Journal of Agricultural and Applied Economics, 29,1(July 1997):45–56

Relationships Between Industrialized Agriculture and Environmental Consequences: The Case of Vertical Coordination in Broilers and Hogs

Laura L. Martin and Kelly D. Zering

ABSTRACT

This paper examines the relationship between industrialized production in the pork and broiler industries and the natural environment. Historical perspectives are presented regarding the movement toward increasingly concentrated and coordinated pork and broiler production units in the South. The relationships between animal by-product management and environmental quality, both at the farm level and within a geographic region, are addressed. Using the North Carolina pork industry as a background, current regulations and potential policy implications to protect environmental quality are discussed.

Key Words: industrialized agriculture, sustainability, vertical coordination.

Whether one chooses to use the term "evolution" or "revolution" to describe the rapidly changing pork industry, there is no doubt this industry is undergoing a radical reorganization of farm size, location, and industry infrastructure. The pork industry is emerging into a sector characterized by highly intensive and specialized hog production and processing units, motivated in part by the need to capture scale economies. As a result, the industry is increasingly concentrated, both at the farm level and within a geographic region.

Balancing the economic advantages from scale economies with environmental sustainability is a challenge facing individuals and rural communities. This problem, however, is not one unique to the hog industry. Increased vertical coordination and concentration in pork production have led many individuals to ask whether tomorrow's pork industry will look like today's broiler chicken industry—closely coordinated with specialized production and labor at each segment of the production-processing chain.

The examination of some of the differences and similarities between the broiler and pork industries, their evolutions, and their relationships to the environment provides a unique and informative perspective for researchers, educators, and policy makers. To that end, this paper provides an overview of "what happened?" "why?" and "what next?" for the pork and broiler industries in the South. Emphasis throughout the paper is on the farm-level relationship between industrialized production in the pork and broiler sectors, and the natural environment.

To frame the relationship between industri-

Laura L. Martin is an assistant professor in the Department of Agricultural Economics, Michigan State University. Kelly D. Zering is an associate professor in the Department of Agricultural and Resource Economics, North Carolina State University. Senior authorship is not assigned.

alized agriculture and the environment, the paper focuses on four issues. The first issue is the nature of the evolution of the broiler and pork industries in the South and reasons for observed changes. The second issue involves by-product and manure nutrient management and environmental regulations. Here, the North Carolina pork industry is used as a backdrop for discussing regulation of industrialized animal agriculture. The third concern is the environmental implications of industrialization and coordination, and the final area of focus is predictions as to "what next" can be expected in both industries.

Evolution of Broiler and Pork Production in the South

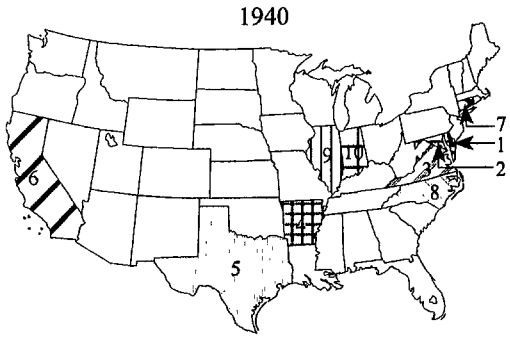
Broilers and hogs have followed similar, yet distinct paths toward intensive, coordinated production in the South. Dating back to the time when most farmers kept at least a few hogs on the farm as "mortgage lifters," pork production has a long history of independent, competitive production, with ownership and management decisions centered at the farm level. In contrast, the broiler chicken "industry" was virtually nonexistent in the first half of the twentieth century. Instead, chickens were kept for home consumption of eggs and meat. Young chickens would be marketed as the "spring hatch" by-product of the laying flocks (Tobin and Arthur). But when an industry did emerge after World War II, it rapidly evolved into a highly coordinated, intensive industry.

