levels and with the exogenous characteristics of an average operation. The index is simply the ratio of what can be produced using the contracting technology relative to what can be produced using the independent technology with the same input bundle.

Model Specification

Data from feeder pig-to-finish operations were used to estimate both forms of the sample selection model. Appendix table II-1 includes mean values for the variables used in the estimation and results of tests of equal means between contract and independent operations for the variables used in the estimations. Each operation was categorized into one of five scale classes based on the total hundredweight (cwt) of gain produced on the operation. Regional differences among hog operations were accounted for using binary variables indicating whether the operation was in one of five regions. County-level measures of income and hog farm concentration were included as measures of the availability, and consequently the net benefits, of contracting to growers. Five measures of productivity were developed based on the ratio of total output (cwt of animal gain) to the input levels of feed, labor, capital, other inputs, and all inputs.

Since contractors provide some of the inputs used in the production of hogs, care was taken to account for inputs supplied by both the grower and the contractor. Fortunately, the survey explicitly asked respondents for both the contractor's and grower's contribution for all the components in the "other inputs" category, including medicine and marketing. However, for some capital items it was not possible to determine the contractor's contribution. For this reason, we excluded feed handling and livestock hauling equipment, such as feed grinders and mixers, feed wagons, feed trucks, and stock trailers from the capital variable, as these items are associated with services often provided by a contractor, but not recorded in the survey. The labor variable included all paid and unpaid labor used on the hog operation. For paid labor, the survey asks for the contributions from the operator and partners, landlord, and contractor so we are able to compute the total quantity. However, for unpaid labor we only know the contribution from the grower. Consequently, if the contractor provides unpaid labor towards production activities performed by an independent operation (such as feed milling or hauling hogs) this would not be included in the labor variable, and labor productivity would appear higher for contract operations. However, because labor represents such a small share of the total cost (about 8 percent) it is unlikely that this would significantly alter the results of the total factor productivity or production function estimates.

The information presented in Appendix table II-1 highlights several clear differences between the two groups. On average, contract growers were younger and have much less experience in the hog business. Contract growers were also more likely to have their major occupation be something other than farming or ranch work. Contract growers do not have significantly more total assets employed in farming, yet they produce over three times as much pork. Among the five geographical regions in which the sample is divided, contracting is significantly more common than independent production only in the Eastern States. Independent production is more common in all the other regions except the Northern States, where there is no significant difference between the modes of production.

Model Results

Appendix table II-2 lists the results of the first-stage probit explaining the decision to contract versus produce independently. The results of the probit are used to compute the inverse Mills ratio used in the two-stage procedure, the results of which are used as starting values for the likelihood estimation. The model is significant and correctly predicts 83 percent of operators' choices. Most variables had signs consistent with expectations. Estimation results indicate that for an average operation, an increase in education or years of experience in the hog business lowers the probability that the farmer will contract, while having a primary occupation off-farm raises the likelihood of contracting. It is possible that more

Appendix table II-1—Variable means for independent and contract hog operations used in the contract impact model

