The Changing Economics of U.S. Hog Production

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National Agricultural Library Cataloging Record:

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A Report from the Economic Research Service

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Abstract

The increasing size and specialization of hog operations reflect structural change in U.S. swine production during the past 15 years. The number of farms with hogs has declined by over 70 percent, as hog enterprises have grown larger. Large operations that specialize in a single phase of production have replaced farrow-to-finish operations that performed all phases of production. The use of production contracts has increased. Operations producing under contract are larger than independent operations and are more likely to specialize in a single phase of production. These structural changes have coincided with substantial gains in efficiency for hog farms and lower production costs. Most of these productivity gains are attributable to increases in the scale of production and technological innovation. Productivity gains likely contributed to a 30-percent reduction in the price of hogs at the farm gate.

Keywords: Hogs, farm productivity, production contracts, pork prices, scale of production, farm structure, total factor productivity

Contents

Summary

The increasing size and specialization of hog operations reflect significant structural change in U.S. swine production during the past two decades. Once dominated by small operations that practiced crop and hog farming, the industry has become increasingly concentrated among large operations that produce hogs on several different sites. Further, large operations that specialize in a single phase of production have replaced farrow-to-finish operations that performed all phases of production. Organizational change in hog production, particularly the widespread use of contracting, has enabled individual producers to grow by specializing in a single phase of production. Technological innovation has also been a driving force behind the changes and has contributed to substantial increases in farm productivity.

What Is the Issue?

As the industry has changed, hog producers have had to adjust the size, organizational structure, and technological base of their operations, or cease production. The effects of the changes have extended beyond the industry, as restructuring has heightened environmental risks and nuisance impacts, raised concerns about the integrity of rural communities in farming-dependent areas, precipitated controversy over animal welfare, and lowered pork prices for consumers. By providing information about changing structural characteristics and economic relationships in hog production, and what these suggest for the future of hog farms, this report provides context for these broader issues as well.

What Did the Study Find?

Scale and organization - The number of hog farms fell by more than 70 percent between 1992 and 2004, whereas the hog inventory remained stable. The average hog operation grew from 945 head in 1992 to 2,589 head in 1998 and to 4,646 head in 2004. The share of the hog inventory on operations with 2,000 or more head increased from less than 30 percent to nearly 80 percent. Operations with 5,000 or more head held more than 50 percent of the hog inventory in 2004.

Traditional farrow-to-finish production has given way to operations specializing in a single phase of production. Specialized finishing operations increased their share of output from 22 to 77 percent during 1992-2004, whereas the share of production from farrow-to-finish operations fell from 65 to 18 percent. Hog operations organized under production contracts grew from 3 percent of operations in 1992 to 28 percent in 2004 and accounted for more than two-thirds of hog production (sales and removals) in 2004. Operations producing under contract were larger than independent operations and were more likely to specialize in a single phase of production.

Regional trends - The rapid growth of hog operations along the east coast of the United States during 1992-98 slowed in subsequent years partly because the North Carolina State legislature placed a moratorium on expanded hog production in the State (a leading hog producer) in response to environ-

mental concerns. In contrast, the size of hog operations increased more rapidly in Midwestern hog-producing States during 1998-2004 as contract production expanded in those areas.

Productivity gains - Structural change in the industry coincided with substantial gains in efficiency for hog farms, particularly on specialized hog-finishing operations. Feeder-to-finish operations had annual reductions in the amount of feed and labor used per unit of output of 4.7 percent and 13.8 percent, respectively, between 1992 and 2004, while their real, or inflation-adjusted, production costs per hundredweight of gain declined at an average annual rate of 4.7 percent.

For feeder-to-finish farms, total factor productivity increased at an average annual rate of 6.4 percent from 1992 to 1998 and 6.3 percent from 1998 to 2004. Most of these productivity gains were attributable to increases in the scale of production (scale efficiency) and technological innovation. Increases in the size of production operations helped account for almost half of the total increase in farm productivity. Further increases in scale efficiency likely will be limited for large farms. However, there is greater scope for efficiency gains in the sector as a whole from further increases in scale.

Trends in farm productivity in two major hog-producing regions, the Southeast and the Heartland, mirrored trends in farm output: productivity increased more in the Southeast between 1992 and 1998 and increased more in the Heartland between 1998 and 2004. Growth in average farm size and the resulting improvements in scale efficiency accounted for most of the differences in productivity growth between the Heartland and Southeast since 1992. Farms in both regions had similar rates of technical advance over the study period.

The use of production contracts continues to be associated with higher farm productivity. The estimates of productivity gains associated with contracting suggest that these productivity advantages helped encourage the recent growth in contracting in the hog industry. Increases in hog farm productivity benefit society through lower food prices for consumers. Productivity gains contributed to about a 30-percent reduction in the price of hogs at the farm gate.

How Was the Study Conducted?

Data used in this report come from USDA surveys of U.S. hog producers conducted for 1992, 1998, and 2004. ERS used a regression analysis to measure hog farm total factor productivity growth between 1992 and 2004 and decompose it into changes in four components: (1) technical change, the increase in the maximum output produced from a given level of inputs; (2) technical efficiency, the farm's ability to achieve maximum output given its set of inputs; (3) scale efficiency, the degree to which a firm optimizes the scale of its operations; and (4) allocative efficiency, a farm's ability to select levels of inputs such that input price ratios equal the ratios of the corresponding marginal products. The study examined variation in economies of scale by farm size, analyzed how increases in scale contributed to productivity growth, and investigated whether scale economies have increased over time. The analysis took advantage of differences in regional growth rates of farm size to examine how limits on the scale of production can affect productivity change. ERS also estimated potential increases in retail pork prices had there been no change in farm productivity.

Introduction

The increasing size and specialization of hog operations reflect significant structural change in U.S. swine production during the past two decades. Once dominated by small operations that practiced crop and hog farming, the industry has become increasingly concentrated among large operations that produce hogs on several different sites. Further, large operations that specialize in a single phase of production (see glossary) have replaced farrow-to-finish operations that traditionally performed all phases of production. Organizational change in hog production, particularly the widespread use of contracts with growers, has played a key role in the structural shift within the industry by allowing individual producers to grow by specializing in a single phase of production. Technological innovation has also been a driving force behind the structural shift and has contributed to substantial increases in farm productivity.

Changes in the industry have pressured hog producers to adjust the size, organizational structure, and technological base of their operations to remain competitive. The effects of the changes have extended beyond the industry, as restructuring has heightened environmental risks and problems associated with odor, raised concerns about the integrity of rural communities in farming-dependent areas, precipitated controversies over animal welfare, and lowered consumer prices for pork.

This report analyzes changes in the characteristics, production practices, and production costs of U.S. hog operations over the past 15 years. The objective is to emphasize economic relationships that have affected the size and ownership structure of hog production and the impact of these changes on industry productivity.

Data

This report relies on data from detailed surveys of U.S. hog producers for 1992, 1998, and 2004. Data for 1998 and 2004 come from USDA's annual Agricultural Resource Management Survey (ARMS), and data for 1992 come from the ARMS predecessor, USDA's Farm Costs and Returns Survey (FCRS). The surveys cover a cross-section of U.S. hog operations and collect information on size, production costs, business arrangements, production facilities and practices, and farm operator and financial characteristics. The sampling resulted in 1,221 responses from 20 States in 1992, 1,633 responses from 22 States in 1998, and 1,198 responses from 19 States in 2004. Producers in 16 States, including all major hog-producing States, were part of all three surveys in each year (fig. 1). These 16 States represented nearly 90 percent of U.S. hog production in each survey year.

Hog farms were chosen from a list of farm operations maintained by USDA's National Agricultural Statistics Service (NASS). The target population of each survey was farms with 25 or more hogs on the operation at any time during the year. The hog producer surveys collect the information necessary to estimate the average cost of production for hog operations. Screening out farms with hog inventories below 25 head excludes farms raising hogs primarily for onfarm consumption and other noncommercial

Figure 1

States as part of the 1992, 1998, and 2004 surveys of hog producers

Producers in the 16 States surveyed in 1992, 1998, and 2004 accounted for nearly 90 percent of the hog and pig inventory on U.S. farms in each year

- Surveyed in all 3 years
- Surveyed in only 2 years
- Surveyed in only 1 year
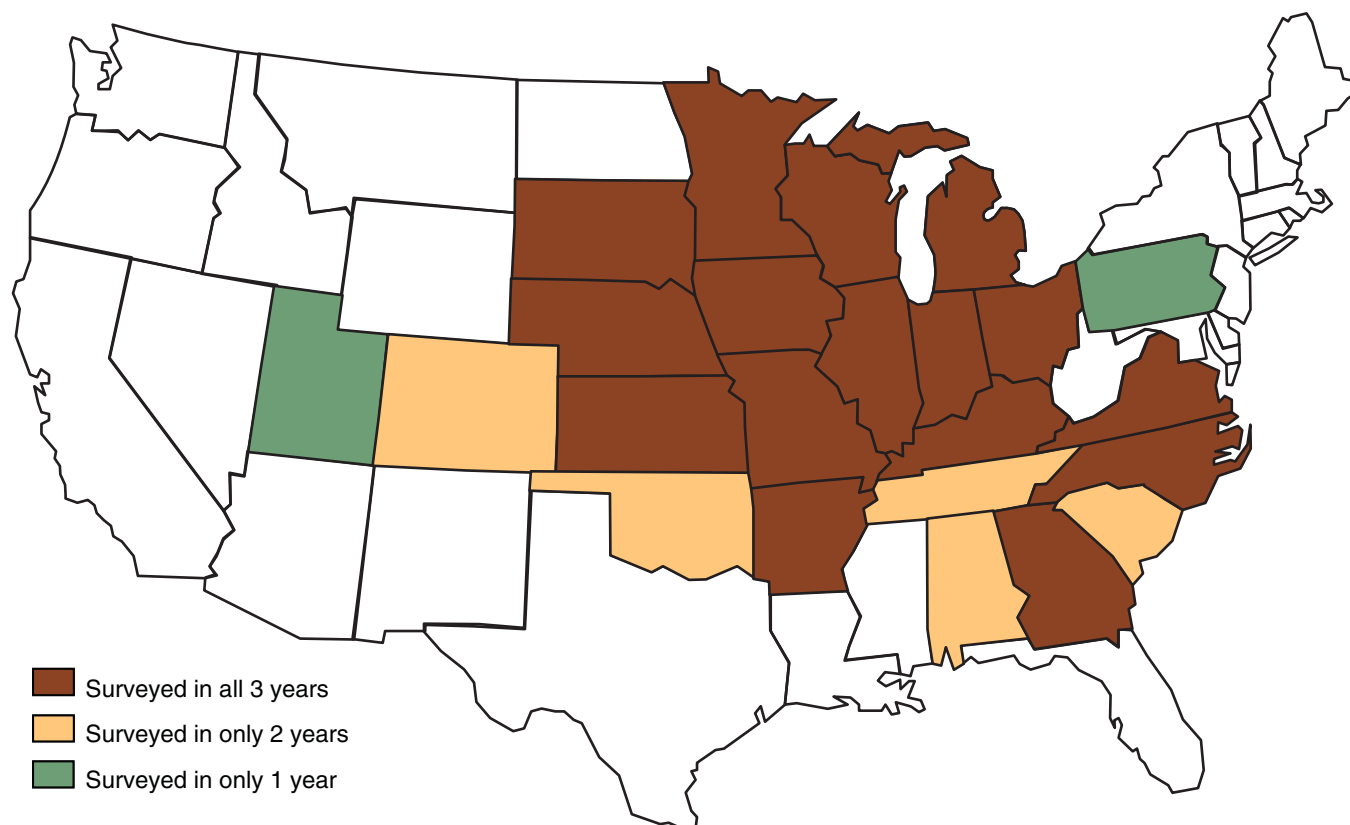
Source: USDA, Economic Research Service.

activities, such as youth projects. Each sample included operations with hogs regardless of who owned the hogs, and thus included producers who raised hogs under contract with the hogs' owner. Therefore, results differ from those of surveys of hog owners, such as described by Boessen et al. (2004) (see box, "Hog Producers Versus Hog Owners"). The sample population of hog owners includes very large operations with hogs produced under contractual arrangements on multiple sites.

Each surveyed farm represents a number of similar farms in the population as indicated by the surveyed farm's expansion factor. The expansion factor, or survey weight, was determined from the farm's selection probability and thereby expands the sample to represent the target population. The expanded samples in each survey represent more than 90 percent of the hog and pig inventory on U.S. farms in each survey year (USDA, NASS, July 2005). However, the hog samples expand to cover just over half of the farm operations that had any hogs or pigs (USDA, NASS, January 2005; 1995-99), due to the 25-head threshold.

