Economics of Industrial Farm Animal Production

A Report of the Pew Commission on Industrial Farm Animal Production

TOPIC:

An Economic Analysis of the Social Costs of the Industrialized Production of Pork in the United States

Harwood D. Schaffer
Pracha Koonnathamdee
Daryll E. Ray, PhD

CONTENTS

PCIFAP Staff Summary on the Economics of Industrial Farm Animal Production

The Pew Commission on Industrial Farm Animal Production was established by a grant from The Pew Charitable Trusts to the Johns Hopkins Bloomberg School of Public Health. The two-year charge to the Commission was to study the public health, environmental, animal welfare, and rural community problems created by concentrated animal feeding operations and to recommend solutions.

When analyzing any commercial endeavor, it is impossible to perform a complete analysis without including a study of the economics involved. In particular, it is useful to look at the economic assumptions that lead to the creation and perpetuation of a certain model of production. For that reason, the Commission would be remiss in its study of industrial farm animal production (IFAP) if it were to ignore the economics of this most common form of food animal production. It is important to note that the production of food animals is very different today than it was on the farms of the past, a fact that significantly changes the economics of farming.

Today, we have larger farms, producing more food with less labor than at any time in history. Farms in the United States have moved away from a diversified model, where feed grains, some vegetables, and some animals are raised on each farm, to a specialized system in which many grain farmers do not raise animals and most animal farmers specialize in only one species. This is particularly evident in food animal production, where large numbers of animals and standardized, routinized tasks have resulted in an industrial style of animal production. By the mid-20th century, the broiler industry was well into the process of industrialization with the integration of the supply chain from hatch to dispatch. It was not until the 1980s that the production processes for pork were sufficiently standardized and routinized, leading to the industrialization of the hog industry and the development of hog concentrated animal feeding operations (CAFOs). As of 2001, 75% of the US hog inventory was held on farms with 2,000 head or more, a size consistent with industrialized CAFO systems.

Proponents of IFAP claim that the reason such large industrial farms came into existence, and the reason they remain, is that they are more cost efficient and provide the consumer with a less expensive source of animal protein. However, critics of the industrial model in its present form argue that this efficiency is gained by externalizing many of the costs associated with the model—that it only seems efficient because important costs of IFAP are not reflected in either the cost of the production system or its products, but are instead paid for by the public in other ways. These "externalities" may include anything from changes in property values near industrial farming operations, to health costs from polluted air, water, and soil, and spreading resistant infections or diseases of animal origin, to environmental degradation or cleanup costs—all of which are "paid" by the public, though they are not included in the cost of producing or buying the meat, poultry, eggs, and milk that modern industrial animal agriculture provides.

This technical paper aims to evaluate these differing perspectives by developing a theoretical model with which the externalities associated with swine production, both positive and negative, can be internalized and quantified. Rather than arriving at a single dollar value to represent the cost of a given externality, a menu of pricing options is offered that identifies the different values that various stakeholders may assign to each externality, indicating that more than one computation of an externality can be defended. Using this methodology, the study shows that when externalities are taken into account, the industrial production of pork is more expensive than production systems organized around smaller-scale technologies and systems.

This analysis suggests that it is not the scale of production that has allowed IFAP-style production to lower the cost of pork for the consumer. Rather, it has been the ability of IFAP operations to externalize a significant portion of their costs that has made them appear to be more cost efficient than smaller-scale, more traditional production systems or even newer systems like hoop production. This report calls into question the economic sustainability of the IFAP system of food animal production that exists today and, by extension, raises questions about other forms of IFAP.

By releasing this technical report, the Commission acknowledges that the authors fulfilled the request of the Commission on the topics reviewed. This report does not reflect the position of the Commission on these, or any other, issues. The final report, and the recommendations included in it, represents the consensus position of the Commission.

Project Overview

The years following the end of World War II have seen significant shifts in the nature and structure of agricultural production in the United States. Nowhere has this been more apparent than in the production of animals for meat. The move has been away from a diversified production system, in which each farm produced a number of crops and a variety of animals for household and commercial consumption, to a production system in which many farmers specialize in crop production and raise no animals for meat, egg, or milk production. In addition, those who raise animals for commercial production usually limit themselves to one species. Some key elements in this transformation have been the availability of stored energy, primarily in the form of liquid fossil fuels, and the technological innovations that have taken place using this stored energy. The substitution of stored energy for human and animal labor, coupled with technological advances, has resulted in the development of larger farms and rapidly improving productivity. Another factor in this increased productivity in labor is increasing specialization, with some farmers specializing in grain production and others shifting to animal production (Ray, 2004), resulting in a decreasing number of farmers raising both animals and grain. Today, we have larger farms, producing more food with less labor than at any time in history.

Using methods that were developed in the industrial sector, farmers have sought to standardize and routinize tasks in order to increase their efficiency. Nowhere has this been truer than in animal production, where large numbers of animals and standardized, routinized tasks have resulted in the industrial style of animal production (Hurt, 1994; Rhodes, 1995). By the mid-20th century, the broiler industry was well into the process of industrialization with the integration of the supply chain from hatch to dispatch. Turkey production quickly followed the pattern set by broilers. It was not until the 1980s that the production processes for pork were sufficiently standardized and routinized, leading to the industrialization of the hog industry and the development of hog concentrated animal feeding operations (CAFOs). At the beginning of the first decade of the 21st century (2001), 75% of the US hog inventory was held on farms with 2,000 head or more (McBride and Key, 2003), a size consistent with industrialized CAFO systems.

The legitimating discourse for the development of the industrialized model of food production and, in particular, industrialized farm animal production is that it is more cost efficient than traditional modes of production and provides the consumer with a lower-cost source of protein (Davis and Lin, 2005; Key and McBride, 2003; McBride and Key, 2003). Critics of this model argue that these lower costs are achieved by externalizing some costs onto society at large, thus reducing the costs directly borne by the producer and transmitted to the consumer through costs other than the cost of the animal product (Mikesell et al., 2004; Stofferahn, 2006; Sullivan et al., 2000). These critics argue that if these externalized costs—air and water pollution, negative health experiences of workers, and the impact of the subtherapeutic use of antibiotics in meat production, for example—were added into the cost of production, the industrialized methods would not be cost efficient. They only seem cost efficient because the industrialized model does not bear all of the costs that result from industrialized production.

To evaluate this difference in perspective, this paper begins by examining the role and nature of swine

production in the United States. Attention is given to identifying the relative firm-level production costs for different production systems. Because firm-level costs do not reflect costs that are borne by others in society, these externalized consequences are identified.

The paper then develops a theoretical framework within which these externalities can be conceptualized and quantified. Rather than arriving at a single dollar value to represent the cost of a given externality, a menu of pricing options is offered that identifies the different values that various stakeholders may assign to that externality, indicating that more than one computation of an externality can be defended. The theoretical framework also recognizes that some impacts of various externalities are best captured by a descriptive rather than a quantitative methodology.

Using this methodology, the study shows that when externalities are taken into account, on average, the industrial production of pork is more expensive than production systems organized around smaller-scale technologies and systems. When some externalities and subsidies are taken into account, pork produced using the hoop system costs 25% per hundredweight (cwt) less to produce than pork produced using a CAFO system. Without considering those externalities, pork produced using the CAFO system was one-half of one percent lower in cost than the pork produced using the hoop system. Similarly, without taking externalities into account, pork produced using the pasture system costs 12% per cwt more than pork produced using a CAFO system. Once externalities are taken into account, the cost advantage swings by 12%per cwt for pasture-raised hogs. On average, small farrow-to-finish production systems are more expensive than CAFOs even when externalities are taken into account. However, it should be noted that within each production system some operators have lower costs of production than the average for the other systems, even before externalities are taken into account.

It is not simply the scale of production that has allowed CAFOs to produce lower cost pork for the consumer. Rather, the analysis of this paper suggests that it has been the ability of CAFO operations to externalize a significant portion of their costs that has made them appear to be more cost efficient than smaller-scale, more traditional production systems or even newer systems like hoop production.

History and Trend of Swine Production

The swine industry is an important element of the agricultural sector of the US economy. It contributes economically to a variety of sectors along the supply chain, including grain producers, feed supplement processors, swine producers, the pharmaceutical industry, meat processors, shippers, and food retailers. In 2005, the industry produced an estimated 550,000 domestic jobs, supported by more than $97 billion in total sales. According to the National Pork Producers Council (NPPC), this activity generated more than $34.5 billion in the US gross national product (NPPC, 2007b). The US swine industry is experiencing increased growth as it continues to meet international consumer demand for what has become the most popular meat product worldwide (Davis and Lin, 2005; NPPC, 2007b). The United States is one of the world's leading swine-producing countries and pork exporters. In 2006, the US exported about 1.3 million metric tons of pork valued at $2.8 billion. At the same time, the United States is the world's second largest consumer and importer of pork and pork products (ERS, 2006). Pork ranks third in annual US meat consumption, averaging 51 pounds per person (Davis and Lin, 2005).

The production of pork contributes to grain and feed sectors of the US economy through the utilization of corn, soybean, and other inputs including vitamins and minerals. Feed is the major production input to the swine industry. In fact, feed accounts for more than 65% of all production expenses (NPPC, 2007b). According to the United States Department of Agriculture (USDA), the "US pork industry used 1.08 billion bushels of US corn and 265 million bushels of US soybeans in 2004." By the same token, in 2006, pork production used 1.216 billion bushels of corn and 353.1 million bushels of US soybeans. On average, each hog consumes 12 bushels of corn and 130 pounds of soybean meal (NPPC, 2007b). The pharmaceutical industry benefits from the subtherapeutic use of 10.3 million pounds of antibiotics in the production of pork (Mellon et al., 2001).

The US hog inventory has remained at approximately 60 million head since 1990, mostly in the Corn Belt area, while total production has increased from 15.4 billion pounds in 1990 to 21.7 billion pounds in 2007 (USDA, 2007). These increases, in the face of steady hog numbers, came about as the result of larger pig litters, more rapid weight gain, and heavier market weights. These factors are closely related to the management systems put in place by the industrial producers. The major producing states in the Corn Belt are Iowa, Minnesota, and Illinois. North Carolina is the major producer in the Southeast.

The structure of the hog production sector has changed dramatically during the past two decades, with CAFOs becoming increasingly dominant. In 2002, the number of US farms with hogs on them was about 79,000 farms (USDA, 2002), a decrease of half from 20 years earlier and down from three million in the 1950s (McBride and Key, 2003; Rhodes, 1995). Because the total hog numbers have remained relatively constant over this period, the number of large operations increases as more of the small operations exit the industry. Historically, hog production was dominated by a large number of small operations. In recent years, hog production has shifted from a craft process, in which the farmer was involved directly in all phases of hog production, to an industrial model based on the division of labor and the utilization of mass production management systems. Today, more than half of all pork operations produce 5,000 or more pigs per year (USDA, 2007).

This major shift in the structure of the hog industry results from the rapid increase in the use of production contracts, which improves the firm-level efficiency of both the production and the marketing of pork through systematic management practices, improved animal genetics, feed production efficiencies, improved market coordination with slaughter plants, and increased veterinary and nutritional supervision of hog production. Contract operations account for a large share of hog production (Sullivan et al., 2000), resulting in a substantial increase in factor productivity and technological improvement over independent production (Key and McBride, 2003). When a contractor moves or expands into a new region, new contracts can be negotiated in the new location (Sullivan et al., 2000), shifting the economic leverage from the producer to the contractor. As a result, the growth of contract hog production has also been a major force behind the changing location of hog production. For example, the rapid increase in hog production in the Southeast, particularly in North Carolina, is due in part to the increase in contracting by a few large integrators. Hog production in North Carolina developed around the need to find alternative sources of economic activity to replace the declining importance of tobacco production (Kliebenstein and Lawrence, 1995). From the producer's point of view, North Carolina was a desirable location with a plentiful supply of labor, anti-union sentiment, and weak environmental protection laws (Kliebenstein and Lawrence, 1995; Lyford and Hicks, 2001; Rhodes, 1995). During the development phase of the hog industry in North Carolina, the weakness of its environmental protection laws compared to other states can be seen in the lack of regulations concerning local control, facility design approval, geologic testing, setbacks, and nutrient management plans (Metcalfe, 2000).