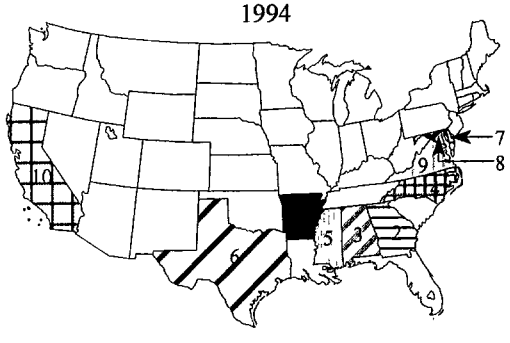
In the early 1950s, the broiler industry, complete with its own infrastructure, emerged as independent from the traditional poultry industries. By 1952, technological improvements in housing, feeding, breeding, and disease control enabled commercial broiler production to surpass farm chickens as the primary source of chicken meat in the U.S. (Watts and Kennett). Live broiler prices were highly variable, causing many farmers to conclude that the industry provided too many risks given the significant capital investments required for production.

Roy (1972) noted that feed dealers initiated contracts with growers in an effort both to stabilize broiler prices and to secure a market for their feed. Contract agreements initially began as simple credit arrangements with the feed dealer extending credit to the farmer, usually in the form of feed or chicks. For various reasons, this type of agreement was replaced by profit-sharing arrangements, followed by variations of a flat fee contract, and finally a production contract based on a flat fee and feed conversion payment. In this latter production contract, the performance of each contract grower tended to be rated against the performance of similar contract growers. (For further discussion on the evolution of broiler production contracts, refer to Roy 1963, or Martin.) A "production contract" is used to describe a contract between two parties to jointly produce a product, with each party contributing inputs to production.

In the case of modern broiler production contracts, companies or "integrators" contract with growers to house and care for their growing birds in exchange for a contractual fee. The fee is similar to the flat fee and feed conversion agreement of earlier times. These companies are typically integrated firms that own feed mills, growing birds, and processing plants. Because live broilers have limited transportability, broiler farms generally are located within close proximity to the integrator/processor. Consequently, shifts in geographic production regions have occurred to correspond with shifts in production and processing infrastructure.

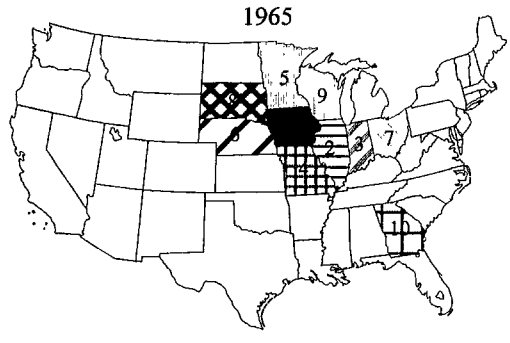
In the first half of this century, most broiler enterprises were located in the Delmarva area (Delaware-Maryland-Virginia peninsula), New England, Arkansas, East Texas, and California (Tobin and Arthur). For a number of reasons, including the loss of U.S. War Food Administration markets, boll weevil outbreaks in cotton producing states, and heavy apple crop failures in Arkansas, the geographical concentration of broiler production shifted to the South in the post-World War II period (figure 1). The relatively less expensive land, labor, and capital provided a major incentive for this shift. In addition, the lack of alternative economic opportunities, the eagerness of feed

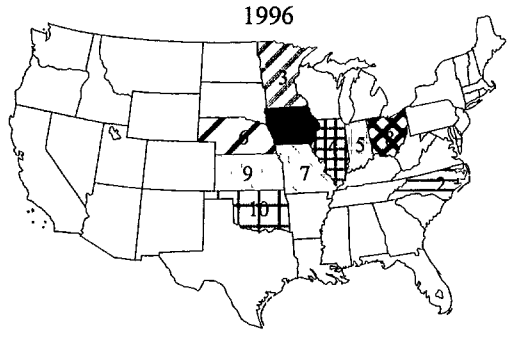




Source: Watts and Kennett.

Figure 1. Top ten broiler producing states





Source: USDA/NASS, Total Hog Inventory.

Figure 2. Top ten pork producing states

dealers to extend credit, and the increased social acceptance of contract production in this region due to the history of sharecropping made contract broiler production an attractive alternative to traditional farm enterprises.

