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Scale, Efficiency, and Risks

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The Transformation of U.S. Livestock Agriculture: Scale, Efficiency, and Risks

James M. MacDonald and William D. McBride

Abstract

U.S. livestock production has shifted to much larger and more specialized farms, and the various stages of input provision, farm production, and processing are now much more tightly coordinated through formal contracts and shared ownership of assets. Important financial advantages have driven these structural changes, which in turn have boosted productivity growth in the livestock sector. But structural changes can also generate environmental and health risks for society, as industrialization concentrates animals and animal wastes in localized areas. This report relies on farm-level data to detail the nature, causes, and effects of structural changes in livestock production.

Keywords: Livestock, dairy, broilers, hogs, fed cattle, farm structure, scale economies, contract agriculture, CAFOs, growth-promoting antibiotics

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Contents

Summary

Livestock agriculture has undergone a series of striking transformations. Production is more specialized—farms usually confine and feed a single species of animal, often with feed that has been purchased rather than grown onsite, and they typically specialize in specific stages of animal production. Today's livestock farms tend to be tightly linked to other stages of production and processing through formal contracts. While the farms are usually owned and operated by a family, they rely increasingly on hired labor. And the farms that account for most production are much larger than they were in the past.

What Is the Issue?

Strong financial pressures have driven the industrialization of U.S. livestock farms. Larger operations are able to realize lower costs and higher returns, while tighter coordination among firms at different processing stages can reduce financial risks. But growing to a more efficient scale also concentrates livestock in a limited area, and excess concentrations of manure-based nutrients can lead to increased air and water pollution. Large operations are also more prone to use antibiotics intensively in order to pre-empt the spread of animal disease and to accelerate animal growth. Extensive antibiotic use in livestock raises concerns about increased pathogen resistance and related risks to human health. This report assesses the driving forces behind structural change in fed-cattle, dairy, hog, and broiler production, and describes the effects on productivity, prices, and pollution/health risks. It concentrates on changes in the size structure of farms, their organization and production practices, and their contractual links with processors and integrators.

What Did the Study Find?

U.S. livestock production is shifting to much larger enterprises, in part because of scale economies. Between 1987 and 2002, the production locus (the farm size, in annual sales, at which one half of national production comes from larger farms and half from smaller) increased by 60 percent in broiler, 100 percent in fed-cattle, 240 percent in dairy, and 2,000 percent in hog production. Recent surveys indicate that production has continued to shift to larger operations since 2002.

While most large livestock and poultry farms are family owned and operated businesses, they are becoming more closely linked to input providers and processors through formal contracts, joint ownership of animals, and vertical integration. Tighter vertical coordination can ease management of financial risks and speed the diffusion of innovations.

Structural change has led to increased productivity and, through that, to lower commodity costs of production. For example, the largest dairy farms (1,000 cows or more) had average costs of $13.59 per hundredweight in 2005, 15 percent below the average for farms in the next largest size class (500-999 head) and 35 percent below the costs for farms with 100-199 head (estimated $20.82 per cwt). Lower costs of production typically lead to lower

wholesale and retail prices. However, structural change in livestock agriculture has had less felicitous effects as well.

Livestock wastes are becoming more geographically concentrated in the United States, and excessive applications of the nutrients contained in manure pose risks to air and water resources. There is a clear association between farm size and the concentration of manure—larger operations are more likely to ship manure to other operations and apply manure to their own fields more intensively. However, the cost to large farms of removing manure is still modest in relation to their production cost advantages, and there are a variety of ways to mitigate the risks from the concentration of manure. One such example is to reformulate the feed to reduce the amount of nutrients excreted by the animals.

Many hog and broiler operations provide subtherapeutic doses of antibiotics routinely in feed and water to promote animal growth and to prevent disease. The commercial value of such practices appears to be substantial in some stages of production, like nursing in hogs, but marginal in others. Other technologies, including expanded sanitation and testing procedures, can be substituted for subtherapeutic antibiotics in some stages of production.

Individual producers may have little incentive to take costly actions to mitigate the harmful effects of livestock industrialization. Livestock production is highly competitive, and operations with high costs may jeopardize their own survival in policing themselves. However, steps can be taken, at modest cost, that preserve the benefits of industrialized livestock production while limiting its harmful effects.

How Was the Study Conducted?

This report draws on recent ERS reports, which in turn rely on farm-level data drawn from the Census of Agriculture and from the annual Agricultural Resource Management Survey (ARMS). The Census provides an indepth source of information on levels and changes in farm size, specialization, and location, while ARMS surveys the financial conditions and production practices of farm businesses, and the well-being of farm households. Some ARMS versions contain detailed questions on the production and marketing practices, expenses, and revenues associated with specific commodities. This report draws on surveys of producers of hogs (in 1992, 1998, and 2004), dairy products (in 2000 and 2005), and broilers (2006).

Introduction

Livestock agriculture has undergone a striking transformation. Today, meat and dairy products typically originate on farms whose herds of cattle or hogs, or flocks of chickens, are much larger than in the past. These enterprises usually house a single species in buildings or in open-air pens, and provide them with feed that has been purchased rather than grown onsite. While most such farms are family owned and operated, they rely heavily on hired labor and are tightly linked to other stages of production and processing through formal contracts, alliances, and joint financing or common ownership of assets.

Most large dairy farms encompass several stages of production—in addition to producing milk, most still grow at least some of their own feed, produce and raise replacement heifers, and market dairy products and culled animals. But the beef cattle, hogs, or chickens fed on large operations are usually born elsewhere and marketed by other entities, as these grow-out farms specialize in single stages of livestock production. Producers are increasingly paid for the services that they provide, and not for the products that they sell.

This report analyzes the major shifts toward large-scale industrialized production systems in beef cattle, broilers, hogs, and milk, the four largest industries in the U.S. livestock sector. It focuses on the forces driving change and the major effects of those changes, drawing on findings from recent Economic Research Service (ERS) research that focuses on specific industries or practices. It does not assess the economics of organic or other alternative production systems, which have a growing but still small presence in the livestock sector.

Elements of Structural Change

Four elements distinguish the transformation of the livestock sector—increased farm size, changes in production technologies, increased enterprise specialization, and tighter vertical coordination between the stages of production. This report emphasizes farm size, with secondary attention to the other factors.

Most livestock are now fed in confined conditions in a barn, house, or fenced lot. Successful confinement feeding required a series of technological developments. The animals are bred to gain weight or produce milk efficiently, while also yielding specific meat or milk characteristics. Feed milling and delivery is automated, and herds and flocks are often grouped according to age and other characteristics and provided with feeds that are especially formulated for the group.

Another important feature of structural change is specialization. Some large farms produce only a single commodity, such as dairy farms that produce only milk or hog birthing operations that produce only nursery pigs, with no crop production. But such highly specialized operations are still the exception. Most large livestock operations also produce crops, but they increasingly specialize in a single stage of livestock production, such as hog finishing. Many of these operations may also loosen the links among their

different commodity enterprises; for example, a grain and hog farm may sell its grain and purchase the feed provided to its hogs.

Today's livestock farms are increasingly reliant on contracts and other agreements to govern the links between production stages. Traditionally, farmers relied on cash markets as the primary mechanism for organizing production. They borrowed money for input expenses from lenders, raised their livestock to market weight, and sold livestock and livestock products to processors for a price determined at the time of sale.

More formal and long-term contractual relationships now cover over half of all livestock production (MacDonald and Korb, 2008). Some contracts commit processors and farmers to a specific volume of production to be delivered over time, with pricing formulas based upon product quality, volumes, and market conditions. Other arrangements pay farmers a fee for growing livestock provided by the contractor. Still others specify joint livestock ownership and financing between a farmer and contractor.

Causes and Effects of the Transformation

New technologies, which underpin modern livestock agriculture, have also driven the growth in farm size. Just as a single family can now farm far more acres than in the past, with greater yields, so too can a single family raise far more animals or poultry and realize greater yields of meat or milk.

The enabling technologies are mechanical, biological, and chemical. Larger and faster equipment allows a single producer to till, seed, fertilize, spray, or harvest more acres; to house and feed more livestock or poultry; or to milk more cows in a single day. Improvements in animal breeding have led to larger animals that gain more weight or produce more milk for a given amount of feed and labor, just as improvements in seeds have done for crop productivity. Chemical fertilizers and herbicides have increased the amount of feed that can be produced, while animal pharmaceuticals reduce mortality and increase meat or milk yields under the same level of inputs.

Many large farm businesses are run by extended families of several generations, siblings, or cousins. Others may be managed by several unrelated business partners. Larger management teams allow individual operators to specialize in crop production, herd management, or marketing, so this too can lead to increases in farm size. Improvements in information technology have facilitated the management of large-scale field operations, herd performance, and finances.

New technologies often reduce costs directly, by allowing more meat and milk to be produced for a given amount of land, feed, labor, and capital. But the new technologies also create scale economies, which reduce costs more for larger operations. As a result, larger farms realize higher profits, on average, which provides a strong incentive for operators to grow larger. In turn, lower industrywide farm costs lead to lower prices for farm commodities. Lower prices can squeeze smaller farms with higher costs, causing many to exit, to grow, or to explore niche markets for differentiated products. Lower commodity prices lead in turn to lower retail food prices, such

that the benefits from technological improvements and larger farms flow to consumers.

While the transformation benefits society via lower food prices, it is not without costs. Large confined herds concentrate large quantities of manure, which must be removed from housing facilities, stored, and then moved to and spread on crop and pasture land. Animal manure contains nutrients like nitrogen, phosphorus, and potassium, and can therefore replace commercial fertilizers. But if not properly managed, manure can pose environmental risks. Excess nutrients do not contribute to further crop growth, but instead may damage air and water resources. Manure also contains bacterial pathogens that can pose direct threats to animal and human health.

Another environmental concern over increased scale is the widespread use of antibiotics. Large livestock operations tend to use animal antibiotics more intensively than smaller operations, as a way to control the spread of animal diseases and to promote faster growth. Antibiotics may enter natural resources through manure, and excessive use may contribute to increased resistance to antibiotics among animal and human pathogens.

Terminology: CAFOs and Large Livestock Operations

The environmental risks associated with the transformation of animal agriculture have led to ongoing discussion over the appropriate legal and regulatory responses to the risks. The farms that are the focus of this report are referred to as CAFOs (concentrated animal feeding operations) in those discussions, and the term is now in wide use.

In the U.S. Environmental Protection Agency's (EPA) designation, a CAFO is an animal feeding operation (AFO) that has been designated as a point source of pollutants. An AFO is a lot or facility where animals are confined and fed for 45 days or more in any 12-month period, and where crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any part of the lot or facility. The key elements in the definition are that the animals are confined; that they are fed, rather than grazed on grass or other vegetation; and that the "facility" refers to a structure, and not to an entire farm.

CAFOs are further defined by size. Large CAFOs are defined by animal inventories—at least 700 dairy cattle, 1,000 beef cattle, 2,500 pigs if they weigh over 55 pounds or 10,000 if they do not, and 30,000 broilers if the AFO has a liquid manure handling system or 125,000 if it does not. Medium-size CAFOs fall within intermediate size ranges and discharge wastewater or manure to surface waters, while small CAFOs are below the medium-size threshold but are designated by local permitting authorities as significant contributors of pollutants.[1]

The EPA's definition of a CAFO captures key elements of the transformations described above—a production process that concentrates large numbers of animals in relatively small and confined spaces, and that substitutes structures and equipment (for feeding, temperature controls, and manure management) for land and labor. While the EPA has a precise definition for a CAFO, the term is now used broadly and interchangeably with terms like industrial-

[1] The lower bound threshold for medium CAFOs is 200 dairy cows, 300 beef cattle, 750 pigs if they weigh more than 55 pounds and 3,000 if they don't, and 9,000 broilers on those AFOs with liquid manure handling systems (37,500 otherwise).

ized agriculture or factory farms to refer to a production process that features confined feeding of large herds or flocks (Pew Commission, 2008; Union of Concerned Scientists, 2008; Starmer and Wise, 2007).

Data To Analyze the Transformation

We detail structural change with data from two large farm-level USDA databases that provide a unique and highly detailed picture of livestock agriculture in the United States. One is the census of agriculture, conducted every 5 years by USDA's National Agricultural Statistics Service (NASS). The census is an indepth and comprehensive source of information on changes in farm size, specialization, and location, and we utilize publicly available census data as well as confidential farm-level census records from the period covering 1982-2002.

The second data source is the Agricultural Resource Management Survey (ARMS), an annual survey of U.S. farms that links farm financial and production data, farm marketing and production practices, and farm household characteristics and finances. ARMS has several versions. Two focus on all farm types: a personally enumerated version (#1) that provides detailed whole-farm data and a shorter mail version (#5). Other enumerated versions target large, representative samples of producers of specific commodities; they include the whole-farm and farm household questions in version 5, but also include detailed questions on the expenses, revenues, equipment and structures, production practices, and contractual and marketing relationships associated with the commodity under study. Commodity versions are directed to producers in leading States—those that collectively account for 90 percent of production—and focus on operations whose livestock or poultry inventories exceed threshold levels (10 cows, 25 pigs, 1,000 broilers).

We use data from a 2006 ARMS broiler survey, dairy surveys from 2000 and 2005, and hog surveys from 1992, 1998, and 2004.[2] There have been no fed-cattle versions of ARMS because the concentrated nature of the industry does not lend itself to the sampling strategy used in the commodity versions.[3] As a result, our analyses of fed cattle rely solely on other USDA sources, such as census records and NASS *Cattle on Feed* reports. Because of the coverage of our data sources, we emphasize developments since 1980, with some background information on earlier developments drawn from ERS reports and other studies.