Figure 2 compares hog farms and inventory by size category from the 2004
ARMS and 2004 NASS hog and pig statistics. Both surveys define hog
producers as sites where hogs are located (see box, "Hog Producers Versus
Hog Owners"), but the NASS data include all locations with any hogs, and
ARMS screens out those with fewer than 25 head. Because of the
minimum-size threshold, the share of farms and the share of hog inventory
on farms with fewer than 100 head are significantly lower in ARMS than in
the NASS statistics. While these small hog operations represent about 60
percent of U.S. hog farms, they include only 1 percent of the hog inventory.
The distribution of hog inventory by farm size in the ARMS sample is much
like that in the NASS statistics. This pattern of coverage among the different
sizes of hog operations in 2004 is nearly identical to that in 1992 (McBride,
1995) and 1998 (McBride and Key, 2003).

Estimates from the surveys in 1992, 1998, and 2004 are comparable because
of the consistent way in which the surveys were conducted and processed.
Each survey had broad national coverage, represented the same target popu-
lation (operations with 25 head or more), involved a complex sampling
scheme designed to represent the target population, was conducted the same
way (hand enumerated) by the same organization (NASS), and collected
much the same information in a similar format. Also, the definitions of
different types of hog producers used to summarize the data were identical
in all years.

Figure 2

Survey coverage of U.S. hog farms and inventory by size of operation, 2004

*Because of screening, ARMS coverage represented
a small portion of farms with fewer than 100 head*

Percent of farms
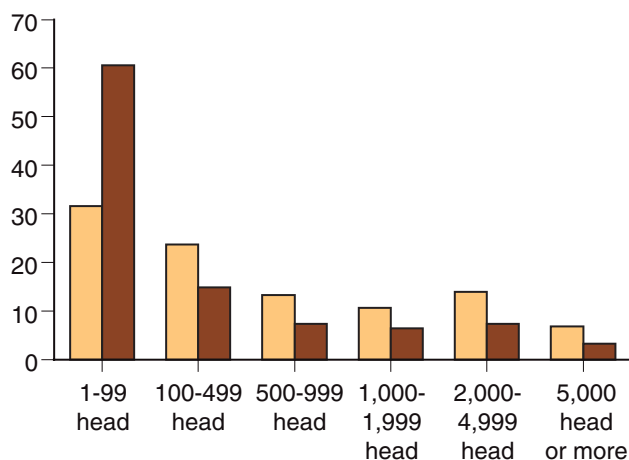
*However, ARMS and NASS statistics are similar for hog
inventories in most size groups*

Percent of inventory (end-year)
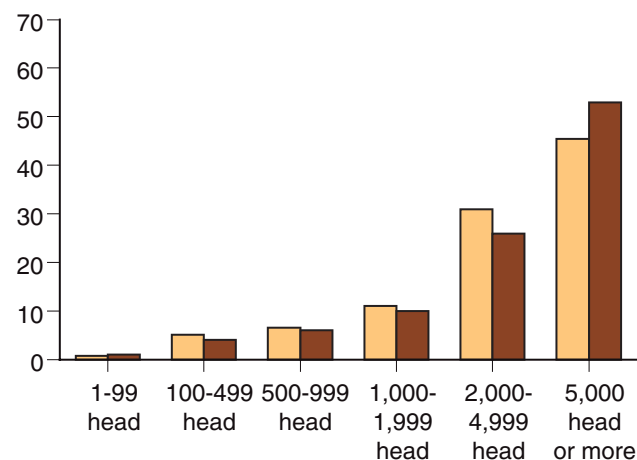
Note: Both the ARMS and NASS estimates are based on surveys of farms with hogs on the operation and thus differences between the
estimates are primarily due to the screening out of farms with less than 25 head of hogs in ARMS, and the sampling and nonsampling
error in each survey.

Sources: USDA, ERS using data from USDA, NASS, January 2005 and USDA's 2004 Agricultural Resource Management Survey.

Hog Producers Versus Hog Owners

The rapid growth of contract production increasingly has separated hog production from hog ownership. Contract production is an arrangement in which a hog owner (a contractor) engages a producer (a 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. Contractors typically furnish inputs for growers, provide technical assistance, and assemble the commodity to pass on for final processing or marketing. Contractors often market hogs through marketing contracts or other arrangements with packers or processors. Packers or processors also act as contractors and have production contracts directly with producers.

The 1992, 1998, and 2004 surveys summarized in this report targeted farms with 25 or more hogs located on the operation at any time during the year regardless of who owned the hogs. Therefore, the survey samples included operations where hog producers own their hogs and contract grower operations that are producing hogs owned by a contractor. Contractors are often large conglomerate or corporate organizations that contract with many growers to produce hogs. For example, Smithfield Foods, a packing company, was by far the largest contractor in 2004 with about 800,000 sows (Successful Farming, 2005). ARMS collects information about the hogs owned by contractors such as Smithfield Foods by contacting their contract growers.

The table below shows a comparison of the number of U.S. hog producers versus hog owners and the share of hog inventories of each by size group as reported by USDA's National Agricultural Statistics Service (USDA, NASS, January 2005) for 2004.

The NASS data show about 8,600 fewer hog owners than hog producers (locations with hogs) in 2004, indicating that several hog owners had hogs on multiple operations. The hog inventory was also heavily concentrated among the largest owners, as those with 5,000 head or more owned 75 percent of the inventory. Of these, the largest 110 hog owners, those with 50,000 or more head, owned 54 percent of the inventory. Data reported by Boessen et al. (2004) for 2003 suggest that the very largest hog owners, those with 500,000 or more head, accounted for 40 percent of U.S. hog slaughter, and 23 percent of these hogs were wholly or partially owned by a packer or processor. Study findings by USDA's Grain Inspection, Packers, and Stockyard Administration (USDA, GIPSA, 2007) show that 20 to 30 percent of hogs were owned by packers during 2002-05. The GIPSA study also reports that 89 percent of the total finished-hog volume was marketed through alternatives to the traditional cash or spot market, such as forward contracts, marketing agreements, and packer ownership.

In evaluating the results of these different studies, it is important to recognize that hog industry surveys have different target populations and, hence, provide complementary, rather than duplicate information. GIPSA data are drawn from reports filed by packing plants and are based on the flow of market hogs to slaughter plants. Data reported by Boessen et al. (as well as earlier surveys administered by Lawrence and Grimes) are based on surveys of packers and other hog owners. Owners may be integrators who have their hogs raised on many different contract farms. The ARMS data used here are derived from surveys of sites with hog production facilities, which include farms where hogs are grown under contract for contractors, farms owned by contractors, and independent operations that grow their own hogs and sell them locally or directly to packers.

Head	Hog producers		Hog owners	
	Operations	Share of inventory	Operations	Share of inventory
	Number	*Percent*	*Number*	*Percent*
1-99	42,095	1.0	41,980	1.0
100-499	10,358	4.0	9,800	4.0
500-999	5,155	6.0	3,830	4.5
1,000-1,999	4,449	10.0	2,300	6.0
2,000-4,999	5,137	26.0	1,850	9.5
5,000 or more	2,306	53.0	1,150	75.0
U.S. total	69,500	100.0	60,910	100.0

Source: USDA, ERS using data from USDA, NASS, January 2005.

Industry Structure and Organization

Changes in the Scale and Approach to Hog Production

The scale of hog production has changed considerably during the past two decades. While the number of farms in the United States remained fairly constant, the number of hog farms fell by more than 70 percent between 1992 and 2004, from over 240,000 to fewer than 70,000 (fig. 3). Despite fewer hog farms in the United States, the hog inventory was stable during the period, averaging about 60 million head, with cyclical fluctuations between 56 million and 63 million head (USDA, NASS, 1995-99; January 2005). Thus, hog production consolidated considerably during this period as fewer and larger farms accounted for an increasing share of total output. From 1992 to 2004, the share of the U.S. hog and pig inventory on farms with 2,000 head or more increased from about 30 percent to nearly 80 percent (fig. 4). In 2004, farms with 5,000 head or more accounted for more than half of all hogs and pigs.[1]

The sector's approach to hog production also has shifted. An industry characterized by operations that traditionally handled breeding and gestation, farrowing, nursery, and growing-finishing phases (see glossary) of production has given way to one in which operations increasingly specialize in a single phase. Farrow-to-finish units accounted for more than half of hog operations in 1992 but only about a third in 2004 (table 1). Feeder-to-finish operations, specializing in the growing-finishing phase of production, rose from 19 percent of all hog operations in 1992 to 40 percent in 2004.

[1]Hog inventory is the number of hogs and pigs on an operation at a point in time. Often, this is the beginning or ending of a year but may refer to the maximum number of hogs on the operation at any time during a year. In contrast, hog production refers to the flow of hogs on and off the operation during a year.

Figure 3

Number of U.S hog operations[1] and hog inventory

Between 1992 and 2004, the number of hog operations fell by more than 70 percent while the hog inventory remained stable between 56 million and 63 million head
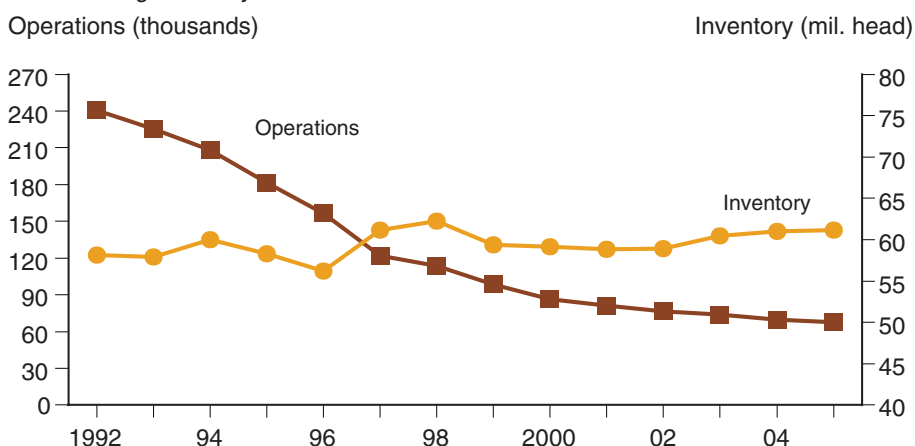
[1]An operation is any place having one or more hogs on hand at any time during the year.
Source: USDA, ERS using data from USDA, NASS, January 2005.

Figure 4

U.S. hog and pig inventory on the largest operations

*Farms with 2,000 head or more accounted for nearly 80 percent of the total
U.S. hog and pig inventory in 2004, up from only 30 percent in 1992*

Percent of inventory
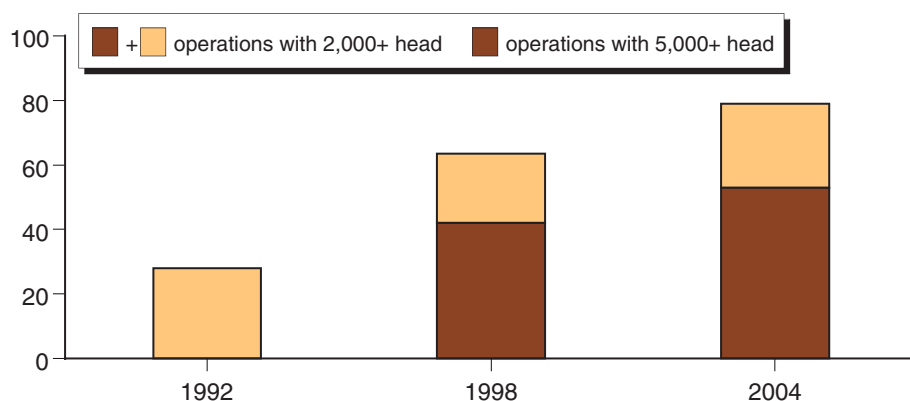
Note: Operations with 5,000+ head were not reported in 1992.

Sources: USDA, ERS using data from USDA, NASS, 1995-99 and January 2005.