Today, approximately 90% of all broiler chickens are raised by farmers under production contracts, with the remaining broilers fed on integrator-owned farms. Open market transactions have disappeared in commercial broiler production. Over the last four decades, many of the major broiler integrators also have disappeared, while others have either expanded or merged. In 1972, the four largest broiler firms accounted for 17% of all broilers processed. By 1994, the top four firms (Tyson Foods, Gold Kist, Perdue, and ConAgra) processed more than 40% of the broilers produced, with the top 20 firms accounting for 80% of processing (Watts and Kennett). The result is a highly industrialized industry with intensive production and processing units.

Pork production is following a similar course toward vertical coordination. Historically, hogs have been viewed by farmers as a means to add value to local corn production. This perception has led to the dominance of pork production in the U.S. Cornbelt and the emergence of a competitive industry characterized by many producers with relative ease of entry and exit.

Fueled by technological change and economic opportunity, the historic patterns of geographic location, farm size, packing plant size, and organization of pork production are changing at exceptional rates in the United States and in the South (figure 2). The number of swine farms keeps falling, with the majority of those exiting the industry keeping fewer than 1,000 head in inventory. In contrast, total inventory of farms with at least 2,000 head is growing rapidly (from 16.3 million on December 1, 1992, to 28.6 million on December 1, 1996). Forty percent of the growth in this category occurred in North Carolina. Farms with more than 2,000 head accounted for 28% of U.S. inventory on December 1, 1993, and 51% on December 1, 1996.

Why the dramatic changes in production, marketing, and processing in the pork indus-

try? Certainly technological improvements have led to substantial economies of scale in production. Similar to broilers, improved housing facilities and disease control measures, coupled with advances in nutrition and feeding regimes, have permitted large-scale, specialized pork production units to flourish. For broilers, these improvements coincided with the emergence of a new industry—for swine, the evolution of an existing one. In the early 1970s, well after vertical coordination and contract production were common in the broiler industry, stakeholders in pork production were still speculating on the possibility of industrialized pork production. This concept is best expressed by Erikson who, circa 1972, postulated the following:

> It is intriguing to speculate upon the possibilities of setting up a large, efficient processing plant ringed by hog-feeding lots and ringed in turn by hog farrowing units with only the grain transported from outlying locations. Under such an arrangement, considerable hog marketing, shrink, bruise and transportation costs might be saved. However, progress in disease and pollution control would probably be a requirement for such a system (p. 16).

Clearly, the pork production system as envisioned by Erikson was based on the already existing industrialized broiler chicken industry. Furthermore, with few exceptions, such a pork system is now emerging in the South.

Traditionally, hog farms in the South have been smaller than those in the rest of the country, and so reductions in the number of farms keeping at least one pig have been more dramatic in the South.[1] In 1989, the South was home to one-third of the 306,210 farms in the country which kept at least one pig. By December 1996, the South accounted for one-quarter of the 157,450 U.S. farms with at least one pig. The South's share of the national swine inventory has risen dramatically, from 15.8% in 1989 to 26.7% in 1996. Between 1989 and 1996, growth in North Carolina (+6.73 million head), Oklahoma (+1.09 million), Arkansas (+115,000), and Mississippi (+60,000) offset declines in other states to add nearly 6.5 million hogs to the region's inventory (U.S. Department of Agriculture).

Southern pork production is increasingly characterized by contract production. Large hog firms contract with growers to house and care for their growing pigs. Relative to the corresponding 90% in broiler production, it is estimated that 17% of all hogs slaughtered in the U.S. in 1994 were finished on contract (Grimes and Rhodes). However, industry experts suggest a much higher percentage of contract production in the South. This figure would include the more than 80% of total production in North Carolina which is estimated to be contract finished.