[2] The reference year refers to the year of the data; that is, the 2004 survey was administered in early 2005, and obtained data for 2004. The 2004 ARMS hog version collected data from 1,168 producers in 19 States. The 2005 dairy version covered 1,462 farms in 24 States. The 2006 broiler version covered 1,568 farms in 17 States.

[3] ARMS commodity versions select representative random samples of producers of the commodity, and livestock and poultry versions have had 800-1,680 producers in a sample. But since only about 260 feedlots account for most fed-cattle production, a useful survey would need to obtain participation from nearly all major feedlots.

How Has the Structure of Animal Agriculture Changed?

Livestock production has shifted to much larger farms over time. We first describe those changes in size at the aggregate level, by comparing the hog, broiler, dairy, and fed-cattle industries. But each industry has also undergone important changes in how production is organized. Farms, while larger, are more likely to specialize in one stage of production and may be tied to other stages through complex contractual relationships. Size, specialization, and contractual relationships influence the technologies adopted by farm operators as well as the manner in which they are compensated. We describe those elements of structural change industry by industry.

Farm Size

U.S. livestock production features a highly skewed distribution of producers: many small farms raise some chickens, hogs, or cattle, but most production is on much larger farms. As such, simple measures of average size can be misleading. For example, the census of agriculture reports that 105,978 farms sold fed cattle in 2002, and that a total of 28.2 million fed cattle were sold.[4] The average farm therefore sold 266 cattle—28.2 million divided by 105,978 (table 1). But that average (the mean farm size) isn't very informative, or representative, of farms or of cattle. Most farms were much smaller than the average; 91,000 sold less than 100 cattle, and half of those sold less than 10. But most cattle came from farms that were much larger than the average: over 20 million of the cattle sold in 2002 came from farms that sold at least 5,000 head.

[4] Fed cattle are usually shipped to feedlots—which consist of many open-air pens—when they are 6-12 months old. There, they are fed a ration of grain, silage, hay, and/or protein supplements before being shipped to slaughter markets, where they account for most beef production.

As production is the underlying focus of this report, we measure farm size so as to capture the farm on which the typical hog, steer, dairy cow, or broiler resides. To do so, we identify the farm size that's at the center of the distribution of production, where half of annual production comes from larger farms and half comes from smaller farms.[5] We call that operation size the locus of production.

[5] Specifically, the median of the farm size distribution, when weighted by production (Hoppe et al., 2007; Key and Roberts, 2007). We define farm size as the number of head in a dairy milking herd, or as the number of head removed (sold) from other farms.

The production locus is considerably larger than the average (mean) farm size. While the average seller of fed cattle sold 266 head in 2002, the average animal came from a farm that sold 34,494 cattle—half of all fed-cattle sales came from operations that sold 34,494 or more and half came from farms that sold less (table 1). The production locus is larger than the average farm size in all four commodities.

In each industry, the production locus increased over time, nearly doubling for fed cattle and for broilers between 1987 and 2002 (table 2). The broiler and fed-cattle industries underwent major changes before 1987 (Gee at al., 1979; Lasley, 1983; Hart, 2003), with more recent shifts of production to larger operations occurring while vertical organization remained stable.

Consolidation in the hog and dairy sectors is more pronounced. Half of all 1987 dairy production came from farms with no more than 80 milk cows in the herd. As very large operations (with 1,000 or more cows) grew more

Table 1: Average livestock farm size, 2002

	Mean farm size	Production locus
Fed cattle sold	266	34,494
Broilers sold	265,585	520,000
Hogs sold	2,255	23,400
Milk cows in herd	99	275

Note: The mean farm size is the total number of head sold, divided by the number of farms selling the species. The production locus measures the size of farm at which half of production came from larger farms, and half from smaller.

Source: 2002 Census of Agriculture and Hoppe et al. (2007).

Table 2: Consolidation in livestock production, 1987-2002

	1987	1992	1997	2002
		Production locus (head sold/removed)		
Broilers	300,000	384,000	480,000	520,000
Fed cattle	17,532	23,891	38,000	34,494
Hogs	1,200	1,880	11,000	23,400
		Production locus (milk cows per farm)		
Dairy	80	100	140	275

Note: The production locus measures the size of farm at which half of production came from larger farms, and half from smaller.

Source: Hoppe et al. (2007).

common, the locus of production grew to 275 cows by 2002. The shifts in hog production were even more dramatic. In 1987, half of all hogs marketed came from farms that sold no more than 1,200 hogs. That locus rose to 23,400 by 2002, reflecting a major reorganization of production into stages, as well as shifts to larger operations in every stage of production.

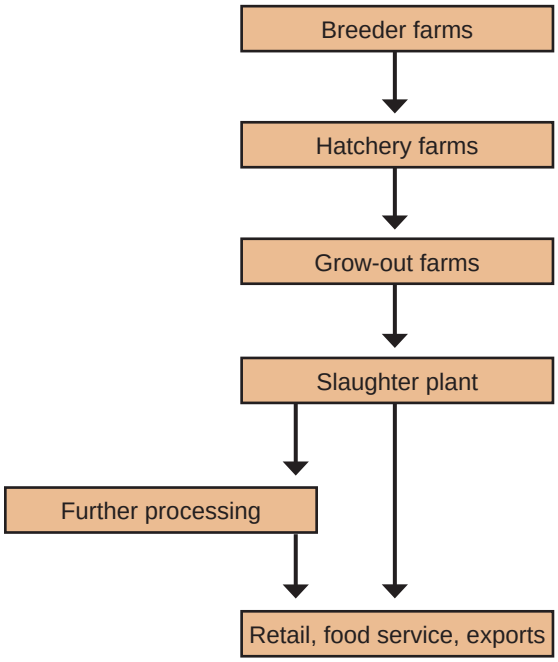
So livestock production has shifted to much larger operations over time. Other elements of structural change—specialization, contractual relationships, technology—tend to be specific to each commodity.

Broilers

Broiler production has a distinctive organization (fig. 1). Firms called integrators own hatcheries, processing plants, and feed mills. Integrators then contract with farmers to "grow out" broiler chicks to market weight, and to produce replacement breeder hens for hatcheries. Under a production contract, the integrator provides the farmer/grower with chicks, feed, and veterinary and transportation services, while the farmer provides labor, capital in the form of housing and equipment, and utilities. The birds are sent to slaughter after 5-9 weeks on the farm, and the farmer is paid for the growing services provided.

The organizational innovations developed in broiler production have been adopted in other commodities, but the methods of grower compensation remain distinctive (MacDonald, 2008). Growers receive a base payment for each flock of birds and an incentive. The incentive payment depends on the grower's performance, relative to other growers delivering birds to the integrator during the same period. Those growers who can convert feed to meat more efficiently, while having fewer birds die, realize higher payments.

Figure 1
Organization of broiler production



While contracts in other commodities may specify incentive payments, they are set against fixed standards and not relative performance.

The industry's current form developed during the 1950s and 1960s as integrators devised grow-out contracts, built production complexes, and developed breeding flocks (Hart, 2003; Lasley, 1983). Early grow-out farms weren't very large, but that changed (fig. 2). In 1959, farms producing at least 100,000 broilers in a year accounted for 28.5 percent of production. That share doubled by 1969 and continued to grow rapidly until the 1990s. Today, hardly any commercial growers produce fewer than 100,000 broilers in a year. The industry's basic organization remains unchanged, but production continues to shift to larger operations, from a production locus of 300,000 broilers in 1987 to 520,000 in 2002 and 600,000 by 2006.[6]

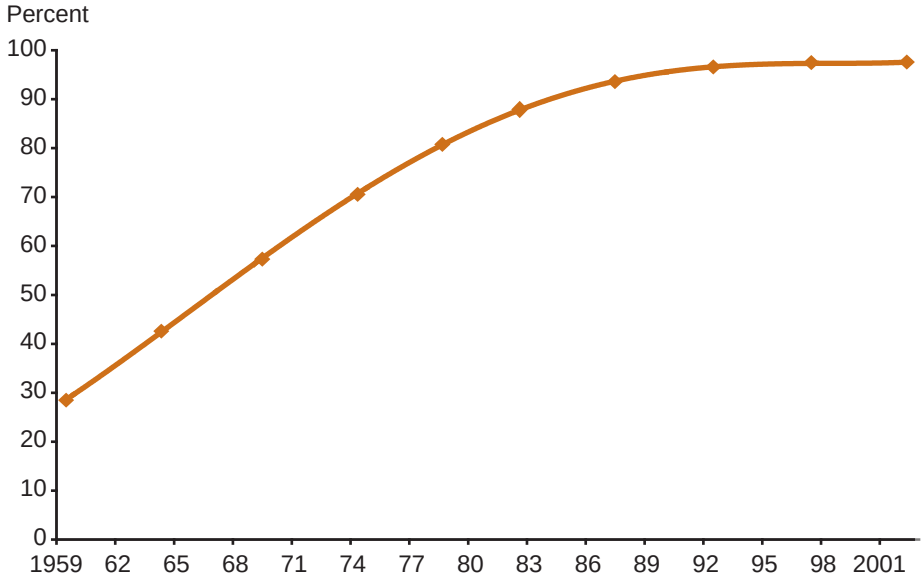
Broiler houses are the grower's major expense. A pair of new houses can cost from $350,000 to $750,000, depending on size and location. Because of the significant initial investment in housing, lenders are important, both for funding and advice. Housing and equipment improvements are an important source of innovation and cost reduction in the industry.[7]

Measured by the gross farm income received by growers, broiler grow-out is still dominated by small farms. A farm at the 2006 production locus (600,000 broilers) would generate fees from broiler production of about $156,000 if it received the industry's average payment of 26 cents a head (MacDonald, 2008). Most realize additional farm revenues from crop production, but broilers account for most of gross income, and the production locus farm would likely realize a gross farm income, from all sources, of $180,000-$200,000. That is not a large farm—for agriculture as a whole, two-thirds of commodity sales come from farms with at least $250,000 in gross income.

[6] Table 2. The 2006 estimate is drawn from the 2006 ARMS broiler version.

[7] Breeding improvements provide a major source of productivity growth, but improved lighting and climate controls can reduce mortality and improve feed efficiency in flocks.

Figure 2
Share of broiler production held by farms selling at least 100,000 broilers



Source: U.S. Census of Agriculture.

Hogs

Hog production has been transformed in the last two decades. Today, operations tend to specialize in single stages of production and are linked to one another by integrators using production contracts. However, there are some important differences between broiler and hog organization.

Hog production can be described in three stages (fig. 3). In the farrowing stage, sows bred by natural or artificial insemination produce nursing pigs, which are weaned at 2-3 weeks of age, when they weigh 8-12 pounds. In the nursery stage, weaned pigs are fed for about 6 weeks until they weigh 40-55 pounds. Finally, in the finishing stage, feeder pigs are fed for up to 6 months until they reach market weights of 250-290 pounds.

In 1992, most market hogs still came from independent farrow-to-finish operations that combined all three stages of production and that sold their hogs to meatpackers through cash markets (table 3). Today, most production is organized by integrators who coordinate production among growers specializing in separate stages (Martinez, 2002). Some combine farrowing and nursery stages into a farrow-to-feeder operation, and some have broken the nursery stage into two. Most market hogs now come from feeder-to-finish operations that receive feeder pigs from integrators (table 3).

Some integrators organize hog production exactly as broiler integrators do—they own packing facilities and feed mills and they contract with growers to raise hogs. Others focus on organizing contract hog production, while purchasing feed from mills and selling their hogs to packers under cash sales or marketing contracts. About 40 major integrators now coordinate production of 75 percent of the 100 million hogs marketed annually in the United States, with smaller integrators and traditional producers accounting

Figure 3
Organization of hog production

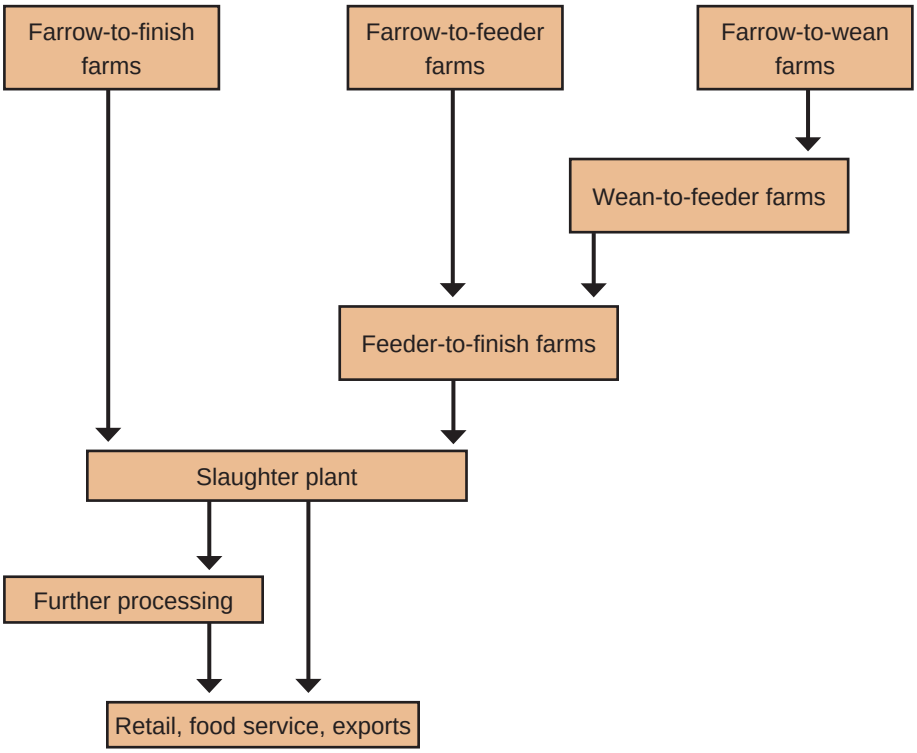


Table 3: Structural change in market hog production, 1992-2004

Type of operation	1992	1998	2004
Farrow to finish			
Percent of operations	54	49	31
Percent of market hogs removed	65	38	18
Percent of feed home-grown	55	51	38
Percent of hogs removed under contract	na	na	na
Market hogs removed (head per farm)	886	1,239	1,472
Feeder to finish			
Percent of operations	19	31	40
Percent of market hogs removed	22	55	77
Percent of feed home-grown	45	22	15
Percent of hogs removed under contract	5	40	67
Market hogs removed (head per farm)	945	2,589	4,656

Note: Other operations, such as wean-to-finish, account for small shares of market hogs.
na = Not available.
Source: Key and McBride, 2007.

for the rest. Major integrators typically contract with providers of genetics services to help improve their breeding herds (Hart, 2003).