Table 1

Size and structural characteristics by type of hog producer

Item	1992	1998	2004
Farrow-to-finish			
Operations[1] (percent of operations)	54	49	31
Market hogs sold/removed[1] (percent of hogs)	65	38	18
All hog sales/removals (head per farm)	886	1,239	1,472
Contract operations (percent of operations)	id	id	id
Contract production (percent of hogs)	id	id	id
Farm production from hogs (percent of value)	48	47	59
Farm-grown grain fed (percent of feed fed)	55	51	38
Feeder-to-finish			
Operations[1] (percent of operations)	19	31	40
Market hogs sold/removed[1] (percent of hogs)	22	55	77
All hog sales/removals (head per farm)	804	2,756	4,730
Contract operations (percent of operations)	11	34	50
Contract production (percent of hogs)	22	62	73
Farm production from hogs (percent of value)	35	54	72
Farm-grown grain fed (percent of feed fed)	45	22	15
All hog and pig producers			
Operations[1] (percent of operations)	100	100	100
Market hogs sold/removed[1] (percent of hogs)	100	100	100
All hog sales/removals (head per farm)	945	2,589	4,646
Contract operations (percent of operations)	3	15	28
Contract production (percent of hogs)	5	40	67
Farm production from hogs (percent of value)	46	56	71
Farm-grown grain fed (percent of feed fed)	49	35	19

Note: id indicates insufficient data for legal disclosure.

[1]The sum of operations and sales/removals for the producer types will not equal 100 percent because not all producer types are shown.

Source: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Surveys.

Figure 5

U.S. hog production by producer type

The proportion of total market hogs produced from farrow-to-finish operations fell from 65 to 18 percent between 1992 and 2004, while production from specialized hog finishing operations increased from 22 to 77 percent

Percent of market hog sales and contract removals

Sources: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Survey.

Changes in the scale of production varied considerably across different types of hog producers. The average size of farrow-to-finish operations grew 66 percent between 1992 and 2004, but specialized hog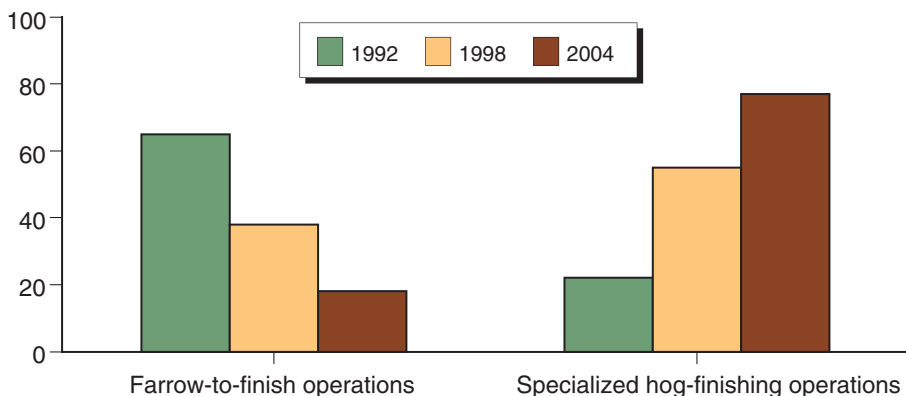-finishing operations were more than five times larger in 2004 than in 1992. Consequently, total hog production from specialized operations increased considerably. The share of total U.S. hog production from farrow-to-finish operations fell from 65 to 18 percent between 1992 and 2004, while production from specialized hog-finishing operations increased from 22 to 77 percent of all market hogs sold or removed under contract (fig. 5).

Growing numbers of operations specializing in farrowing (farrow-to-wean) and the raising of weanlings (wean-to-feeder) provide further evidence of changing approaches to hog production.[2] These highly specialized operations, rarely reported in surveys prior to 2004, accounted for 7 percent of operations in 2004. They are typically large operations, averaging more than 33,000 and 22,000 head, respectively, sold or removed under contract during 2004. The short time that animals spend in the single production phase of these operations accounts for the large number of hogs that move through during a year. Multiple litters per sow each year also contribute to the high production levels on farrow-to-wean operations.

Changes in the Organization of Hog Production

Changes in production scale and approach have been made possible, in part, by changes in the organizational structure of hog operations as evident in the substantial growth of contract production (see glossary). Production contracts govern the relationship between growers (hog producers) and hog owners ("integrators," or "contractors"), specifying the inputs provided by each party (feeder pigs, feed, labor, capital, energy, transport, and veterinary

[2]Specialized farrowing and weanling rearing operations provide feeder pigs to feeder-to-finish operations that finish hogs to a market weight. Hog-finishing operations may also obtain feeder pigs from other countries. The number of hogs imported for finishing from Canada has grown significantly in recent years (Haley, 2004).

services and supplies) and the compensation due to each. Contractors typically retain ownership of the hogs on contract operations and compensate growers based on a fee-for-service arrangement, rather than the market price for hogs. Such an arrangement allows individual producers to grow significantly by specializing in one phase of production.

Production contracts differ from marketing contracts, which often govern the relationship between hog owners and hog packers. Marketing contracts specify expected hog quantities and qualities, the location and timing of delivery, and compensation as a hog price or a price formula. The same hog produced under a production contract between a contractor and grower can be sold to a packer under a marketing contract between the contractor and a packer. In this report, contract operations refer to production contracts because the focus is on the growing stage, not on packer procurement (see box, "Hog Producers Versus Hog Owners").

Hog operations with production contracts accounted for only 3 percent of overall U.S. hog operations and 5 percent of U.S. hog production (sales and removals) in 1992 but grew to 28 percent of operations and 67 percent of production (sales and removals) by 2004 (see table 1). Half of feeder-to-finish operations and more than 70 percent of production on feeder-to-finish farms were under production contracts in 2004. Likewise, 67 percent of specialized farrowing operations and more than 90 percent of specialized weaning operations used contractual arrangements. In contrast, contract production was virtually nonexistent on farrow-to-finish farms.

The average size of hog operations increased from 1992 to 2004 but grew the fastest for operations producing under contract (fig. 6). Contract feeder pig-to-finish operations averaged about 1,000 more head produced in 1992 than did other operations. By 1998, contract operations averaged 3,700 more head than other operations, and the difference reached 4,500 head in 2004.

Figure 6

Size of hog-finishing operations by business arrangement
Average size of contract hog finishing operations was significantly greater than that of other operations in each year and was nearly three times larger in 2004
Head of hogs sold/removed per farm
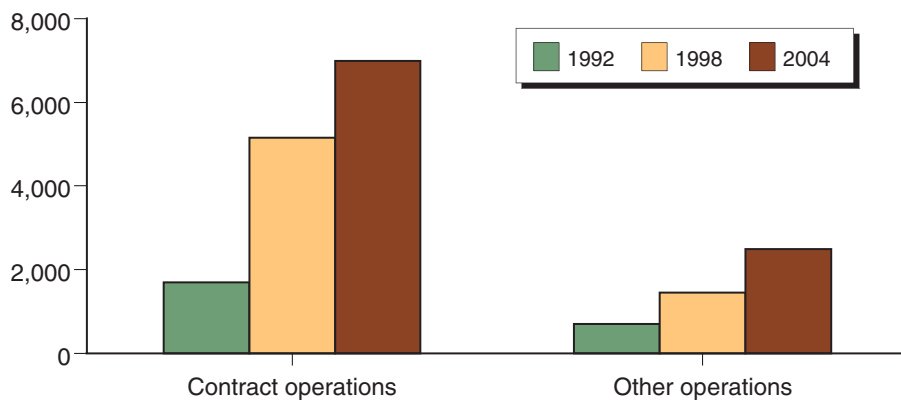
Sources: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Survey.

Contract hog-finishing operations produced 7,000 head annually on average in 2004, compared with 2,500 head on other operations.

Among farms with hogs, the average value of farm production from hog enterprises increased from 46 to 71 percent during 1992-2004 (see table 1). That is, hogs generated 71 percent of the total value of farm production on these farms. The share of farm product value from hogs increased most rapidly, from 35 to 72 percent, on hog-finishing operations. Sources of hog feed also indicate increasing specialization in hog production. Grain produced on the same farm accounted for half of the feed consumed by hogs in 1992 but fell below 20 percent by 2004. Again, specialized hog-finishing operations accounted for the fastest change (from 45 to 15 percent). The resulting farms—with greater shares of production value from hogs and more hog feed from off-farm sources—often produce hogs under contract. Under these arrangements, contractors deliver feed from off-farm sources to their growers, allowing individual growers to use their time and financial resources to increase the scale of hog operations rather than expand crop acreage for feed production.

Regional Shifts in Hog Production

Geographical shifts in hog production have accompanied the structural and organizational changes in the industry. Historically, hog production was concentrated in Corn Belt States, where an abundant supply of corn provided a cheap source of hog feed. During the 1980s and 1990s, however, hog production grew dramatically in nontraditional areas, driven mainly by the growth of large contract operations. For example, in North Carolina, the inventory of hogs and pigs more than doubled between 1987 and 1992, as the State's rank in total hog inventory went from sixth to second and then more than doubled again between 1992 and 1998 (fig. 7). Since 1992, hog production also has moved aggressively into Western States, where the

Figure 7

Hog inventories in selected States

Hog numbers grew rapidly in North Carolina between 1992 and 1998 but slowly through 2004. Growth has been steady in Western States since 1992.

Mil. head of hogs
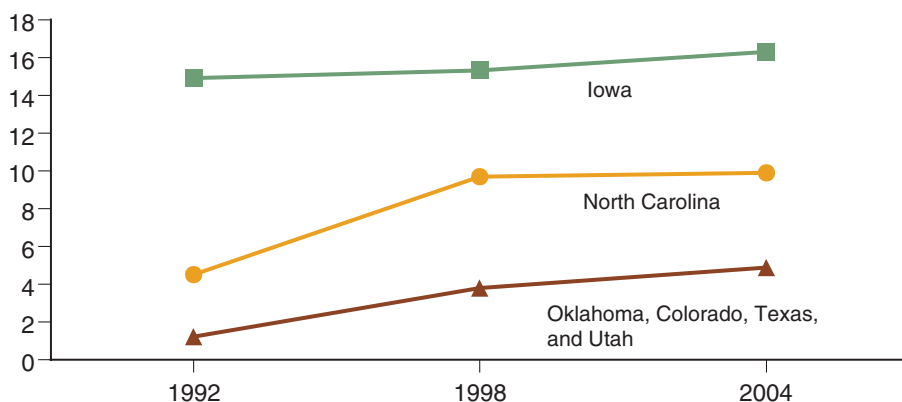
Source: USDA, ERS using data from USDA, NASS, 1995-99.

combined inventory of Oklahoma, Colorado, Texas, and Utah grew from 1.2 million to 4.9 million head between 1992 and 2004.

Rapid growth in the North Carolina hog industry ended after a State law enacted in August 1997 placed a moratorium on the construction of new and expanded hog operations with 250 or more hogs (North Carolina General Assembly, 1997). The purpose of the moratorium, extended for 4 additional years in 2003, was to provide State and local government time to adopt zoning ordinances and gather information on environmental impacts and alternative waste technologies. Restricted growth in North Carolina may explain the particularly rapid growth of the industry in Western States. Open space and a relatively low population density in these States provide greater flexibility in managing animal waste.