Changes in the number, size, and location of packing plants also are occurring. Hayenga et al. (1985, figure 6.1) reported there were 12 packing plants in the South that each slaughtered more than half a million hogs in 1982. By December 1996, only nine such plants remained. New large plants opened in Guymon, Oklahoma, and Tar Heel, North Carolina, while Georgia and Tennessee each saw their two plants close. Although hogs can be shipped several hundred miles to market, transportation costs sharply reduce profits. Consequently, swine production is likely to decline in areas that lack packing capacity. Unlike the broiler industry, less than 2% of hogs marketed in the country in 1993 were produced by packers (Hayenga et al. 1996). Most contractors in North Carolina sell market hogs to packers under term marketing agreements.

Why has pork production, and in particular large-scale intensive production, shifted to the South? Several factors help to explain this trend. For the most part, pork in the South was not an economically important commodity prior to the 1970s. The political climate surrounding traditional cash crops (i.e., peanuts and tobacco) left many farmers uncertain as to whether there was a profitable future with these commodities. Given the small farm size and low-yielding soils, individuals recognized the need to search for and develop alternative

[1] Here, the South refers to the following 13 states: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

farm enterprises. In North Carolina, beginning in 1960 (Jones), a concerted effort was made by the state government, land grant university faculty, and entrepreneurs to develop a pork industry that could effectively compete on a national level. Because the region was not hampered by existing capital, producers and processors were able to adopt the newest technologies and build associated infrastructures in order to capture economies of scale, both internal and external. Even though southern farmers face higher feed prices than their midwestern counterparts, implementation of such technologies as all-in/all-out production, split-sex feeding, and segregated early weaning, coupled with lower labor and land costs, offsets the higher feed expense. In 1994, Good found that hog production costs for a large specialized farm in North Carolina were 10.6% less than for a traditional hog farm in the Midwest.

New technologies by themselves cannot account for the rapid growth of the South's pork industry. An additional contributor is the receptive political and social environment. The large capital requirement of modern, confined pork production units has led stakeholders to search for alternative methods to deal with risk and financing. In contrast to other regions of the U.S., the South was already familiar with and relatively accepting of production contracts due to their widespread use in broiler production. Recognizing that price and some production risk is shifted to the integrator with production contracts, lending institutions have been more willing to provide financing for construction of new hog units. Finally, environmental regulations, zoning regulations, and anti-corporate farming regulations did not present insurmountable barriers to siting and building production units and processing plants in the region.

Although scale economies encouraged the movement toward industrialized broiler and pork production, gains from reduced per unit costs have not been without consequences. Within the last few years, focus in the industries has shifted from economies of scale in production and processing to recognizing the environmental impacts of intensive livestock and poultry production and to searching for methods to sustain production and environmental quality.

By-product Management and Environmental Consequences

Increased growth in intensive broiler and pork production and processing has multiple consequences. There are significant economic benefits to rural communities in the forms of alternative farm income, employment opportunities, and increased tax revenues. There are also environmental costs, both perceived and real, involved with intensive production and processing units.

The majority of environmental concerns are associated with manure management and include pollution of air, groundwater, surface water, and soils. Air quality concerns surrounding manure include ammonia volatilization, methane emissions, dust, and most importantly, odor. Groundwater and surface water issues predominantly involve the potential risk for large-scale nitrogen leaching and runoff from animal facilities, from manure holding or storage structures, and from fields receiving manure. Soil concerns are based on the potential for nutrient build-ups in the soil which may be harmful to plant productivity as well as a risk to groundwater and surface water.

Recognizing both the nutrient source and the environmental concerns associated with manure management leads to two questions. First, is manure an associated cost or potential benefit to broiler and pork production? Second, do broiler and swine units face similar environmental risks and constraints in manure nutrient management?

The following is an economic definition of a waste: any product that costs more to apply (use) than it is worth once applied (used). There is no question that all manure has intrinsic value: it contains nitrogen, phosphorus, potassium, and other nutrients essential to plant and animal growth. A problem in using manure (and many other organic by-products) is that the nutrients are dilute, they are mixed together, they are in relative proportions that are inappropriate for most plant and animal

uses, and nutrient content of manure may vary over time and from sample to sample.