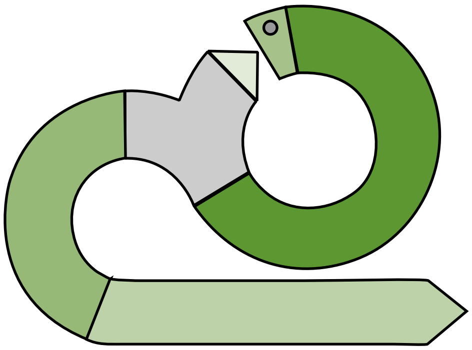
Like two sides of a coin, the structural change in the system of hog production both contributes to the US economy and imposes costs on society in the form of externalities. The structural shift to industrial hog production has resulted in significant environmental consequences as the result of the large volume of hog manure concentrated in a smaller area. The long-term storage of untreated waste from CAFOs is a source of air and water quality degradation resulting from the anaerobic digestion and subsequent evaporation of toxic gases. The land spreading of these accumulated waste products results in runoff to surface water, and leaching to groundwater (Aillery et al., 2005). The Environmental Protection Agency (EPA) only requires CAFOs[1] to have National Pollution Discharge Elimination System (NPDES) permits in order to develop and implement a comprehensive nutrient management plan for the waste products. In addition, local governments may control the hog operations with their own regulations and requirements.[2] Therefore, it has been hypothesized that hog production has expanded in areas in the South and in nontraditional areas of the West because of possibly less stringent environmental regulations, the so-called pollution haven hypothesis.

The pollution haven hypothesis suggests that polluting industries will relocate to jurisdictions with less stringent environmental regulations. A study of this hypothesis (Appendix A: Hogs Run) found a difference in the pollution haven hypothesis between two periods, suggesting at least two possible meanings. First, in the earlier period, those seeking to engage in integrated hog production systems found their potential profits reduced by strict environmental regulations in the grain belt and looked for the hog havens. However, in the later period, because of substantial investments made in their current location, adopting the new technology to meet environmental requirements is less costly and thus more likely to be current practice than selling out at a loss and relocating to areas with less stringent levels of regulation. It is also possible that environmental regulations are not fully implemented in an area where local revenue is derived mainly from the farm. Therefore, a good explanation for the expansion of hog production is derived from the conventional idea of profit maximization. It cannot be denied that when locating the site for an industrial operation, operators may seek hog havens. Environmental regulations are put in place after people suffer and complaints are made. Hog operations will then adopt the new technology through contracts and/or government supports in order to meet those regulations. The result thus favors production in the form of larger operations.

Pork production

The costs associated with hog production vary from one stage of production to another due to differences in labor, facility, and feed requirements. Swine production is usually divided into two distinct periods, breeding (reproduction) and growing. This division arises because the inputs to these two periods are quite different from each another. Another major reason for the classification is the need to segregate younger animals from older ones for disease control (Pitcher and Springer, 1997). In order to understand the swine production process, the biological hog cycle[3] must be examined because it imposes constraints on swine production management, facilities design, and productivity. The biological hog cycle is about 20 months from the time a sow is bred and farrows (gives birth to a litter), a retained gilt (young female) reaches breeding age, and her offspring reach slaughter weight. A sow can produce an average of slightly more than two litters per year and serve for four litters, each consisting of an average of nine pigs. Swine biology may be thought of as a flowing cyclical process, as shown in Figure 1.

Figure 1. The Biological Hog Cycle (Source: Pitcher and Springer, 1997)



In hog production, it takes about 32 weeks to proceed from birth to breeding age, or when a gilt is ready to reproduce. The reproduction process begins with the mating of a gilt capable of conception and a boar, or with artificial insemination of the gilt with semen from a desired boar. Once the gilt has been bred successfully, she will farrow in approximately 16 weeks. The sow then nurses her piglets for an average of 2–3 weeks before they are weaned. This phase is normally called the farrow-to-wean production. After weaning, sows can be bred again after a short recovery period (Kephart et al., 2004; Pitcher and Springer, 1997).

At an average weight of 10–20 pounds, the weaned pigs are moved on to the next phase of production known as wean-to-feeder pig. During this phase, piglets are fed rations varying in protein content until they reach an average weight of 20–60 pounds. This phase takes about six weeks. From the feeder pig stage, the animals enter an intense feeding stage and remain there until they reach the desired weight, ranging from 240–270 pounds. Operations of this type are known as the feeder pig-to-finish phase.

The hog operation can be called the farrow-to-finish operation if it operates from gestation period to slaughter weight market. This operation takes about 40–44 weeks. Figure 2 illustrates hog production phases and completion times. In conclusion, the production of hogs can be divided up into five different production processes: farrow-to-wean, feeder pig or nursery, finishing, breeding stock, and farrow-to-finish.

Figure 2. Hog Production Phases and Completion Times (Source: Adjusted from USDA) Note: Phases and times are reasonable examples only. Actual industry values will vary by season, phase of the production cycle, region, and firm.

Production phase	Length of time
Breeding and gestation of producing female	15 weeks
Birth to breeding age	32 weeks
Gestation	16 weeks
Birth	
Weaning	2–3 weeks
Nusery, growing, backgrounding	6 weeks
Finishing	16–20 weeks

In the commercial swine operation, the types of production are consistent with the production phases. Among independent producers, the type of production chosen depends on the interest, experience, labor, land, and available capital of the producer, as well as the equipment, facilities, and feed supply. Specializing in only one segment of the production scheme allows the producer to develop more refined management skills and facilities for a particular production process as opposed to being an expert in all phases of production, allowing them to be more cost efficient. Different production processes also allow the operator to manage labor requirements to be integrated with other farming or off-farm occupations (Holden and Ensminger, 2006). In addition, the social and environmental implications associated with manure management are issues affecting the type of production chosen (Kephart et al., 2004).

For grain-hog farmers, grain production capacity (primarily corn) can be a factor in deciding on the type of production system the producer chooses to engage in. On the other hand, many producers only raise hogs and do not have a grain production operation. For them, the cost of purchasing feed may be a deciding factor in favor of a particular type of production. Table 1 lists the percentage of the total feed required for each of the production types mentioned. The farrow-to-wean system requires only 14% of the total feed needed to produce a slaughter hog, while the wean-to-finish system consumes 86% of the feed. Generally, farrow-to-finish production has been the historic type of pork production and still remains the most profitable production method (Holden and Ensminger, 2006).

Farrow-to-finish

Farrow-to-finish producers breed sows, farrow them, produce pigs to the weaning stage, and finish them for the market. The operators of farrow-to-finish systems must have expertise in all phases of swine production. The farrow-to-finish operation has the greatest long-run market potential and flexibility for an independent operator. In this system, a small number of sows can fit into a crop operation nicely when farrowings are scheduled to avoid peak harvest times. Farrow-to-finish operations demand the most capital and labor, and require a long-term commitment to the swine business (Kephart et al., 2004).

Farrow-to-feeder pigs

Feeder pig producers raise pigs from birth to about 10–60 pounds, and then generally sell them to finishing operations. Farrow-to-feeder pig production is best suited for producers who have a surplus of labor available and a limited feed supply (Holden and Ensminger, 2006). In addition, it decreases the need for facilities, operating capital, and the amount of manure handled. However, farrowing houses and nurseries are the most expensive facilities used in pork production.

Feeder pig-to-finish

Producers that finish pigs buy either the weaned or feeder pigs and then grow them to slaughter weight. This type of production allows for minimum overhead per hog, low labor requirements, and no long-term commitment in the case of independent producers. Normally, producers with large grain supplies and limited labor and facilities can purchase feeder pigs, providing a good means of marketing their grains. The operation also may capitalize on the fertilizer value of the manure.

Most producers use only one production system.[4] Most hog producers use some type of confinement production, with specialized, environmentally modified facilities. Confinement production allows year-round production by protecting hogs from seasonal weather changes, while reserving productive land for crops.

The key in the pork production process is number of feeder pigs which either come from the number of sows and gilts or the number of feeder pig imports. In the past, with farrow-to-finish, each gilt retained for breeding had some impact in slowing pork production gains during the 12–18 months before her first offspring are sold. But that impact is steadily decreasing, with litter size approaching nine pigs and most sows farrowing at least twice a year, allowing pork producers considerable ability to respond to market opportunities.

Table 1. Expected Feed Inputs (Source: Holden and M.E. Ensminger, 2006)

Types of Production	Percentage of Total Feed
Farrow-to-finish (includes all feed)	100%
Farrow-to-wean (includes gestation, lactation, boar feed)	14%
Farrow-to-feeder pigs (includes farrow-to-wean plus starter feed)	22%
Wean-to-finish (includes starter and finishing feed)	86%
Feeder pig-to-finish (includes finish feed only)	78%

Table 2. Hog Inventory (Source: USDA)
Note: Hog inventory is in million heads.

State	2002 rank	2002 inventory	2002 % of US inventory	1992 rank	1992 inventory	1982 rank	1982 inventory	1974 rank	1974 inventory
Iowa	1	15.49	25.94	1	14.15	1	14.33	1	11.48
North Carolina	2	9.89	16.56	3	5.10	8	2.05	10	1.41
Minnesota	3	6.44	10.78	4	4.67	3	4.47	4	2.99
Illinois	4	4.09	6.85	2	5.64	2	5.99	2	5.33
Indiana	5	3.48	5.83	5	4.62	4	4.30	3	3.35
Nebraska	6	2.93	4.91	6	4.19	5	3.96	6	2.74
Missouri	7	2.91	4.87	7	2.91	6	3.19	5	2.91
Oklahoma	8	2.25	3.77	24	.26	25	.21	25	.23
Kansas	9	1.52	2.55	10	1.58	10	1.71	9	1.52
Ohio	10	1.42	2.38	9	1.96	7	2.08	7	1.81
South Dakota	11	1.38	2.31	8	1.98	9	7.76	8	7.58
Pennsylvania	12	1.23	2.06	13	1.07	15	.87	19	.49
2002 Top 12		53.03	88.8		83.5%		76.5%		59.1%
United States		59.72			57.65		58.70		60.61

Changes in the structure and location of pork production

The US hog inventory has remained at approximately 60 million head since the 1970s, with about 66% of 2002 production in the Corn Belt states of Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, and South Dakota, where producers have access to that region's abundant supplies of feed grains and soybean meal. The major producing states in the Corn Belt area are Iowa, Minnesota, and Illinois, with a share of total production of 25.94%, 10.78%, and 6.85%, respectively (Table 2). Outside of the Corn Belt, most of the hogs are located in the Southeast with a significant amount of production in North Carolina (16.56% of total hog inventory). The top five pork producing states, ranked in order, are Iowa, North Carolina, Minnesota, Illinois, and Indiana.

As shown in Table 2, most hog operations were located in the upper-Midwest or the Corn Belt until the second half of 1980s. The Corn Belt's position as "the nation's pork supplier" was the result of its plentiful supply of corn and the development of reliable interregional transportation systems (Roe et al., 2002). It maintained this position for most of the 20th century. However, "[I]n the last 20 years, the Corn Belt's historical dominance in hog production has begun to fade as the result of the development of new railroad configurations and the interstate highway system which have driven down the cost of transportation, allowing feedstuffs to cheaply flow to other regions of the country" (Roe et al., 2002). Therefore, the coordinated hog systems have both changed and expanded during the 1980s and 1990s. The expansion location was not limited to traditional production regions and, in fact, arrived in areas such as the Southeast,[5] where farmers were familiar with contract production systems from poultry (Rhodes, 1995; Roe et al., 2002).

Contracts are important across all components of the hog operation. It is common for the breeding stock to be wholly owned by the breeding or farrowing unit, and to contract with nurseries and growers or finishers to feed the hogs to market weight. The contracted farms are paid a fee and premium that usually depend on weight gain. The selling of the market hog and the price received is often determined long in advance by a contract between the hog's owner and the packer, increasing industry efficiency and stability (Grannis and Seidle, 1998). Most contracts are owned by the concentrated sow operation that has arranged to have their pigs fed to market weight by other farmers. This contract arrangement is not universal, however, since networks where ownership is partial or changes as the animal changes hands are also possible. Feed producers who own pigs are another group using hog producer contracts to guarantee them a market for their feed.

International trade, particularly exports, has taken on an increasingly important role over the last 20 years. In 1987, the US imported 1.2 billion pounds of pork (an amount equal to 8.3% of production) while exporting 0.1 billion pounds of pork (0.76% of production). In 2007, the position of imports and exports had reversed with pork imports staying relatively steady at 1.0 billion pounds (4.6% of production) and exports growing to 3.0 billion pounds (14.0% of production). Nearly one in every seven hogs produced is destined for international markets. Without the increase in exports, pork producers would have had to reduce the US herd by one-seventh. Pork producers have every expectation that pork exports will continue to increase in the coming decade (NPPC, 2007a; USDA FAS, 2008).

Pork Costs

The consumer cost of food and food items such as pork can be observed from the Consumer Expenditure Survey7 (BLS, 2007). On average, US consumers spend about 12–13.6% of their total household income, or $5,491–$6,495 each year, for food which can be separated into food at home (about 55%) and food away from home (about 45%). Meats, poultry, fish, and eggs account for about 20.9–23.9% or $712–$885 at-home household expenditures on food (Table 3). Pork expenditures are about 4% of food expenditures or about 16–23% of meat expenditures. In 2005, a US household spent, on average, between $150 and $163 for pork consumption. However, one could expect that pork consumption/expenditures could be higher if the “food away from home” consumption/expenditures could be incorporated. Using the 2005 average per capita consumption of pork, the average consumer cost of pork is a little over $3 per pound.