Variables	Independent operations	Contract operations	t-stat	Prob >|t|
Operator Characteristics				
Age (years)	50.6	47.0	3.78	0.000
Education (years)	13.0	12.9	0.06	0.953
Major occupation is off-farm (yes=1; no=0)	0.14	0.23	-2.41	0.016
Years in hog business	24.1	14.8	9.03	0.000
Farm Characteristics				
Total farm assets ($100,000)	7.62	8.70	-1.25	0.211
Scale class 1: production (<1,000 cwt.)	0.408	0.065	9.68	0.000
Scale class 2: production (1,000-1,999 cwt.)	0.224	0.098	3.79	0.000
Scale class 3: production (2,000-4,999 cwt.)	0.196	0.221	-0.67	0.505
Scale class 4: production (5,000-9,999 cwt.)	0.130	0.254	-3.47	0.001
Scale class 5: production (=10,000 cwt.)	0.041	0.361	-9.40	0.000
Regional Characteristics				
Northern State (MI, MN, SD, WI)	0.194	0.232	-1.02	0.306
Eastern State (NC, SC, VA)	0.014	0.205	-6.94	0.000
Southern State (AL, AR, GA, MO, KY, TN)	0.085	0.032	2.50	0.013
Western State (CO, KS, OK, UT, NE)	0.159	0.067	3.20	0.001
Midwestern State (IL, IN, IA, OH)	0.548	0.463	3.17	0.064
County net cash return per farm ($1,000)	34.86	46.54	-4.64	0.000
County swine sales per farm ($1,000)	23.63	70.73	-6.8	0.000
Output and Inputs[1]				
Hog production (cwt. gain)	2,678	10,672	-9.67	0.000
Feed (cwt.)	9,874	26,163	-7.84	0.000
Labor (hours paid and unpaid)	1,226	1,608	-3.40	0.001
Capital ($)	22,185	61,091	-8.51	0.000
Other inputs ($)	7,928	24,473	-6.29	0.000
Productivity				
Feed productivity (cwt. hog/cwt. feed) X 10^{-1}	2.69	4.34	-11.13	0.000
Labor productivity (cwt. hog/labor hour)	1.96	6.54	-13.50	0.000
Capital productivity (cwt. hog/$) X 10^{-2}	9.66	17.04	-11.75	0.000
Other inputs productivity (cwt. hog/$) X 10^{-2}	50.01	65.84	-4.16	0.000
Total factor productivity[2] (cwt. hog/$) X 10^{-2}	2.04	3.29	-14.15	0.000
Number of Observations	233	244		

Notes: Data are from the 1998 ARMS except county average variables, which are from the 1997 Agricultural Census. Prob>|t| is the two-tailed significance probabty under the null hypothesis of equal means. Scale class and region are specified with a binary variable equal to 1 if the hog operation is in the group, 0 otherwise.

[1]Feed includes homegrown and purchased feed. Labor includes own and hired labor. Capital is an estimate of economic depreciation and interest using the capital recovery method. Other inputs include veterinary, bedding, marketing, custom work, energy, and repair expenses.

[2]Total factor productivity is defined as the inverse unit cost for all of the input categories.

experienced, better educated, full-time farmers are less likely to accept a contract because these farmers could earn relatively more producing independently than could less educated, less experienced, part-time farmers.

An operation being located in an Eastern State positively increases the likelihood of contracting, as did being located in a Northern State or not being located in a Southern State (all relative to the omitted region, Midwestern States). As expected, being located in a county with more hog production increases the likelihood of contracting, probably because this lowers transactions costs for the contractor. Also as expected, being in a county with a higher average net return to farming lowers the probability that a farmer contracts. Higher incomes mean that growers have a higher reservation wage to be induced into contract production.

The scale of production has a strong positive correlation with the likelihood of contracting. Controlling for other characteristics, operations in a farm scale category other than the smallest are associated with an increased likeli-

Appendix table II-2—Binomial probit maximum likelihood estimates for the decision to produce hogs under contract

Variable	Coefficient	Std. error	t-ratio	P-value
Constant	0.975	0.775	1.259	0.208
Age (years)	0.003	0.009	0.304	0.761
Education (years)	-0.163	0.050	-3.258	0.001
Major occupation is off-farm (yes=1; no=0)	0.631	0.217	2.911	0.004
Years in hog business	-0.024	0.008	-2.870	0.004
Total farm assets ($100,000)	-0.006	0.009	-0.614	0.539
Scale class 2: production (1,000-1,999 cwt.)	1.040	0.261	3.978	0.000
Scale class 3: production (2,000-4,999 cwt.)	1.507	0.267	5.651	0.000
Scale class 4: production (5,000-9,999 cwt.)	1.729	0.259	6.665	0.000
Scale class 5: production (=10,000 cwt.)	2.635	0.325	8.116	0.000
Southern State (AL, AR, GA, MO, KY, TN)	-0.843	0.373	-2.258	0.024
Western State (CO, KS, OK, UT, NE)	-0.309	0.267	-1.159	0.246
Northern State (MI, MN, SD, WI)	0.297	0.185	1.606	0.108
Eastern State (NC, SC, VA)	0.774	0.430	1.801	0.072
County net cash return per farm ($1,000)	-0.015	0.006	-2.544	0.011
County swine sales per farm ($1,000)	0.006	0.003	2.150	0.032

Notes: Dependent variable: Uses a production contract=1; otherwise=0; Number of observations: 477; Log likelihood function: -195.288; Restricted log likelihood: -330.504; Chi-squared: 270.433; Degrees of freedom: 15; Significance level: 0.000; 83 Percent correct predictions.

hood of contracting. The increase in the magnitude of the coefficients with the size groups indicates that the probability of contracting increases with scale.