Farrowing and nursery operations often specialize, with no commodities other than hogs, and they can be very large. The locus of farrow-to-feeder pig production was 50,000 pigs removed in 2004, and the corresponding production locuses were 25,000 pigs removed on wean-to-feeder operations and 60,000 on farrow-to-wean operations.[8]

[8] Using data from the 2004 hog version of ARMS. Few of these specialized types existed in 1987, when market hogs accounted for a high share of all hogs and pigs removed from farms. The reorganization of production, and the large numbers of pigs removed from the operations, accounts for some of the dramatic increase shown in table 1. Nevertheless, hog finishing operations have also gotten larger over time.

Hog finishing operations usually operate under a production contract with an integrator, who provides them with feeder pigs, feed, and associated services, while the grower provides housing, labor, management services, and utilities. The grower receives a fee for services, which includes a flat payment for each hog or hog space, and may also have incentive clauses tied to feed efficiency.

Finishing operations have gotten substantially larger—mean annual removals increased from 945 to 4,656 hogs between 1992 and 2004 (table 3). Most hogs come from much larger farms, and the 2004 production locus fell at 12,000 hogs. Finishing operations are usually diversified farming businesses with crop and hog production. Fees from production contracts form a smaller share of gross farm income on contract hog farms than on broiler farms (because of substantial crop production on hog farms), and the hog farms tend to have substantially larger gross farm income than broiler operations (MacDonald and Korb, 2008). While the crops grown on hog finishing operations are not generally fed to the hogs, the hogs' manure is used to fertilize the farm's cropland.

Capital requirements for a large confinement hog enterprise can be substantial. Finishing houses can cost $100-$140 per hog space, depending on local construction costs and the nature of the equipment needed. For a 1,100-head facility, that suggests an expense of $110,000-$150,000 per house. Most operations have more than a single house, and an operation at the production locus (12,000 hogs) would need 6 houses, and an investment of $600,000-$900,000. For operations in the farrowing stage, capital costs can run to $1,000 per sow (Hart, 2003).

Dairy

Vertical coordination in dairy farming hasn't changed much; most farms still market their milk through dairy cooperatives. But production is shifting to much larger farms, and there have been some important changes in how farms organize themselves.

The production locus on dairy farms rose from 80 cows in 1987 to 275 by 2002 (table 2). That comparison may even understate the nature of the shift because dairy farms cover such a wide range of sizes. Farms with at least 1,000 head in the herd accounted for 10 percent of all cows in 1992, but that share increased to 29 percent by 2002 and to 36 percent by 2007 (table 4). Most of the recent increase has occurred on farms with at least 3,000 head, according to data from the census of agriculture (MacDonald et al., 2007).

The shift toward larger farms is closely associated with some important regional shifts. Very large dairies first appeared in the West, particularly in California but also in Arizona, Idaho, New Mexico, Texas, and Washington. Milk production in those States has increased rapidly, while changing little in the traditional dairy States of the upper Midwest and Northeast, and declining elsewhere in the country. Today, very large farms account for most Western production, while production in all dairy States is also shifting toward larger herds (MacDonald et al., 2007).

Table 4: Size structure of dairy farms, 1992-2007

	1992	2000	2007
	Percent of cow inventory		
Herd size (milk cows)			
1-49	20.4	12.0	7.4
50-99	29.0	22.0	15.4
100-199	19.0	18.0	13.4
200-499	13.7	16.7	14.9
500-999	8.0	12.0	12.5
1,000+	9.9	19.3	36.4

Note: Herd size refers to all dairy cows on an enterprise, including dry cows but excluding calves, heifers, and bulls.

Source: USDA/NASS *Milk Production*, February Issue (1992 and 2000); USDA/NASS *Farms, Land in Farms and Livestock Operations* (2007).

Increased size also led to important changes in dairy farm organization. Whereas traditional smaller dairies relied largely on homegrown feed and pasture forage, large farms purchase a considerable amount of feed—many in Western States purchase all or most of their feed. Some large operations ship their calves to other farms, and contract with those farms to raise them to be returned as replacement heifers. And while most midsize and large dairy farms continue to be owned and operated by a family, they rely extensively on hired labor for milking crews, herdsmen, and cropworkers.

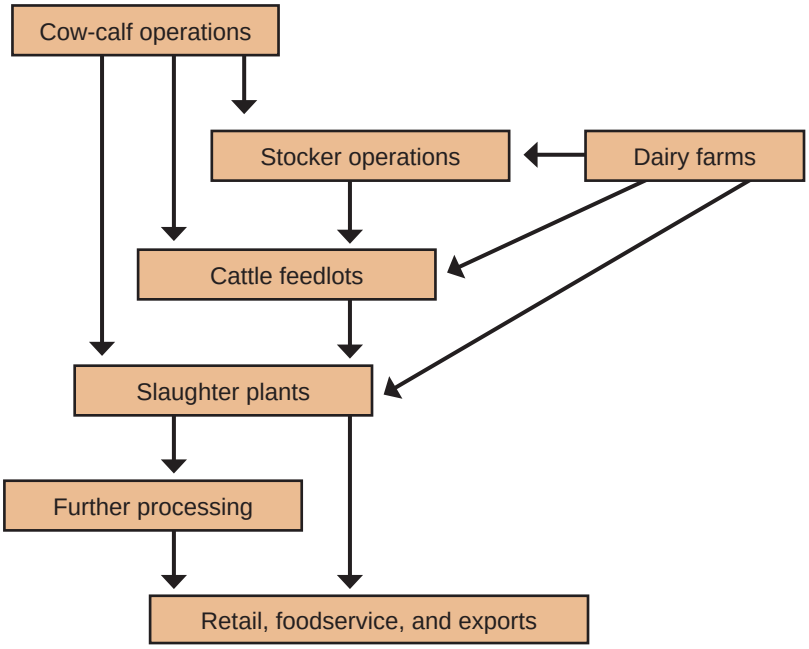
Dairy pricing, and therefore operator compensation, has always been complex, and it remains so today. Farmers are not paid for their services, as broiler and hog growers are under production contracts, but are still largely paid for their products—milk and culled cows. Milk prices can vary, even within regions, with differences in supply and demand for dairy products and because of government policy. But farmers also increasingly receive payments tied to the characteristics of the milk that they produce; most receive premiums for higher levels of butterfat, protein, and other solids, and receive less for milk with high counts of somatic cells, an indicator of bacteria.

Beef

Producers specialize in distinct stages within the cattle industry, and those stages are organized and coordinated differently (fig. 4). The cow-calf stage of beef production includes many farms: 758,000 operations had beef cows in 2007, 10 times as many as had dairy cows. Moreover, there are few really large cow-calf operations. Western cow-calf operations tend to specialize in cattle raising, while those in the Midwest and South tend to combine a cattle business with a crop enterprise. While production has shifted to larger operations over time, cow-calf production is still spread over many modestly sized farms and ranches.

Most calves are weaned between 6-9 months of age, when they weigh 400-700 pounds. They may remain on pasture at the farm or ranch, or be sent to pasture elsewhere. Most move to specialized stocker or backgrounding operations that add 200-400 pounds of weight over 3-8 months. Such operations provide a marketing function by assembling groups of animals of consistent quality, and they can also improve quality through health and nutritional management of the cattle, often with a combination of pasture

Figure 4
Organization of beef production



forage and feed.[9] Most cattle will eventually be moved to feedlots, where they are confined outdoors in pens with other feeder cattle and fed a high-energy ration (RTI, 2005). Feedlots are the industrialized stage of the sector.

Until the mid-1960s, most feeding occurred in small "farmer-feedlots." These farmers, usually in the Midwest, raised their own feed for cattle that they purchased and fed to market weight after harvest, when they had spare time. In 1964, feedlots with capacities of less than 1,000 head handled over 60 percent of U.S. fed-cattle marketings.

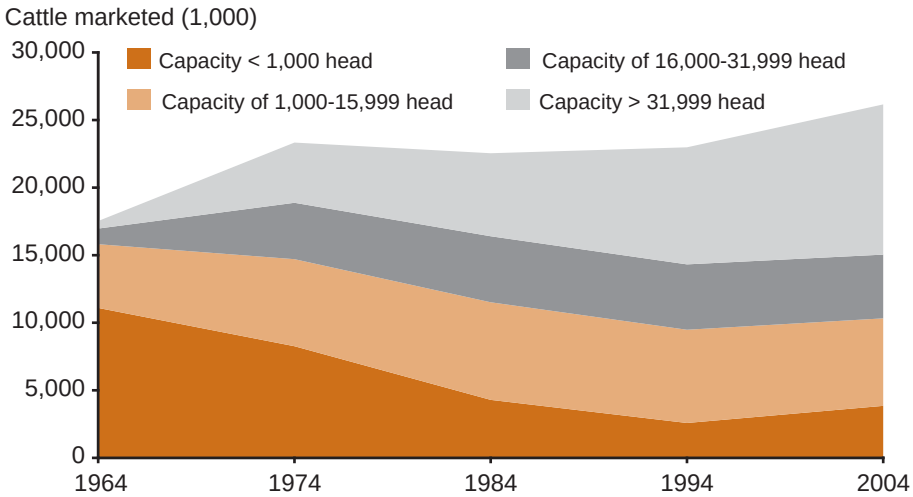
Cattle feeding underwent major changes in the 1960s and 1970s. Production shifted from farmer-feedlots to commercial cattle feeding businesses in the Great Plains and the West (fig. 5). Large commercial feedlots purchase all or most feed ingredients and maintain feedmills, feed delivery systems, and information systems onsite. They employ nutritionists, veterinarians, and sales and management staff, and they buy and sell cattle weekly.

While there are still many farmer-feedlots across the country, such operations feed only one-third as many cattle as they did in the 1960s. Meanwhile, commercial feedlot production has concentrated in larger businesses. In 2007, 262 feedlots had a capacity of at least 16,000 head, and they handled 60 percent of U.S. fed-cattle marketings. The largest can feed 100,000 cattle at a time. Some are owned by meatpackers, some are part of larger diversified firms, and others are specialized cattle feeding businesses, sometimes with a feed production enterprise as well.

Cattle feeders own cattle and market them under their own account, but they also "custom-feed" cattle for others through production contracts. Under those contracts, feeders are paid for their services and an owner may market the cattle or have the feeder handle that service as well. Contractual relation-

[9] Two-thirds of beef calves are born in February, March, or April, so producers can stretch the beef supply out over the year by varying ages for weaning and backgrounding.

Figure 5
Fed cattle shift to large feedlots



Source: USDA/NASS, *Cattle on Feed.*

ships are becoming more complicated as backgrounders or cow-calf operations enter into joint ownership of cattle with feedlots or with processors. Joint ownership provides more sources of financing, and also ties compensation more closely to cattle quality at each stage of the production process.

Drivers of Structural Change: Technology and Scale Economies

Production has shifted to much larger farms in the broiler, dairy, fed-cattle, and hog industries. To what extent do costs account for those shifts? If large farms do realize cost advantages, do they follow from technological scale economies? How large are the scale effects, and is there a level beyond which further size increases have little impact on costs? In evaluating the evidence for each commodity, we find that scale-related cost advantages are important factors in structural change, although the magnitude of the advantages, and the strength of the evidence, varies across commodities.

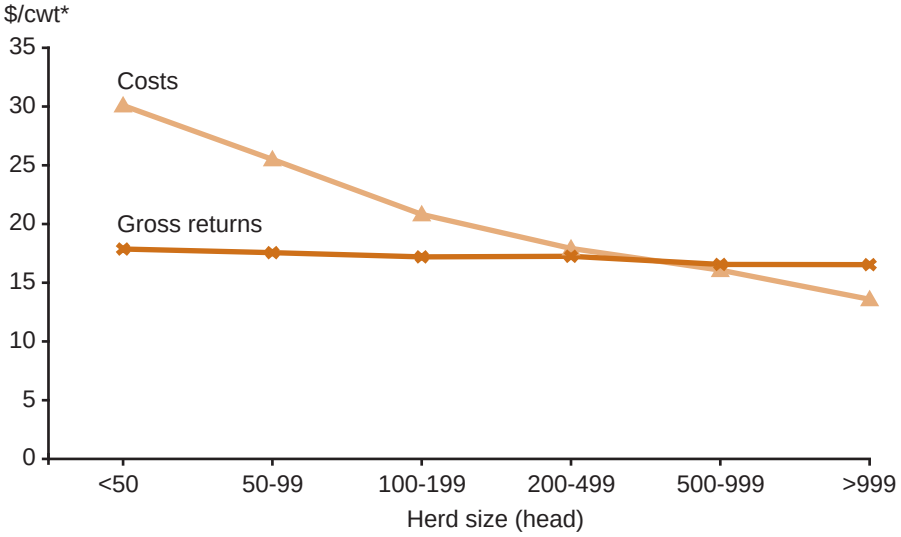
Multiple ARMS hog and dairy surveys provide data to support detailed cost analyses, for periods in which each sector was undergoing important changes. Our evidence for fed cattle and broilers is more limited. We have a single ARMS broiler survey and no fed-cattle survey, and major structural change occurred in the more distant past for those two commodities.