The retail price of pork reported by the USDA is another proxy of consumer cost for meat. Table 4 shows the retail price of pork by type from in 2005. On average, the consumer cost of pork was less than $3 per pound in 2005.

Costs of Hog Production

The costs of hog production can be derived from the costs and returns estimation program that is a part of the annual Agricultural Resource Management Survey (ARMS) (USDA, 2007) based on the survey of actual costs incurred by producers. The costs and returns estimation program uses methods that conform to standards recommended by the American Agricultural Economics Association (AAEA). In general, the commodity costs are estimated based on four basic approaches—direct costing, valuing input quantities, indirect costing, and allocating whole-farm expenses.[6] The four basic approaches can be summarized into two costs, operating costs (direct costing) and allocated overhead (valuing input quantities, indirect costing, and allocating whole-farm expenses). Table 5 presents the detailed costs of hog production.

The total costs listed in 2004 and 2005, averaged over all hog production types, were $57.77 and $60.21 per cwt[7] gain. For overall hog production, variable costs, including feed costs and other costs, are generally three times greater than allocated overhead. Feed costs and the acquisition of feeder pigs are the largest factors influencing the variable cost numbers. The major costs in allocated overhead are capital recovery of machinery and equipment and opportunity cost of unpaid labor.

In looking at costs by type of production, farrow-to-feeder pig type has the highest cost per cwt gain with $121.28 in 2004 and $118.72 in 2005, and the highest costs per cwt of gain in all major categories (Table 5). This higher cost per cwt of gain results from having fewer cwt of production gain (approximately 60 pounds per animal) and all of the nursery costs over which the cost is calculated. In contrast, feeder pig-to-finish has the lowest costs of allocated overhead because the gain per animal (approximately 190 pounds) and the rate of gain is higher. Farrow-to-finish operations have moderate total feed costs comparable to the other types, but they also have the lowest operating costs.

Feed cost is the major expense of any hog production type. Kephart et al. (2004) find that, with 20 sows, a farrow-to-finish operation will spend 75% of total expenses on feed, compared to 50% for farrow-to-feeder operations and 65% for feeder-to-finish operations (100 hogs). Another example from Grannis and Seidle (Grannis and Seidle, 1998) finds that in a large farrowing operation (>1,200 sows) feed cost is about two-thirds of the cost of producing a market hog for farrow-to-finish. For farrowing and nursery pig production, feed cost is about 10% of total costs because baby pigs eat a small amount of feed each day. Because feeder pigs eat more grain per day as they approach market weight, feed costs used in the finishing operation amount to about 80% of total costs.

Both farrow-to-finish and farrow-to-feeder operations showed negative total net returns in one of the two years in Table 5, while feeder-to-finish operations showed positive net returns for both years. This results from a greater sensitivity of the farrow-to-feeder portion of production to changes in feed costs. For farrow-to-finish operations, the feed costs were $4.93 per cwt of gain higher in 2004 compared to 2005. Likewise, farrow-to-feeder operations experienced feed costs that were $7.78 per cwt of gain higher in 2004 compared to 2005. For feeder-to-finish operations, higher feed costs ($2.69 per cwt of gain) in 2004 were more than offset by lower feeder pig acquisition costs ($4.62 per cwt of gain).

Cost of concentrated animal feeding operations

Based on the 1998 ARMS data, the bigger the size of an operation, the lower the feed costs, operating costs, and ownership costs per cwt (Table 6). "The size groups were assigned according to the reported peak hog inventory on the operation during 1988 into (1) small operations (1–499 head); (2) medium operations (500–1,999 head); (3) large operations (2,000–4,999 head); and (4) industrial-scale operations (5,000 head or more)" (McBride and Key, 2003). In addition, average costs on medium-sized farrow-to-finish operations were about 20% less than on small operations, while the average costs of feeder pig production fell 37% between the small and medium farms. Much of the cost reduction by size for feeder pig production was achieved on medium-sized operations. However, the average cost of producing market hogs fell about 11–12% between medium and large farrow-to-finish and hog-finishing operations. Average costs on these farms fell another 2–5% between large and industrial-scale operations. These data suggest that production costs per cwt are reduced significantly by increasing the size of operations from relatively small sizes. They also suggest that there are smaller cost-reducing incentives for operations to grow to the industrial-scale size.

Although average costs by size of operation reveal

Table 3. Consumer Food Expenditure in 2005 (Source: Bureau of Labor Statistics, Consumer Expenditures Survey, 2005)
Note: Pork includes bacon, pork chops, ham (including canned), roasts, sausage, and other cuts of pork.

ITEM	ALL CONSUMER UNITS
Average annual expenditures—all items	**$46,409**
Food	5,931
Food at home	3, 297
Cereals & bakery products	445
Cereals & cereal products	143
Bakery products	302
Meats, poultry, fish, & eggs	764
Beef	228
Pork	153
Other meats	103
Poultry	134
Fish & seafood	113
Eggs	33
Dairy products	378
Fresh milk & cream	146
Other dairy products	232
Fruits & vegetables	552
Fresh fruits	182
Fresh vegetables	175
Processed fruits	106
Processed vegetables	89
Other food at home	1,158
Sugar & other sweets	119
Fats & oils	85
Miscellaneous foods	609
Nonalcoholic beverages	303
Food prepared by consumer unit on out-of-town trips	41
Food away from home	2, 634

information about the relative competitiveness of various-sized operations, the variation in costs give a clearer picture of the industry. McBride and Key (2003) employed the ARMS information and found that the variation in cost was greatest among the small hog operations, and least among the large and industrial-scale operations. This result coincides with the greater diversity among small producers relative to other producers. The cost distributions also show that despite higher average costs among the small- and medium-sized groups, many of these operations produce at a cost that is competitive with larger operations. For example, at a hog price of $40 per cwt, 19% of small producers covered production costs in 1998, compared with 40% of the medium producers and over 50% of the large and industrial-scale producers. However, this 19% corresponded to about 17,000 small operations, compared with about 7,300 medium operations and 4,000 large and industrial-scale operations. Therefore, there is substantial variation in production costs that cannot be attributed to size of operation. This suggests that the managerial ability of individual hog producers is likely to be as important as economies of scale in lowering the costs of hog production (McBride and Key, 2003). This information supports the idea that large facilities are often, but not always, more efficient than small ones.

A recent report from the Iowa State University Extension estimates the budgets for Iowa swine production using common types of technology. Each budget contains estimates of the fixed and variable costs[8] (Ellis et al., 2007). The costs in these budgets (Tables 7 and 8) are full costs and do not take into account any subsidies that producers might receive from the EQIP program, which helps producers reduce the negative environmental impacts of their production system. These budgets were developed at a time when the cost of corn was $3.45 per bushel, well above the cost of production. As a result, the corn costs in these budgets are not reduced by the US commodity program provisions.

One growing system that has not been discussed thus far is the hoop system. The hoop system typically consists of a 30'x70' tarp-covered Quonset-style building with five foot high side walls and openings at both ends. According to Brum et al., "by 2001, Iowa farmers had erected more than 2,100 hoop barns for finishing pigs" (Brum et al., 2007). The buildings are typically oriented toward the prevailing wind. The watering area is established on a concrete slab at one end of the structure, and the straw/cornstalk bedding area at the other end may have either a concrete floor or a packed earthen floor. A facility of this size usually holds 195 head of hogs, providing about 11 square feet per animal. The animals are typically "placed in the facility at 50 pounds and fed to 265 pounds or 215 pounds of gain. Thus, on average, pigs are marketed in 126 days" (Brum et al., 2004). Table 9 provides a comparison of the costs of raising hogs under the hoop system and a confinement system. In general, the hoop system has lower fixed costs and higher operating costs. The cost difference of the two systems is less than a dollar per hundredweight($0.26). This calculation included a premium for lean meat in confinement-raised hogs, which tend to be leaner than those raised under the hoop system. At the same time, it should be noted that hoop system operators may be eligible for premiums (not included in this analysis) from markets seeking "natural, humanely reared, reared with bedding, reared on family farms" (Brum et al., 2007) attributes in their pork products.

Table 4. Price of Pork by Type in June (Source: USDA ERS)

Year	2005
Bacon—Service Meat	$2.59
Fresh Pork Sausage—Service Meat	$2.34
Ham (Total)	$2.32
Pork (All Other Pork)	$2.22
Pork (All Pork)	$2.66
Pork Chops (Total)	$2.92
Pork Ribs (Total)	$2.60
Pork Roasts (Total)	$2.31
Pork Tenderloin (Total)	$4.08

Note: On October 1, 2005, Federal Mandatory Price Reporting Legislation expired and that legislation has not been re-authorized. Funding for the collection and dissemination of this retail scanner–priced data was mandated under that Federal legislation. Continuation of this effort will require explicit direction/legislation requiring the Secretary of Agriculture to continue the collection and dissemination of retail price data on red meat (beef, pork, lamb, and veal) and poultry (chicken and turkey).

Table 5. Hog Production Costs and Returns Per Hundredweight Gain by Types of Operation[1] 2004–2005 (Source: USDA ERS)

ITEM	ALL		FARROW-TO-FINISH		FARROW-TO-FEEDER PIG		FEEDER PIG-TO-FINISH	
	2004	2005	2004	2005	2004	2005	2004	2005
	DOLLARS PER CWT GAIN							
GROSS VALUE OF PRODUCTION								
Market hogs	50.17	51.18	49.90	47.56	.32	.35	58.57	59.82
Feeder pigs	13.97	17.37	.49	.60	91.12	113.66	.02	.02
Cull stock	.73	.74	1.83	1.89	5.96	6.41	0	0
Breeding stock	.06	.06	.19	.19	.11	.12	0	0
Inventory change	-.87	.34	-2.19	.45	1.25	-.08	-.45	.38
Other income[2]	1.74	2.04	1.65	1.94	1.38	1.63	1.77	2.08
Total gross value of production	65.80	71.73	48.78	52.63	100.14	122.09	59.91	62.30
OPERATING COSTS								
Feed								
Grain	2.99	2.32	8.62	6.77	2.80	2.16	1.69	1.29
Protein sources	2.61	1.96	7.19	5.50	2.23	1.71	1.53	1.13
Complete mixes	16.18	14.16	8.15	6.81	51.85	45.23	15.84	13.97
Other feed items[3]	.12	.10	.30	.25	.23	.23	.07	.05
Total feed cost	21.90	18.54	24.26	19.33	57.11	49.33	19.13	16.44
Other								
Feeder pigs	17.98	22.52	.10	.12	0	0	18.83	23.45
Veterinary & medicine	.88	.90	1.23	1.33	4.66	4.81	.49	.50
Bedding & litter	.02	.02	.04	.04	.33	.31	.01	.01
Marketing	.78	.81	.42	.44	1.96	2.06	.48	.50
Custom services	.28	.28	.28	.29	.83	.94	.25	.25
Fuel, lube, & electricity	.96	1.32	1.42	1.94	3.46	4.91	.57	.79
Repairs	.69	.72	1.04	1.09	1.86	2.03	.43	.46
Interest on operating capital	.34	.76	.23	.41	.55	.09	.32	.71
Total operating costs	43.83	45.87	29.08	24.99	70.76	65.48	40.51	43.11
ALLOCATED OVERHEAD								
Hired labor	1.66	1.68	2.76	2.90	9.01	9.54	.54	.55
Opportunity cost of unpaid labor	3.58	3.51	7.67	7.43	11.50	11.29	1.98	1.97
Capital recovery of machinery & equipment[4]	6.68	7.05	9.63	10.16	22.42	24.00	4.03	4.26
Opportunity cost of land (rental rate)	.03	.03	.07	.07	.09	.10	.02	.02
Taxes & insurance	.57	.58	1.03	1.07	1.71	1.76	.34	.35
General farm overhead	1.42	1.49	2.05	2.15	5.79	6.55	.82	.85
Total allocated overhead	13.94	14.34	23.21	23.78	50.52	53.24	7.73	8.00
Total costs listed	57.77	60.21	52.99	48.77	121.28	118.72	48.24	51.11
Value of production less total costs listed	8.03	11.52	-3.42	3.86	-21.14	3.37	11.67	11.19
Value of production less operating costs	21.97	25.86	19.79	27.64	29.38	56.61	19.40	19.19

[1] Developed from survey base year, 2004. Cwt gain = (cwt sold - cwt purchased) + cwt inventory change.
[2] Value of manure production.
[3] Milk replacer, milk, milk by-products, antibiotics, and other medicated additives.
[4] Machinery and equipment, housing, manure handling, feed storage structures, and breeding herd.