In order to estimate the impact of contracting on partial and total factor productivity, a linear function of the explanatory variables was used. There is no theoretical reason to expect county hog production nor county average farm income to affect onfarm productivity, so these were omitted from the estimation. The maximum likelihood estimates of the sample selection model are presented in Appendix table II-3. The estimated coefficients in the top half of the table correspond to the selection equation, and are consistent with the results of the probit model.

The coefficients in the bottom half of Appendix table II-3 correspond to the factor productivity equations. Most of the indicators of scale of production were significant determinants of productivity, except in the case of "other inputs." Among the operator characteristics, age appears to lower labor and total factor productivity, perhaps because some older farmers may be semi-retired, or because older farmers are more likely to be using aging capital equipment that they do not plan to replace due to their impending retirement. Education reduces the probability that a farmer will contract, but also has a significant negative effect on feed and total factor productivity.[21] A further analysis of the data revealed that the highest educated producers (with 16 years of education or more) have smaller scale operations, are more likely to work off-farm, and have greater wealth than do average producers. This relatively affluent, well-educated group may be more likely to view farming as a "hobby" or secondary activity, resulting in lower factor productivity. Having off-farm work as a primary occupation increases the likelihood of contracting, but also, surprisingly, raises productivity. Number of years in the hog business has two confounding effects on productivity: an extra year in business increases productivity directly, but also reduces the likelihood of contracting, which decreases productivity indirectly. The net marginal impact of an extra year in the hog business on productivity is small—on total factor productivity, for example, it is computed to be only 0.00921.

Contracting is significant in all factor productivity equations. The estimated correlation between the errors of the two equations ρ is significant and negative in the labor productivity equation. This result indicates that we would have underestimated the impact of contracting on productivity had we not taken into account the selectivity bias. Using the estimated coefficients on the contracting variable from Appendix table II-3 and evaluating the impact at the mean of each factor productivity measure, contracting raises feed, labor, capital, other inputs, and total factor productivity by 36, 44, 16, 52, and 23 percent, respectively, for the average hog operation.

[21] A quadratic functional form that includes education and education squared in the productivity equations was also tested. The education coefficient was positive and significant and the education-squared coefficient was negative and significant in the quadratic form of both the feed and total factor productivity equations. Hence, the net impact of education appears to be positive at low levels of education and negative at high levels.

Appendix table II-3—Selection model maximum likelihood estimates: partial and total factor productivity