Dairy

ERS estimates of dairy costs of production show that larger farms had substantial cost advantages, on average, over smaller operations (see box "Measuring Hog and Dairy Costs and Returns" for details on how the estimates are constructed) in 2005. Farms in the largest size class—herds of 1,000 or more milk cows—had average costs of $13.59 per hundredweight in 2005 (fig. 6), about 15 percent below the average for farms in the next largest size class (500-999 head) and 35 percent below the estimate ($20.82 per cwt) for operations with 100-199 head. Average costs are much higher among even smaller operations.[10]

One source of scale economies in dairy is capital equipment—large and highly automated milking parlors and feed delivery systems. Structures

Figure 6
Average costs and gross returns in 2005, by size of dairy herd



* Production cost per hundred pounds of milk produced on the farm.
Source: MacDonald et al. (2007).

[10] Similar patterns appear for the 2000 data. Further details and analysis can be found in MacDonald et al. (2007), McBride and Greene (2007), and Mosheim and Lovell (2009).

Measuring Hog and Dairy Costs and Returns

ERS estimates include all costs and returns associated with production, including those borne by integrators and landlords as well as those borne by farm operators. Gross returns include cash receipts received from the sale of hogs, pigs, or milk; the value of livestock removed under production contracts; and the value of secondary products such as culled animals and manure. Cash receipts are reported directly in ARMS. Commodities removed under a production contract are valued using production reported in ARMS and State-average prices. Actual cash receipts are reported for some secondary products, while others are valued with reported production and State-average prices.

Some components of commodity production costs—like purchased feed, feeder animals, hired labor, bedding and litter, and fuels and electricity—are reported directly in the surveys. But significant implicit expenses are also incurred on farms. For example, farm operators and their families contribute their labor to the enterprise, but since that labor often does not receive a wage, an explicit expense can't be recorded. Nevertheless, the opportunity cost of the labor should be recognized since those hours could have earned income in another activity, such as working off the farm.

ERS estimates an opportunity cost of unpaid labor, based on the off-farm labor earnings of farm operators as recorded in version 1 of ARMS, which provides data on the annual hours worked and wages and salaries earned off-farm by respondents.

Hog and dairy farms can also incur implicit expenses for homegrown feed and for capital equipment and structures. ERS uses market price data from other USDA sources to value the quantities of homegrown feed and forages produced on the farm and fed to animals, as reported in ARMS. ERS also estimates the annualized cost of replacing the capital used for livestock housing, feed and manure storage structures and handling equipment, milking facilities, tractors, and trucks, as well as the return that the capital could have earned in an alternative use. Survey respondents report the type, capacity, and characteristics of different types of equipment and structures in the enterprise. ERS analysts add secondary information on acquisition prices and useful lives of various types of capital, and interest rates, to estimate annual capital replacement costs.

ERS reports gross returns and total costs, per cwt of milk for dairy and per cwt of liveweight gain for hogs. Total costs are sorted into operating and overhead costs. Operating costs are further sorted into feed and other costs, while allocated overhead includes labor, capital recovery, the implicit rental rate of land, taxes and insurance, and general farm overhead. Further details, and data, are available at www.ers.usda.gov/Data/CostsAndReturns/

are a second: modern free-stall barns allow large operators to realize lower housing costs per cow. Large, automated manure removal and storage systems also appear to reduce costs of manure handling, per ton, compared to smaller and less automated systems. These facilities allow larger operations to greatly economize on labor and capital costs, per pound of milk produced, by intensively utilizing their equipment and structures. On many small dairy farms, facilities are utilized at less than full capacity, especially if the facilities are nearing the end of their useful life or if the operator is nearing retirement, with no succession plans.

Small farms tend to be located in regions with higher milk prices, so they realize slightly higher average gross returns to milk production than large farms (fig. 6).[11] However, costs still exceeded gross returns, on average, for small farms in 2005, while farms with at least 500 head had gross returns that exceeded their costs.

[11] Milk revenues account for 90 percent of the gross returns from dairy production, with most of the remainder coming from byproducts—sales of cows culled from the herd and the value of the manure produced by the herd.

ERS cost-of-production accounts allow us to assess several different measures of the financial returns to dairy production, and to compare them across farm sizes (fig. 7). Operating costs include expenses for feed, bedding and litter, fuels and electricity, and veterinary services. While farms may fail to realize enough revenue to cover operating expenses over short periods (because of unforeseen emergencies), they won't stay in business for long unless they cover such expenses. No more than 15 percent of farms in each size class failed to cover operating expenses (fig. 7).

A second standard is to compare gross returns to all costs except those for capital recovery. Farms that meet that standard realize enough revenue to cover all operating expenses, all taxes and insurance on the operation, and the opportunity cost of the operator's time. Existing dairy farms have already put their capital structure and equipment in place; if they are not earning enough to pay for the replacement of that equipment, they can still continue

Figure 7
Financial performance, by size of dairy farm

Source: 2005 Agricultural Resource Management Survey, version 4.

operating until the equipment wears out, which can be a long time.[12] Only about 20 percent of farms with fewer than 100 head meet this standard, while 50-70 percent of midsize farms (100-499 head) and 80-90 percent of large farms do (fig. 7). The smallest dairy operations face seemingly strong pressures to exit, as an operator could earn higher returns to his or her labor elsewhere.

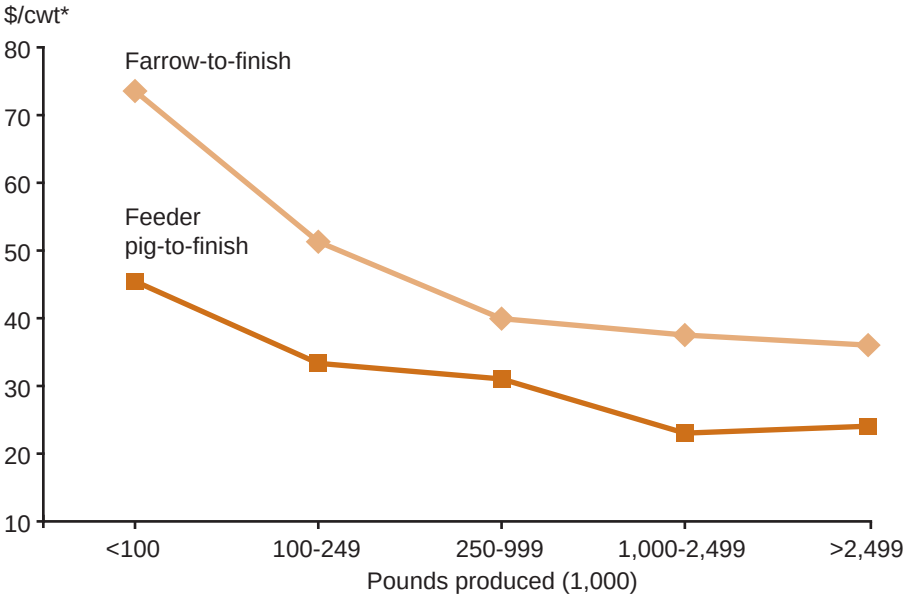
Finally, total costs include capital recovery costs. Farms that cover total costs earn more for their operators' labor than the operators can earn elsewhere, and return more on the farm's capital investment than could be earned elsewhere. Over 70 percent of the largest dairies had gross returns that exceeded total costs, compared to less than 10 percent of small farms and less than 40 percent of midsize farms (fig. 7). That pattern of performance provided strong incentives for existing dairies to expand or to exit, and for producers entering the business to enter at a large size.

Hogs

Key and McBride (2007) and McBride and Key (2003) provide a comprehensive overview of hog production costs and productivity. In 1998, large hog operations had substantial productivity advantages over smaller operations—they used much less feed, labor, and capital for every hundred pounds (cwt, again) of hog production.[13] Many of the highest cost operations closed after 1998, and more efficient small operations were still at a productivity disadvantage in 2004.

Productivity differences translate into important cost advantages for larger operations. Production costs, for farrow-to-finish and feed-to-finish operations of different sizes in 2004, are compared in figure 8. Costs are expressed in dollars per cwt of weight gain: for example, a finishing operation that receives 50-pound pigs and feeds them to 250 pounds would realize 2 cwt

Figure 8
Hog production costs in 2004, by size and type of operation



* Production cost per hundred pounds of weight gained while on the farm.
Source: Key and McBride, 2007

[12] A principal reason why structural change occurs over long periods is because it is economic to operate many high-cost farms, as long as revenues still cover variable costs.

[13] On average, feeder-to-finish operations that removed 5,000 or more hogs in 1998 used 247 pounds of feed and 0.12 labor hour for every 100 pounds of hog weight gain, compared to 342 pounds of feed and 0.39 labor hour for operations that removed 500-2,000 hogs (McBride and Key, 2003).

(200 pounds) of gain for each market hog removed. ERS cost-of-production estimates include all costs incurred, whether borne by the integrator or the grower. Feeder pig costs are excluded from the estimates of costs at feeder-to-finish operations, so one should not compare costs across types; instead, the proper comparisons are among different size classes of each type.

Among farrow-to-finish operations, costs fell quite sharply, from over $70 per cwt to just over $40, as annual output expanded from 100,000 pounds of liveweight production to 1 million pounds (or from 400 hogs to 4,000, for 250 pound hogs). Costs continued to fall after that threshold, but more modestly, to $36 among operations with at least 2.5 million pounds of liveweight production (10,000 hogs).

Feeder-to-finish operations also show a strong association between costs of production and the operation's size. Average production costs fell from $45 per cwt, at 100,000 pounds of production, to $23 per cwt at 2.5 million pounds. Beyond that threshold, costs vary little (fig 8).[14] While there is a range of actual costs around the averages, the evidence from the hog surveys indicates that large industrialized hog operations hold substantial cost advantages over smaller farms. The scale effects may be even stronger in more complex statistical analyses that control for location, production practices, and operator characteristics (McBride and Key, 2003: McBride, Key, and Mathews, 2008).

[14] If we assume that a feeder-to-finish operation takes 50-pound pigs and feeds them to 250 pounds, then 1 million pounds of liveweight production will correspond to 5,000 hogs.

Broilers

Broiler production requires a significant investment in physical capital. Farms use specialized broiler houses, which include automated equipment for providing feed and water to the birds as well as sophisticated climate control systems. Modern farms also use mechanized equipment to gather broilers for shipment to processing plants and to remove litter from the houses. Scale economies arise from innovations in the design and utilization of structures and equipment, which also allow for more effective use of labor. While scale economies in poultry processing are large and extensive (Ollinger et al., 2000), those in broiler grow-out are modest, but they have increased over time.

The most common broiler house built in the last decade covers 20,000 square feet (40 feet wide and 500 feet long).[15] Given typical flock turnover, a single house of that size can produce 115,000-135,000 birds in a year, depending on bird size. However, further economies in the use of feeding and watering equipment, as well as litter removal and storage, can be realized by operating houses in pairs, which raises the minimum efficient scale of an operation to 230,000-270,000 birds a year. Few houses built in recent years are less than 20,000 square feet, and an operation with production well below 230,000 head would see noticeably higher costs arising from limited capacity utilization, or from the higher per-unit costs of building smaller facilities.

[15] The measures described are drawn from the 2006 ARMS broiler survey.

Some grow-out operations have up to 18 houses, but the major technology-related scale economies lie in house size and feeding equipment, so most of the available advantages of scale can be realized at what is a modestly sized operation today. Almost all production in the 1950s and 1960s came from much smaller operations than today. The development of new scale econo-

mies in grow-out houses and equipment has driven the gradual increases in broiler farm size.

Beef Cattle

Cattle feeding requires a significant investment in physical capital. Feedlots use mechanized equipment for feed milling, handling, and storage, and for manure removal, storage, treatment, and transport. They use vehicles for transporting animals, pens for holding them, and other specialized structures (Martin, 1979). Equipment and structures are subject to economies of scale from two sources. First, although larger facilities cost more than smaller facilities, their cost per unit of capacity is often lower. Second, once they are built, the fixed costs of the capital can be spread across more animals if the lot can operate near capacity, so that automation favors year-round intensive use of facilities. As a result, commercial feedlots became year-round operations, while farmer-feedlots often operated seasonally.

Krause (1991) reviewed studies of feedlot scale economies that were performed during the industry's transition in the 1960s and 1970s from small farmer-feedlots to large commercial operations. Two findings stand out, and are common to other studies of livestock feeding costs. First, substantial scale economies, up to a threshold size level, derive from more intensive use of equipment, structures, and labor. Second, above the threshold there were a wide range of large sizes over which costs varied modestly, and did not rise. This bears out the wide range of commercial feedlot sizes that we see persisting to this day.

Our best evidence and most complete data—that for hogs and dairy—shows that costs fall sharply as enterprise size increases, up to some threshold level. Technological scale economies, associated with structures and equipment, seem to account for the cost advantages. The broiler and fed-cattle industries also appear to be subject to size-related cost advantages over some range of production. Moreover, none of the livestock industries appear to display a unique optimal size, once scale economies are exhausted. Farms with 2,000 dairy cows have average costs similar to farms with 1,000 cows, as do farms with 12,000 or 5,000 finishing hogs. Farms can get quite large, without realizing scale diseconomies.