Table 6. Production Costs (dollars per cwt gain) by Size of Operation for Hog Producer Type (Source: Brum et al, 2004)
Note: Small (1–499), Medium (500–1,999), Large (2,000–4,999), Industrial scale (5,000+), Nr—not reported

FARROW-TO-FINISH				
	Feed Costs	**Operating Costs**	**Ownership Costs**	**Total Operating and Ownership Costs**
Small	26.29	32.94	24.87	57.81
Medium	25.14	32.18	13.66	45.85
Large	22.82	30.75	10.05	40.80
Industrial Scale	21.20	30.02	8.92	38.94
FARROW-TO-FEEDER PIG				
	Feed Costs	**Operating Costs**	**Ownership Costs**	**Total Operating and Ownership Costs**
Small	45.55	64.36	47.87	104.81
Medium	29.62	45.09	27.45	66.01
Large	Nr	Nr	Nr	Nr
Industrial Scale	29.34	52.11	21.75	62.97
FEEDER PIG-TO-FINISH				
	Feed Costs	**Operating Costs**	**Ownership Costs**	**Total Operating and Ownership Costs**
Small	23.27	43.24	12.35	55.60
Medium	22.52	43.08	8.51	51.59
Large	19.40	38.80	6.41	45.21
Industrial Scale	18.26	38.80	5.65	44.45

Cost comparisons

Different economists developed each of these three sets of budgets over a range of nine years. Some of the allocation of costs may vary from budget to budget. In this paper, no attempt is made to harmonize the budgets to each other. Rather, each budget was looked at as a unit, and cost comparisons were made among unit sizes within a given budget. Comparisons were not made across the three sets of budgets.

Given that the legitimating discourse for the development of CAFOs depends upon their providing pork protein at a lower cost than less intensive methods, we need to examine the cost differential between CAFOs and other hog production systems. Table 6 showed that the farrow-to-finish cost per hundredweight (cwt) of gain for medium-sized (500–1,999 hogs per year) hog operations was $45.85, while the comparable cost for industrial-sized facilities (5,000+ hogs per year) was $38.94. Although the per cwt costs of production for the farrow-to-finish CAFO was $6.91 less expensive than they were for the medium-sized hog producer, it should be noted that in 1998 with $40 hogs, 40% (7,300) of medium-sized producers were able to cover their costs as compared to over 50% (4,000) of large and industrial-sized operators. Even 19% (17,000) of small operators, who as a group had much higher production costs, were able to cover their costs.

The Iowa State University Extension production budgets (Tables 7 and 8) allow us to compare the per cwt cost of pasture-raised hogs with the per cwt cost of hogs raised in total confinement for farrow-to-finish operations. The break-even selling price for the pasture-raised hogs is $48.82 per cwt, while for total confinement hogs that same number is $43.41. Therefore, by this analysis, it costs $5.41 less per cwt to raise hogs in a total confinement farrow-to-finish operation than it does to raise hogs on a pasture system.

Data from Brum (Brum et al. 2004) in 2004 shows that producers using the hoop system for grow-to-finish operations were able to produce pork for $37.17 per cwt, just 26 cents higher than operators of CAFOs (Table 9). Hoop system operators benefit from lower fixed costs that help cover higher operating expenses.

There are certain factors that are not included in any of these budgets, however.

Table 7: Example for Swine Budget (Pasture) per Litter (Source: Ellis et al., 2007)

PASTURE									
Production Efficiencies									
Weaning average	8.3	pigs per litter							
Pig death loss	4%								
Sow death loss	5%								
Litters per sow per year	2.0								
Litters in sow lifetime	2.0								
INCOME	PRICE	UNIT		QUANTITY	UNIT				TOTAL
Market hogs	$0.00	per lb	x	260	lbs	x	7.97 head	=	$0.00
Cull sows	$0.00	per lb	x	400	lbs	x	0.50 head	=	$0.00
Gross income									$0.00
VARIABLE COSTS	PRICE	UNIT		QUANTITY	UNIT				
Feed Costs									
Corn	$3.45	per bu	x	97	bu			=	$334.65
Soybean meal	$0.09	per lb	x	943	lbs			=	$84.87
Dried distiller grain	$0.05	per lb	x	267	lbs			=	$13.35
Vitamins & minerals	$0.45	per lb	x	35	lbs			=	$15.75
Vitamins & minerals	$0.30	per lb	x	95	lbs			=	$28.50
Pasture	$30.00	per acre	x	.2	ac			=	$6.00
Feed additives									$22.00
Other									$0.00
Total Feed Costs									**$505.12**
Veterinary & health									$34.00
Fuel, repairs, utilities									$35.00
Bedding, marketing, miscellaneous									$45.00
Other									$0.00
Interest on variable costs	9%		x	5	months			=	$23.22
Labor	$14.00	per hour	x	12	hours			=	$168.00
Total Variable Costs									**$810.34**
Income over Variable Costs									**($810.34)**
FIXED COSTS									
Machinery, facilities									$99.00
Breeding, costs, boar/semen									$13.00
Replacement gilts	$155.00	head	x	0.50	head			=	$77.50
Interest, insurance on breeding herd	10%		x	9	months			=	$11.63
Total Fixed Costs									**$201.13**
Total All Costs									**$1,011.46**
Income over All Costs									**$1,011.46**
Break-even selling price for variable costs (per cwt)									$39.11
Break-even selling price for all costs (per cwt)									$48.82

Table 8: Example for Swine Budget (Total Confinement) per Litter (Source: Ellis et al., 2007)

TOTAL CONFINEMENT								
Production Efficiencies								
Weaning average	9	pigs per litter						
Pig death loss	5%							
Sow death loss	5%							
Litters per sow per year	2.3							
Litters in sow lifetime	4.0							
INCOME	PRICE	UNIT		QUANTITY	UNIT			TOTAL
Market hogs	$0.00	per lb	x	260	lbs	x 8.55 head	=	$0.00
Cull sows	$0.00	per lb	x	400	lbs	x 0.50 head	=	$0.00
Gross income								$0.00
VARIABLE COSTS	PRICE	UNIT		QUANTITY	UNIT			
Feed Costs								
Corn	$3.45	per bu	x	105	bu		=	$362.25
Soybean meal	$0.09	per lb	x	1013	lbs		=	$91.17
Dried distiller grain	$0.05	per lb	x	288	lbs		=	$14.40
Vitamins & minerals	$0.45	per lb	x	36	lbs		=	$16.20
Vitamins & minerals	$0.30	per lb	x	110	lbs		=	$33.00
Pasture	$30.00	per acre	x	0	ac		=	$0.00
Feed additives								$25.00
Other								$0.00
Total Feed Costs								**$542.02**
Veterinary & health								$25.00
Fuel, repairs, utilites								$50.00
Bedding, marketing, miscellaneous								$30.00
Other								$0.00
Interest on variable costs	9%		x	5	months		=	$24.26
Labor	$14.00	per hour	x	6	hours		=	$84.00
Total Variable Costs								**$755.28**
Income over Variable Costs								**($755.28)**
FIXED COSTS								
Machinery, facilities								$130.00
Breeding, costs, boar/semen								$13.00
Replacement gilts	$155.00	head	x	.28	head		=	$43.40
Interest, insurance on breeding herd	10%		x	18	months		=	$23.28
Total Fixed Costs								**$209.65**
Total All Costs								**$964.93**
Income over All Costs								**($964.93)**
Break-even selling price for variable costs (per cwt)								$33.98
Break-even selling price for all costs (per cwt)								$43.41

Table 9. Swine Grow-finish Cost Comparison Between Hoop and Confinement Systems (Source: Brum et al., 2007)

ITEM	HOOP	CONFINEMENT
Facility Investment		
Building (per pig marketed) (2.55 turns per year; $180 per pig space for confinement; $62 per pig space for hoop)	$23.42	$70.59
Feed and manure handling equipment (per pig marketed) (2.55 turns per year; $36 per pig space for confinement; $36 per pig space for hoop)	$14.12	$14.12
Total Investment (per pig marketed)	**$38.43**	**$84.71**
Fixed Costs		
Interest, taxes, depreciation, insurance (12.2% of total investment for confinement; 15.5% of total investment for hoop)	$5.96	$10.33
Total Fixed Cost (per pig marketed)	**$5.96**	**$10.33**
Operating Cost		
Feeder pigs (50 lb)	$42.00	$42.00
Interest on feeder pig (10% for 4 months)	$1.40	$1.40
Fuel, repairs, utilities	$1.04	$1.39
Bedding	$2.44	$0.00
Feed		
Confinement (215 lb gain at 2.90 F/G @ $.06 per lb feed)		$37.41
Hoop (215 lb gain at 3.05 F/G @ $.06 per lb feed)	$39.35	
Veterinarian/medical	$1.56	$1.56
Marketing/miscellaneous	$1.53	$1.53
Interest on fuel, feed, etc. (8% for 2 months)	$.61	$.56
Labor		
Confinement (.24 per pig @ $10.00 per hr)		$2.40
Hoop (.29 per pig @ $10.00 per hr)	$39.35	
Total Operating Cost (per pig marketed)	**$92.55**	**$87.97**
Total Overall (per pig marketed)	**$98.51**	**$98.30**
Total Cost per 250-lb market animal (per CWT *live)	**$37.17**	**$37.09**
Lean Premium (per CWT live)	**$0.00**	**$0.60**
Net Cost (per CWT live)	**$37.17**	**$36.91**

*CWT=hundredweight

Externalities

An externality is said to exist if an activity of one party (a household or firm) affects the utility or production possibilities of another party without being priced. The fact that it is not priced implies that the "emitting" party has no incentive to take into consideration the effect, beneficial or detrimental, on the "affected" party. That being the case, the emitting party may devote an inefficient amount of resources to pursuing the activity (Broadway and Wildasin, 1984). The general cause of the existence of externalities is usually taken to be a lack of enforcement of property rights, either because exclusion is not possible or because property rights have not been assigned or cannot be assigned without great difficulty (Coase, 1960). Externalities affecting environmental quality arise when an individual or group creating the effect does not consider the social costs or benefits of the effect, and the impacted entities are not compensated. Within the swine industry, these effects often materialize as odors and pollution moving across the facilities and ultimately impacting residential and public use areas. Few economic incentives exist for animal producers to mitigate these impacts or to compensate those impacted.

Coase's argument that externalities are the result of the lack of the enforcement or assignment of property rights is a helpful step in the development of an understanding of the nature and causes of the existence of externalities.

In and of itself, however, this argument does not go far enough because the problem of the assignment of property rights. This discussion is rooted in the nature of the discipline itself. As an academic discipline, economics is concerned with the allocation of scarce goods among competing uses. The intellectual constructs under which it operates have been in the service of this definition using profit maximization in an individualized economic system as the basis for its analysis. This system does a reasonably good job of analyzing the allocation of scarce goods but fails in the allocation of abundant resources, like clean air, water, and other natural resources. While property rights may be appropriate for goods like a gold ring, an automobile, or a shirt—others can easily be excluded from these goods—abundant goods and resources like air and water do not lend themselves to this exclusionary principle and therefore are not well managed using the concepts of private property rights. The purpose of the paper at this point is to argue that externalities are a function of a system that is focused on private action and the allocation of scarce goods and resources among competing uses; the system has no direct means of allocating abundant goods until they are degraded to the point that someone is willing to pay to have access to clean supplies of these abundant goods.

Because goods like air, water, and the greater environment are in abundant supply, the price for them is very low, if not zero. It is the ready availability and low pricing of these resources that allow producers to be able to externalize the costs that result in damage to the environment and human and animal health. Common property, without any means for the community to exercise control over them (such as the air), becomes a convenient dump for the ammonia, hydrogen sulfide, and a host of other chemicals that can result from the long-term storage of hog waste. In general, economics traditionally treats these externalities as market failures, when in reality what we have is a theoretical failure that does not take into account the finite nature of abundant goods, nor the economic impact of their degradation. The identification of externalities in hog production, both monetized and non-monetized, is one step toward conceptualizing the needed theoretical constructs.

While there are many social, moral, environmental, and health externalities associated with hog production, this study will seek to enumerate only a few of them, and provide an economic analysis of internalizing the cost of one externality: the manure produced in a concentrated area by industrial hog production.

The largest volume of co-product in hog production is manure. On the one hand, manure is an effective, low-cost source of nutrients for crops and pastures. When properly handled and applied, manure can be an asset to pig operations and provide extra income to operators by reducing the need to purchase petroleum-based fertilizer (American Society of Agricultural Engineers, 2003). However, as the number of hogs and the amount of manure have become more concentrated in smaller areas with the development of CAFOs, the potential conflict with neighboring property owners has also increased. The chemicals and odors that emanate from the storage and land spreading of this waste pollute the nearby air and water. As a result, neighbors argue that the presence of CAFO-sized hog operations negatively affects the quality of life, public health, property values, and local economy. For a fuller treatment of these issues, see the "Community and Social Impacts of Concentrated Animal Feeding Operations" section of the PCIFAP report and Stofferahn (2006).