The low concentration of nutrients in manure means that costs of storage, transportation, and application of manure are high per pound of nutrient compared to commercial fertilizers or other feed ingredients. As an example, a ton of fresh swine manure may contain 12 pounds (0.6%) total N, nine pounds (0.45%) P_2O_5, and nine pounds (0.45%) of K_2O. In some cases, the low concentration of nutrients means that the cost of application exceeds the value of the nutrients as fertilizer.

The inappropriate mix of nutrients in manure means that the value of manure in use is less than the sum of the value of the nutrients it contains. For example, a bermuda grass hay field receiving 300 pounds of N from anaerobic lagoon effluent may utilize 45% of plant-available P_2O_5. If the manure is spread over a greater area so that the phosphorus is fully used by the crop, an additional cost of applying the manure is incurred that usually exceeds the value of the additional phosphorus utilized. In addition, a supplemental application of nitrogen is required to meet plant needs, so total application costs may be further increased.

Local conditions also affect the value of manure. Climate, soils, crop selection and yields, extent of other livestock and poultry production, and prices for land, labor, feeds, and fertilizer all affect the cost effectiveness of various manure management systems. Manure management systems can have several components including removal from buildings, storage, treatment, transport, and application. Potential revenues and savings from manure management systems include by-product sales, on-farm use of by-products, reductions in production costs, and increases in quantity or quality of livestock or poultry produced. Basic costs of manure management systems include interest and depreciation on the initial investment in facilities, repairs, property taxes and insurance, electricity and fuel, labor, and supplies. Additional costs of manure management systems include record keeping, permitting and compliance, fines and legal fees, losses of net crop receipts, and land clearing and grading.

By-product Management: Broiler Production Perspective

Even though broiler and pork production units face similar environmental challenges associated with manure nutrient management (e.g., odors and an imbalance between nutrient uptake and placement), broiler units, in general, have more opportunities and choices available to them to increase the value of manure and other by-products. A major factor for this difference is the physical form of the manure itself. In contrast to the liquid product of the swine industry, broiler manure is absorbed by and mixed in with the litter placed on the broiler house floor for bedding. When removed from the house, the litter is a combination of manure, feathers, spilled feed and water, and the original bedding material (e.g., sawdust, wood or paper shavings) (Rahn). Consequently, broiler litter is a more transportable manure product than that from hog units.

To capture the nutrients inherent in the litter, some broiler farmers use equipment to separate the heavy pieces of litter (seemingly those with the most nutrients) and apply this nutrient-rich source to their fields. Still others will compost the litter and transport the composted material out of the area for field application or commercial sale. One broiler producer in Mississippi sells bags of composted manure locally for $4.95 per bag, with an estimated total cost per bag of only $0.55 (Pyenson). Even when transportation costs are significant, alternative markets still develop for dry litter removal (Burt). This transportability allows nutrient surplus areas to sustain broiler production while recycling nutrients and transporting them to deficit areas.

A further option available to broiler producers is the feeding of dry litter to ruminant animals as a feed source. According to Ransom and Strickland, the Tennessee Valley Authority, working cooperatively with Auburn University and other interested parties, has supported activities to increase the use of broiler litter for feed and fertilizer to develop and grow the beef cattle industry in the region.

Manure and litter are not the only recycl-

able resources involved in broiler production. Composting of dead birds is generally permitted in the South. This practice is in contrast to the hog industry, where only a few states allow composting of dead swine and most of those states are outside of the South. Only in North Carolina and Arkansas are producers usually able to obtain special permits to compost dead swine. In areas of concentrated swine and poultry production, dead birds and pigs are collected daily and recycled through rendering. Collection and rendering avoid additional nutrient loading to land surrounding hog and poultry production facilities.

Currently, broiler producers have more opportunities than swine producers for creating a valuable nutrient resource from manure and other by-products. Primarily, these opportunities are due to the dry matter content of broiler litter versus the effluent produced by swine units. A considerable amount of research is being conducted with the objective of enhancing the value of swine manure and reducing the environmental risks associated with large-scale intensive production units. For farmers to adopt such practices, they must be both economically and technically feasible. Until such time, the pork industry is faced with increasing regulatory actions and enforcement.