	Feed		Labor		Capital		Other inputs		TFP	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Selection equation										
Constant	1.256	0.164	1.239	0.189	1.159	0.130	0.954	0.309	1.127	0.199
Age	-0.001	0.932	-0.003	0.756	0.001	0.911	0.003	0.780	0.003	0.796
Education	-0.177	0.003	-0.162	0.010	-0.174	0.001	-0.162	0.011	-0.172	0.006
Off-farm occup.	0.631	0.013	0.607	0.013	0.774	0.001	0.625	0.015	0.595	0.017
Years in bus.	-0.022	0.029	-0.021	0.038	-0.022	0.010	-0.025	0.013	-0.024	0.010
Total farm assets	-0.005	0.706	-0.004	0.798	-0.003	0.790	-0.005	0.718	-0.005	0.682
Scale class 2	0.990	0.003	0.956	0.004	0.966	0.001	1.006	0.002	0.945	0.004
Scale class 3	1.518	0.000	1.249	0.000	1.583	0.000	1.476	0.000	1.450	0.000
Scale class 4	1.793	0.000	1.789	0.000	1.714	0.000	1.717	0.000	1.790	0.000
Scale class 5	2.638	0.000	2.647	0.000	2.193	0.000	2.608	0.000	2.585	0.000
Southern State	-0.664	0.160	-0.706	0.154	-0.854	0.016	-0.853	0.073	-0.713	0.121
Western State	-0.395	0.307	-0.321	0.346	-0.318	0.296	-0.308	0.403	-0.313	0.389
Northern State	0.303	0.109	0.213	0.306	0.527	0.002	0.281	0.168	0.337	0.079
Eastern State	0.710	0.277	0.867	0.159	0.675	0.087	0.723	0.261	0.738	0.220
Co. net returns	-0.015	0.055	-0.013	0.077	-0.016	0.009	-0.014	0.103	-0.015	0.045
Co. swine sales	0.007	0.149	0.006	0.162	0.007	0.028	0.006	0.186	0.006	0.180
Factor productivity										
Constant	3.707	0.000	3.584	0.003	6.935	0.090	54.456	0.021	2.738	0.000
Age	0.002	0.862	-0.030	0.023	0.031	0.534	0.261	0.335	-0.008	0.098
Education	-0.133	0.007	-0.104	0.174	0.488	0.065	-2.130	0.107	-0.092	0.000
Off-farm occup.	0.627	0.004	-0.203	0.568	-0.885	0.487	-8.451	0.246	0.158	0.159
Years in bus.	0.010	0.260	0.007	0.589	-0.050	0.312	0.136	0.577	0.013	0.001
Total farm assets	0.000	0.997	0.024	0.034	0.026	0.656	-0.096	0.745	0.002	0.693
Scale class 2	0.414	0.078	0.496	0.547	-0.654	0.680	11.482	0.120	0.591	0.000
Scale class 3	0.448	0.154	1.141	0.111	2.393	0.099	11.656	0.138	0.997	0.000
Scale class 4	1.056	0.000	2.915	0.000	4.451	0.004	2.699	0.755	1.482	0.000
Scale class 5	1.480	0.000	6.566	0.000	4.261	0.023	7.465	0.456	2.043	0.000
Southern State	0.699	0.008	0.409	0.444	7.319	0.000	22.103	0.003	0.591	0.000
Western State	-0.083	0.786	0.551	0.212	3.334	0.034	20.820	0.001	0.462	0.000
Northern State	-0.013	0.942	0.379	0.330	2.268	0.040	-2.821	0.665	0.316	0.001
Eastern State	-0.358	0.320	0.258	0.514	-1.676	0.386	-24.693	0.070	-0.520	0.006
Contract	1.328	0.000	2.308	0.000	3.054	0.020	26.402	0.000	0.661	0.000
Sigma	1.460	0.000	2.376	0.000	8.619	0.000	39.111	0.000	0.765	0.000
Rho	-0.230	0.112	-0.328	0.006	-0.519	0.000	-0.093	0.552	-0.269	0.051
Log likelihood	-1,047.4		-1,274.4		-1,909.1		-2,620.2		-737.2	

Notes: Table presents maximum likelihood parameter estimates for the sample selection model. Dependent variable in the selection equation: uses a production contract=1, otherwise=0; Dependent variables in the factor productivity equations are feed, labor, capital, other inputs, and total factor productivity. The P-value is the value for a two-tailed test of the hypothesis that the coefficient equals zero.

The second approach used to measure the impact of contracting on productivity involves estimating a production function, taking into account the selection process. Appendix table II-4 reports the result of the maximum likelihood estimation of the production function where for convenience input levels have been normalized by dividing by their mean value. The top of the first column presents the estimates of the bivariate selection equation, which again are similar to those obtained in the probit equation. The remaining coefficients correspond to the production function.

The analysis of the impact of contracting on the production technology yielded similar results as the analysis of the impact on factor productivity. Statistical testing indicated that contract and independent operations were using different levels of technology. The index of technical change constructed from production functions for the contract and independent operations indicate that contracting raises productivity, on average, by about 20 percent.