The US Environmental Protection Agency (EPA) requires a hog operation with an inventory of more than 1,000 animal units or 2,500 head to have National Pollution Discharge Elimination System (NPDES) permits for manure storage, or confirm that there is no runoff from the farm. However, interpretation of the regulation varies from state to state, and many states pursue enforcements only in response to residential complaints (EPA, 2003; Sullivan et al., 2000).

While it could be argued that a percentage of the external costs of manure are internalized in the operation costs (since the CAFO hog producers pay for the NPDES permits and would pay a fine if complaints were investigated and substantiated), CAFO-sized hog operations have been identified as a source of significant environmental and health costs due to environmental issues. For example, leakage from large waste lagoons attracted public attention in 1999, when millions of gallons of manure overflowed in North Carolina in the aftermath of Hurricane Floyd. In addition, while the NPDES relates to the land disposal of waste and water impairment, it does not deal with the impact of industrial hog production on the air in and around the CAFO. It should also be noted that medium-sized hog operations that lack adequate area for land application can create more water pollution than larger operations that have waste management plans (McBride and Key, 2003). These medium-sized operations are often exempt from federal and state regulation, resulting in an uneven regulatory environment and providing some incentive for their proliferation.

The type of manure storage facility differs substantially between the major hog-producing regions (McBride and Key, 2003). In the Southeast (e.g., North Carolina), 98% of the larger swine facilities use lagoons as storage systems, while that number is 66% in the Corn Belt (e.g., Iowa, Minnesota). The remaining 34% in the Corn Belt use pits or tanks. Manure in both regions is handled in liquid form. Since hog production is usually concentrated within specific small areas, it may be limited by the lack of land area for manure application. In areas without limits on land application, an inadequate area for land application may result in problems of the over-saturation of soil nutrients (Guan and Holley, 2003). Odor, dust, and various volatile compounds emitted from the production facilities and/or the land application of manure result in air, water, and soil pollution, and have been identified as the cause of reducing the property value of neighboring land parcels (Abeles-Allison, 1992; Herriges et al., 2003; Palmquist et al., 1997), excessive flies, and other nuisance factors (Herriges et al., 2003; Mikesell et al., 2004).

Aerosolized compounds produced by the long-term storage of hog manure negatively impact the public health of workers in CAFOs (Lobao, 2000; Stofferahn, 2006), as well as neighbors.

Because hogs are produced under market failure in which abundant resource allocation is not accounted for, hog producers have no incentive to internalize these externalities.

Subsidies

National Pork Producers Council literature states that *"…Historically, there have been few government subsidies to support producers in times of low prices. If supplies are low and/or demand is high, prices will be high. If supplies are high and/or demand is low, prices will be low"* (NPPC, 2007b). In fact, the average US market price of soybeans and corn dropped 21%and 32%, respectively, over the 10 years following the passage of the 1996 Farm Bill. In most years, corn and soybeans were sold on the market at prices below what they cost to produce. Thus, US agricultural policy during that period contributed implicit subsidies by supporting grain production at prices well below the cost of production, which in turn benefits commodity purchasers, especially the industrial operations that use the commodities, corn and soybeans, as raw material inputs. For example, the broiler industry gained monetary benefits averaging $1.25 billion per year between 1997 and 2005 when, following the passage of the 1996 Farm Bill, market prices for broiler feed ingredients dropped far below production costs. In contrast, broiler industry gains from low market prices averaged a much smaller $377 million per year between 1986 and 1996 (Starmer et al., 2006). As a result, the previous literature shows that the corporate broiler industry is a major winner from changes to US agricultural policy that has allowed feed prices to fall.

Therefore, we could apply the same method to the case of hog industries and calculate the subsidized costs. Over the 1997–2005 period, the average corn price was $0.54/bu below the cost of production; for soybeans, the average price was $0.76/bu below the cost of production (calculated from USDA-ERS). Government subsidies were paid to grain farmers to help them cover their cost of production. In purchasing these commodities, hog farmers directly benefited from the $0.54/bu subsidy on corn and the $0.76/bu subsidy on soybeans. CAFO owners benefited from subsidized commodity production to the tune of $6.48 per head for corn and $1.73 per head for soybeans, or an average total of $3.28 per hundredweight of pork production. The total hog industry subsidy for the commodities they were able to purchase at below the cost of production as the result of government subsidies of these commodities amounts to $221 million a year for soybean meal and $644 million a year for corn or a total of $865 million per year (Starmer et al., 2006).[9]

Table 10 shows the extent to which grain users like animal feeders benefited from US commodity programs through the purchase of corn and soybeans at prices well below the cost of production in most years. These subsidies benefited large purchasers of grain like CAFOs by providing them with subsidized grain. This benefit does not accrue to smaller operators who grow their own feed ingredients because the subsidy goes to cover grain production costs instead of reducing grain acquisition costs. When the full social costs are calculated, no subsidies are reported for farmers who grew their own feed, while they are reported for integrators who purchased their feed requirements.

According to the National Pork Producers Council, pork producers received $37.8 million dollars in EQIP funding between 2003 and 2005, or an average of $12.6 million a year. With annual pork production at 210 million cwt, the average subsidy would be $0.06 per cwt of hog production. The data does not indicate the size of the producer who received the EQIP funds. It can be assumed that the bulk of the EQIP funds went to the larger producers with greater environmental problems (NPPC, 2007b; Ribaudo et al., 2004).

Table 10: Imputed Subsidies Calculated as the Difference Between the Cost of Production for Corn and Soybeans and the Season Average Price Received by Farmers (Calculated from USDA Agricultural Outlook Tables and Cost of Production Data)

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Corn	$.25	$.74	$.99	$.95	$.57	$.16	$.23	$.09	$.85
Soybeans	$0.00	$0.57	$1.78	$1.75	$1.99	$.60	$.14	$0.00	$0.00

Calculating the social cost of production: A theoretical framework

We have discussed the firm-level costs of various sizes and styles of hog operations. The total cost in that discussion does not take into account either subsidies or externalities. In fact, hog operations have benefited from the government's policies, e.g., subsidized feed grains, the Commodity Purchase Programs, the Environmental Quality Incentives Program (EQIP), and emergency aid that are not included in the hog budget. In addition, the potential for growing conflicts of interest between nearby residents and hog producers over issues such as odor, water, soil and air pollution, and other environmental problems associated with concentrated production are some externalities, but the cost of these is usually not quantified or included in the price of hog and pork. Therefore, the "real" costs of hog production will be discussed using the context of the social cost.

In general, social cost incorporates the total of all the costs associated with an economic activity. It includes both costs borne by the economic agent and also all costs borne by society. It includes the costs reflected in the organization's production function and the costs external to the firm's private costs. Social costs of hog operation can be defined as follows:

(1)

$$
\begin{aligned}
SC = DC + S_i + E_{ja} &+ N_k \\
&\text{or } + E_{j\beta} \\
&\text{or } + E_{jx} \\
&\ldots
\end{aligned}
$$

Where:

SC = Net full social cost of production, including all indirect costs and externalities

DC = Direct costs experienced at the firm level by the producer

S_i = Governmental subsidies, where the individual i s are various subsidies

Eja = Externalized costs and benefits that can be monetized, where the individual j s are various externalities like chemicals released in the air, air particulate matter, worker health costs not borne by the producer, benefits to the local community from real estate taxes, employment opportunities; and the individual a s are alternate means of determining the externalized cost for a given j; benefits appear as "negative costs" for calculation purposes[10]

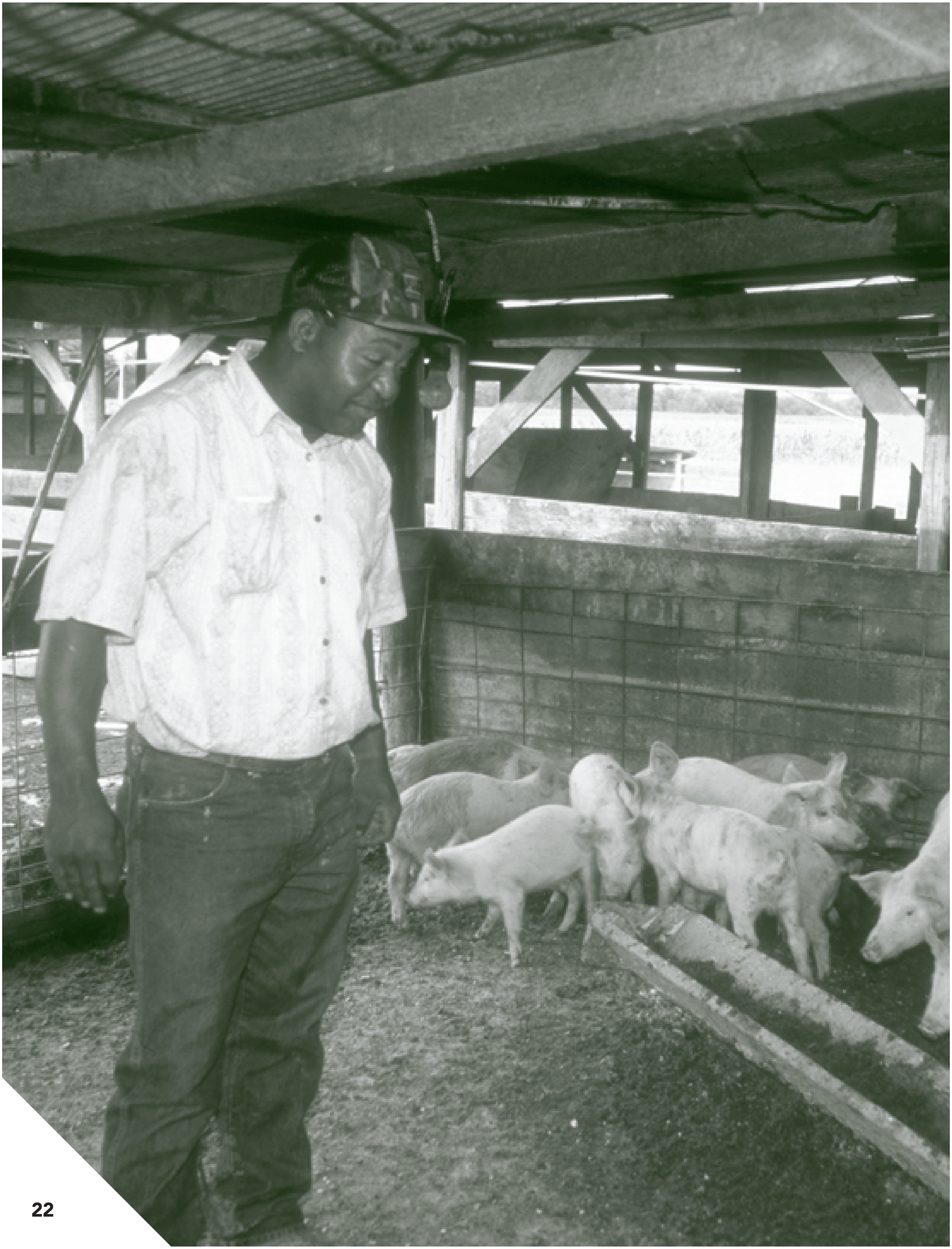
N_k = Externalized costs and benefits that cannot be monetized, where the individual k s are the various non-monetized costs and benefits that occur

The variables for both monetized and non-monetized externalities include the issues described briefly here, and in more depth in other Pew Commission on Industrial Farm Animal Production (PCIFAP) technical reports. These issues include: animal well-being; the impact of production methods on public health; the connection between industrial production methods and past, current, and emerging public health epidemics; farm animal waste management; the environmental impacts of CAFOs; and the connection between industrialized farm animal production, the presence of antimicrobial resistant (AMR) pathogens, and human exposure to AMR pathogens.

The E_{ja} variable can be used for those externalities that can be monetized, such as property value depreciation, public health costs from asthma or respiratory disease in workers and neighboring residents, cleanup costs for manure spills, and water pollution. This variable can also be used for benefits such as employment provided, taxes paid, and support for community activities that, in effect, become negative costs. Standard economic analysis usually identifies a single number for each externality, be that a permitting fee or the depreciation of adjacent properties. This analysis moves away from that practice by acknowledging that each stakeholder—integrator, producer, worker, neighbor, water user, or commercial fisher in the Mississippi Delta—may have a different perspective on the externality and its effect upon them. Consequently, each stakeholder, based on their individual values and the degree to which that person is impacted by the externality, may have a different idea of how the externality should be mitigated and/or accounted for. The result is a "cafeteria menu" of costs for any given externality from which the social body politic may choose one as the preferred method at any one time. As that which is socially acceptable changes over time, the cost identification for a given externality may change as well. The crucial issue with the cafeteria menu is to promote a discussion of values that drive the selection of the various methods for placing a monetary value on a given externality. This discussion also offers all stakeholders an opportunity to talk about how they are impacted by the externality and how that affects their preferred measuring solution. One of the roles of the economist is to aid each stakeholder in identifying the monetary impact of their preferred solution. The cafeteria menu offers an opportunity to add human values to economics as a driver of policy discussions.