Other Drivers of Structural Change

This report has focused on technological economies of scale as a major factor in structural change, and has therefore presented data on the links between the size of an operation and costs. But other factors may also matter. We first focus on complementarities among stages—the possibility that large processing plants may give rise to large livestock farms, independent of any scale economies. We next discuss the argument that Federal commodity payments for feed grains implicitly subsidize large livestock operations, thereby causing structural change. Finally, many small farms continue to survive and prosper despite the cost advantages accruing to large farms, and we evaluate some factors behind their survival.

Complementarities Among Stages

The shift to larger livestock farms has occurred at the same time that livestock and poultry slaughter plants became much larger so as to realize scale economies and lower processing costs (MacDonald et al., 2000; Ollinger et al., 2000). Larger, more automated processing plants must obtain large and steady flows of uniform animal and bird types if they are to realize any potential scale economies (RTI, 2007a). Different strategies have been devised to manage those flows, but they all rely on tighter coordination of the production process. They may also encourage larger farms.

Hog and broiler integrators achieved steady flows of uniform animals to their plants by directly controlling the production process. They time chick and pig placement on grow-out farms so as to optimize flows to processing plants 6 weeks (small broilers) to 6 months (hogs) later. They can also realize uniformity by controlling the genetics of their pigs and chicks and by controlling the length of the feeding period.

Large cattle slaughter plants and large feedlots emerged during the 1970s and 1980s in the same geographic areas of the Great Plains. Beefpackers do not use the tight system of integration and production contracts that broiler and hog firms use. Instead packers use a combination of packer ownership and financing, long-term marketing agreements, and cash market purchases to manage cattle flows to plants.[16]

[16] Large packers and feedlots maintain long-term relationships even for cash market sales, conducted weekly.

The coincident timing of structural changes to large processing plants and large production facilities suggests a complementary relationship between them. Each needed an opposite party willing to provide or receive large flows of uniform animals, shipped on a regular basis, so that they could reduce the risks of large-scale investment. And each needed some mechanism, such as contracts or other long-term commitments, to make the process work. In that sense, the emergence of large, capital-intensive processing plants may have encouraged a shift to larger and more specialized farms, aside from any internal scale economies in those operations.

Input Prices

Large and small farms use different combinations of inputs. For example, large dairy farms use more purchased feed and less homegrown feed and pasture forage than small farms. These differences imply that input price

changes can affect farms differently. For example, increases in purchased feed prices or wage rates for hired labor would raise costs more at large farms than at small farms, because those inputs typically account for higher shares of large farm costs.

Two recent reports argue that Federal commodity programs reduce prices for a particular input, purchased feeds, and that those reductions drive structural change (Pew Commission on Industrial Farm Animal Production, 2008; Union of Concerned Scientists, 2008). Specifically, they assert, drawing on Starmer and Wise (2007), that policy encourages increased production of feedgrains, that the increased production substantially reduces feedgrain prices, and that the buyers of purchased feed benefit from lower feed prices. While producers of homegrown feed have been the direct recipients of commodity payments, the reports argue that the payments have not been large enough to offset lower commodity prices, so that commodity programs have largely benefited large-scale animal feeding operations at the expense of smaller diversified crop and livestock farms.

However, the size-related differences in production costs that are summarized in figures 6-8 cannot be attributed to the effects of commodity programs. In developing cost-of-production estimates, ERS prices homegrown feed at its market value—that is, the price that homegrown feed would have drawn as feed in regional feed markets—and does not attempt to estimate the actual cost of producing the feed. To the extent that larger operations realize lower feed costs in ERS estimates, it is because they use less feed per cwt of production and not because purchased feed costs them less.

But even if commodity policies reduce purchased feed prices, there's no reason why that should alter the size structure of livestock farms. No technological barrier prevents small farms from replacing homegrown feed with purchased feed: if purchased feed prices are lower than the costs of growing feed, then small livestock operations can simply buy feed and realize the same savings as large farms.[17] A difference between the price of purchased feed and the cost of homegrown feed does not explain why feeders build large rather than small operations.

[17] While large hog and dairy operations are more likely to purchase all of their feed, most small hog operations also purchase all feed, as do many small dairy farms.

Many Small Operations Survive

Even as cattle feeding has shifted to large commercial feedlots, small feedlots of less than 1,000 head capacity still feed nearly 4 million cattle a year, and their share of the fed-cattle market has stabilized or even grown lately (fig. 5). Similarly, while large dairy farms hold substantial cost advantages over smaller farms, and production continues to shift to larger operations, many small farms remain in business and some are profitable (fig. 7).

Some of the size-specific variation in farm financial performance reflects unexpected events--related to weather, disease, accidents, or market changes—that temporarily affect revenues or costs. But other factors may be more systematic. Farms may persist in spite of poor financial performance because operators are willing to accept lower earnings than they could earn elsewhere. Others may have underutilized assets, in capital or the farm operator's time, that would not otherwise be used except in the livestock operation (this is a traditional reason for feeding small lots of cattle outside of busy

growing seasons). In this case, ERS estimates may overstate the true opportunity cost to the enterprise of using the inputs.

Some farms can realize substantially higher revenues than others because they are in a favorable location, or because they produce a niche product. For example, large hog operations usually produce hogs bred and fed to gain weight quickly and efficiently. The low-cost pork derived from those animals may not have the flavor or texture that some buyers seek. Smaller operations that specialize in specific breeds may have higher production costs, but can still prosper if they find enough buyers willing to pay a premium for a differentiated pork product.

Substantial differences in managerial and technical skills may also affect farm financial performance. Better farmers likely maintain lower costs and perform better financially. Some small operations remain profitable simply because their operators are unusually good at their jobs.[18]

[18] Tauer (2001) and Tauer and Mishra (2006) argue that most of the observed difference in cost among dairy farms reflects differences in managerial quality, not technological scale economies. They argue that operators of larger farms tend to be better dairy farmers, able to achieve systematically lower average costs. However, dairy production is shifting to larger farms, and the largest are much bigger than in the past. In order for differences in managerial skills to account for these shifts, there has to be a large increase in the number of highly capable dairy farm managers, or a new technological development that allows capable managers to handle much larger farms. While these possibilities may have occurred, there is no systematic evidence that they have.

Impacts of Structural Change

Livestock production is shifting to much larger farms. Farms are specializing in stages of livestock production, and contracts are increasingly being used to coordinate the actions of farmers in different stages. These shifts, often quite dramatic, have important impacts. To the extent that scale economies and greater efficiency are driving the shifts to large size and to contract production, then the shifts will lead to improved agricultural productivity—more meat and dairy products for a given commitment of land, labor, and capital resources—and lower wholesale and retail prices for meat and dairy products.

But structural change leads to other impacts as well. Structural changes in farming and processing, toward larger plants and fewer buyers, have occurred in tandem. Larger farms concentrate animals in small areas, heightening pollution risks from excess manure nutrients in land, water, and air resources. Finally, farmers with large herds or flocks in confined areas are more vulnerable to the rapid spread of animal diseases, which they combat with the widespread use of animal antibiotics. This has led to concerns that such widespread use creates human health risks if animal antibiotics accelerate the development of resistance among human pathogens.

Productivity and Prices

Major structural changes often generate large increases in productivity. Increased productivity reduces production costs, leading to lower commodity and retail prices. Productivity improvements also free land, labor, and capital resources that can then be used to produce more of the commodity or of other goods and services.

The broiler industry improved its productivity greatly as its vertically integrated system of production was introduced in the 1950s and then refined through improvements in breeding, feed formulations, housing, and management practices. In 1955, when modern integrated broiler complexes were being introduced (Hart, 2003), it took 73 days to produce the average broiler, which weighed 3.1 pounds, and every 100 pounds of broiler production required 285 pounds of feed and 4 hours of labor. By 1980, it took 52 days to produce a broiler that weighed about 4 pounds, and every 100 pounds of broilers required 208 pounds of feed and 30 minutes of labor (Lasley, 1983).

Because broilers could be produced with less feed, labor, and capital (less time means less capital per broiler), broiler production costs were only slightly higher in 1980 than in 1955, even though prices for production inputs had risen. As a result, retail prices for broilers rose by only 30 percent between 1955 and 1980, while the overall consumer price index for food more than tripled.[19]

Improvement continued after 1980, but at a slower rate. By 2006, it took 49 days to raise the average bird, which weighed 5.4 pounds, and producers used 195 pounds of feed for every 100 pounds of broiler production.[20] With slowing productivity growth, retail chicken prices increased only slightly less than beef or food prices after 1980.[21]

[19] Productivity in broiler production (output per unit of input) rose by 154 percent in this period (or 3.8 percent per year), an exceptionally high rate of growth.

[20] Larger birds take more time to produce, and have higher feed conversion rates. Four- pound birds (comparable to the 1980 average) took 39 days to produce in 2006 and required 188 pounds of feed, or 25 percent less time and 10 percent less feed than 26 years earlier.

[21] Using the relevant Consumer Price Indexes, chicken prices increased by 95 percent between 1980 and 2006, compared to 107 percent for beef and 125 percent for all food.

We have more limited data on cattle productivity, and existing studies use annual industrywide data to analyze the drivers of change in prices paid for feeder cattle. Marsh (2001) measured beef cow productivity over time as annual beef production divided by the Nation's inventory of beef cows (adjusted for imports). Beef production per cow can be increased by raising birth rates of live healthy calves, reducing cow and calf mortality, increasing the mature size of fed cattle, and speeding the time it takes to reach market weight. While the steps to increase birth rates and reduce cow mortality occur in the cow-calf stage, the other routes to boosting productivity may occur in the fed-cattle stage.

Marsh's measure of beef cow productivity increased by 35.5 percent, or 1.6 percent per year, from 1980 to 1999. He attributed the growth to improvements in breeding, animal nutrition, and animal health in both cow-calf operations and feedlots. Productivity growth led to reduced costs and lower feeder cattle prices over the period.

Hog sector structural changes occurred more recently. Key and McBride (2007) compared industry-average production costs for hogs in 1992, 1998, and 2004, with separate estimates for feeder-to-finish and farrow-to-finish operations. As with broilers, industrywide efficiency improvements reduced the amount of inputs needed to produce pork. In the feeder-to-finish sector, average feed conversion rates (pounds of feed required for every cwt of weight gain) fell from 383 pounds in 1992 to 214 pounds in 2004. Labor use (per cwt of weight gain) fell from 53 minutes to 9 minutes. As a result, average production costs fell from $37.54/cwt in 1992 to $26.59/cwt in 2004, despite increases in the prices paid for capital, labor, feed, and other inputs. In real terms (all input prices in 2004 dollars), industrywide average costs dropped by 44 percent between 1992 and 2004.

Key et al. (2008b) estimated that productivity on feeder-to-finish farms grew at an average annual rate of 6.3 percent from 1992 to 2004. When compounded over 12 years, that estimate implies that the amount of hog production that could be realized from a given set of feed, labor, capital, and other inputs more than doubled. Key et al. attributed nearly half of the growth to the realization of scale economies by larger farms and almost all of the remainder to innovations in breeding, feed formulations, and equipment that raised productivity across all farm sizes.

Milk production has benefited from ongoing improvements in breeding, feed formulations, equipment, and management practices, all of which are independent of shifts to larger farms. Still, MacDonald et al. (2007) estimated that industrywide milk production costs were 8 percent lower in 2006 than they would have been had production not shifted to larger and lower cost farms during 2000-2006. The analysis held input prices constant, so the estimated cost declines did not reflect lower prices for inputs, but instead reflected less labor and capital used for a given amount of milk production on larger farms. The calculation captures a short window of time, and the effects over a 10- to 20-year window would likely be commensurately larger.

Structural changes in each livestock commodity have led to substantial cumulative reductions in the resources needed to produce a given amount of

meat or milk, and to lower producer and consumer prices. But other consequences have been less felicitous.

Processor Concentration

As farm production shifted to larger operations and tighter vertical linkages, the livestock processing industries became much more concentrated. Most producers now face just a few buyers for their livestock, livestock products, or grower services. While mergers among processors have played a role in increased concentration, the major factor has been increases in plant size which have allowed processing plants to realize scale economies and lower costs (MacDonald et al., 2000; Ollinger et al., 2000). If those lower costs reduced retail prices and led to increased quantities demanded, growers could benefit from increased processor concentration. But increased concentration could also confer market power on processors, enabling them to impose lower prices on growers and higher prices on consumers.

Table 5 summarizes concentration trends among cattle, hog, and broiler processors.[22] The four largest meatpackers held 79 percent of steer and heifer slaughter in 2005, up from 36 percent in 1980, an extraordinary increase that attracted widespread attention.[23] Concentration ratios in cow and bull, hog, and broiler processing have also risen steadily and are substantially higher than in 1985.

National concentration measures understate the concentration that many farmers face in local and regional markets. For example, although feeder animals may move across North America, fed cattle and market hogs rarely move far to slaughter, and feedlots and market hog sellers usually have access to just three or four buyers.

Larger plants allowed packers to realize lower processing costs through economies of scale, with the gains from lower costs passed to consumers and to farm operators (Brester and Marsh, 2001; Ollinger et al., 2000; MacDonald and Ollinger, 2005). However, production is no longer shifting to large processing plants, and there are widespread concerns that packers and integrators may be able to exploit high levels of concentration and reduce the prices that they pay for livestock, livestock products, and grower services.