Appendix table II-4—Selection model maximum likelihood estimates: production function

	Coeff.	P-value
Selection equation		
Constant	1.195	0.211
Age	0.000	0.992
Education	-0.165	0.008
Major occup. off-farm	0.603	0.033
Years in hog business	-0.025	0.020
Total farm assets	-0.005	0.729
Scale class 2	0.974	0.005
Scale class 3	1.428	0.000
Scale class 4	1.691	0.000
Scale class 5	2.565	0.000
Southern State	-0.765	0.095
Western State	-0.383	0.373
Northern State	0.288	0.169
Eastern State	0.722	0.291
Co. farm net return	-0.015	0.052
Co. swine sales	0.007	0.153
Production function		
Constant	-0.864	0.000
lnx1	0.619	0.000
lnx2	0.173	0.044
lnx3	0.366	0.000
lnx4	0.066	0.374
lnx1lnx1	-0.004	0.911
lnx2lnx2	-0.120	0.028
lnx3lnx3	0.010	0.829
lnx4lnx4	-0.017	0.686
lnx1lnx2	-0.020	0.786
lnx1lnx3	-0.003	0.961
lnx1lnx4	0.040	0.531
lnx2lnx3	0.116	0.125
lnx2lnx4	0.062	0.432
lnx3lnx4	-0.036	0.662
Production function (cont.)		
C (Contract)	0.509	0.000
C*lnx1	-0.095	0.509
C*lnx2	-0.078	0.578
C*lnx3	-0.092	0.541
C*lnx4	0.089	0.399
C*lnx1lnx1	-0.158	0.265
C*lnx2lnx2	0.108	0.374
C*lnx3lnx3	0.327	0.144
C*lnx4lnx4	-0.062	0.463
C*lnx1lnx2	0.291	0.165
C*lnx1lnx3	-0.184	0.562
C*lnx1lnx4	0.334	0.045
C*lnx2lnx3	-0.513	0.036
C*lnx2lnx4	-0.014	0.932
C*lnx3lnx4	-0.235	0.201
Age	0.002	0.432
Education	-0.012	0.338
Major occup. off-farm	0.008	0.889
Years in hog business	0.001	0.766
Total farm assets	0.002	0.291
Southern State	0.223	0.005
Western State	0.170	0.007
Northern State	-0.055	0.271
Eastern State	0.013	0.914
Sigma	0.356	0.000
Rho	-0.211	0.321

Notes: Table presents maximum likelihood parameter estimates for sample selection model. Dependent variable in the selection equation: uses a production cotract=1, otherwise=0; Dependent variable in the production function equation is log of production ($x10^{-4}$). The P-value is the value for a two-tailed test of the hypothesis that the coefficient equals zero. In the regression, all inputs (x1=feed, x2=labor, x3=capital, x4=other) have been normalized relative to the sample mean. Log likelihood function=-371.44.

Appendix III: Modeling the Returns to Contract Production

The net returns of contractors and growers in contract production arrangements were examined by estimating the following empirical model:

(1) $W = X_1\beta_1 + \varepsilon_1$

(2) $\Pi_g \equiv W - C_g = X_1\beta_1 + X_2\beta_2 + \varepsilon_2$

(3) $\Pi_c \equiv R_c - W - C_c = X_1\beta_1 + X_3\beta_3 + \varepsilon_3$

(1) expresses the fees paid by the contractor and received by the grower as a function of X_1, a matrix of variables that influence the contract fee schedule including variables that impact the incentive payment. (2) and (3) describe the returns of the grower and contractor. Πg is the grower's returns, measured as fees W paid the grower by the contractor net of grower costs C_g. Πc is the contractor's returns from the hogs sold R_c, net of the fees W paid to the grower and other contractor costs C_c. Both X_2 and X_3 are matrices of exogenous variables that shift such factors as: 1) the contractor's return from the hogs produced R_c; 2) the contractor's and the grower's costs C_c and C_g; and 3) the grower's opportunity wage for contracting.

Model Specification and Estimation

Contract fees were measured as the payment per head made by contractors to growers for hog production services. Since incentive payments are an important determinant of the contract fee, the type of payment scheme used in the contract was included as an explanatory variable in (1). The survey data included an indicator of whether or not each contract had a bonus incentive payment scheme that was specified as a binary variable equal to one if the contract provided an incentive payment, zero otherwise. The data, however, did not specify the type of bonus mechanism used in the contract (e.g., payment tied to death loss, feed conversion, or other factors).