By-product Management and Environmental Regulation: The Case of North Carolina's Pork Industry

Since North Carolina accounts for 60% of the South's total hog inventory and 40% of recent growth in farms with more than 2,000 head, and because it receives the majority of attention in the public press regarding environmental impacts of intensive pork production, it seems only fitting to use this state as a background for a discussion of by-product management and environmental regulation.

Prior to 1992, livestock and poultry were regulated by the state of North Carolina as nondischarging agricultural operations. Farms were "deemed permitted" unless they were found to be discharging waste to the waters of the state. It was illegal for farms to discharge waste to the waters of the state including streams, rivers, and lakes. Farms were expected to follow Soil Conservation Service and Cooperative Extension Service guidelines to construct and operate manure management systems. The minimum setback allowed was 750 feet from the nearest residence.

In 1992, North Carolina adopted regulations referred to as ".0200." These rules required all new hog farms to have waste management plans certified by qualified engineers or by others designated by the state. All existing hog farms were required to register with the state Department of Environment, Health, and Natural Resources and to develop a certified waste management plan by December 1997. Such a plan must state how many animals are on the farm, the size of the treatment lagoon, and the acres of each crop receiving effluent. Nitrogen in the effluent can be applied to cropland at no more than agronomic rates on the acres of each crop included in the plan. Such was the setting for environmental regulations prior to the summer of 1995.

In June of 1995, after 21 inches of rain had fallen over a three-week period, the dike impounding an above-ground lagoon at Oceanview Farms near Jacksonville, North Carolina, broke. The entire contents of the lagoon, estimated at more than 20 million gallons, escaped and drained across neighboring fields and a highway into the New River above Jacksonville. Approximately 5,000 fish valued at $6,500 were killed. Boaters and riverside businesses downstream complained of odorous water and were warned to avoid contact with the water. Also that summer, four other hog lagoons and a poultry lagoon experienced spills. Since most hog lagoons in North Carolina are excavated rather than above-ground impoundments, the other spills were of much smaller volume and only two of them reached streams directly.

In response to the lagoon spills and growing environmental awareness, the governor ordered inspections of all livestock and poultry lagoons in the state. More than 4,000 lagoons were inspected. Approximately 2.8% were found to have illegal discharge devices such as overflow pipes, or overflowing lagoons, or some other fairly serious problem. Another

400+ lagoons had lesser problems such as eroded lagoon banks or insufficient freeboard. One producer with a 14-year-old farm was found to have no sprayfield. He apparently had been discharging effluent into a swamp. This producer had his farm shut down by the state attorney general's office and was facing felony charges. Later in the summer and fall of 1995, millions of fish died in the Neuse River. Coastal residents and fishermen were alarmed and expressed their concern. Environmental advocates blamed the fish kills on the hog industry and demanded action.

Responding to the incidents that occurred in 1995, the state legislature passed a law increasing the minimum setback for hog facilities to 1,500 feet from the nearest residence and 2,500 feet from the nearest school, church, or other public facility. In North Carolina, counties do not have authority to zone against farming operations in rural areas. The governor, the speaker of the state house, and the president pro tem of the state senate each appointed members to a Blue Ribbon Panel on Agricultural Waste. The panel conducted hearings over several months and developed recommendations for further regulation of the livestock and poultry industries. Those recommendations, with some additions, were adopted by the state government in 1996.

The new rules (referred to as Senate Bill 1217) specified that all farms with more than 250 swine must obtain a general permit to operate. Two inspections are required each year: one by the Division of Soil and Water Conservation and one by the Division of Water Quality. Farmers must pay an annual inspection fee of $50 to $200. The rules require that a certified waste applicator be on the farm whenever waste is being land applied. In order to become certified, the operator must attend 10 hours of training, pass an examination, and attend six hours of additional training every three years. The new rules also require a setback of 500 feet from property lines for facilities and lagoons in addition to the previously established setbacks from residences, schools, and churches. Reflecting the fact that in 1993, broilers generated about 50% more plant-available nitrogen than hogs (Barker and Zublena, table 3), S.B. 1217 also requires poultry producers using the litter manure handling system to have certified nutrient management plans.