Highly concentrated local markets for agricultural products aren't new, and some widely used agricultural marketing institutions are designed to limit the exercise of market power and to induce farmers to commit to production in markets with few buyers. For example, farmer-owned cooperatives

Table 5: Concentration in poultry and livestock procurement

	Share of purchases by four largest processors					
Commodity	1980	1985	1990	1995	2000	2005
	Percent					
Cattle						
Steers and heifers	36	50	72	79	82	79
Cows and bulls	10	17	20	23	32	49
Hogs	34	32	40	46	57	64
Broilers	na	34	41	46	49	53

Source: USDA Grain Inspection, Packers and Stockyards Administration (GIPSA), *Assessment of the Livestock and Poultry Industries* (various years).

[22] The measure, a four-firm concentration ratio, captures the share of livestock or poultry slaughter held by the four largest processors of each commodity.

[23] Steers and heifers are a separate economic market from cows and bulls. Steers and heifers move from feedlots to specialized plants in the Great Plains. Those plants produce different beef products than cow plants, which usually locate in dairy production regions.

play a major role in milk handling and processing—70 percent of producers, accounting for 76 percent of milk production, ship their milk to plants operated by their own cooperative.[24]

[24] According to data derived from the 2005 ARMS dairy version.

Many fed cattle are sold to packers in cash markets where prices are determined on a daily and weekly basis. Most smaller producers, and most small packers, use cash markets exclusively, while large producers and packers use a variety of marketing channels (RTI, 2007a). The market is characterized by high buyer concentration, and by several features of bidding that would seem to discourage aggressive competition among packers (MacDonald, 2006; Xia and Sexton, 2004).

Because of its size, high concentration, and readily available data, there are many studies of competition and pricing in the fed-cattle industry. Some find that prices look like those that would prevail in competitive markets—that is, they find no evidence of packer market power (Morrison-Paul, 2001). Others find that prices are below those that would prevail in competitive markets—that is, they find evidence of monopsony on the part of packers—but the estimated effects on prices are small (Azzam, 1997). Despite high concentration and bidding practices that might facilitate the exercise of market power, the studies find little evidence of extensive market power in fed-cattle (Koontz, 2003). However, increases in concentration from current levels could provide packers with the power to force cattle prices down. In markets with only three or four buyers, mergers among buyers will attract close scrutiny, particularly where there are no apparent offsetting efficiency gains.[25]

[25] These issues lie at the heart of the U.S. Justice Department's recent court filing opposing the proposed acquisition of National Beef Packing, the 4th largest beef packer, by JBS-Swift, the 3rd largest packer. See www.usdoj.gov/atr/cases/f238300/238388.htm

Growers of broilers, and growers of hogs under production contracts, operate in a different environment. They do not sell livestock in commodity markets, but instead are hired to grow for an integrator who links stages in a production complex that covers just a few counties. The competitive issues in these businesses, therefore, refer to labor markets for grower services and not to product markets for livestock. While hog growers tend to have three or more integrators operating in their area, sometimes with cash market alternatives, broiler growers are likely to have only one or two integrators, with no cash market outlets (MacDonald and Korb, 2008).

In markets for grower services, potential hog or broiler growers have choices—they can invest their time or money in other agricultural commodities, or in nonfarm employment—and integrators must compete with those activities to attract growers. Production contracts commit the integrator to provide chicks or pigs, and commit the integrator to a compensation agreement--contracts therefore offer more assurance to growers than they would get in a highly concentrated cash market, where no such assurances exist.

The competitive risk to contract growers arises after they have made a substantial capital investment in housing, when the initial contract expires. Many production contracts are short term, as little as the 35-45 days it takes to grow a flock, even though the grower makes a long-term financial commitment. At that point, an integrator may be able to impose extra costs or lower payments on a grower as a condition of contract renewal. However, an integrator that develops a reputation for exploiting growers will have difficulty attracting new growers. And growers—especially hog producers who have more options—may contract with other integrators or shift to cash markets.

Spot Markets and Marketing Information

Spot market transactions provide benefits to all market users because transaction terms—including prices, locations, and observable quality characteristics—are readily available and easy to record. Accurate and widely available market information helps speed the discovery of a "market price" through arbitrage, as buyers try to avoid paying unnecessarily high prices and sellers try to avoid accepting unnecessarily low prices. Visible, accurate, and reliable market price information should provide important signals such as value differences, regional price differences, and quantities available to buyers and sellers. In turn, those signals should guide production decisions, giving producers incentives to produce what buyers want.

USDA collects information from market transactions in the livestock and grain industries, and provides regular reporting of prices, quantities, and transaction characteristics in its *Market News* program. Traditionally, *Market News* reporters collected information firsthand at major auction markets, and by telephone from producers, processors, retailers, distributors, and brokers. Reports were available to all interested parties, and were widely used in the trade. Some *Market News* reports were highly localized, detailing quantities and prices received during a narrow time period at an auction market. Other more aggregated reports summarized terms across a wide geographic area for a week, month, or year.

As transactions, particularly in the hog and fed-cattle sectors, shifted away from spot markets and toward contractual relationships, the amount and quality of information available for *Market News* declined (Perry et al., 2005). Participants in contract sales frequently did not provide information to reporters, reducing the amount of information available. In addition, to the extent that contract purchases covered animals with different qualities than those traded in spot markets, public reporting might no longer be representative of the market. This development is of concern to all market participants, and not just those in the spot market, because many prices in many contracts are based on reported market prices.[26]

[26] Tighter coordination, through contracts or vertical integration, may provide producers with better incentives to deliver animals of higher or more consistent quality. That is, the growth of contracts can result from deficiencies in the effectiveness of existing spot market reporting.

In response to these concerns, Congress passed The Livestock Mandatory Reporting Act of 1999 which requires the reporting of all livestock sales transactions of large meatpackers. The Act established a program of reporting information regarding the marketing of cattle, swine, lambs, and products of such livestock. This program provides information on pricing, contracting for purchase, formulated sales, and supply and demand conditions for livestock, livestock production, and livestock products that can be readily understood by producers, packers, and other market participants.

Environmental Impacts

The livestock industry also produces wastes in the form of manure, urine, and bedding material. Manure contains organic material and nutrients for crop and pasture growth, but animal wastes can also despoil water and air resources and compromise their commercial and recreational uses. Wastes can be transmitted to surface water through the runoff of nutrients, organic matter, and pathogens from fields and storage; to ground water through the leaching of nutrients and pathogens; and to the atmosphere through

the volatilization of gases and odors. Pollutants may originate at structures where animals are kept; at manure storage facilities such as tanks, ponds, or lagoons; or on land where manure is stored or is applied as fertilizer.

Industrialized production concentrates manure on limited land areas. Consequently, some producers apply manure to their land at intensities well above the agronomic needs of their crops, thereby increasing pollution risks. Others may need to remove manure to be spread on cropland at other operations. We detail the basic links between farm size, manure production and management practices, and land use in table 6, using data from the ARMS hog (2004), dairy (2005), and broiler (2006) versions.

For comparison purposes, the farm size classes in table 6 are defined according to onfarm inventories of animal units (AU)—1,000 pounds (liveweight) of livestock or poultry.[27] There are significant differences between broiler operations and the other two commodities, so we discuss them separately.

Farmers can apply manure to their own fields, remove it for application on other farms, or remove it for processing.[28] About 5 percent of dairy farms and 10 percent of hog farms, accounting for 12 and 19 percent of production, have no cropland and must therefore remove all of their manure (table 6). But farms with cropland also remove manure, especially if the cropland is far from manure storage facilities.[29] In total, 19 percent of the manure on dairy farms, and 26 percent of that on hog farms, is removed. The share of manure that's removed rises quite sharply with farm size, which suggests that many large farms have insufficient land for manure application.

Large operations that apply manure typically have a lot of cropland—over 1,000 acres, on average, at the largest dairy and hog farms (table 6). But manure is usually applied to only a fraction of the farm's cropland, a pattern also apparent in the 1998 hog and 2000 dairy ARMS data (Ribaudo et al., 2003). Large farms often operate some cropland at considerable distances from manure storage facilities, and may produce some crops with limited nutrient needs.

Manure application intensities—the number of animal units per acre of land receiving manure—largely determine the amount of manure applied per acre. This measure rises quite sharply with farm size.[30] The largest dairy farms have more than three times as many animal units per acre as farms in the smallest class, and the largest hog farms have six times as many as the smallest hog farms (table 6).

Waste management practices on broiler operations differ in some important respects. A third of broiler farms have no cropland, and 60 percent of broiler litter is removed. Most farms that apply manure apply it to all of their land (manure may be applied to pastureland, which is why acres applied exceeds total cropland in several size classes in table 6). But farm size still matters. Larger broiler operations are more likely to remove all of their manure, and larger operations have higher land application rates.

Large livestock operations store substantial quantities of manure onsite. The manure is generally applied to cropland much more intensely than on smaller farms, and large volumes of manure must still be removed from the

[27] For conversion to AUs, mature dairy cows and bulls were assumed to weigh 1,350 pounds and breeding swine were assumed to weigh 375 pounds. Livestock destined for slaughter only reach market weight when they leave the farm, so we had to estimate average onfarm weights. Broilers were set at half of the average weight at removal reported for the farm, while market hogs were assumed to weigh the average of their market weight and their weight when entering the farm's inventory.

[28] A few farms incinerate or process manure onsite, but almost all manure that stays on the farm is applied to fields.

[29] A farm's cropland isn't necessarily contiguous. If some parcels are miles away from livestock operations, removal to another farm's nearby cropland could be economic.

[30] We reduced estimated inventories of animal units by the share of manure removed from the farm, and then divided the adjusted inventories by the amount of acres receiving manure.

Table 6: Manure management on dairy, hog, and broiler operations, 2004-06

Commodity and size class	All farms: Percent with no cropland	All farms: Manure removed (percent)	Farms that apply manure to fields: Average cropland acres	Farms that apply manure to fields: Acres with manure applied	Farms that apply manure to fields: Animal units per acre
Dairy					
Across farms	5	5	305	156	1.6
Across production	12	19	720	484	2.6
By size class (AU)					
<300	3	3	255	117	1.4
300-649	12	12	561	327	2.5
650-999	12	23	822	591	3.1
1,000-1,999	22	37	1264	844	3.3
2,000 or more	26	49	1500	1091	4.8
Hogs (market)					
Across farms	10	16	599	97	3.5
Across production	19	26	922	228	8.4
By size class (AU)					
<300	7	13	536	63	1.9
300-649	10	20	722	168	5.7
650-999	14	29	718	197	7.0
1,000 or more	27	33	975	261	13.5
Broilers					
Across farms	32	58	133	131	2.1
Across production	29	60	185	177	2.3
By size class (AU)					
<300	33	56	105	105	1.9
300-649	30	63	169	172	2.6
650-999	28	63	223	268	2.7
1,000 or more	9	68	598	335	3.0

Notes: One animal unit equals 1,000 pounds (liveweight) of livestock or poultry in inventory. Average liveweight of animals in inventory was assumed to be 1,350 pounds for cows and bulls; 375 pounds for breeding swine; for slaughter swine, one-half of the difference between market weight and weight when entering the farm's inventory; and half of the average weight at removal for broilers.

Source: Authors' calculations, based on data from the Agricultural Resource Management Survey, version 4, 2004 (hogs), 2005 (dairy), and 2006 (broilers).

operation. High concentrations of manure—whether stored in lagoons, pits, or ponds prior to transport or application—raise the likelihood of leaching or volatilization, threatening groundwater and air quality. And farms that intensively apply manure to cropland and pasture may apply it at rates that exceed the ability of crops to absorb nutrients, with the excess nutrients transmitted to water and air resources. Analysis of pollution risks from manure must therefore consider nutrient loadings and uses.

Gollehon et al. (2001) used confidential farm-level data from the census of agriculture to estimate the production of manure nutrients, and excess manure nutrients, between 1982 and 1997. Specifically, the census collects farm-level information on animal inventories, by type of animal, and acreage by type of use (farmland and cropland, by crop). Gollehon et al. combined the animal inventory data with estimates of annual manure and nutrient production by animal type to estimate nitrogen and phosphorus quantities produced on each

farm. They then combined data on nutrient uptake by crop to estimate the amount of manure-based nutrients that could be used by onfarm crops. The difference between nutrient production and potential nutrient use provides an estimate of excess nutrient production on a farm.

Some farms in all size classes produced enough manure-based nutrients to exceed the farm's potential assimilative capacity.[31] However, the largest livestock and poultry operations were most likely to produce excess nutrients, and they accounted for a preponderant share of total excess nutrient production at the farm level. Excess nutrient production increased substantially between 1982 and 1997 and it increased in every region, especially those with high concentrations of large livestock and poultry operations.[32]

Manure can be moved from one farm to another for application, but high transportation costs limit the practical distance manure can travel. Gollehon et al. found that, in 1997, crop nutrient needs in most counties were high enough to use all available manure-based nutrients. However, about 5 percent of counties did not have crop needs sufficient to use all the available manure-based phosphorus produced in the county (the corresponding figure for nitrogen was 2 percent). Those counties tended to be centers of industrialized livestock production.

Regulation of Manure Practices

Federal, State, and local governments have responded to the environmental problems posed by livestock operations with regulations and conservation programs. The U.S. Environmental Protection Agency introduced Clean Water Act regulations in 2003 for controlling runoff of manure nutrients from the largest animal feeding operations. Farms designated as CAFOs must develop and implement a nutrient management plan that bases nutrient applications on agronomic rates, a provision that requires many CAFOs to spread their manure over a much larger land base than they are currently using. Most will need to move manure off-farm.[33]

Many States have also enacted regulations that address environmental issues, including some not addressed at the Federal level. Some had manure application restrictions in place prior to EPA's 2003 regulations, some of which extended to smaller operations. Odor is a persistent local issue, and many States are using setback requirements to separate animal operations from residential areas. Ammonia emissions from large animal feeding operations have prompted California to enact regulations in the San Joaquin Valley to protect heavily populated areas downwind. North Carolina imposed a partial moratorium in 1997 on the construction of new hog farms in the State, in response to widespread concerns over waste management.