ERS has constructed a set of farm resource regions that depict geographic specialization in production of U.S. farm commodities (fig. 8). Table 2 shows changes in average production of hog operations during 1992-2004 by farm resource region. The average per farm size of Heartland hog operations grew steadily during the period from just under 1,000 head to more than 5,000 head. In contrast, Southern Seaboard operations increased in average per farm size from 1,200 to over 10,000 head. Most of the growth in Western State operations occurred between 1992 and 1998. Specialized

Figure 8

Farm Resource Regions

Hog production has traditionally been concentrated in the Heartland, but during the 1980s and 1990s it expanded rapidly in the Southern Seaboard and more recently in western regions, particularly in the Prairie Gateway and Basin and Range
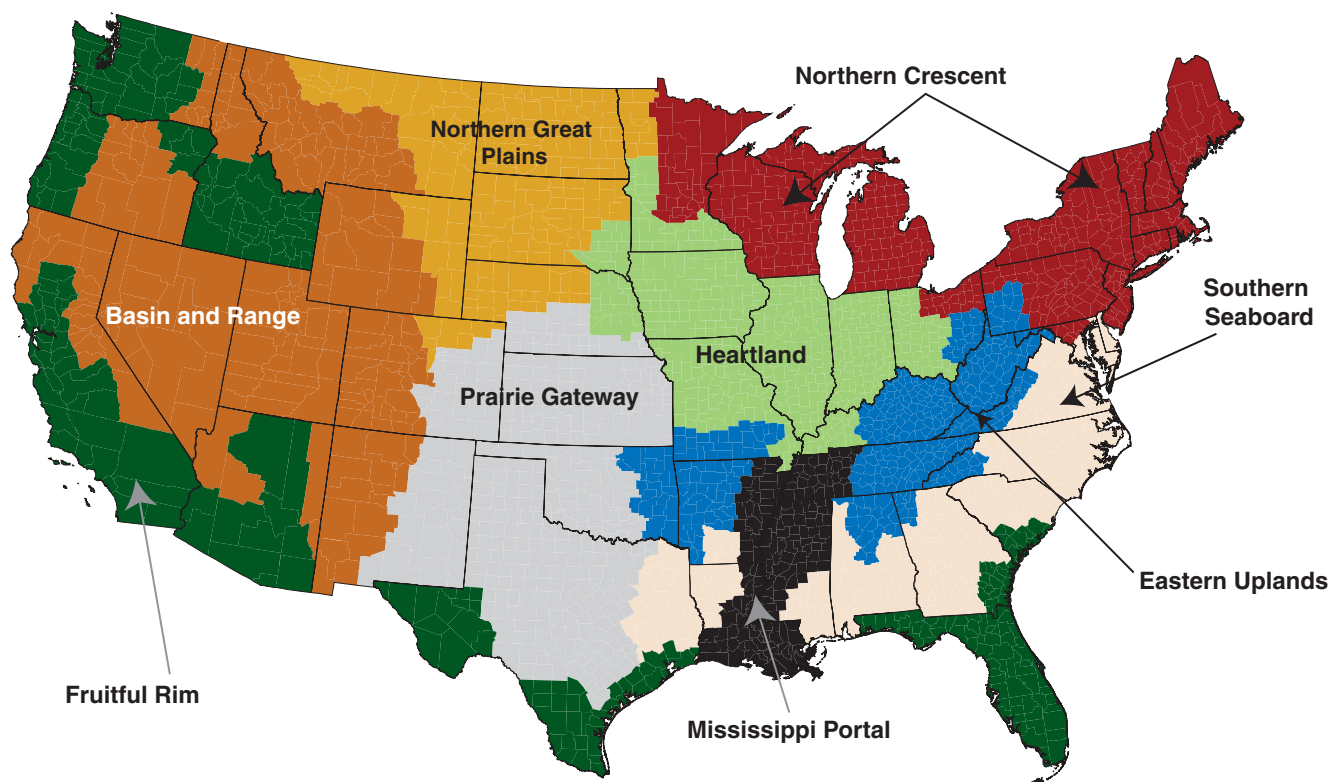
Source: USDA, ERS.

Table 2
Regional hog and pig sales and contract removals by type of hog producer

Item/Region	1992	1998	2004
	Average head per farm		
Farrow-to-finish			
Heartland	901	1,288	1,851
Southern Seaboard	1,093	1,163	1,068
West	621	1,305	1,459
Feeder-to-finish			
Heartland	833	1,972	4,152
Southern Seaboard	1,035	10,951	12,057
West	358	3,589	3,255
All hog and pig producers			
Heartland	975	2,098	5,106
Southern Seaboard	1,206	10,021	13,995
West	702	2,231	1,859

Source: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Surveys.

hog-finishing operations accounted for much of the increased operation size in all regions.

Increasing size and specialization of hog-finishing operations accompanied rapid growth in regional contract production during this period. The share of hogs finished under contract in the Heartland increased from only 4 percent in 1992 to 26 percent in 1998 and to almost 50 percent in 2004 (fig. 9). Contract production in the Southern Seaboard increased from 12 to 85 percent between 1992 and 1998 and accounted for virtually all market hogs produced in 2004. The 1992 survey did not measure any contract production of market hogs in the Western States but by 2004, nearly half of market hogs were produced under contract.

Figure 9

Market hogs removed under contract by region

The use of production contracts for finishing hogs increased in all regions between 1992 and 2004, and in 2004 accounted for virtually all hogs produced in the Southern Seaboard

Percent of market hogs
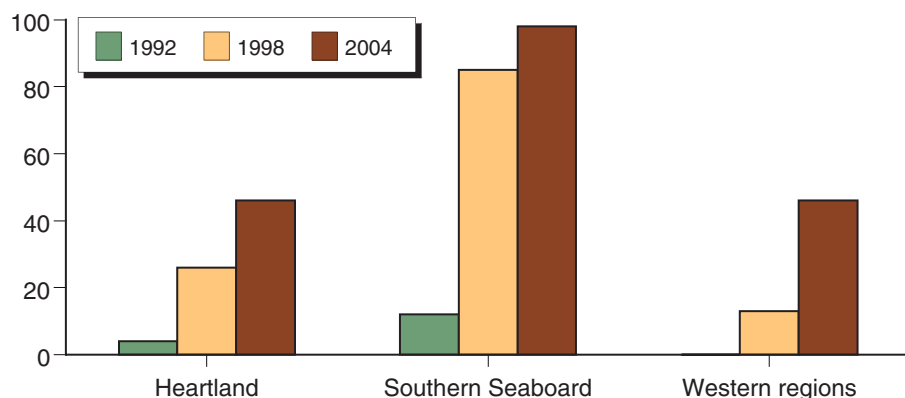
Sources: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Survey.

Technological Innovation in Hog Production

Like contract production, technological innovation has facilitated change in hog production. Technological innovation 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.

Data from USDA's National Animal Health Monitoring Service (NAHMS) surveys conducted in 1990, 1995, and 2000 show technological innovation on hog operations with 100 or more head (USDA, APHIS, 2005). For example, artificial insemination (AI) improves the genetic potential of the swine herd and the conception rates of breeding animals. Between 1990 and 2000, the share of hog operations using AI increased from 7 to 23 percent, while the share of sows and gilts mated by AI increased from 1 to 73 percent. Another innovative practice to enhance productivity, all-in/all-out housing management, commingles pigs of a similar age and weight and keeps the entire group together as it moves through each production phase. The hogs are marketed a room at a time, and rooms are washed and disinfected after each group leaves. The NAHMS data revealed that the use of all-in/all-out management for finishing hogs increased from 25 percent of hog operations in 1990 to 57 percent in 2000; by 2000, about 85 percent of finished hogs were managed with all-in/all-out systems.

The 2004 ARMS collected information about use of AI, all-in/all-out management, and other technologies, including terminal crossbreeding programs, commercial seed stock obtained from high-quality breeding animals, and phase feeding, which varies feed to match animal diets with changing nutritional requirements. Analysis of 2004 ARMS data reveals that specialized hog producers were more likely than farrow-to-finish operations to use these practices. Farrow-to-wean operations more often used AI, terminal crossbreeding, and commercial seed stock than did farrow-to-finish operations (fig. 10).

Figure 10

Practices used by operations farrowing pigs, 2004
The use of production-enhancing practices was much higher on specialized farrowing operations than on farrow-to-finish operations

Percent of farms
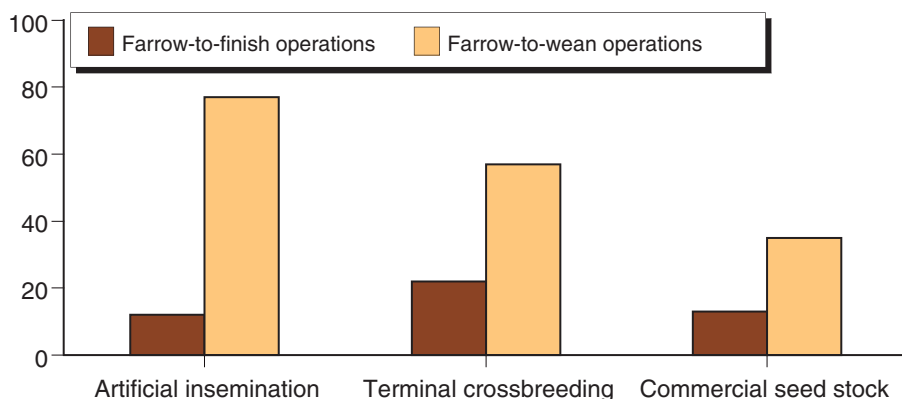
Source: USDA, ERS using data from USDA's 2004 Agricultural Resource Management Survey.

Feeder-to-finish operations more often used phase feeding and all-in/all-out management of finishing facilities (fig. 11). There also appears to be a strong relationship between the use of these practices and the size of an operation (table 3). AI was used on only 4 percent of the smallest farrow-to-finish operations in 2004 but on 92 percent of the largest. As farrow-to-finish operations and feeder-to-finish operations increased in size, use of all-in/all-out finishing increased from 14 to 83 percent of farms and from 66 to 92 percent of farms, respectively. Because large, specialized hog operations can spread fixed costs over more production and more easily take advantage of resulting productivity gains, they are better able to invest in innovative hog-production technologies.

Figure 11

Practices used by operations finishing hogs, 2004

Greater input efficiency on specialized finishing operations may be due to greater use of performance-enhancing practices

Percent of farms
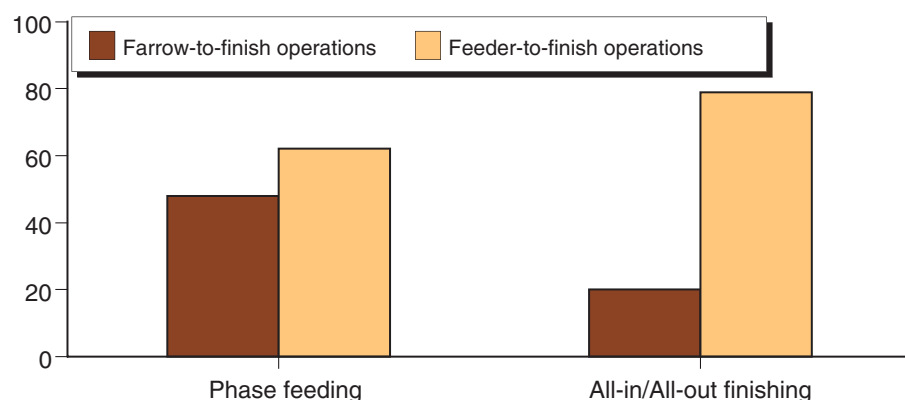
Source: USDA, ERS using data from USDA's 2004 Agricultural Resource Management Survey.

Table 3

Production practice use by size and type of hog producer, 2004

Item	Size of operation[1]			
	Fewer than 500 head	500-1,999 head	2,000- 4,999 head	5,000 head or more
	Percent of farms			
Farrow-to-finish operations				
Artificial insemination	4	12	51	92
Terminal crossbreeding	11	38	43	73
Commercial seed stock	5	24	36	26
Phase feeding	42	53	61	84
All-in/all-out finishing	14	20	54	83
Feeder-to-finish				
Phase feeding	51	60	72	72
All-in/all-out finishing	66	80	86	92

[1]Size of operation is the maximum number of hogs and pigs on the operation at any time during 2004.

Source: USDA, ERS using data from USDA's 2004 Agricultural Resource Management Survey.

Improvements in Hog Farm Productivity: Causes and Consequences

Substantial increases in hog farm productivity have coincided with the industry's pronounced structural changes. Farm productivity can be measured as the average quantity of inputs used in production per unit of output. ARMS collected detailed information about hog production, including inputs and output. This analysis measures output in terms of *hog weight gain*—the weight added during the prior calendar year to purchased/placed hogs that were later sold/removed, plus the total weight added to the hog inventory. Hog weight gain, unlike the alternative output measure "number of head removed," accounts for changes in inventory and for differences in the weights of feeder and finished pigs across operations.[3] ARMS asked farmers about changes in their hog inventory and about the quantity and weights of hogs moved on and off the farm. The survey also asked farmers about the amount and types of feed purchased by the operation or contractor, the amount of homegrown feed used, and the number of hours of labor spent on the hog enterprise (including time by the operator and paid and unpaid labor).

The average quantity of feed required per hundredweight of gain declined 14.9 percent (1.3 percent average annual decline) for farrow-to-finish operations between 1992 and 2004 and declined 44.1 percent (4.7 percent annually) for feeder-to-finish operations (table 4). The average quantity of labor used per hundredweight declined even more—falling 52.5 percent (6.0 percent annually) for farrow-to-finish operations from 1992 to 2004, and falling 83.1 percent (13.8 percent annually) for feeder-to-finish operations.

Productivity gains contributed to a decline in production costs between 1992 and 2004. For all farrow-to-finish hog producers, average production costs per hundredweight of gain, expressed in 2004 dollars, were 27.9 percent lower in 2004 than in 1992. This change amounts to a 2.7-percent average annual rate

[3]Each head produced represents approximately a 2-cwt gain (250 pounds for a typical finished market hog minus 50 pounds for a typical feeder pig). Therefore, ignoring losses due to animal mortality, a farm with an output of 6,000 cwt gain removes 3,000 head per year. Assuming three hog cycles per year, annual production of 6,000 cwt implies an operation has an inventory of 1,000 head.