Environmental Implications of Industrialization and Coordination

Two distinct characteristics of evolving broiler and pork production systems have implications for environmental impacts. The first is the shift to large, specialized operations concentrated in small geographic areas; this shift often is described as industrialization. The second characteristic is the shift away from independent sole proprietorships exchanging products through open spot markets to farms, feed mills, and processors linked by production contracts, marketing agreements, or common ownership.

Implications of Industrialization

The shift to larger, specialized farms means greater concentration of by-products, and therefore *potential* for greater disaster. However, the movement toward industrialization also means a greater concentration of resources, knowledge, and incentives for sustaining environmental quality. Industrialization may generate greater dependence on management and technology, thereby creating greater potential for mismanagement. On the other hand, large, specialized farms employing full-time labor can spread the cost of proper manure management over more production, minimizing average cost per animal. Furthermore, because large, capital-intensive farms imply large investments, owners of these farms are highly motivated to avoid liability for environmental damage.

Just as economies of scale reduce costs on larger production facilities, they present greater opportunity for treatment and alternative utilization of by-products (e.g., Powers). The concentration of large quantities of by-products at one farm and in a small geographic area increases the potential for offsite marketing. Such concentration increases the potential for specialized by-product management ser-

vices such as custom poultry litter applicators. From a policy perspective, professional applicators can be more easily trained and monitored than a large group of farmers.

Greater concentration of production imposes diseconomies of by-product dispersion (e.g., see Henry and Seagraves). Barker and Zublena note that several counties in North Carolina produce more nutrients in swine and poultry manure than can be used by crops grown in those counties. Concentration of large farms creates greater potential for centralized processing and export terminals. Centralized by-product treatment facilities can actually improve environmental quality by removing material that was previously buried or land applied. For example, a central dead bird and pig collection site established by the Greene County (North Carolina) Livestock Association allows smaller, independent livestock producers to recycle their dead livestock.

Not all centralized systems are economically feasible. Centralized pig manure drying facilities in the Netherlands have been abandoned because the transportation and drying costs are too high. Denmark has used centralized anaerobic digestors to treat manure and capture methane. These facilities are only feasible with a substantial subsidy from the government. Centralized composting and shipping facilities for poultry litter are profitable in some situations. In the pork industry, systems for separating, collecting, and marketing solids from treated swine manure are being evaluated.

Another issue associated with large-scale farms concentrated in a small area is that these areas may become large importers of feed such that nutrients in by-products accumulate more rapidly than they can be applied to cropland. Nitrates are the primary concern, given their mobility in groundwater and surface water. Further treatment of manure to convert the nitrogen to N_2 gas or to separate and export N, P, Zn, and Cu are options in such situations (Barker). Producers and regional leaders weigh the costs of reducing build-ups of less mobile nutrients (P, Zn, Cu) in the soil against the costs of further treatment and export. While previous feeding programs mainly emphasized rapid productivity gain, increased attention is being placed on improving feeds to sharply reduce the surplus phosphorus and other minerals excreted by swine and poultry (Cromwell and Coffey). Broiler feed efficiency improved from 3.0 to 2.04 pounds of feed per pound of gain (Havenstein et al.) between 1957 and 1992. Large, specialized farms in North Carolina use 3.0 pounds of feed to produce a pound of live hog compared to averages of 3.5 or greater on traditional Midwest farms. Reduced feed use results in reduced surplus nutrients to be managed.

Large, specialized farms are highly visible and easily inspected compared to a similar number of livestock scattered over many smaller farms. Consequently, increased attention from the general public and from regulators seems to accompany industrialization. Such attention puts pressure on existing farms to upgrade technology. Often, older farms are already only marginally profitable and the imposition of requirements for new capital investment may cause them to close. Thus, the process of industrialization may create interim environmental problems. Rapid increases in farm size may result in farms outgrowing popular technology; for example, systems that worked well for 100 sows may not be as well suited to farms with 5,000 sows, and setbacks that seemed adequate for 100 sows may prove inadequate for 5,000 sows. Because industrialization is profit driven, large firms that are profit oriented are unlikely to spend more than they judge profitable over the long run on by-product management. Myopia and underinvestment in social goods such as environmental protection are potential problems, particularly among marginally competitive firms.