Equations for the grower (2) and contractor (3) were estimated using gross returns net of operating and asset ownership costs as the dependent variable. Since the contractor is the residual claimant to the final product, gross returns of the contractor were defined by the value of the finished hogs.[22] Gross returns of the grower were the fees paid by the contractor, which is a cost to the contractor. Other costs, including feed, other variable inputs, and capital, were charged to each contract participant according to their contribution. The hog costs and returns were expressed on a per hundredweight of gain basis, because gain is an indicator of the product added that results from the inputs used.

Regressors specified in the contract fee (1) and net return (2 and 3) equations included the type of contractor, contract size, years under contract with the current contractor, and characteristics of the grower and the grower's operation. A set of binary variables was used to specify the type of contractor, indicating whether the contractor was an integrator, vertically integrated firm, other farmer, or among all other types of contractors (see Glossary, p. 43, for definitions). Contract size was the number of hogs removed under contract from the operation in 1998.[23] Age of the production facilities was included as an indicator of the point in time when the facilities were constructed and thus the age of the technology used in the production process. Grower experience and education were specified as indicators of the managerial ability of the grower and may also reflect a grower's opportunity cost for contracting. A binary variable that indicated whether or not the grower's major occupation was off-farm employment was also included in the net return equations. Off-farm employment would likely reduce a grower's operational and managerial time available for hog production, and may require the hiring of additional labor.

Another set of binary variables was used to specify the services provided by the contractor. The services were part of the contract arrangement, and included whether the contractor provided facility financing, provided facility specifications, hauled the hogs, delivered the feed, monitored animal health, and/or provided planning and other assistance with manure management. This specification was used to determine what role the provision of common services provided by contractors had in establishing contract fees and in the net returns of contractors and growers. One might expect that more services provided by the contractor would result in lower fees paid to the grower.

[22] Actual market hog prices received by the contractor were not collected in the ARMS, so State average prices were used to value the finished hogs (USDA, NASS, *Agricultural Prices*). This cash market price is likely to be less than what contractors may receive under marketing arrangements with packers. However, this method of valuing the hog production should have a limited impact on the analysis of relative contractor and grower returns since the contractor typically bears all of the price risk in these type of arrangements (Rhodes; Knoeber and Thurman).

[23] This is the size of the grower's operation. Contractor size was not available from the survey data.

Other regressors in the net return equations include the degree to which the grower's operation specialized in hog production and measures of resource use efficiency, including variables for facility capacity utilization and feed efficiency. Specialization may be associated with the operational and managerial time devoted to the hog operation. Capacity utilization is an indicator of the overall management of the operation where unit costs are reduced if facilities are used more intensively, spreading fixed costs over more output. Feed efficiency is also an indicator of the overall management of the operation that is impacted by such factors as the genetic capability of the animals and animal health and husbandry. A variable indicating whether or not the operation was in a Southern State (AL, AR, GA, KY, NC, SC, TN, or VA) was also included. The milder climate in Southern States impacts the type and design of hog housing and manure handling facilities, and thus may affect contract fees, production costs, and returns to contracting. Being in the South may also impact the employment opportunities available to contract growers and thus their opportunity wage for contracting.

The parameters of equations 1, 2, and 3 were estimated using the seemingly unrelated regression (SUR) procedure proposed by Zellner. Because the equations are closely related, it is likely that some unmeasurable or omitted factors could have similar effects on the disturbances in all three equations; thus, the errors may be correlated. When a system of equations has correlated error terms, SUR provides estimators which are asymptotically more efficient than those obtained by applying ordinary least squares to each equation. The set of equations was estimated using SUR with the ARMS survey weights to account for the complex sample design (Dubman).

Model Results

SUR parameter estimates for the equations used to describe the factors affecting contract fees per head and the returns to hog finishing arrangements are shown in Appendix tables III-1 and 2. The model explained 42 percent of the variation in these variables as indicated by the system-weighted R-squared. A negative parameter estimate in the contract fee equation (Appendix table III-1) implies that an increase in the explanatory variable results in lower payments per head to growers from contractors, while positive estimates indicate variables associated with higher contract payments. Parameter estimates for the net return equations (Appendix table III-2) indicate the impact that each explanatory variable had on the net returns of growers and of contractors.