The N_k variable represents externalized costs that cannot be monetized. These may include issues like animal welfare, the enjoyment of fresh air, the desire to enjoy living on a farm that is downwind from a hog facility but has been in the family for a century and a half, the importance of wildlife that live along and in waters adjacent to fields on which manure has been spread, etc. This variable is descriptive and supplements the discussion that can ensue as a result of the use of the cafeteria menu for examining variables that can be monetized.

The economic system described in the above equation operates within an overarching social context that shapes the ways in which the US portion of the global food system—including industrialized farm animal production—operates. This social context is not fixed



but changes over time and differs from one country to another and even from one group to another within a given country. In part, the specifics of our analysis of externalities are shaped by the interplay of the various social contexts[11] that impact current production systems.

The argument that industrialized farm animal production is more economically efficient than traditional production systems rests on the classical economic assumption, in the absence of market failure, that $SC = DC$ because the subsidies, monetized externalized costs (both positive and negative), and non-monetized externalized costs are either ignored or assumed to be zero.

Using the cafeteria menu formula,

$$SC = DC + S_i + E_{ja} + N_k$$

which includes the subsidies, monetized externalized costs (both positive and negative), and non-monetized externalized costs, provides a more complete picture of the full cost of production for various hog production systems.

Analysis

More than any other externality, the odor problem—ammonia, hydrogen sulfides, and the "pungent hog smell"—has been the focus and motivating factor for much of the public concern about the CAFO production of pork. Hog operations are often faced with the problem of dealing with odors coming from urine and fecal matter. Because lagoons are visible, they are often the targets of complaints. However, in the case of pit storage, most odors are coming from inside the buildings where the animals are kept. Concentrations of ammonia (NH_3) gas, hydrogen sulfide (H_2S) gas, and other noxious gases cause stress (and health problems) on the animals and the workers (Mikesell et al., 2004). Animal welfare costs, the portion of lost wages above the disability payments from workers' compensation program payments, as well as pain and suffering the disabled worker experiences are not internalized by the production unit. A stressful environment results in animals that are less productive and more susceptible to sickness. In a confined area, NH_3 and H_2S (H_2S at levels as low as 10 ppm, NH_3 somewhere around 50 ppm) can be very dangerous and become toxic to workers and animals (American Society of Agricultural Engineers, 2003).

One of the authors observed that until the late 1980s and early 1990s, farmers were generally very tolerant and even protective of the agricultural practices of their neighbors. Other than the issue of noxious weeds, farmers were reluctant to see regulations put on the farming practices of others because they feared that would open them up to regulations on their practices as well. In principle, farmers formed what might be characterized as a "blue jean line" of solidarity—"Thou shalt not speak evil about thy neighbor's farming practices"—against what they viewed as interference by non-farmers in determining proper agricultural practices. At the local elevator and coffee shop, farmers are often critical of the farming operations of others—"Look at his weedy fields"—but in public that discussion is left unsaid.

With the increased development of hog CAFOs in the early 1990s, that blue jean line began to fade as grain farmers began to object to having their homes surrounded by industrial hog production so that no matter which direction the wind came from they had to endure the pollution and pungent hog smells coming from those facilities. Residents of the neighboring small towns became alarmed as the manure was pumped from deep pits under the hog houses and the pungent slurry was surface-spread on farmland adjacent to the municipal limits. It was often a week or more before the manure was incorporated into the land and the odor began to abate.

In response to complaints about the odor, and in the absence of a strong county, state, or federal response, a newspaper reported in 1997 and 1998 that township trustees in places like Silver Lake Township, Martin County, Minnesota, begin to impose moratoriums on the construction of new CAFOs until the odor issue could be dealt with. Over time, the county stepped in and developed some consistent regulations with regard to setbacks, and land spreading regulations for local CAFO operators. Lyford and Hicks compare the differing experiences in Oklahoma and North Carolina to increased local control (Lyford and Hicks, 2001). In 1994, only Minnesota allowed local regulation of swine production facilities. By 1998, particularly following Hurricane Floyd, 11 states permitted local governmental units to exercise some degree of control over issues relating to CAFO production (Lobao and Kraybill, 2005; Metcalfe, 2000).

Given the intensity of the debate around the odor issue, of all the possible externalities to consider, this paper, in examining the cost of externalities, will focus on the issue of hog manure and the associated odor problem. The cafeteria menu concept is used to identify the various externalized costs associated with odors emanating from

the deep pits and lagoons used to store hog manure for extended periods of time.

Regulation and permitting fees

As previously mentioned, because the EPA has regulations and a permitting process regarding the discharge of water from CAFOs of a certain size, it could be argued that the permitting fees and the cost of compliance with the EPA regulations have internalized the cost of what previously was an externality. The limit to this argument is that it deals with discharges into waterways but has no impact on the discharge of aerosolized chemicals into the airstream surrounding the facility. At some point, the government may increase their regulations concerning air quality at a given distance from a facility, acceptable methods for the land spreading of manure, and setbacks to protect waterways and neighboring properties. All of these potential regulations are ways to force the operator to bear the cost of some aspects of the externalities into their profit and loss accounting. However, their usefulness will still depend upon enforcement of regulations.

Depreciation

A second alternative for pricing the odor is to assess the CAFO operator/integrator a fee that is equal to the loss in either the use value or the market value of adjacent properties due to the odors produced by the CAFO. In some cases, it may be cheaper for the CAFO operator to purchase the adjacent property. Depending upon the area, the costs could be upwards of thousands of dollars an acre. For some affected neighbors, the sale of the land or the sale of an air pollution easement might be acceptable and would represent a fair compensation for the loss of property value. But in some of the communities in which these CAFOs are located, property owners may be the fifth or sixth generation to live on that place. For them, the land is a legacy and a representation of the hard work and sweat that was given by their forebears. No amount of money could therefore compensate for the loss of the use of their century farm. In this case, the cost of the externality to the century farm owner cannot be monetized and instead must be captured in descriptive terms for the purpose of public policy discussion on ways to mitigate the impact of the externality.

Lawsuits

In the absence of the consistent enforcement of regulations or the ability of CAFO operators and their neighbors to come to an agreement for compensation for the loss of property value and usability, lawsuits are an option that have the potential to force the CAFO operators to internalize the costs that result from the discharge of pollutants from their facilities. Lawsuits are, however, uncertain in their results, both for the producer and the adjacent landowner. They have the potential to overcompensate some while providing very little compensation for others. Depending upon the litigatory climate, either producers or neighbors may feel forced into an agreement that represents the best that they can achieve at that time.

It is a fact that rural neighbors registered few complaints when nearly everyone had livestock. But the dramatic increase in the concentration of ownership now means that far fewer rural residents have a large financial interest in livestock. Complaints and lawsuits about livestock operations are now much more common. One well-known case involves the four farm couples—two of which had raised livestock—who sued Iowa Select Farms in 2002 for the production of offensive odors, noxious gases, and excessive flies emanating from the company's 30,000-head hog facility in Sac County, Iowa. The plaintiffs were awarded $1.06 million in actual damages, plus $32 million in punitive damages (Herriges et al., 2003). The punitive damages were later eliminated in a settlement while the case was on appeal.

In economics, this amount of money is equivalent to the proxies of damage. If emitting parties know that they have to pay this amount for compensating people around a facility, they have a strong incentive to find the best management practice to minimize the fine and/or maximize their profit. Therefore, this method is one option to internalize the externalities from the CAFOs.

Secondary or Tertiary Wastewater Treatment of Hog Manure

Some stakeholders may argue that the air on the leeward side of the hog facility should be as odor-free as it is on the windward side, in effect forbidding the producer to use the air as a waste dump for aerosolized chemicals. Treating hog waste so as to eliminate unpleasant and noxious odors is a way to internalize the costs that result from the airborne emissions. Various methods of treating the manure in the pits and lagoons with chemicals and microorganisms have been attempted.[12] The basic goal has been to convert the anaerobic reaction taking place in the manure into an aerobic reaction, eliminating the production of noxious chemicals. There are a number of these systems being offered, but, to date, none of them have taken hold in the industry either because of costs or lack of effectiveness. While directly treating manure in the holding container has the potential to achieve the goal of odor elimination, the technology that has a proven record in eliminating the odor and disease-spreading effects of animal sewage is the use of secondary and tertiary municipal wastewater treatment facilities. Ricardo Salvador (undated) illustrates the paradox between the way we treat human waste and hog waste:

> Municipal sewage treatment facilities and private septic systems in Iowa process about 6 million pounds of human waste each day. On that same day, Iowa's 15 million hogs (about a third of the country's

entire herd) produce about 100 million pounds of manure at the rate of nearly 1,200 pounds per second. For the most part, this manure goes into lagoons, underground storage pits and other holding areas until it can be applied as nutrients on nearby farm land.

Why do we put elaborate systems into place to treat human manure when more than 16 times the output of human manure is generated by hogs and accumulates daily on the countryside?

As a means of illustrating the nature of the cafeteria menu model, this paper shows how one set of stakeholders might calculate the cost of internalizing waste-related environmental degradation by examining the cost of the secondary/tertiary wastewater treatment of hog manure. Alternate technologies like the use of methane digesters as a means of treatment for hog manure also could have been used to illustrate the nature of the cafeteria menu. Methane digesters have been used to convert animal waste into biogas that can be used as an energy source.

The technique of using wastewater treatment plants for the processing of hog waste has been employed in Taiwan, where intensive hog raising produces a remarkable 730 millions tons of swine manure each year (Guan and Holley, 2003). This expensive waste treatment system is similar to the municipal sewage treatment systems used in North America. The full-blown engineered system includes aerobic treatment as a part of the process. The system combines liquid flushing with manure treatment. The flush water is purified and discharged into a river or recycled and used as flushing water in the barns. The solid waste is transported to central composting sites to be converted into organic fertilizers (Beghin and Metcalfe, 1999). Using this system, swine manure is not directly spread on cropland and thus is less likely to affect public health (Guan and Holley, 2003).

While the cost of building a wastewater treatment plant may seem like overkill, the advantage of using such a system is that it mitigates multiple externalities all at the same time. The use of a wastewater treatment plant to process hog manure minimizes the potential for both air and water pollution. The chance of massive environmental degradation due to untreated waste is reduced to the level of current human wastewater treatment technology. Because of their close proximity to the source of waste, newer and better piping could be used to transport waste from the barns to the plant, giving wastewater treatment plants dedicated to a hog facility an advantage over municipal systems, which are likely to suffer storm water infiltration due to leaky pipes and cause discharges of unprocessed or partially processed waste during heavy rains. The ongoing flushing of waste from the barns would improve the air quality in the barn, reducing negative respiratory health outcomes for workers and animals. Likewise, the elimination of ammonia and hydrogen sulfides in the air would eliminate many of the negative odor issues for persons living near CAFOs.

In this paper, the cost of building and operating a wastewater treatment facility for processing hog manure is based on a municipal facility capable of serving a population of 10,000. Many CAFOs are designed around four barns, each containing just under 2,500 hogs each—staying just under the 1,000-animal unit level (2.5 hogs is equivalent to 1 animal unit) that triggers a more stringent level of EPA regulations. Together, the four buildings contain just under 10,000 hogs at one time.

In designing a municipal system, it is assumed that each person produces a plant throughput of 100 gallons a day, so a population of 10,000 requires a one-MGD (million gallon a day) plant (conversations with Pringle[13]). Construction costs for a wastewater treatment are budgeted at about $6.00 per gallon of capacity, so a one-MGD plant will cost approximately $6 million. Amortized over a 20-year period at six% interest, the annual cost of principal and interest on a one-MGD plant would be $537,120. Over one year, the four CAFO barns served by the plant would run 25,500 hogs through them (assuming 2.55 turns a year and no death loss), producing 67,575 cwt of pork at a 265-pound market weight for each hog. Therefore, the cost of the facility per cwt of marketed pork is $7.95.

However, because hog waste contains more solids and less water than human waste, the plant would have to be more robust than a comparably sized municipal system. In addition, the waste treatment facility incurs operating costs that include labor, insurance, chemicals, repairs, and taxes. In the absence of a full engineering study, it is assumed that including the operating costs and building a more robust plant will add 50% to the initial facility costs. That would bring the per cwt cost of building and operating a wastewater treatment plant to $11.93 per cwt.

The next section of this paper examines the cost comparisons made in Tables 6–9, adding in the cost of subsidies and the use of wastewater treatment plants by CAFO-sized operation to account for the externalities.