Table 4

Efficiency and production costs per cwt by type of hog producer

Item	1992	1998	2004
Farrow-to-finish			
Feed conversion rate (lbs per cwt gain)	416	374	354
Labor rate (hrs per cwt gain)	1.13	0.72	0.54
Production costs, current dollars[1]	46.63	43.50	42.44
Production costs, 2004 dollars[1]	58.89	49.20	42.44
Feeder-to-finish			
Feed conversion rate (lbs per cwt gain)	383	282	214
Labor rate (hrs per cwt gain)	0.89	0.24	0.15
Production costs, current dollars[1]	37.54	31.08	26.59
Production costs, 2004 dollars[1]	47.41	35.15	26.59

[1]Production costs are the sum of operating and capital costs less costs for feeder and nursery pigs. Pig costs are excluded because they are not an input contributing to weight gain. 1992 and 1998 costs are deflated to 2004 dollars using the national GDP implicit price deflator (Bureau of Economic Analysis).

Source: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Surveys.

of decline. Real costs declined faster for feeder-to-finish hog producers, falling 43.9 percent between 1992 and 2004, or 4.7 percent annually.

Sources of Productivity Growth

Economic competition and the incentive to maximize profits drive structural changes in the hog industry. If larger operations are more profitable than smaller ones, competitive pressures may be expected to result in a larger average farm size in the long run. Similarly, operations that are first to adopt a cost-saving technology, in regions with lower input costs, or closer to markets, have a competitive advantage that makes them more likely to survive and grow. Relationships between farmers and processors also evolve to reflect more cost-effective modes of production. Since 1992, the use of production contracts has increased dramatically at the expense of independent production. The organizational structure of the industry also reflects efficiency gains from increased specialization of the various phases of hog production on separate operations.

Given output and input prices, the total factor productivity (TFP) of the farm determines returns. TFP is the quantity of farm output per unit of inputs (with all inputs aggregated). TFP reflects the production technology available (which determines the rate at which inputs can be combined to make outputs), whether farms are operating at an efficient scale of production, how efficiently inputs are combined given the production technology, and how well the farmer takes into account the relative prices of inputs.

The production technology used by a farm is a fundamental determinant of its productivity. In hog production, the production technology incorporates livestock genetics, feed mixtures and feed equipment, housing and handling equipment, and veterinary and medical services used. The term *technical change* (or *progress*) describes the increase in productivity resulting from adopting more efficient production technologies.

An increase in the scale of production is another source of productivity growth when there are increasing returns to scale—that is, when a proportional increase in all inputs results in a more than proportional increase in output. The returns to scale of a particular production technology are measured by its "scale elasticity"—the percentage increase in output obtained from a 1-percent increase in all inputs.[4] The movement toward the optimal scale of production (the scale at which the scale elasticity equals one) is said to increase *scale efficiency.*

Table 5 suggests increasing returns to scale in each survey year—per unit production costs decline as the scale of production increases.[5] It seems likely that some of the decrease in average unit costs shown in table 4 has resulted from the growth in the size of operations. That is, between 1992 and 2004, some farms responded to the economic incentive to reduce average costs by expanding the scale of their operations, some smaller, less-efficient operations exited the industry, and new operations entered at a larger, more efficient scale.

While increases in scale efficiency and technological change are likely the largest sources of productivity growth, farms also may become more

[4]For example, if a farm has an estimated scale elasticity of 1.25, then a 1-percent increase in all inputs would result in a 1.25-percent increase in output. Scale elasticity above 1 implies increasing returns to scale. Scale elasticity equal to 1 implies constant returns to scale—that is, there is no productivity gain (or loss) from increasing the scale of production. Scale elasticity below 1 implies decreasing returns to scale—efficiency would actually decline if production were increased.

[5]Increasing returns to scale are usually associated with declining per unit costs as output increases. However, declining per unit costs do not always imply increasing returns to scale. Lower per unit costs for large producers may also result if technical efficiency or allocative efficiency increases with scale, or if input costs decrease with scale. In addition, it is not necessarily the case that all inputs increased proportionately as scale increased.

Table 5
Production costs per cwt by type and size of hog producer

Item	1992	1998	2004
	Dollars per cwt gain		
Farrow-to-finish			
Cwt gain<1,000	72.38	78.39	73.55
1,000≤cwt gain< 2,500	63.26	57.70	51.29
2,500≤cwt gain<10,000	54.88	46.91	39.94
10,000≤cwt gain<25,000	54.12	39.35	37.52
25,000≤cwt gain	id	38.61	36.03
Feeder-to-finish			
Cwt gain<1,000	61.99	57.49	45.46
1,000≤cwt gain< 2,500	46.07	48.02	33.34
2,500≤cwt gain<10,000	43.70	36.03	31.03
10,000≤cwt gain<25,000	id	26.97	23.03
25,000≤cwt gain	id	26.26	24.06

Note: Production costs are the sum of operating and capital costs less costs for feeder and nursery pigs. Pig costs are excluded because they are not an input contributing to weight gain. 1992 and 1998 costs are deflated to 2004 dollars using the national GDP implicit price deflator (Bureau of Economic Analysis).
id = insufficient data for legal disclosure.

Source: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Surveys.

productive by increasing technical and allocative efficiency. Holding the scale of production and the technology constant, *technical efficiency* increases if farmers use inputs more efficiently in the production process. For example, a farm manager might increase technical efficiency by carefully blending the contents of feed to maximize animal weight gain per unit of feed. The farmer does not use a new technology or produce more, but the productivity of the farm increases because input expenditures per unit decline.

Farmers increase *allocative efficiency* if they can improve productivity by choosing the mix of inputs to better reflect their relative costs. For example, if the price of feed increases relative to the price of capital, then it becomes more efficient to substitute capital for feed (say, by using machinery that more accurately rations feed).

This study focuses on measuring and understanding changes in *farm-level* total factor productivity. It uses ARMS data to disaggregate changes in farm TFP into changes in four constituent parts: technical change, technical efficiency, scale efficiency, and allocative efficiency. Productivity gains at the industry level have accompanied substantial farm-level productivity gains. Industry-level efficiency gains result in part from increasing specialization in the various stages of hog production. As discussed in the previous chapter, the hog industry has seen finished hog production move from one to two or three separate operations. That is, since 1992, the share of hog output produced by farrow-to-finish operations has declined, while the share of output produced by feeder-to-finish operations has increased. Feeder-to-finish operations obtain feeder pigs from separate operations that raise feeder pigs (farrow-to-feeder or farrow-to-wean and wean-to-feeder). As production shifted from less efficient farrow-to-finish operations to more efficient specialized operations, the total costs of producing finished hogs industrywide may have declined substantially, resulting in industry-wide

improvements in productivity. This study does not assess industrywide efficiency gains from changes in specialization.[6] Instead, it examines productivity growth at one important stage of hog production—feeder-to-finish —which now accounts for most finished hog output (having increased from 22 percent to 77 percent of all output between 1992 and 2004 (see table 1).[7] Feeder-to-finish operations make an interesting case study because their large and increasing share of output suggests these farms will dominate the industry in the future, and they have had the fastest productivity growth since 1992 (see table 4) and the greatest increase in scale of production (see table 1).

Disaggregating Productivity Growth

Disaggregating the observed increases in total factor productivity into technical change, technical efficiency change, scale efficiency change, and allocative efficiency change provides insights into the forces that drive structural change. The methodology used here to disaggregate TFP follows Orea (2002) and is described in more detail in the appendix. The approach requires estimation of a production frontier—a parametric relationship between input quantities and the maximum output achievable from those inputs. The frontier describes the amount that technically efficient operators could produce if they used the best practices available in the industry. Since no producers are perfectly technically efficient, production occurs within the frontier.

The assumed functional relationship between the inputs and output is "flexible" in that it imposes few *a priori* restrictions on the characteristics of the production technology, such as constant returns to scale. The parameters describing the frontier are estimated using a maximum likelihood technique that accounts for the facts that: (1) we do not observe the distance of the actual production levels from the frontier, and (2) input and output levels are measured with error (Battese and Coelli, 1992).

Economists calculate an index of technical efficiency as a farm's ratio of observed output to what could be produced with the same inputs if the farm operated on the estimated production frontier. If the same farm could be observed over time, changes could be tracked in this index (a measure of technical efficiency). However, because ARMS is a repeated cross-section rather than a panel, the study estimates technical efficiency change for a representative (average) farm.

The estimation method permits the parameters of the production frontier to vary over time to allow for technical change. Technical change measures output changes resulting from changes in production technology, holding efficiency, scale, and prices constant. Scale efficiency change captures TFP changes caused solely by changes in input levels, holding technical efficiency, the production function, and prices constant.

Allocative efficiency change measures TFP changes resulting from changes in the "cost effectiveness" of inputs. Relative to their contributions to output, some inputs may be relatively "expensive," and others may be relatively "cheap." Allocative efficiency improves when a firm uses more of the

[6]ARMS did not survey enough farrow-to-wean or wean-to-feeder pig operations in 1992 and 1998 to measure industry-wide efficiency gains from increased specialization.

[7]Feeder-to-finish operations are those on which feeder pigs (weighing 30-80 pounds) are purchased/placed, finished, and then sold/removed for slaughter (weighing 225-300 pounds).

relatively inexpensive inputs, and less of the relatively expensive inputs. TFP is an index of output produced per unit of inputs, where inputs are aggregated into an index using prices as weights. Allocative efficiency change is the residual difference between the total change in TFP (which depends on prices) and the change in the TFP explained by changes in production technology, efficiency, and scale (changes that do not depend on prices).

By definition, the percentage change in TFP equals the sum of technical change plus changes in technical efficiency, scale efficiency, and allocative efficiency. For all farms, TFP more than doubled between 1992 and 2004, with an average increase of 6.3 percent per year (table 6). This is a very high rate of growth—about three times the historical growth rate in productivity for the agricultural sector as a whole (Ahearn et al., 1998). Average annual TFP growth rates were similar in both periods between the ARMS surveys—with average increases of 6.4 percent from 1992 to 1998 and 6.3 percent from 1998 to 2004.

Technological change and increases in scale efficiency accounted for most of the growth in TFP (increasing 3.0 percent and 3.4 percent annually, respectively). The contribution of technological change to productivity growth increased substantially in the second period—from 2.1 percent annually between 1992 and 1998 to 3.9 percent annually between 1998 and 2004. In contrast, the scale effect diminished over time: scale efficiency increased 4.5 percent annually between 1992 and 1998 but only 2.2 percent between 1998 and 2004.

Average technical efficiency changed little over the 12-year study period. Allocative efficiency change also played a small role in TFP change—increasing at an annual rate of 0.5 percent.

Implications for Scale of Production

Increases in scale efficiency contributed significantly to productivity gains between 1992 and 2004 as farms grew in size to take advantage of increasing returns to scale. Estimates of returns to scale provide insight into farmers' incentives to undertake further increases in scale.

The top of table 7 shows the change over time in the share of total finished-hog output produced by farms in each farm-size category. The increase in share was particularly notable for large operations. For example, so few farms were producing more than 25,000 hundredweight gain that they were not even sampled in the 1992 survey. By 1998, these operations produced 35.7 percent of total output, and the share rose to 43.4 percent by 2002.

The bottom of table 7 reports two estimates of average scale elasticity for all farms in each survey year—the mean and weighted mean. The mean scale elasticity for all farms ranges between 1.12 and 1.16, which indicates that a 10-percent increase in inputs produces an 11.2- to 11.6-percent increase in output for the "typical" farm. The mean weighted by farm output is the scale elasticity associated with the "typical" quantity of output. The weighted mean is smaller than the unweighted mean because larger farms produce more output and the scale elasticity declines with size of the opera-

Table 6
Decomposition of total factor productivity change (feeder to finish)

Item	1992-98	1998-2004	1992-2004
		Factor change (Annual growth rate)	
		Percent	
Technical efficiency	-1.7	0.8	-0.9
	(-0.3)	(0.1)	(-0.1)
Technology	13.5	25.6	42.5
	(2.1)	(3.9)	(3.0)
Scale efficiency	30.6	13.8	48.6
	(4.5)	(2.2)	(3.4)
Allocative efficiency	2.6	3.9	6.7
	(0.4)	(0.6)	(0.5)
Total factor productivity	45.1	44.1	109.1
	(6.4)	(6.3)	(6.3)

Source: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Surveys.