Contractor type was specified in the contract fee equation with the variable indicating that the contractor was an integrator as the base for comparison. The results indicate that whether the contractor was an integrator, vertically integrated firm, or other farmer did not have a statistically significantly effect on the level of contract fee paid (Appendix table III-1). Among the contract characteristics, the coefficient on length of time with the contractor was significant and had a negative effect on contract fees. Contract fees also declined with the age of the production facilities. A possible reason for these results is that more recent contracts compensated growers for inflated facility costs in recent years relative to facility investments made under older contracts. Also, technologies used in older facilities may be less efficient and contract fees could reflect the lower productivity from these facilities.

The variable indicating that an incentive payment was a part of the fee schedule had a positive and statistically significant impact on contract fees. The coefficient indicates that contract growers earned about 83 cents per head from bonus incentives. Among contractor services, the monitoring of herd health by contractors was the only service that had a statistically significant impact on contract fees. Counter to prior expectations, providing this service had a positive impact on contract fees that was substantial at $1.83 per head. The positive impact may indicate that more attention was given to animal health when contractors monitored herd health, reducing death and disease and raising contract payments tied to animal performance. The provision of other services, such as facility specifications and assistance with manure management, did not significantly impact the level of contract payments.

Both grower experience and education had a positive and statistically significant effect on the level of contract fees. These characteristics may indicate a willingness of contractors to pay more to growers who likely bring a higher level of management skill to the operation, and/or indicate growers who have a higher opportunity wage for contracting. Experience and education may also be indicative of growers that had more skill in contract selection and negotiation. Also, growers in Southern States were paid significantly lower contract fees. This could reflect the lower investment requirement of contract growers for production facilities in Southern States due to the milder climate. It could also reflect a lower opportunity wage among growers in the South due to fewer alternative employment options.

Contractor type was also specified in the net return equations with the variable indicating that the contractor was

Appendix table III-1—SUR results for contract fees in contract hog finishing arrangements, 1998

Variable	Estimated coefficient	Standard error
Intercept	8.5360**	2.1612
Contractor type 1: Vertically integrated[1]	-0.7037	0.8188
Contractor type 2: Other farmer[1]	0.2392	0.7943
Contractor type 3: All others[1]	-1.8749*	1.0082
Contract size (1,000 head removed)	-0.0700	0.0450
Contract years (years with contractor)	-0.2108**	0.0610
Incentive payment (fixed plus bonus)	0.8295*	0.4695
Contractor service 1: Facility financing	-1.2960	0.9385
Contractor service 2: Facility specifications	-0.8688	0.7075
Contractor service 3: Animal hauling	0.7874	1.6779
Contractor service 4: Feed delivery	1.4159	1.7814
Contractor service 5: Monitoring herd health	1.8260**	0.6449
Contractor service 6: Manure management	0.5634	0.6163
Facility age (years)	-0.2444**	0.0328
Grower experience (years producing hogs)	0.0512**	0.0244
Grower education (years of schooling)	0.2024*	0.1158
Location (Southern State)	-1.7611**	0.8620
Sample size	227	
System-weighted R-squared	0.42	

Notes: Contract fees were the per head compensation paid by contractors to growers for services provided in contract hog finishing arrangements; single (*) and double asterisks (**) denote significance at the 10-percent and 5-percent levels, respectively.

[1]Coefficients interpreted relative to the deleted group, integrators.