Implications of Contracts and Coordination for Environmental Effects

The second major characteristic of evolving broiler and pork production systems is the use of production contracts and other forms of coordination. An important question raised is: Are independent contractors motivated and capable of proper manure and mortality man-

agement? The answer partially depends on the terms of the contract. Currently, production contracts seldom address environmental impacts, and rarely are clauses found in contracts to address sustainability and nutrient balancing. However, most production contracts do require growers to comply with all state, federal, and local regulations in constructing and operating their facilities and in the disposal of dead animals. Failure to comply can result in termination of the contract—potentially a substantial financial loss to the grower. A large swine contractor in North Carolina reportedly removed 5,000 hogs from a grower's facilities overnight after the grower was cited for violation of state environmental regulations. Contract growers have relatively large investments in facilities. Therefore, they are highly motivated to avoid liability. The inspections of lagoons in North Carolina in 1995–96 found a relatively small proportion of problems on farms associated with the large contractors.

One benefit of contract coordinated production is that large contractors tend to employ specialized professional management. Large swine contractors generally employ engineers and others to train farm operators, to keep records, and to provide manure management services on both company-owned and contract growers' farms. Consequently, integrators are better positioned to adopt environmental clauses in contracts and offer services to growers who could not afford such services on their own. Access to professional assistance may help contract growers avoid problems.

Integrated broiler and pork firms that sell branded products, or firms with marketing agreements that include environmental quality assurance as a stipulation, are highly motivated to avoid environmental damage.[2] The reputational capital associated with names like "Tyson" or "Perdue" provides increased incentive for integrators to work cooperatively with contract growers. A damaged reputation may be costly to an integrator selling branded products. An additional incentive for environmental protection will be created in a vertically coordinated system when premiums associated with differentiated markets for branded "green" products arise.

Summary and Conclusions (What Next?)

Industrialization, production contracts, and coordination have a range of implications for environmental impacts of animal agriculture. Concentration of by-products at a single site and of numerous large sites in a single area increases the potential for large-scale accidents and environmental damage. This fact has caused many states to adopt more stringent permitting, inspection, certification, record keeping, and education requirements for hog farms and other farms using liquid manure handling systems. Often, the regulation of one industry reaches out to multiple livestock and poultry sectors. Such was the case in North Carolina when the movement toward basin-wide management plans led to the imposition of certified nutrient management plans for poultry producers using dry litter systems. Regardless of whether one discusses pork or poultry, the potential impact is the same for smaller operations: economies of scale result in a greater cost per head of regulatory compliance for smaller operations—consequently, the movement to regulate larger farms seems to accelerate the rate of change.

With change, however, comes opportunity. Large farms and concentration of large farms create opportunities for adoption of improved recycling of nutrients and large-scale treatment and marketing of by-products. Research is underway to evaluate various alternatives for managing by-products. Economic analysis is a critical component of current research as leaders strive for optimal resource allocation in the midst of political debate.

Optimal resource allocation with respect to livestock and poultry production is defined by multiple objectives including economic prosperity for individuals and rural communities. Optimal resource allocation is constrained by the local resource base, settlement patterns in-

[2] Not all vertically coordinated systems are large or made up of large farms. Community Supported Agriculture is a form of high coordination between producers and consumers that enhances demand for products from local farms that are typically smaller in size.

cluding farm sizes and numbers, livestock and poultry production technology, and by-product management technology. Public and private investments are being made to develop improved technology and markets for by-products of pork and poultry production. Efforts are underway to develop alternative methods of efficient coordination to foster long-term competitiveness of independent producers. Regulations are evolving to ensure environmental protection without causing unnecessary financial harm to rural communities and existing producers. New production and processing facilities are being built in places where the cost of environmental protection is low. Sustainability will be defined by environmental quality, community prosperity, and long-term economic optimality rather than by a prescribed set of behaviors.

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