Because of expanding State and Federal regulations, certified nutrient management plans (CNMPs) are coming into widespread use. According to 2004-2006 ARMS data, 62 percent of U.S. hogs, 60 percent of broilers, and 49 percent of dairy cows are on operations that have CNMPs.[34] The intensity of nutrient applications will need to be reduced to comply with many of the plans, with several paths to compliance. More cropland acres for manure application may be found by applying manure to more of the farm's cropland, acquiring more cropland, or removing manure from the farm and

[31] The estimates are conservative, because Gollehon et al. did not take into account the additional nutrients that farms could apply in commercial fertilizers.

[32] These include the hog and poultry production region stretching from eastern North Carolina through north Georgia and Alabama; the fed-cattle production region covering eastern Colorado, southwestern Kansas, and the Texas and Oklahoma Panhandles; and the dairy production regions of central and southern California.

[33] Some AFOs that are not defined as CAFOs must also implement nutrient management plans in order to be covered under the stormwater exemption of the Clean Water Act. The 2003 regulations were the subject of continuing litigation, which barred implementation. EPA issued a final rule on October 31, 2008.

[34] In 2004 (hogs), 2005 (dairy), and 2006 (broilers). Correspondingly, 30 percent of hog farms, 32 percent of dairy farms, and 60 percent of broiler farms had a CNMP. The plans cover larger shares of animals than of farms because larger farms are more likely to be required to have one.

applying it to crops on other farms. The amount of manure nutrients associated with animal production can be reduced by changing feed formulations or altering breeding to improve feed efficiencies. Stages of animal production can be moved nearer to locations with sufficient cropland. Finally, manure may be treated to reduce transportation costs, enabling it to travel farther and to be used as a feedstock for energy generation and manufacturing.

Ribaudo et al. (2003) evaluated the potential impacts of compliance with environmental regulation, with a focus on the first option—reducing intensity by expanding acreage. They found that most CAFOs would need a much larger land base for manure application than they were currently using, or that they would need to remove much more manure from their operations. In turn, the effect of manure removal on the source farms' financial performance depended on the willingness of nearby crop farms to accept manure. Commercial fertilizers are often preferred to manure because they are easier to apply and because they can be formulated to contain the precise combinations of nutrients needed for particular applications. However, manure fertilizers may be acceptable, at the right price.

There's little empirical evidence on the willingness to accept manure (WTAM) among crop producers, so Ribaudo et al. modeled the costs of compliance for WTAM ranging from 10 percent to 80 percent of farms. Costs of removal will also vary across regions, depending on the available cropland and manure production, and across farm sizes, since larger farms will generally need to remove more manure to comply.

Manure removal would raise total production costs for dairy and hog operations, and would raise them by more on large farms. But the estimated cost increases were modest. With a 20-percent WTAM, Ribaudo et al. estimated that compliance would raise hog production costs on the largest operations (1,000 or more animal units) 1-3 percent, compared to 1 percent or less on small operations. Production costs on the largest dairy operations (also 1,000 or more animal units) would increase an estimated 2-3 percent, compared to 1 percent on small operations. If nearby farmers were less willing to accept manure, large operations would face higher costs, up to 5 percent in some regions. Nevertheless, a cost increase of this magnitude is more than offset by the production cost advantages of large operations (figures 6-8), so it is unlikely that farm structure would be altered by compliance costs that fall in the range reported in Ribaudo et al.

Much manure is currently removed from operations—about 19, 26, and 61 percent of dairy, hog, and broiler manure (table 6). Some is sold, and some is removed for a fee, but most is given away (table 7).

Even when farmers pay to have manure removed, the cost of removal was not prohibitive. Among those dairy farms that removed manure in 2005, fees added 39 cents per cwt to the cost of production, or 3 percent of production costs at the largest farms (fig. 6). Similarly, fees paid for manure removal by hog producers in 2004 amounted to 34 cents for every cwt of weight gain, or 1.4 percent of the average cost of production on large finishing operations (fig. 7). Broiler farms that paid for litter removal incurred fees amounting to 0.3 cent per pound of meat produced, or less than 1 percent of the cost of production.[35] Livestock farms will likely have to remove more manure under

[35] The hog and broiler costs of production are total costs, including those borne by integrators as well as those borne by growers. Manure removal fees account for about 6 percent of the contract payments received by growers.

Table 7: Manure removal from livestock operations, 2004-06

	Dairy	Hogs	Broiler
	Percent of total production		
Manure removed from operation	19	26	61
--Sold by operation	4	5	22
--Operation paid to haul it away	7	3	3
--Operation gave it away	8	18	36
	$ per cwt of production		
Prices			
Revenue from manure sales	0.28	0.22	0.20
Expenses to haul manure away	0.39	0.34	0.31

Source: Authors' calculations, based on data from the Agricultural Resource Management Survey, version 4, 2004 (hogs), 2005 (dairy), and 2006 (broilers).

CNMPs in the future. As removals increase, more producers will likely have to pay to have manure removed, and removal fees will likely rise. However, those fees would have to increase five- to ten-fold to offset the current production cost advantages held by large operations.

Manure transport is not the only option for reducing nutrient loadings. There is evidence that the amount of manure and nutrients associated with a given amount of livestock production can be reduced, and that CNMPs may be driving some reductions. Key et al. (2008a) use ARMS hog data to investigate two options. First, they find a substantial increase, between 1998 and 2004, in the use of microbial phytase, which is used as a feed additive to reduce the amount of phosphorus excreted in manure. Phytase use in feeding helps producers manage phosphorus levels in manure to comply with phosphorus-based nutrient management plans. In 1998, 4 percent of hog producers, accounting for 12 percent of production, added phytase to their feed. By 2004, 13 percent of producers, accounting for 30 percent of production, were doing so.[36] Second, improvements in breeding and in feed formulations have led to a substantial decline in the amount of feed used to produce pork; between 1998 and 2004, the amount of feed used to produce 100 pounds of pork fell from 282 pounds to 214 pounds, a 24-percent decline. Since feed that is not converted to meat is excreted, this implies a 24-percent decline in the quantity of nutrients excreted per animal produced, assuming the nutrient composition of feed and meat has not changed substantially over this period.[37]

Antibiotic Use and Health-Related Impacts

Livestock producers take a variety of steps to prevent the emergence and spread of animal diseases among their herds and flocks. Practices include pathogen testing, vaccinations, provision of antibiotics, segregation of herds or flocks by age, sanitary protocols in housing units, and physical biosecurity measures. Antibiotics are used to treat sick animals, but they are also administered in subtherapeutic doses, usually in water or feed, to protect animals against disease and to promote growth. Subtherapeutic antibiotics (STAs) can promote growth, particularly in poultry and hogs, by improving nutrient absorption and by depressing the growth of organisms that compete for nutrients, thereby increasing feed efficiency.

[36] About 27 percent of broiler operations were also adjusting the nutrient content of litter in 2006 by using additives like phytase in feed or directly in litter. Such strategies were less common on dairy operations where 5 percent of farms, accounting for 11 percent of cows, were adjusting the nutrient content of manure through feed additives.

[37] Feed efficiency is positively correlated with the scale of production in the hog sector– larger operations generally use less feed per hog produced.

Many drugs used to treat animals are the same as, or similar to, drugs used for human health care. Consequently, there is concern that the widespread use of antibiotics, especially STAs in animals, could promote development of drug-resistant bacteria that could pass from animals to humans, thus posing a danger to human health. In response to these concerns, the European Union (EU) has banned the use of antimicrobial drugs for growth promotion, and they are coming under growing scrutiny in the United States (U.S. Government Accounting Office, 2008).

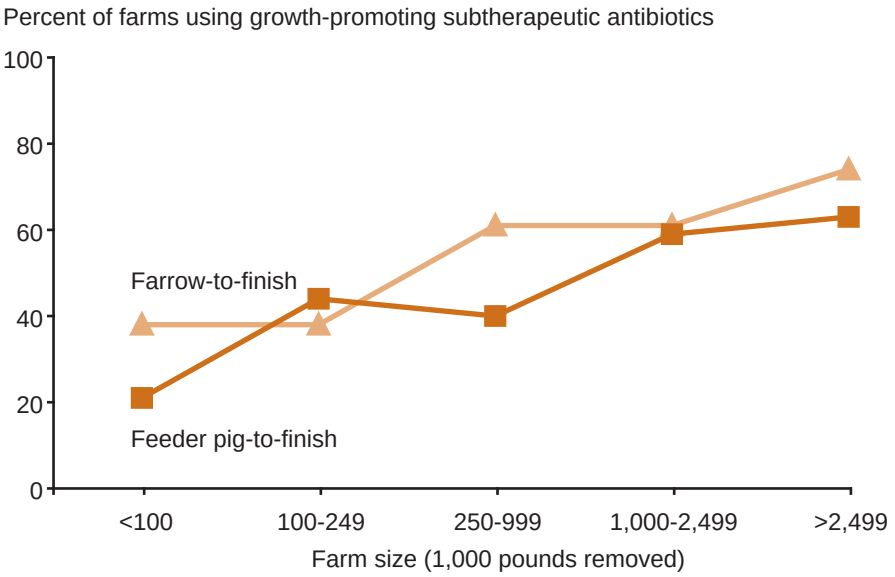
Recent ARMS hog and broiler versions have included questions about antibiotic use as well as other health management technologies and practices on farms. The data obtained cannot be used to assess resistance and health hazards, but they can be used to identify the extent of STA use on livestock operations, the impacts of STAs on costs and productivity at different types of operations, and alternatives to STAs for disease prevention and growth promotion.

In the ARMS 2004 hog version, producers were asked whether they provided antibiotics, the purpose for provision (growth promotion, disease prevention, or disease treatment), and the types of animals receiving the drugs (breeding animals, nursery pigs, or finishing hogs). Antibiotics were used most widely on nursery pigs in specialized wean-to-feeder operations (McBride et al., 2008). Eighty percent of the surveyed farms used antibiotics for disease treatment, and 85 percent provided STAs for either disease prevention or growth promotion.

Among farms that finish hogs, STAs are widely provided for growth promotion, and larger operations are considerably more likely to provide them (fig. 9). About 20 percent of small feeder-to-finish operations provided their animals with growth-promoting STAs in 2004, compared to 60 percent of the largest operations. Farrow-to-finish operations are generally more likely to provide STAs—nearly 40 percent of smaller operations and 75 percent of the largest.[38]

[38] Similar patterns hold for STAs provided for disease prevention: the smallest class of producers are less likely to use them than the largest, where 65-75 percent of producers use them.

Figure 9
Larger hog farms are more likely to use growth-promoting subtherapeutic antibiotics



Source: 2004 Agricultural Resource Management Survey, Version 4.

STAs add to farm expenses, but can also add to productivity by increasing the amount of meat that can be produced from a given combination of breeding animals, feed, and time. This productivity impact likely varies over time and across operations, depending on factors such as animal genetics, feed formulations, production practices, housing features, and management skills.

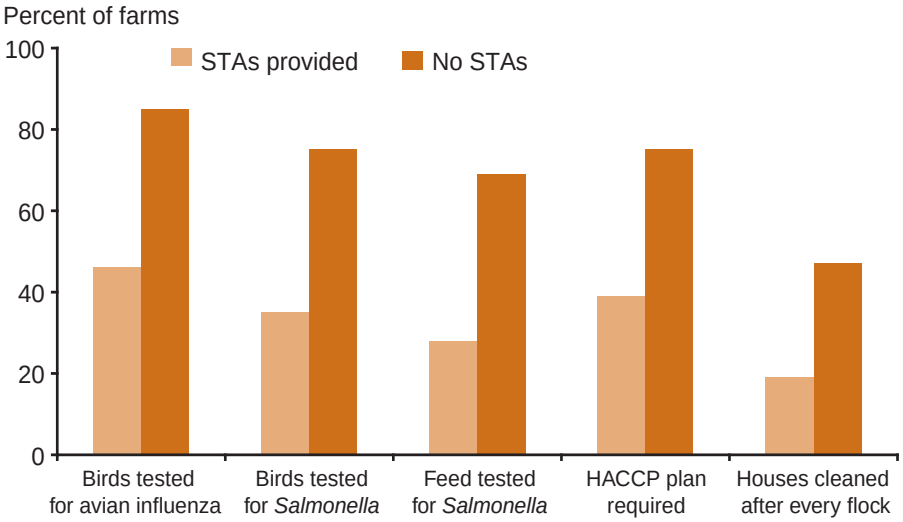
McBride et al. (2008a) investigated which hog farms provided STAs and the effects of provision on farm-level productivity. The provision of STAs seemed to reduce costs at the nursery stage: operations that did not use STAs at the nursery stage had costs that were 30 percent higher than those that did (in a model with controls for the size of the operation, its location, and a variety of production practices). This evidence suggests that STAs reduce mortality and improve feed efficiency among nursery pigs.

In contrast, McBride et al. found little impact of STAs on production costs at the finishing stage—farms that used STAs had costs of production that differed little from those that did not. Any productivity improvement from STAs was not large enough to offset the additional expenses, suggesting the viability of alternative practices or technologies to reduce disease or improve feed efficiency at finishing stages. These results are consistent with studies of the EU ban on STAs, which also suggest that farm-level benefits vary across stages of production and are most pronounced in the nursery stage.