Table 7
Share of output and scale elasticity by farm size and year (feeder to finish)

Farm size category	1992	1998	2004
		Share of total output (percent)	
Cwt gain < 1,000	14.7	1.9	0.5
1,000 ≤ cwt gain < 2,500	35.0	6.7	3.0
2,500 ≤ cwt gain < 10,000	41.0	26.5	16.7
10,000 ≤ cwt gain < 25,000	9.3	29.2	36.3
25,000 ≤ cwt gain	id	35.7	43.4
		Scale elasticity	
Cwt gain < 1,000	1.20	1.24	1.27
1,000 ≤ cwt gain < 2,500	1.13	1.16	1.22
2,500 ≤ cwt gain < 10,000	1.08	1.12	1.17
10,000 ≤ cwt gain < 25,000	1.07	1.09	1.12
25,000 ≤ cwt gain	id	1.03	1.05
All farms (mean)	1.16	1.12	1.14
All farms (output-weighted mean)	1.10	1.05	1.07

id = insufficient data for legal disclosure.

Source: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Surveys.

tion. Both the mean and weighted mean values imply increasing returns to scale in all periods.

As expected, scale elasticity declines as farm size increases—large farms obtain smaller gains from increasing scale than do small farms. The technology used by farms in the largest category exhibits positive returns to scale. However, the potential for efficiency gains from further increases in scale appear limited for large farms—farms producing more than 25,000 hundredweight had an average scale elasticity of 1.05 in 2004. On the other hand, potential scale efficiency gains remain in the sector as a whole—farms producing less than 25,000 cwt accounted for more than half of all output in 2004.

Returns to scale increased in all size categories between 1992 and 1998 and between 1998 and 2004. This implies that holding output constant (output is approximately constant within each category), returns to scale increased steadily over time. Hence, the reduction in the contribution of scale efficiency to TFP (see table 6) results from a slowdown in the growth of average farm output (see table 1), not from a reduction in the optimal scale of production.[8] Because average farm size increased substantially over the study period, the average scale elasticity for all farms showed little change.

Regional Differences in Productivity Growth

Productivity growth in the U.S. hog sector varied substantially by region between 1992 and 2004 (table 8). For feeder-to-finish farms, this study focuses on two major hog-producing regions: the Heartland (IA, IL, IN, KY, MO, and OH) and the Southeast (AL, AR, GA, NC, SC, and VA). Producers in the remaining surveyed States (CO, KS, MI, MN, NE, OK, PA, SD, TN, TX, UT, and WI) are placed in the "other regions" category.

Production shifted from the Heartland to the Southeast and other regions during 1992-98. The share of output produced by farms in the Southeast increased 12.2 percentage points, even though the share of feeder-to-finish operations located in this region declined 5.6 percentage points. A large increase in scale of production accounts for this increase in output share despite a decline in share of farms: average farm size in the Southeast increased almost tenfold. Farms in the Heartland, while representing roughly half of all feeder-to-finish hog farms in both 1992 and 1998, experienced smaller proportional increases in average farm output over this period, and, consequently, their share of total output declined by 22.5 percentage points.

[8]The procedure for estimating the stochastic production function allows some parameters to vary over time, which permits scale elasticity and optimal scale to vary also. See the definition of scale elasticity in the appendix for more details.

Table 8
Summary statistics by region (feeder to finish)

Item	1992	1998	2004
	Percent		
Share of feeder-to-finish farms			
Heartland	54.7	55.9	48.9
Southeast	15.2	9.6	10.7
Other regions	30.1	34.5	40.4
Share of feeder-to-finish output			
Heartland	57.9	35.4	45.2
Southeast	20.1	32.3	24.7
Other regions	22.0	32.3	30.0
	Hundredweight gain		
Mean farm output			
Heartland	1,716	5,399	11,313
Southeast	2,333	20,771	25,074
Other regions	1,097	10,516	12,933

Source: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Surveys.

During 1998-2004, feeder-to-finish output share rebounded in the Heartland and declined in the Southeast. Heartland farms doubled in size while farms in the Southeast had much smaller proportional increases (though starting from a larger average size). As a result, the Heartland increased its share of output 9.8 percentage points over this period, while the Southeast decreased its share by 7.6 percentage points.

The decline in the output share and in the rate of growth in average farm size in the Southeast during 1998-2004 can probably be attributed largely to policy changes at the State level. Over the three survey periods, farms in North Carolina produced on average about 92 percent of total output in the Southeast region. In 1997, North Carolina passed the Clean Water Responsibility and Environmentally Sound Policy Act, which imposed a moratorium on the construction of new and expanded hog operations with 250 or more head. The moratorium contained several exceptions, including new construction using "innovative animal waste management systems that do not employ an anaerobic lagoon."[9] Though the moratorium was originally set to expire in 1999, North Carolina extended it several times in modified form through 2007.

[9]For full text of the bill, see: http://ssl.csg.org/dockets/99bsc-bills/2499b01nchb515cleanswine.html

Except for "other inputs" in the Southeast, all partial factor productivity measures in the three regions increased at similar annual rates between 1992 and 2004 (table 9). However, this pattern masks substantial differences in factor productivity between the Heartland and the Southeast during the two subperiods. While each of the three regions began in 1992 with approximately the same levels of factor productivity, from 1992 to 1998, farms in the Southeast experienced much larger increases in feed, labor, and capital productivity than did farms in the Heartland. Between 1998 and 2004, this pattern reversed, with farms in the Heartland increasing their feed, labor, and capital productivity more rapidly than farms in the Southeast.

Disaggregating the change in productivity for each region shows the extent to which changes in the scale of production, or differences in rates of technological change, allocative efficiency change, or technical efficiency change caused these shifts in productivity (table 10).[10] The regional changes in TFP are consistent with changes in partial factor productivity previously discussed (see table 9).

[10]For each region, the disaggregation used the estimated parameters for all farms and the input levels corresponding to the farms in that region. In other words, the production technology was assumed to be the same across regions, but the input mix varied according to the sample.

The average annual growth rates imply that between 1992 and 1998, TFP almost doubled in the Southeast but increased by only about a third in the Heartland over the same 6-year period. Between 1992 and 1998, technical progress contributed roughly equal amounts to the growth in TFP for farms in both the Heartland and the Southeast regions. However, the contribution of scale efficiency to TFP was much greater in the Southeast than in the Heartland (increasing annually at 9.0 percent versus 3.1 percent). The large increase in scale efficiency in the Southeast resulted from the region's rapid increase in the scale of production (see table 8), given the increasing returns to scale of the production technology.

Between 1998 and 2004, productivity in the Heartland rebounded—increasing by almost 60 percent, compared with only 36 percent in the Southeast. Increases in scale efficiency drove faster growth in productivity in the Heartland in the second period—scale efficiency increased at an

Table 9
Partial factor productivity by region and year (feeder to finish)

Input/Region	Partial factor productivity			Annual growth rate, 1992-2004
	1992	1998	2004	
Feed productivity (cwt gain per cwt feed)				
Heartland	0.286	0.314	0.764	8.5
Southeast	0.281	0.443	0.629	6.9
Other regions	0.243	0.313	0.625	8.2
Labor productivity (cwt gain per unit of hog enterprise labor[1])				
Heartland	2,070	3,019	6,187	9.6
Southeast	2,237	6,151	6,918	9.9
Other regions	2,584	2,919	5,373	6.3
Capital productivity (cwt gain per dollar[2])				
Heartland	0.091	0.097	0.238	8.3
Southeast	0.099	0.156	0.252	8.1
Other regions	0.075	0.111	0.234	9.9
Other inputs productivity (cwt gain per dollar[3])				
Heartland	0.327	0.491	0.541	4.3
Southeast	0.456	0.359	0.485	0.5
Other regions	0.248	0.491	0.490	5.8

[1]The labor input is a weighted index (Tornqvist index) of paid labor plus unpaid farm household labor that uses the labor expenditure shares for paid and unpaid labor as weights. The labor expenditures for paid labor are observed. Labor expenditures for unpaid labor are estimated using an imputed wage for unpaid labor.
[2]Capital is the "capital recovery cost"—the estimated cost of replacing the existing capital equipment (barns, feeding equipment, etc.).
[3]Other inputs are defined as real expenditures on veterinary services, bedding, marketing, custom work, energy, and repairs.

Source: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Surveys.

Table 10
Decomposition of total factor productivity change (feeder to finish)

	Annual growth rate		
	1992-98	1998-2004	1992-2004
Heartland			
Technical efficiency	-0.5	0.2	-0.2
Technology	2.2	3.9	3.0
Scale efficiency	3.1	4.4	3.7
Allocative efficiency	0.9	0.6	0.8
Total factor productivity	5.3	8.1	6.7
Southeast			
Technical efficiency	0.1	-0.6	-0.3
Technology	2.3	4.4	3.4
Scale efficiency	9.0	2.2	5.5
Allocative efficiency	1.4	-0.7	0.4
Total factor productivity	11.5	5.2	8.3
Other regions			
Technical efficiency	0.1	0.2	0.1
Technology	2.1	3.7	2.9
Scale efficiency	5.6	-1.5	2.0
Allocative efficiency	-0.7	1.1	0.2
Total factor productivity	6.7	3.6	5.2

Source: USDA, ERS using data from USDA's 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Surveys.

annual average rate of 4.4 percent, compared with only 2.2 percent in the Southeast. The Heartland actually lagged slightly behind the Southeast in technological progress during this period.

In sum, average farm-size growth and the resulting improvements in scale efficiency explain most differences in productivity growth between the Heartland and Southeast since 1992. While the rate of technical change approximately doubled between the periods in each region, farms in all regions had similar rates of technical advance. This suggests that the adoption of new technologies, information, and genetic improvements diffused at similar rates across the Nation. Because farms in the Heartland operate at a smaller average scale than do farms in the Southeast, the Heartland retains greater scope for further scale efficiency gains.

Organizational Structure and Productivity

As documented earlier, the use of production contracts increased dramatically among feeder-to-finish hog operations since at least 1992 (see table 1). Production contracts offer several potential advantages over independent production that help explain their growing use: contracts can reduce information asymmetries between growers and processors, improve coordination and timing of product delivery, and lower income risk for growers. Production contracts also may raise farm productivity by improving the quality of farm management decisions, speeding the transfer of technical information to growers, improving growers' access to credit, and facilitating the adoption of more efficient technologies.

Recent ERS research showed a link between the use of production contracts and hog farm productivity. Using the 1998 ARMS survey of feeder-to-finish hog farms, Key and McBride (2003) compared the productivity of similar independent operations and contract operations, controlling for unobservable differences that might be associated with the decision to contract. The authors found that production contracts were associated with an average increase in total factor productivity of about 23 percent.

Given the scope of structural changes in the industry since 1998, it is possible that the observed differences in productivity between contract and independent operations have diminished. Many less-efficient independent operations have exited the industry, and some independent operations have begun to contract. Key and McBride (2007) used data from the 2004 ARMS to examine whether production contracts remain associated with greater farm productivity. The authors used an instrumental variables technique to isolate the effect of contracts on productivity. As in the earlier study, the authors found that contract operations were substantially more productive than similar independent operations. A 10-percent increase in the prevalence of contracting would increase average total factor productivity by 5 percent.

The estimates of the magnitude of the productivity gains attributable to contracting suggest that these productivity advantages contributed to the recent growth in contracting in the hog industry. The apparent continuing link between contracts and productivity, along with lower grower income risk and improved coordination and timing of product delivery for contrac-

tors, suggest that the use of production contracts is likely to continue to expand.

The connection between contracts and productivity suggests that 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 enhance the competitive position of larger producers vis-à-vis smaller producers.

Implications of Productivity Gains for Consumers

A main potential benefit to society of increases in hog farm productivity is lower food prices for consumers. How much have productivity gains in hog production been reflected in retail prices? One way to address this question is to estimate how much hog prices would have increased had there been no change in farm productivity. This counterfactual can be estimated by examining input prices. In a competitive market, the price received by farmers for finished hogs equals the total cost of inputs plus a "normal" rate of return. Consequently, if the normal rate of return were constant and farm productivity did not change, then hog prices would be expected to track input prices.

Figure 12 shows price trends for the major inputs to hog production. Each input price index is scaled so that the index at the beginning of the series (January 1992) equals the longrun average input cost share estimated using ARMS data. Specifically, at the beginning of the series, input costs comprised feed costs (55 percent), capital (20 percent), labor (17 percent), and other inputs (8 percent). The total input cost index is the sum of the input price indices, which equals 1.0 by definition in January 1992. The figure shows that feed costs, which fluctuated between 51 and 73 percent of total costs, drive the variation in the total cost index. A linear time trend fitted to the total cost index (heavy black line) indicates that input prices increased 28.5 percent over the study period. Since hog prices reflect the costs of production on the farm, this result implies that the gross farm value would have increased by about 28.5 percent between 1992 and 2004 if total factor productivity had not changed.