Comparison of the social cost of the industrial production of pork with other production systems

A comparison of the preliminary calculation of the social cost of production of pork using a variety of production methods is included in Table 11. The cost numbers from Table 7 dealing with small (1–499), medium (500–1,999), large (2,000–4,999) and industrial-scale (5,000 and over) (CAFO)-size operations in a farrow-to-finish operation are examined in the first section of Table 11. The second section of the table makes a comparison between pasture-raised and CAFO hogs in a farrow-to-finish operation. The third section provides a comparison between hogs raised under a hoop system and those raised under a CAFO system using a grow-to-finish operation. A column appears for the non-monetized externalities to remind the reader that these are descriptive and should be taken into account in policy making.

In examining the issue of externalities, this paper has not examined the upstream externalities that are associated with the provision of inputs into the farming operation, either the traditional production system or the CAFO production system. To do so would involve an examination of the externalities that result from the production and delivery of fossil fuels, the growing of grain and oilseeds, the manufacturing of farm implements, etc. To conduct such a global analysis is beyond the scope of this paper. The focus of this analysis has been the major externality that is created by the collection of large amounts of concentrated hog waste in the operation of CAFOs. The paper has not examined other externalities that may be produced in the production of pork by either large or small producers, but the cafeteria menu offered in this paper can be used to examine those externalities as well.

The first section analyzes the costs of production of hogs on operations of different sizes identified in Table 6. The data year for this section is 1998. While there was a per animal subsidy of $0.74 for corn and $0.57 for soybeans resulting from the commodity programs, this cost is not added to the Table 6 production costs for the small farrow-to-finish operations because these operators typically grow their own corn, and thus the subsidy was used to cover actual costs to produce the corn that was fed to the hogs. Unlike producers who purchase their feed on the open market, the hog producers who produce their own feed always bear the full cost of production for their feed inputs. The dispersed production systems typically used by small-scale producers have few problems with hog waste management and produce few externalities. With minimal environmental problems, no EQIP subsidy was included. For the small producer, the social cost equals the direct cost, which was $57.81 per cwt. The same conditions hold for most medium-sized producers, so the social cost is the same as the direct cost, $45.83 per cwt. Production costs for medium-sized producers, are nearly $12.00 per cwt lower than they are for the small producer.

The industrial-sized farrow-to-finish operation benefited from a $0.74 corn subsidy and a $0.57 soybean subsidy. This per animal commodity subsidy amounted to $8.88 for corn (12 bu @ $0.74) and $1.235 for soybeans (1.667 bu @ $0.57) and amounts to $3.82 per cwt. A six-cent EQIP subsidy was also included for the larger farms, which may have a greater impact upon the environment. In addition, the monetized externality for the wastewater treatment facility of $11.93 per cwt was included. The cost of externalities such as antibiotic resistance resulting from the prophylactic use of antibiotics were not quantified or included in the calculation. Thus, with the inclusion of government subsidies, and the partial inclusion of externalities, the social cost of producing pork using CAFOs comes to $54.75 per cwt, nearly $9 per cwt higher than pork produced in medium-sized operations.

The second section analyzes the cost of production based on production method, regardless of size. For the pasture-raised hogs (from Table 7), the social cost is held to equal the production cost because the waste is spread over a large area at a rate at which it can be decomposed by the environment without causing odor or runoff problems. In addition, the feed is typically grown by the producer who bears the full cost of its production, so no subsidy is included. At the time these worksheets were produced in early 2007, the price of corn and soybeans were both well above the cost of production, so no subsidies resulted from the commodity program. For the CAFO-raised hogs (from Table 9), the six-cent EQIP subsidy is included, as well as the $11.93 per cwt for wastewater treatment. Instead of being $5.41 per cwt cheaper than pasture-raised hogs, when subsidies and externalities were added to the price, CAFO-raised hogs were $6.58 per cwt more expensive.

Before including externalities, CAFO-raised hogs in a grow-to-finish operation are only $0.26 per cwt cheaper than grow-to-finish hogs raised under the hoop system. Hoop systems do not produce the environmental and odor externalities that result from CAFO production systems (Brum et al., 2007). When subsidies and externalities are accounted for, the cost for producing pork under hoop systems is $12.16 per cwt less expensive than producing pork using a CAFO.

In Table 11, only the small farrow-to-finish operation had higher costs than a CAFO operation when subsidies and one measure of externalities are taken into account.

Table 11. Comparison of Social Costs of Various Production Systems (Source: Data from Tables 6, 7, 8, 9, 10 and p. 50).

Production System	Social Cost	Production Costs	Subsidies	Monetized Externailities	Non-Monetized Externalities
Small FTF	$57.81 =	$57.81 +	$0.00 +	$0.00 +	
Medium FTF	$45.85 =	$45.85 +	$0.00 +	$0.00 +	
Industrial CAFO FTF	$54.75 =	$38.94 +	$3.88 +	$11.93 +	
Grain subsidy				$3.82	
EQIP			$0.06		
Wastewater Treatment				$11.93	
AB Resistance					
Pasture-raised FTF	$48.82 =	$48.82 +	$0.00 +	$0.00 +	
Industrial CAFO FTF	$55.40 =	$43.41 +	$0.06 +	$11.93 +	
Grain subsidy			$0.00		
EQIP			$0.06		
Wastewater Treatment				$11.93	
AB Resistance					
Hoop-raised GTF	$37.17 =	$37.17 +	$0.00 +	$0.00 +	
Industrial CAFO GTF	$49.33 =	$36.91	$0.49 +	$11.93 +	
Grain subsidy			$0.43		
EQIP			$0.06		
Wastewater Treatment				$11.93	
AB Resistance					

Conclusion

Without including externalities, CAFOs are about $6.00 per cwt less expensive than pasture or traditional systems of hog production. Comparing the hoop system to CAFOs, the CAFOs have only a 26-cent advantage. However, if CAFOs had to deal with some environmental and health externalities by using a secondary wastewater treatment plant, the additional cost could be $11.93 per cwt. Based on this information, hogs produced using the hoop system (a system compatible with small- to medium-sized farm operations) would have the lowest cost, and pasture and traditional system producers would have a $12.16-advantage over CAFO operators. This data indicates that when externalities are taken into account, and a given means of abatement is adopted, the CAFO production of pork may be *more, not less, expensive than traditional production systems. CAFOs appear to be efficient because they can externalize significant costs onto others and society at large.*

Appendix A, Hogs Run: A Test of the Existence of CAFOS and Pollution Haven Hypothesis

Over the past two decades, the US swine sector has undergone a rapid change in size and ownership structure. Previously, swine production was dominated by many small operations as an integral part of traditional crop-hog farms. These farms were primarily located in the traditional Corn Belt states. Currently, hog production has become highly concentrated in large operations (Concentrated Animal Feeding Operations—CAFOs[1]) controlling production on several different sites. In addition, this shift has created new and varied challenges for the industry. The traditional Corn Belt states, where an abundant supply of corn has provided a relatively low-cost source of animal feed, have been challenged by Southeastern, Great Plains, and Mountain states in terms of lowering the Corn Belt's national share of hog production. By offering swine production and marketing contracts, the newcomer hog operations have attempted to locate large-scale facilities where there are fewer people, lower land and labor costs, and less stringent environmental regulations (Drabenstott, 1998; Hurt, 1994; Rhodes, 1995).

It has been hypothesized that, in order to maximize their profit, hog producers have shifted the nature of their operations from the traditional crop-hog farm to CAFOs where many of the operators are not engaged in crop farming[2] (Hurt, 1994; McBride and Key, 2003). The expansion of CAFOs to areas outside the Corn Belt was made possible by the adoption of new technology and the use of production contracts (Kliebenstein and Lawrence, 1995). The location of these new operations was influenced by lower property taxes and less stringent environmental regulations, creating what some have called hog havens (Sullivan et al., 2000). Operations in a hog haven can offset their higher animal feed costs—due to higher cost of transporting grain from the Corn Belt—with lower environmental, land, and labor costs. The existence of hog havens is consistent with the predictions of the pollution haven hypothesis, which states that pollution-intensive industries seek locations with weak environmental standards, turning these locations into "pollution havens" (Dean et al., 2004).

This study is designed to answer two questions: (1) whether or not the supply of hogs in different locations, without regard to the industrial structure, is consistent with the pollution haven hypothesis and (2) whether or not the existence of CAFOs (in both traditional locations and new locations) is consistent with the pollution haven hypothesis. To answer these questions, this study proposes several empirical models to test the relationship between the presence of hog CAFOs and related factors, e.g., cost variables, environmental regulation variables, etc. This study hypothesizes that the pollution haven hypothesis accounts for the spatial distribution of the hog industry in the United States. The estimated results have the potential to show the usefulness of the pollution haven hypothesis in describing the location of CAFOs and whether or not there is a "trade-off" between low environmental regulations and resource abundance. Employing a two-step model, this study measures the impact of CAFOs on the hog supply—analyzing the way in which environmental regulations along with economic conditions affect producers' decision to establish CAFOs—followed by the testing of the pollution haven hypothesis.

This paper is organized as follows. Section 2 provides a brief description of the US swine industry and a discussion of the pollution haven hypothesis. Section 3 presents the theoretical framework. Section 4 discusses the empirical model, data and variable construction, and the empirical results. Section 5 summarizes the results.

US Swine Industry and Pollution Haven Hypothesis

The United States is the world's third largest producer and second largest consumer, exporter, and importer of pork and pork products. Pork ranks third in annual level of meat consumption in the United States, behind beef and chicken, averaging 51 pounds per person, with imports accounting for about 5% of that. Exports account for about 6% of domestic production.

The US hog herd stands at approximately 60 million animals, with about 68% of them in the Corn Belt, where they have access to that region's abundant supplies of feed grains and soybean meal. The major producing states in the Corn Belt are Iowa, Minnesota, and Illinois, with a share of total US production of 26%, 11%, and 7%, respectively. Another 20% of hogs are produced in the Southeast, where North Carolina is the largest producer with a share of total production of 16%.

In 2002, the number of US farms engaged in hog production was about 79,000 farms, a 50% reduction from 1982. Despite this, the total hog inventory has remained relatively constant as some operations exit and the average operation gets larger. In the past, hog production was dominated by many small operations using more traditional methods of production; more recently, hog production has become more industrialized. Industrialization generally involves an increase in farm size along with specialization in phase of production, specialization of labor, adoption of advancements in technology, increased off-farm management control, and the coordination of marketing with the needs of food processors and retail firms (Rhodes, 1995; Weersink and Eveland, 2006). Rhodes (1995) examined the transition in hog production over the last quarter century, focusing on changes in firm size, organization, and location. He concluded that the primary forces contributing to industrialization are innovational profits and economies of scale. He argues that the prospect of significant profits obtainable by those who utilize new technologies and practices has been the driving force behind the trend toward greater industrialization. Technological innovation in hog production has been particularly rapid during the last decade in the fields of nutrition, health, breeding and genetics, reproductive management, housing, and environmental management (Boehlje, 1992).

The major shift in the industrialization of the hog industry has coincided with the rapid increase in the use of production contracts. Contract operations account for a large share of hog production (Sullivan et al., 2000), with a substantial increase in factor productivity as the result of the implementation of technological improvements not possible with independent production (Key and McBride, 2003). The growth of contract hog production has also been a major force behind the changing location of hog production. For example, the rapid increase in hog production in the Southeast, particularly in North Carolina, is due, in large part, to the increase in contracting by a few large integrators. One factor influencing the development of hog production in North Carolina was the need to find alternative sources of economic activity to replace tobacco production, which was declining in importance (Kliebenstein and Lawrence, 1995).

The structural change from the traditional hog operation to the industrialization of hog production has changed the nature of the environmental impacts due to the large volume of hog manure concentrated in fewer operations and in a smaller area. Hog waste from CAFOs is a potential source of air and water quality degradation resulting from the evaporation of gases and the infiltration of liquefied wastes into surface water and groundwaters (Aillery et al., 2005). The Environmental Protection Agency (EPA) only requires CAFOs to have National Pollution Discharge Elimination System (NPDES) permits in order to develop and implement a comprehensive nutrient management plan. The development of a NPDES increases production costs.[3] In addition, local governments may control the hog operations with their own regulations and requirements.[4]

Therefore, it has been hypothesized that hog production has expanded in areas in the South and in nontraditional areas of the West to take advantage of less stringent state and local environmental regulations. This argument is consistent with the "Pollution Haven Hypothesis."

According to Levinson's definition in the *New Palgrave Dictionary of Economics*, the pollution haven hypothesis suggests that polluting industries will relocate to jurisdictions with less stringent environmental regulations. He notes that econometric studies of the pollution haven effect have typically focused on reduced-form regressions of a measure of economic activity on some measure of regulatory stringency and other covariates. Evidence in favor of the pollution haven hypothesis would be an estimated inverse relationship between economic activity and regulatory stringency.