A study of STAs in broiler grow-out operations provided evidence consistent with the findings for hogs. Graham et al. (2007) evaluated the results of a large nonrandomized control trial run by one large integrator in which growth-promoting STAs were removed from some broiler houses, whose flocks' performance was then compared to flocks from houses on the same farm that continued to use STAs. STAs boosted feed efficiency slightly, but not enough to offset the expense, so non-STA houses performed slightly better financially.

Producers and integrators may be able to substitute other practices and technologies for STAs in broiler production. In the 2006 ARMS broiler version, 42 percent of respondents stated that STAs were not provided to their flocks. In contrast to hog finishing operations, there was no relation between farm size and the use of STAs in broiler grow-out (virtually all broiler grow-out farms are contract operations, so it might be argued that all broiler production is industrialized). Farms not providing STAs instead used extensive testing and expanded sanitation controls (fig. 10). Specifically, farms that did not provide STAs usually tested their birds (for avian influenza, salmonella, and other pathogens), and their feed (for salmonella), while farms that relied on STAs were much less likely to test. Farms that did not provide STAs were also much more likely to fully clean out and sanitize their houses after every flock, and typically were required to have a HACCP (Hazard Analysis and Critical Control Point) plan in place to guide food safety actions.

Figure 10
Testing and sanitation substitute for subtherapeutic antibiotics (STAs) in broiler production



Source: 2006 Agricultural Resource Management Survey, Version 4.

Conclusions

Powerful economic forces are driving the shift to large industrialized livestock operations. There are substantial economies of scale up to certain threshold sizes, and farms can operate efficiently at sizes that are much larger than the thresholds. In addition, tighter vertical coordination lowers costs and improves consistency for many products. Each provides strong financial incentives for producers to expand their operations and to enter into more formal contractual relationships with buyers and input suppliers.

The transformed production systems lead to improved productivity, with more production of livestock and livestock products from any given amount of labor, feed, and capital. Productivity improvements lead to lower wholesale and retail prices for meat and dairy products, while freeing land, labor, and capital resources for expanded commodity production or for other uses.

But industrialized livestock production has external costs. High concentrations of animal manure can lead to increased air and water pollution, with adverse health and environmental consequences. Concentrated livestock can also create odors that offend neighbors and reduce property values. A heavy reliance on antibiotics for growth promotion and for disease prevention may spawn antibiotic-resistant strains of bacteria, with human health risks. Changes in farm structure are intertwined with these concerns because larger operations concentrate manure more and rely more heavily on growth-promoting antibiotics than smaller operations.

Individual producers may have little incentive to take costly actions on their own to reduce the external costs arising from intensive applications of manure and antibiotics. Livestock production is highly competitive, and operations with relatively high costs jeopardize their own survival. However, there are ways to reduce the risks from high concentrations of manure nutrients on limited land areas. Nutrient management plans, which base nutrient applications on agronomic rates, are coming into widespread use as part of Federal, State, and local regulations. The plans have guided reductions in nutrient applications, and they are likely to compel more in the future through changes in breeding, feed attributes, farm location, and manure distribution.

Growth-promoting antibiotics are a feature of industrialized hog and poultry operations, and they are substantially more likely to be used on larger hog operations. However, many large operations do not use them, and they may be more valuable to producers at some stages of animal production than at others. Many producers that don't use growth-promoting antibiotics rely on alternative strategies, such as extensive testing and sanitary protocols, to prevent disease and promote growth. The evidence adduced so far suggests that steps can be taken, at modest aggregate costs, to limit the external costs associated with antibiotic use in industrialized operations.

References

Aillery, Marcel, Noel Gollehon, Robert Johansson, Jonathan Kaplan, Nigel Key, and Marc Ribaudo. 2005. *Managing Manure To Improve Air and Water Quality*. U.S. Department of Agriculture, Economic Research Service. ERR-9. Sept.

Azzam, Azzedine M. 1997. "Measuring Market Power and Cost-Efficiency Effects of Industrial Concentration," *Journal of Industrial Economics* 45 (June): 377-386.

Brester, Gary W., and John M. Marsh. 2001. "The Effects of U.S. Meat Packing and Livestock Production Technologies on Marketing Margins and Prices," *Journal of Agricultural and Resource Economics* 26 (Dec.): 445-462.

Gee, C. Kerry, Roy N. Van Arsdall, and Ronald A. Gustafson. 1979. *U.S Fed-Beef Production Costs, 1976-77, and Industry Structure*. U.S. Department of Agriculture, Economic Research Service. AER-424. June.

Gollehon, Noel, Margriet Caswell, Marc Ribaudo, Robert Kellogg, Charles Lander, and David Letson. 2001. *Confined Animal Production and Manure Nutrients*. U.S. Department of Agriculture, Economic Research Service. AIB-772. June.

Graham, Jay P. John J. Boland, and Ellen Silbergeld. 2007. "Growth-Promoting Antibiotics in Food Animal Production: An Economic Analysis." *Public Health Reports* 122 (Jan.): 79-87.

Hart, John Fraser. 2003 *The Changing Scale of American Agriculture*. Charlottesville, VA: University of Virginia Press.

Hoppe, Robert, Penni Korb, Erik J. O'Donoghue, and David E. Banker. 2007. *Structure and Finances of U.S. Farms: Family Farm Report, 2007 Edition*. U.S. Department of Agriculture, Economic Research Service. EIB-24. June.

Key, Nigel, William D. McBride, and Marc Ribaudo. 2008a. "Changes in Manure Management in the Hog Sector." Paper presented at the Annual Meetings of the American Agricultural Economics Association, Orlando, Fl, July.

Key, Nigel, William D. McBride, and Roberto Mosheim. 2008b. "Decomposition of Total Factor Productivity Change in the U.S. Hog Industry," *Journal of Agricultural and Applied Economics* 40 (April): 137-149.

Key, Nigel, and William D. McBride. 2007. *The Changing Economics of U.S. Hog Production*. U.S. Department of Agriculture, Economic Research Service. ERR-52. Dec.

Key, Nigel, and Michael Roberts. 2007. *Commodity Payments, Farm Business Survival, and Farm Size Growth*. U.S. Department of Agriculture, Economic Research Service. ERR-51. Nov.

Koontz, Stephen R. 2003. "Market Power in the United States Red Meatpacking Industry." *The Veterinary Clinics of North America: Food Animal Practice* 19 (July): 519-544.

Krause, Kenneth R. 1991. *Cattle Feeding, 1962-89: Location and Feedlot Size*. U.S. Department of Agriculture, Economic Research Service. AER-642. April.

Lasley, Floyd. 1983. *The U.S. Poultry Industry: Changing Economics and Structure*. U.S. Department of Agriculture, Economic Research Service. AER-502. July.

MacDonald, James M. 2008. *The Economic Organization of U.S. Broiler Production*. U.S. Department of Agriculture, Economic Research Service. EIB-38. June.

MacDonald, James M. 2006. "Agricultural Contracting, Competition, and Antitrust," *American Journal of Agricultural Economics* 88 (Dec.): 1244-1250.

MacDonald, James M., and Penni Korb. 2008. *Agricultural Contracting Update*, 2005. U.S. Department of Agriculture, Economic Research Service. EIB-35. April.

MacDonald, James M., Erik J. O'Donoghue, William D. McBride, Richard Nehring, Carmen Sandretto, and Roberto Mosheim. 2007. *Profits, Costs, and the Changing Structure of Dairy Farming* U.S. Department of Agriculture, Economic Research Service. ERR-47. Sep.

MacDonald, James M., and Michael Ollinger. 2005. "Technology, Labor Wars, and Producer Dynamics: Explaining Consolidation in Beefpacking," *American Journal of Agricultural Economics* 87 (Nov.): 1020-1033.

MacDonald, James M., Michael Ollinger, Kenneth Nelson, and Charles Handy. 2000. *Consolidation in U.S. Meatpacking*. U.S. Department of Agriculture, Economic Research Service. AER-785. Feb.

Marsh, John M. 2001. "U.S. Feeder Cattle Prices: Effects of Finance and Risk, Cow-Calf and Feedlot Technologies, and Mexican Feeder Imports," *Journal of Agricultural and Resource Economics* 26 (Dec.): 463-477.

Martin, J. Rod. 1979. "Beef" in Lyle P. Shertz (ed.) *Another Revolution in U.S. Farming?* U.S. Department of Agriculture. Economics, Statistics, and Cooperatives Service. AER- 441. Dec.

Martinez, Steve. 2002. *Vertical Coordination of Marketing Systems: Lessons from the Poultry, Egg, and Pork Industries*. U.S. Department of Agriculture, Economic Research Service. AER-807. May.

McBride, William D., Nigel Key, and Kenneth Mathews. 2008. "Sub-therapeutic Antibiotics and Productivity in U.S. Hog Production." *Review of Agricultural Economics*. 30(2):Summer: 270-288.

McBride, William D., and Nigel Key. 2007. *Characteristics and Production Costs of U.S. Hog Farms, 2004*. U.S. Department of Agriculture, Economic Research Service. EIB-32. Dec.

McBride, William D., and Catherine Greene. 2007. "A Comparison of Conventional and Organic Milk Production Systems in the U.S." Paper presented at the Annual Meetings of the American Agricultural Economics Association, Portland, OR, July. Available at http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=26239&ftype=.pdf

McBride, William D., and Nigel Key. 2003. *Economic and Structural Relationships in U.S. Hog Production*. U.S. Department of Agriculture, Economic Research Service. AER-818. Feb.

Mosheim, Roberto, and C.A. Knox Lovell. 2009. "Economic Efficiency, Structure, and Scale Economies in the U.S. Dairy Sector." *American Journal of Agricultural Economics* 91. Forthcoming.

Morrison-Paul, Catherine J. 2001. "Cost Economies and Market Power: The Case of the U.S Meat Packing Industry," *Review of Economics and Statistics* 83 (May): 531-540.

Ollinger, Michael, James M. MacDonald, and Milt Madison. 2000. *Structural Change in U.S. Chicken and Turkey Slaughter*. U.S. Department of Agriculture, Economic Research Service. AER-787. Oct.

Perry, Janet, James MacDonald, Ken Nelson, William Hahn, Carlos Arnade, and Gerald Plato. 2005. *Did the Mandatory Requirement Aid the Market? Impact of the Livestock Mandatory Reporting Act*. U.S. Department of Agriculture, Economic Research Service. LDP-M-135-1. Sept.

Pew Commission on Industrial Farm Animal Production. 2008. *Putting Meat on the Table: Industrial Farm Animal Production in America*. April. www.ncifap.org.

Ribaudo, Marc, Noel Gollehon, Marcel Aillery, Jonathan Kaplan, Robert Johansson, Jean Agapoff, Lee Christensen, Vince Breneman, and Mark Peters. 2003. *Manure Management for Water Quality: Costs to Animal Feeding Operations of Applying Manure Nutrients to Land*. U.S. Department of Agriculture. Economic Research Service. AER-824. June.

Rogers, George. 1979. "Poultry and Eggs" in Lyle P. Shertz (ed.) *Another Revolution in U.S. Farming?* U.S. Department of Agriculture. Economics, Statistics, and Cooperatives Service. AER-441. Dec.

RTI International. 2005. *Spot and Alternative Marketing Arrangements in the Livestock and Meat Industries*. Interim Report prepared for Grain Inspection, Packers and Stockyards Administration, U.S. Department of Agriculture. July. http://archive.gipsa.usda.gov/psp/issues/livemarketstudy/LMMS_Interim_Report.pdf

RTI International. 2007a. *GIPSA Livestock and Meat Marketing Study. Volume 3: Fed Cattle and Beef Industries*. Study prepared for Grain Inspection, Packers and Stockyards Administration, U.S. Department of Agriculture. Jan. http://archive.gipsa.usda.gov/psp/issues/livemarketstudy/LMMS_Vol_3.pdf

RTI International. 2007b. *GIPSA Livestock and Meat Marketing Study. Volume 4: Hog and Pork Industries*. Study prepared for Grain Inspection, Packers and Stockyards Administration, U.S. Department of Agriculture. Jan. http://archive.gipsa.usda.gov/psp/issues/livemarketstudy/LMMS_Vol_4.pdf

Starmer, Elanor, and Timothy A. Wise. 2007. "Living High on the Hog: Factory Farms, Federal Policy, and the Structural Transformation of Swine Production." Tufts University. Global Development and Environment Institute. Working Paper No. 07-04. Dec..

Tauer, Loren W. 2001. "Efficiency and Competitiveness of Small New York Dairy Farms," *Journal of Dairy Science* 84: 567-569.

Tauer, Loren W. and Ashok Mishra. 2006. "Can the Small Dairy Farm Remain Competitive in U.S. Agriculture?" *Food Policy* 31 (Oct.): 458-468.

Union of Concerned Scientists. 2008. *CAFOs Uncovered: The Untold Costs of Confined Animal Feeding Operations*. April. www.ucsusa.org

United States Government Accountability Office. 2008. *Concentrated Animal Feeding Operations: EPA Needs More Information and a Clearly Defined Strategy to Protect Air and Water Quality from Pollutants of Concern*. GAO-08-944. Sept.

Van Arsdall, Roy N., and Kenneth E. Nelson. 1985. *Economies of Size in Hog Production*. U.S. Department of Agriculture, Economic Research Service. TB-1712. Dec.

Xia, Tian, and Richard Sexton. 2004. "The Competitive Market Implications of Top of the Market Pricing and Related Contract-Pricing Clauses," *American Journal of Agricultural Economics* 86 (Feb.): 124-139.