Figure 13 illustrates price trends at the farm, packer, and retail levels. The gross farm value is the value of the hog when it is sold, measured in cents per pound of retail weight. The wholesale value is the average value of the meat as it leaves the packing plant, measured in cents per pound of retail weight. The retail value is the average value of selected cuts of meat at the grocery store, measured in cents per pound of retail weight. The heavy black line shows an estimated linear time trend in the gross farm value of hogs. The estimated trend indicates that hog prices declined 3.3 percent between 1992 and 2004.

To summarize, input price increases imply that finish hog prices would have risen by 28.5 percent with no change in productivity. However, hog prices at the farm level actually declined by 3.3 percent. The difference between

Figure 12

Historical pork prices—Gross farm value, wholesale value, and retail value, January 1992-December 2004
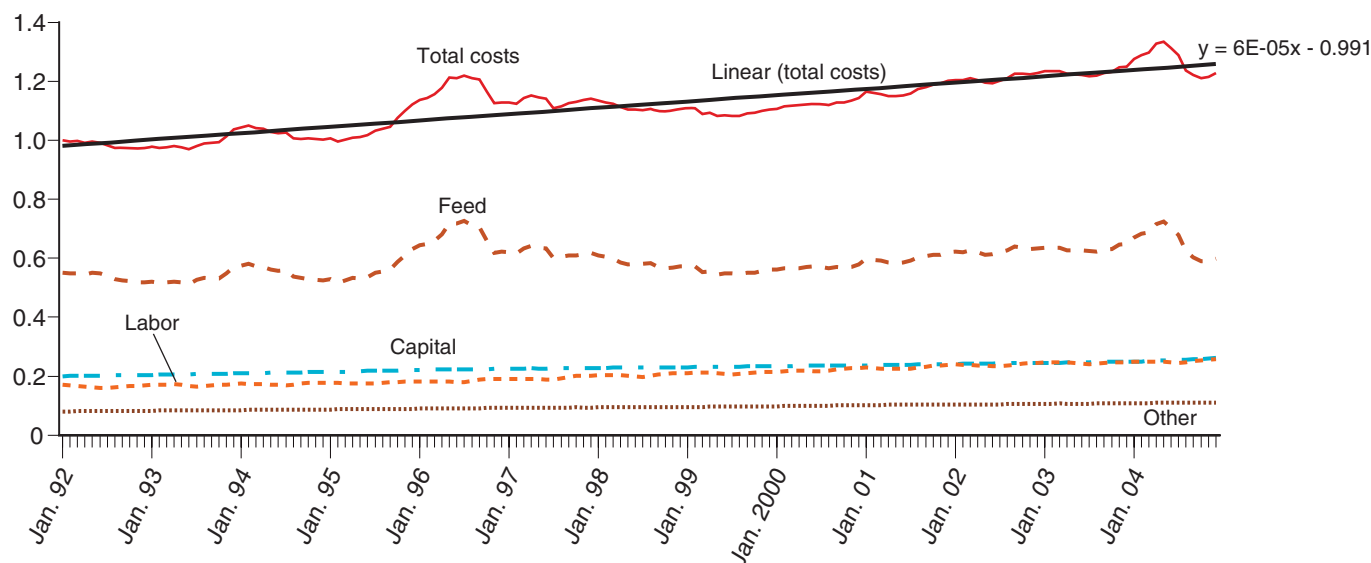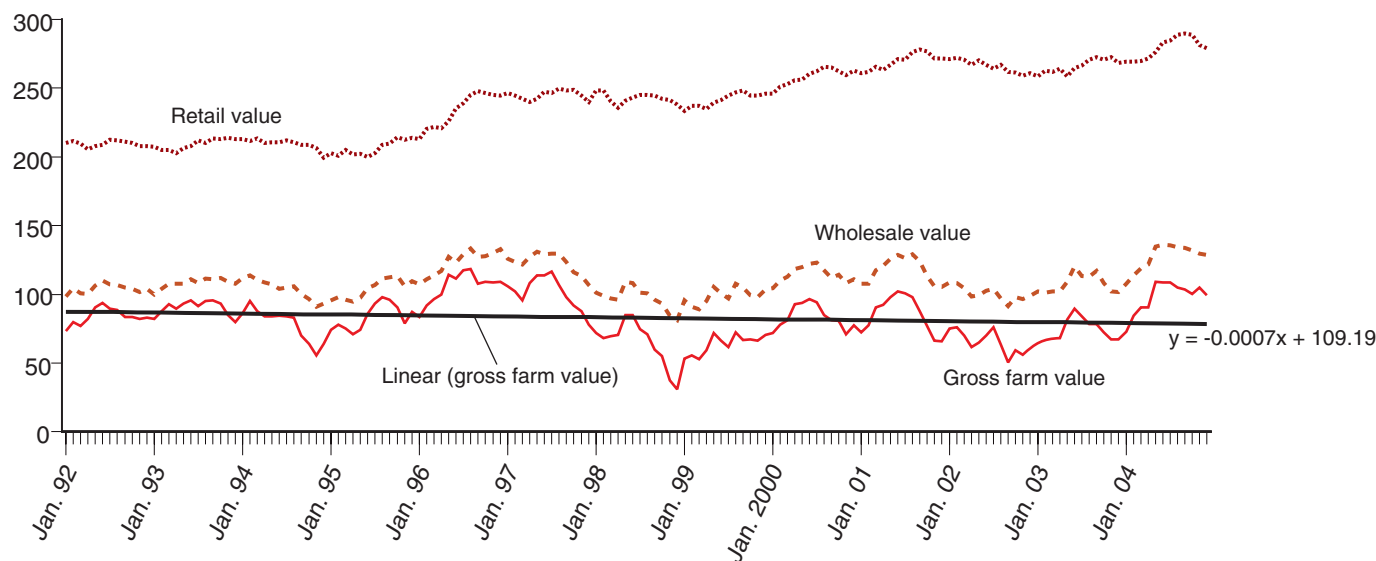
Price index

Sources: USDA, ERS using data from USDA, NASS, (farm wage rate); BLS (CPI; swine feeds, complete; farm machinery and equipment).

Figure 13

Feeder-to-finish hog production input price index, January 1992-December 2004

Price index

Sources: USDA, ERS using data from USDA, AMS, (wholesale and gross farm value); BLS (retail).

these price trends, 31.8 percent, represents the estimated decrease in the price of hogs at the farm gate attributable to productivity increases.

Productivity gains that lower finish-hog prices do not directly translate into lower retail prices. The cost of hogs represents less than a third of the total cost of retail pork (hogs must be slaughtered and processed, and pork must be transported and marketed).[11] Assuming finish hogs at the farm gate

[11]The share of the farm value of pork (net byproducts) in the retail value fluctuated between 26 and 33 percent between 2003 and 2006, and averaged 28.9 percent (see www.ers.usda.gov/data/meatprice-spreads/data/pork.xls).

accounted for 29 percent of the total cost of pork sold at retail, farm-level productivity gains would lower retail pork prices by 9.2 percent (29 percent of 31.8 percent), compared with estimated prices without the productivity gains. Wholesale pork prices (at the packing house) show a very similar trend to the farm gate prices (see fig. 13). In contrast, retail pork prices increased substantially over the same period. Factors that may have contributed to the rapid increase in retail prices include slower productivity growth in the retail sector, greater input price inflation for retailers, and increasing value added (see Hahn (2004) for more information about meat price spreads).

The estimated 31.8-percent decline in hog prices attributable to productivity gains is consistent with the estimates of TFP gains for feeder-to-finish operations. The estimated 109-percent growth in TFP for feeder-to-finish operations between 1992 and 2004 (see table 6) implies a 52-percent decline in average costs for these operations over this period.[12] The cost decline in feeder-to-finish operations is expected to exceed the overall hog price decline for several reasons. First, finish hog prices are determined partly by the supply of hogs from farrow-to-finish operations, in addition to feeder-to-finish operations. As shown in table 4, farrow-to-finish farms achieved substantially smaller productivity gains than feeder-to-finish farms, implying a smaller decline in costs. Second, the total cost of producing finish hogs supplied by feeder-to-finish operations includes the cost of producing feeder pigs. However, feeder-pig costs are not included in this study's productivity analysis (output was measured in terms of hundred-weight gain). If feeder-pig operations realized smaller efficiency gains than feeder-to-finish operations, the total cost of supplying finish hogs would decline by less than 52 percent.

[12]A TFP index is proportional to the inverse of an average cost index. From table 3, TFP was estimated to increase by 109.1 percent between 1992 and 2004, implying that a TFP index equal to 1.0 in 1992 would increase to 2.091 in 2004. The inverse of this index (the average cost), would fall from 1.0 to 0.478—a 52.2-percent decline.

Summary and Conclusions

The U.S. swine industry has undergone significant changes in its size and structure during the past two decades that have coincided with substantial increases in hog farm productivity. In terms of structural change:

- The industry consolidated as the number of hog farms fell more than 70 percent between 1992 and 2004 while the hog inventory remained stable. Fewer and larger farms account for an increasing share of total output. The average size of U.S. hog operations grew from 945 head in 1992 to 2,589 head in 1998 and to 4,646 head in 2004. The share of the hog inventory on operations with 2,000 or more head increased from less than 30 percent to nearly 80 percent. Operations with 5,000 or more head accounted for more than 50 percent of the hog inventory in 2004.

- The organizational structure of U.S. hog farms changed considerably during the period as traditional farrow-to-finish operations gave way to large operations that specialize in a single phase of production. The share of market hogs produced by farrow-to-finish operations fell from 65 to 18 percent during 1992-2004. In contrast, the share produced by specialized hog-finishing operations increased from 22 to 77 percent.

- The expanded use of production contracts helped drive consolidation and specialization of hog production. The share of hogs delivered under production contracts grew from 5 percent of output in 1992 to 67 percent in 2004. Contracting operations are larger than independent operations and more likely to specialize in a single production phase.

- Farms with hogs became more specialized in the hog enterprise during 1992-2004 as the share of value of farm production from hog enterprises increased from 46 to 71 percent and the share of farm grain produced for hog feed fell from about half to below 20 percent. Changes have been particularly notable for specialized hog-finishing operations, where much of the production is under contract.

- The rapid growth of hog operations in the Southeast during 1992-98 slowed during subsequent years because of a moratorium on hog farm expansion in North Carolina, enacted in response to environmental concerns. In contrast, the size of hog operations increased faster in the traditional hog-producing States of the Midwest during 1998-2004.

Structural change has coincided with substantial efficiency gains for hog farms, particularly on the more specialized feeder-to-finish operations:

- Feeder-to-finish operations reduced the amount of feed used per unit of output by 4.7 percent annually between 1992 and 2004 and reduced the quantity of labor per unit by 13.8 percent annually.

- For feeder-to-finish producers, real average production costs per hundredweight of gain declined 4.7 percent annually between 1992 and 2004.

Productivity is a fundamental determinant of farm profitability and, hence, of farm growth and survival. This study used ARMS data to disaggregate changes in farm total factor productivity into changes in four constituent parts: technical change, technical efficiency, scale efficiency, and allocative efficiency. For feeder-to-finish farms:

- Total factor productivity increased annually by 6.4 percent from 1992 to 1998 and by 6.3 percent from 1998 to 2004. Most of these productivity gains were attributable to increases in the scale of production (scale efficiency) and technological change.

- The production technology displayed increasing returns to scale. Increases in farm size since 1992 explain almost half the total increase in farm productivity. Further increases in scale efficiency are likely limited for large farms, but scope for efficiency gains in the sector remains as smaller operations increase in scale or are replaced by larger operations.

- Technological advances helped drive almost half the total productivity increase since 1992.

Among findings related to a comparison of the two major hog-producing regions—the Southeast (mainly North Carolina) and the Heartland (mainly Iowa and Illinois):

- Regional trends in farm productivity mirrored trends in farm output: productivity increased more in the Southeast between 1992 and 1998 and increased more in the Heartland between 1998 and 2004.

- Average farm-size growth and the resulting improvements in scale efficiency explain most of the differences in productivity growth between the Heartland and Southeast since 1992. Farms in both regions had similar rates of technical advance over the study period. However, in the Southeast, rapid growth in average farm output during 1992-98 resulted in relatively large gains in scale efficiency. From 1998 to 2004, farms grew faster in the Heartland, leading to greater productivity growth in that region.