Appendix table III-2—SUR results for the net returns of contractors and growers in contract hog finishing arrangements, 1998

	Grower		Contractor	
Variable	Coefficient	Std. error	Coefficient	Std. error
Intercept	-12.4046**	2.5792	38.1958**	8.2030
Contractor type 1: Vertically integrated[1]	2.4371**	0.8788	-8.7032**	2.7920
Contractor type 2: Other farmer[1]	1.7468**	0.8681	-9.3367**	2.7587
Contractor type 3: All others[1]	1.4498	1.0688	-3.9380	3.3953
Contract size (1,000 head removed)	0.0322	0.0470	-0.0866	0.1492
Contract years (years with contractor)	0.0950	0.0625	0.2596	0.1985
Incentive payment (fixed plus bonus)	-0.2053	0.4957	-2.3397	1.5745
Contractor service 1: Facility financing	-1.9926**	0.9586	-5.0156	3.0437
Contractor service 2: Facility specifications	0.5040	0.7164	-2.1478	2.2746
Contractor service 3: Animal hauling	2.4973	1.6809	-6.1497	5.3361
Contractor service 4: Feed delivery	0.6539	1.7862	-1.3552	5.6704
Contractor service 5: Monitoring herd health	0.9886	0.6533	-3.2451	2.0742
Contractor service 6: Manure management	0.7631	0.6222	-5.0135**	1.9752
Facility age (years)	-0.1154**	0.0344	-0.6832**	0.1092
Grower experience (years producing hogs)	0.0099	0.0260	0.0653	0.0825
Grower education (years of schooling)	0.0982	0.1314	-1.0566**	0.4173
Location (Southern State)	-0.0042	0.8764	-1.1157	2.7827
Grower occupation (off-farm)	-0.6781	0.6119	-1.3487	1.9549
Grower specialize (farm value from hogs)	0.0409**	0.0108	-0.0453	0.0344
Capacity utilized (head removed/head space)	0.3878**	0.1030	1.4335**	0.3291
Feed conversion (lbs. Fed/lb. gained)	-0.1861**	0.1052	-1.3916**	0.3362

Notes: Net returns were defined as returns above the operating and ownership costs per hundredweight of gain for each contract participant; single (*) and double asterisks (**) denote significance at the 10-percent and 5-percent levels, respectively.

[1]Coefficients interpreted relative to the deleted group, integrators.

an integrator as the base for comparison. Statistically significant coefficients on the contractor type variables indicate that growers who contracted with integrators had lower net returns than growers who contracted with vertically integrated firms or other farmers (Appendix table III-2). Contractors who were integrators had significantly higher net returns than contractors who were vertically integrated firms or other farmers. Integrators have generally been in the business of hog contracting longer than the other contractor types and are the most specialized type of hog contractor. This experience and specialization in hog production may have enhanced their ability to produce hogs more efficiently than the other types of contractors. Also, integrators may have been larger hog producers than other contractor types, allowing them to achieve greater economies of scale. It is also possible that integrators were better at designing contracts that extract more of the economic surplus from these business arrangements.

The coefficient on contract size was not statistically significant in either the grower or contractor equations. This result suggests that contractors did not offer more or less favorable terms to operations with larger contracts relative to those with smaller contracts. Facility capacity utilization was significant and positively associated with net returns in both equations. Since growers bear the facility ownership costs, using facilities more intensely allows these fixed costs to be spread over more units of production. The fact that capacity utilization was also positive and significant for contractor returns may be indicative of the overall better management of these operations. Improved feed conversion (i.e., less feed per pound of gain) is also an indicator of more efficient production that resulted in significantly greater returns for both growers and contractors.

Only a few of the services provided by contractors impacted either grower or contractor returns. Despite having a positive impact on contract fees, bonus incentives and herd health monitoring were not statistically significant in the net return equations. Contractor financing of the production facilities was associated with lower returns for contract growers, but this practice was included in only 6 percent of contracts. Likewise, providing plans or assistance for manure management was associated with lower contractor returns. Manure management assistance was most likely provided to operations with limited land for manure disposal and/or operations facing a more stringent regulatory environment. Issuing contracts to growers in these situations would likely require that contractors assist with manure handling, increasing contractor costs. Facility age was highly significant and had a negative impact on contractor and on grower returns, a possible result of lower animal performance in older facilities relative to those using a more recent technology.

Among grower characteristics, grower specialization had a significant positive impact on grower returns while grower education had a negative relationship with the net returns of contractors. Operations more specialized in hog production may spend more time and effort in hog production, and the added labor and management input may have been reflected in higher grower returns. As indicated in the estimated contract wage equation, more educated growers commanded higher contract payments possibly because they have more employment options, resulting in higher costs for contractors.