Recent ERS research associated use of production contracts with substantial increases in farm productivity. The estimates of productivity gains attributable to contracting suggest that these productivity advantages contributed to recent growth in contracting in the hog industry. The apparent continuing link between contracts and productivity, along with other benefits from contracts, suggests that the use of production contracts is likely to continue expanding. Because contract operations are generally larger operations, contracting may disproportionately benefit larger farms.

Cheaper food is one of the main potential benefits to society of greater hog farm productivity. The study found that productivity gains contributed to about a 30-percent reduction in the price of hogs at the farm gate, compared with prices estimated without the productivity gains. ERS did not estimate the extent to which the reduction in hog prices lowered retail pork prices.

While productivity gains can benefit consumers in terms of lower food prices, structural changes that enable efficiency gains may also generate environmental concerns. Increases in the scale of production resulting in greater animal density may require operations to store manure in larger lagoons/pits—creating concentrated levels of odor, ammonia emissions, and the potential for larger manure spills. The concentration of hog manure makes it more costly to use as fertilizer as more land is needed and transportation costs to fields are greater. On the other hand, concentrating manure sources in fewer locations potentially affects fewer people. Additionally, greater concentration may make some manure treatment technologies feasible (e.g., energy from biowaste, or processing into concentrated fertilizer).

Glossary

All-in/all-out housing commingles pigs of a similar age and weight and keeps them together as they move through each production phase. Marketing is done a room at a time, and rooms are washed and disinfected after each group of pigs leave to help decrease the spread of infectious diseases.

Commercial seed stock producers specialize in the production and sale of high-quality breeding hogs.

Contract production is an arrangement in 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.

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 (USDA, ERS).

Hog operations are defined as farms that had a hog inventory of 25 head or more on the acres operated at any time during survey years 1992, 1998, and 2004. Hog operations include independent hog producers and growers who produced hogs under contract.

Hundredweight gain equals hundredweight of hogs sold or removed under contract less hundredweight of hogs purchased or placed under contract, plus hundredweight of inventory change each year, expressed as:

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

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

Operating costs are the costs for purchased 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.

Phase feeding feeds hogs or pigs diets of varying protein and energy content at different stages, or phases, of their life to more closely match the diet with their changing nutritional requirements.

Phase of production refers to one of four commonly used categories that describe stages in 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 from immediately after weaning until about 30-80 pounds, and; (4) growing/finishing—the feeding of hogs from 30-80 pounds to the slaughter weight of 225-300 pounds.

Terminal crossbreeding programs concentrate on using all possible heterosis of the breeds and thus capitalize on breed strengths. These programs use two-, three-, or four-breed first-cross females that excel in maternal traits bred to boars from breeds that are superior for growth and carcass traits. All the progeny from these matings are marketed and not kept for replacement gilts.

Total economic costs are the full ownership costs (cash and noncash) for being engaged in the enterprise. These include both operating and owner-ship costs, plus opportunity costs for unpaid labor and land, and costs for general farm overhead items.

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 each survey could not be classified using the following criteria:

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, these operations were defined as farms on which 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 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, these operations were defined as farms on which 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.

Farrow-to-wean 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. Using the survey data, these operations were defined as farms on which 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.

Feeder-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, these operations were defined as farms on which more than 75 percent of pigs came from feeder pig purchases or contract place-ments and more than 75 percent of the value of hogs and pigs left through market hog sales or contract removals.

Wean-to-feeder 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. Using the survey data, these operations were defined as farms on which 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.

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Appendix

Decomposition of total factor productivity

This study uses a stochastic frontier analysis to decompose TFP growth into four components: (1) technical change, which is the increase in the maximum output that can be produced from a given level of inputs (a shift in the production frontier); (2) technical efficiency change, which is the change in a firm's ability to achieve maximum output given its set of inputs (how close it is to the production frontier); (3) scale efficiency change, which is the change in the degree to which a firm is optimizing the scale of its operations; and (4) allocative efficiency change, which is the change in a firm's ability to select a level of inputs so as to ensure that the input price ratios equal the ratios of the corresponding marginal products.[13]

Orea (2002) shows that if firm i's technology in time t can be represented by the translog output-oriented distance function $D_o(q_{it}, x_{it}, t)$ where q is output, x_{it}, a K-dimensional input vector with elements $(x_{it1}, \ldots x_{itk} \ldots x_{itK})$, then the logarithm of a generalized output-oriented Malmquist productivity index $\ln M_o$ can be decomposed into changes in technical efficiency (EC), technical change (TC), and scale efficiency change (SC), between time periods r and s:

(1) $\qquad \ln M_{Oi} = EC_i^{rs} + TC_i^{rs} + SC_i^{rs}$

where

(2) $\qquad EC_i^{rs} = \ln D_O(q_{is}, x_{is}, s) - \ln D_O(q_{ir}, x_{ir}, r)$

(3) $\qquad TC_i^{rs} = -\frac{1}{2}\left[\frac{\partial \ln D_O(q_{is}, x_{is}, s)}{\partial t} + \frac{\partial \ln D_O(q_{ir}, x_{ir}, r)}{\partial t}\right]$

(4) $\qquad SC_i^{rs} = \frac{1}{2}\sum_{k=1}^{K}\left[\frac{\varepsilon_{is} - 1}{\varepsilon_{is}}\varepsilon_{isk} + \frac{\varepsilon_{ir} - 1}{\varepsilon_{ir}}\varepsilon_{irk}\right] \cdot \ln\left(\frac{x_{isk}}{x_{irk}}\right)$

where $t = (r,s)$, $\varepsilon_{it} = \sum_{k=1}^{K}\varepsilon_{itk}$ is the scale elasticity such that $\varepsilon_{itk} = \partial \ln D_O(q_{it}, x_{it}, t)/\partial \ln x_{itk}$.

With one output, a translog distance function can be defined:

(5) $\qquad \ln D_O(q_{it}, x_{it}, t) = \ln q_{it} - f(\beta, x_{it}, t) - v_{it}$

where β is a vector of parameters, v_{it} is a normally distributed random error with mean zero and:

(6) $\qquad f(\beta, x_{it}, t) = \beta_0 + \sum_{k=1}^{K}\beta_k \ln x_{itk} + \frac{1}{2}\sum_{k=1}^{K}\sum_{j=1}^{K}\beta_{kj} \ln x_{itk} \ln x_{itj} + \sum_{k=1}^{K}\beta_{tk}t \ln x_{itk} + \beta_t t + \frac{1}{2}\beta_{tt}t^2$.

To account for technical inefficiency, we estimate a stochastic production function model of the form:

(7) $\qquad \ln q_{it} = f(\beta, x_{it}, t) + v_{it} - u_{it}$

where u_{it}, a nonnegative random variable associated with technical ineffi-ciency, is drawn from a truncated normal distribution (Battese and Coelli, 1992). An output-oriented measure of technical efficiency is the ratio of observed output to the corresponding stochastic frontier output:

(8) $\quad TE_{it} = \dfrac{q_{it}}{\exp(f(\beta,x_{it},t)+v_{it})} = \dfrac{\exp(f(\beta,x_{it},t)+v_{it}-u_{it})}{\exp(f(\beta,x_{it},t)+v_{it})} = \exp(-u_{it})$

Using (7), it can be shown that the technical efficiency factor (8) equals the distance function (5):

(9) $\quad \exp(-u_{it}) = \exp(\ln q_{it} - f(\beta,x_{it},t)-v_{it}) = D_0(q_{it},x_{it},t).$

The technical efficiency measure (8) can be estimated conditional on $e_{it} = v_{it}-u_{it}$. It follows from (2) and (8) that the efficiency change can be estimated:

(10) $\quad EC_i^{rs} = E(-u_{is}\mid e_{is}) - E(-u_{ir}\mid e_{ir})$

or

(11) $\quad \exp(EC_i^{rs}) = E(\exp(-u_{is}\mid e_{is}))/E(\exp(-u_{ir}\mid e_{ir}))$,

where the numerator and denominator in (11) are the estimated technical efficiency scores in periods s and r, respectively, which have values between zero and one.

Using (3), (5), and (6), the technical change index can be derived:

(12) $\quad TC_i^{rs} = \dfrac{1}{2}\left[\sum_{k=1}^{K}\beta_{tk}\ln x_{isk} + \sum_{k=1}^{K}\beta_{tk}\ln x_{irk} + 2\beta_t + 2\beta_{tt}(r+s)\right].$

From (6), the scale elasticity is:

(13) $\quad \varepsilon_{it} = \sum_{k=1}^{K}\varepsilon_{itk}$, where $\varepsilon_{itk} = \beta_k + \dfrac{1}{2}\sum_{j=1}^{K}\beta_{kj}\ln x_{itj} + \beta_{tk}t$

This can be used to compute the scale efficiency change index (4).

To estimate allocative efficiency change, ERS compared the Malmquist TFP index (1) to the logarithm of the Tornqvist TFP change index (with one output):

(14) $\quad \ln TFP_i^{rs} = \ln q_{is} - \ln q_{ir} - \dfrac{1}{2}\sum_{k=1}^{K}[(\sigma_{isk}+\sigma_{irk})\cdot(\ln x_{isk} - \ln x_{irk})]$

where σ_{itk} are the input cost shares. Any difference between the Tornqvist TFP change calculated in (14) and the Malmquist TFP index calculated in (1) must be due to allocative efficiency change. Hence, it can be shown that the allocative efficiency change is:

(15) $\quad AC_i^{rs} = \dfrac{1}{2}\sum_{k=1}^{K}\left[\left(\left(\dfrac{\varepsilon_{isk}}{\varepsilon_{sk}}-\sigma_{isk}\right)+\left(\dfrac{\varepsilon_{irk}}{\varepsilon_{rk}}-\sigma_{irk}\right)\right)\cdot(\ln x_{isk} - \ln x_{irk})\right]$

In the analysis, output is defined as "hog weight gain"—the weight added to purchased/placed hogs and existing hog inventory in the calendar year prior to the year of the survey. Feed is defined as the total weight of feed applied. The labor input is a Tornqvist quantity index comprised of paid labor and unpaid farm household labor using the labor expenditure shares for paid and unpaid labor as weights. Capital is the "capital recovery cost"—the estimated cost of replacing the existing capital equipment (barns, feeding equipment, etc.). "Other inputs" is defined as expenditures on veterinary services, bedding, marketing, custom work, energy, and repairs. Labor wages are deflated using the Bureau of Labor Statistics (BLS) Blue Collar Total Compensation index; feed prices are deflated using a weighted average of the BLS corn and soybean Producer Price Index (PPI); Capital is deflated using the BLS farm machinery PPI, and other inputs are deflated using the CPI. In the estimation, ERS rescaled all logged values of the variables as deviations from the sample mean to facilitate interpretation of the coefficients.

The appendix table presents the estimated coefficients of the stochastic production function (6). Because the variables are expressed as deviations from their means, the first-order parameters of the translog function can be directly interpreted as estimates of production elasticities evaluated at the sample means. The production elasticities with respect to feed, capital, and other inputs have plausible values and are statistically significant.

Appendix table 1
Stochastic production function parameter estimates

Parameter		Coefficient	Standard error	t-statistic
β_0	constant	0.377	0.0385	9.8
β_1	feed	0.473	0.0214	22.2
β_2	labor	0.045	0.0119	3.8
β_3	capital	0.319	0.0258	12.4
β_4	other inputs	0.280	0.0193	14.5
β_{11}		0.101	0.0323	3.1
β_{22}		-0.028	0.0148	-1.9
β_{33}		0.092	0.0609	1.5
β_{44}		0.081	0.0337	2.4
β_{12}		-0.0055	0.0188	-0.3
β_{13}		-0.0791	0.0383	-2.1
β_{14}		-0.0738	0.0268	-2.8
β_{23}		0.0060	0.0207	0.3
β_{24}		-0.0183	0.0174	-1.1
β_{34}		0.0226	0.0366	0.6
β_t	time	0.0619	0.0034	18.2
β_{tt}	time-squared	0.0046	0.0017	2.7
β_{t1}		-0.0257	0.0045	-5.7
β_{t2}		0.0012	0.0029	0.4
β_{t3}		0.0065	0.0058	1.1
β_{t4}		0.0212	0.0043	4.9
σ^2	$(=\sigma^2_v + \sigma^2_u)$	0.355	0.0300	11.8
γ	$(=\sigma^2_v + \sigma^2_u)$	0.725	0.0536	13.5
Observations		1,181		

Source: USDA, ERS using data from the 1992 Farm Costs and Returns Survey and USDA's 1998 and 2004 Agricultural Resource Management Surveys.