An analysis of the way environmental regulation and enforcement at the state and county level (instead of at the federal level) have affected location decisions by industrial agriculture can provide some insight into whether or not the pollution haven phenomenon applies to the development and location of CAFOs. In addition, this analysis may help to explain why efforts to regain some national control over the regulatory process by implementing national standards have engendered negative reactions. For example, producers could pressure Congress into not appropriating funds for the enforcement


TECH

of new environmental regulations when the US Environmental Protection Agency (EPA) tightens existing federal water quality laws through the increased regulation of confined animal feeding operations.

The hypothesis has been tested empirically for various elements of the livestock sector within the United States as a possible explanation for the significant regional shifts in production shares. Environmental regulations are a reason for the spatial changes in the broiler and hog industry (Martin and Zering, 1997), and for the US dairy sector (Isik, 2004). Roe et al. (2002) found that the stringency of environmental regulations affected the expansion of hog production at the county level for 15 US states. Earlier, Mo and Abdalla (1998) concluded there was no support for the hypothesis that the stringency of state environmental regulations impacted hog inventory growth over the 1988–1995 period for 13 hog-producing states. In addition, it should be noted that factors such as marketing channel development and infrastructure support had a larger effect on changes in US livestock inventory levels at the state level than environmental compliance costs (Park et al., 2002). None of these papers studied the relationship between producer decisions to establish CAFOs and stringent environmental regulations.

The purpose of this paper is to assess the producer decision to adopt the CAFO system of hog production and the impact of this decision on the supply of hogs, and to test whether or not the pollution haven hypothesis predicts the spatial spread of the hog industry in the United States. Because hog CAFOs have been regulated differently in various states, taking into account the siting of CAFOs would be fruitful. The existence of CAFOs in a county is indicated by a 0, 1 dummy variable. The pollution haven hypothesis is tested by observing the sign of the coefficient of the environmental regulation variable in the hog inventory equation in each county. In addition, the estimates of the coefficients can be used to identify the likelihood of whether a producer adopts a corn-hog or a CAFO-type operation.

Theoretical Framework

A representative farmer in county *i* maximizes his utility,

(1) $$U(\pi_{i,t}(\mathbf{p}_{i,t}, \mathbf{w}_{i,t}) + n_i - q_i)$$

where *U*(.) is the farmer's utility function, which is assumed to have conventional properties. $\pi_{i,t}$ is the annual profit from farming, n_i is the income generated from nonfarm sources, and q_i is the annual tax paid. The farmer's profit function is

(2) $$\pi_t = \mathbf{p}_i f(\mathbf{y}_i, \mathbf{x}_i, \ddot{\mathbf{a}}_i) - \mathbf{w}_i \mathbf{x}_i - \mathbf{c}_i$$

where $\mathbf{p}_i$ is a vector of output prices, $f(\mathbf{y}_i, \mathbf{x}_i, \ddot{\mathbf{a}}_i)$ is a combined output production technology, $\mathbf{y}_i$ is a vector of outputs, $\mathbf{x}_i$ is a vector of inputs, $\ddot{\mathbf{a}}_i$ is a vector of technology shifters, $\mathbf{w}_i$ is a vector of input prices, and $\mathbf{c}_i$ is a vector of fixed costs associated with production and operations (e.g., fixed capital costs of new buildings and the fixed cost of meeting state environmental regulations and handling local complaints). The supply of hogs can be derived from (2) by Hotelling's lemma. By the law of supply, increases in relative output price causes a farmer to produce more. The supply of hogs will expand, for example, when a farmer applies fewer resources to accommodate environmental regulations and local complaints or when property taxes are lowered.

Empirical Model and Results

Based on the Hotelling's lemma in the profit function, the hog supply can be written in the general econometric model as

(3) $\mathbf{y} = \mathbf{x}\hat{\mathbf{a}} + \mathring{\mathbf{a}}$

where $\mathbf{y}$ is an $N \times 1$ vector of hog production variables in each of the N counties for a given time period, $\mathbf{x}$ is the $N \times k$ matrix of explanatory variables, $\hat{\mathbf{a}}$ is a $k \times 1$ parameter vector to be estimated, and $\mathring{\mathbf{a}}$ is an $N \times 1$ vector of normally distributed error terms with zero mean and variance σ^2.

To measure the impact of CAFOs on the hog supply, we employ the treatment effect sample selection model (Greene, 2000). The model assumes a joint normal distribution between the errors of the selection equation (CAFOs/no CAFOs) and the regression equation (supply of hogs). As discussed in the introduction, this approach accounts for the fact that unobservable variables may be correlated with both the operators' decision to adopt the CAFO structure and the hog supply, allowing for an unbiased estimate of the impact of CAFOs on total supply. The treatment effect approach is used here rather than an instrumental variables approach because there are too few variables available with which to instrument the CAFOs dummy variable.

A hog supply equation is

(4) $s_i = \hat{\mathbf{a}}'\mathbf{x}_\mathbf{i} + \delta C_i + \varepsilon_i$

where $\mathbf{c}_i$ is a dummy variable indicating whether or not the county has at least one CAFO. Let latent variable C_i^* equal the number of hog farms in each county whose herd hog is greater than 1,000 animal units:

(5) $C_i^* = \tilde{\mathbf{a}}'\mathbf{w}_\mathbf{i} + u_i$

$C_i = 1$ if $C_i^* > 1$, 0 otherwise

where w_i is a vector of regional characteristics. If the latent variable is greater than one, then the dummy variable indicating CAFOs (C_i^*) equals 1, and equals 0 otherwise. We cannot simply estimate (4) because the decision to site a CAFO may be determined by unobservable variables (management ability, regional characteristics, environmental regulations, etc.) that may also affect performance and/or number of hogs produced. If this is the case, the error terms in (4) and (5) will be correlated, leading to biased estimates of $\hat{\mathbf{a}}$ and δ. To give details, suppose the errors have a joint normal distribution with the following form:

$$\varepsilon : N(0, \sigma_\varepsilon)$$
$$u : N(0,1)$$
$$corr(\varepsilon, u) = \rho$$

When $\rho \neq 0$, standard regression techniques applied to (4) yield biased results. Coupled with our supply equation, we find that

(6) $$E[y_i | C_i = 1] = \hat{\mathbf{a}}'\mathbf{x}_i + \delta + E[\varepsilon_i | C_i = 1] = \hat{\mathbf{a}}'\mathbf{x}_i + \delta + \rho\sigma_\varepsilon\lambda(-\tilde{\mathbf{a}}'\mathbf{w}_i)$$

where

$$\lambda(-\tilde{\mathbf{a}}'\mathbf{w}_i) = \frac{\phi(-\tilde{\mathbf{a}}'\mathbf{w}_i)}{1 - \Phi(-\tilde{\mathbf{a}}'\mathbf{w}_i)}$$

is the inverse Mills ratio. (6) implies that omitting λ in an ordinary least squares regression of (4) would lead to omitted variable bias in estimates of β and δ. To derive consistent parameter estimates, we can use a two-stage approach starting with a probit estimation of (5). In the second stage, estimates of $\tilde{\mathbf{a}}$ are used to compute the inverse Mills ratio, which is included as an additional term in an OLS estimation of (4). This sample selection procedure is consistent, but not efficient. Asymptotically efficient maximum likelihood parameter estimates can be obtained by maximizing

$$L(\gamma, \beta, \sigma, \rho) = \prod_{C_i=0} \int_{-\infty}^{0}\int_{-\infty}^{\infty} f(C_i^*, s_i; \gamma, \beta, \sigma, \rho)\, ds\, dC^* \cdot \prod_{C_i=1} \int_{0}^{\infty}\int_{-\infty}^{\infty} f(C_i^*, s_i; \gamma, \beta, \sigma, \rho)\, ds\, dC^*$$

where

$$f(C_i^*, s_i; \gamma, \beta, \sigma, \rho)$$

is the joint normal density function, which is a function of the parameters.

Data

To observe the relationship between CAFOs in the hog industry and the pollution haven hypothesis, this study will employ county level data for 15 states, resulting in a total of 1,320 observations for 1992 and 2002, representing both traditional (Ohio, Michigan, Indiana, Illinois, Wisconsin, Missouri, Iowa, and Minnesota) and nontraditional locations of hog production (South Dakota, Nebraska, Kansas, Oklahoma, Arkansas, Pennsylvania, and North Carolina). These states held about 90% of the hog inventory in 2002 as recorded by the 2002 Census of Agriculture.

Data is drawn from five sources. Swine industry data, e.g., hogs and pigs (inventory and sales), the price per animal unit of hogs, and the price of corn, is drawn from the 1992 and 2002 Census of Agriculture (USDA, 1992, 2002) and National Agricultural Statistics Service, United States Department of Agriculture (USDA-NASS, 2008). Socioeconomic data, e.g., county area, population density, housing density, and etc., is drawn from the 1990 and 2000 Census of Population (Census, 1990, 2000). Farm income and expenses are drawn from the Bureau of Economic Analysis, United States Department of Commerce (USBEA, 2007). Property taxes data is drawn from the 1992 and 2002 Census of Governments (Census, 1992, 2002). Environmental regulation data is drawn from several sources such as

Copeland (Copeland, 1994), NACPTF (NACPTF, 1998), and Metcalfe (2000a and 2000b).

Dependent variables considered are the county's total hog inventory (*Hog*) for the supply equation, and the dummy variable determining the CAFOs operation (*Dcafo*) in a county for the selection equation. The conventional variable of the supply equation is the hog price (*Price*), which is calculated by the ratio of total revenue of hogs and pigs sold to the number of hogs and pigs sold. Input variables are the price of corn (*Pmz*), feed purchases (*Feed*), and livestock purchases (*Pigpur*) as a proxy for pig purchases. Cash receipts for livestock (*Cash*) is defined as the return for livestock, and government subsidies (*Sub*) are investment variables. Per capita income (*Pci*) is used as the proxy for average population assets. A variable representing property taxes per square miles (*Pt*) is used as one of the costs of hog production. Total number of farms (*Farm*) will be used to determine the supply equation, while the total number of CAFOs (*CAFO*) will be used to construct the *Dcafo*. Regulatory stringency variables include two variables: (1) the state-level index of environmental regulation including local control (*Envreg*), and (2) the cost share program (*Costshr*)—for example, the Environmental Quality Incentive Program (EQIP). Details of regulatory stringency variables are shown in Table 1. Urban and population characteristics employed in the selection equation include population density (*Pden*) and housing density (*Hden*). In addition, the acceleration terms of density are included in the selection equation (*P2* and *H2*). The variables used in estimation are summarized in Table 2.

Table 1. Legislation Description

Legislation	Description
Local control	Some regulation is imposed at a county or natural resource district level.
Facility design approval	State has requirements for appropriate engineering of the feeding operation.
Waste system approval	State has requirements for appropriate engineering of the waste-collection and/or storage system.
Geological testing	Testing of the soil and/or groundwater near the feeding operation is required.
Public notice	Public notice and/or public hearings are required when the operation is purposed.
Setbacks	Distances are regulated for facility and/or manure storage separation from property lines and/or surface water and groundwater.
Nutrient management engineering	A plan is required demonstrating that nutrient field application occurs at agronomic rates.
More stringent then NPDES	State legislation imposes size restrictions more stringent than federal NPDES permit program.
Bonding	Proof of financial responsibility is required for manure leaks and spills as well as system closures.
Moratoria	Severe restrictions have been imposed on size of operations or on total production.
Cost-share programs	State has cost-share program(s) to help operations adopt approved manure-management practices.

Table 2. Summary Statistics

	1992			2002			
VARIABLE	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**UNIT**
Hog	38530.2	0	1149704	39043.9	0	2166185	Animal Unit
Price	100.6	0	288.8	73.2	0	412.3	$1,000/AU
Pmz	2.4	2.13	2.80	2.32	2.1	2.8	$/Bushel
Feed	9512.4	0	244655.8	8717.4	0	240903.7	$1,000
Pigpur	11163.0	0	313848.4	9280.6	0	322225.1	$1,000
Cash	43980.9	0	700992.2	36705.0	0	650042.1	$1,000
Sub	7276.7	0	38041.1	9477.5	0	72834.71	$1,000
Pci	19.4	9.4	41.7	23.0	8.5	46.2	$1,000
Pt	46887.2	175.6	6082427.0	59004.7	305.8	7212274.0	$1,000
Farm	106.9	0	972	39.9	0	528	Number
Cafo	8.2	0	161	8.6	0	324	Number
Dcafo	0.7	0	1	0.6	0	1	Dummy
Envreg	3.7	1	8	7.2	3	9	Index
Costshr	0.3	0	1	0.7	0	2	Index
Area	737.8	87.5	6859.9	737.8	87.5	6859.9	Sq. miles
Pop	64003.6	462	5199839	68898.0	400	5365567	Persons
Pden	112.9	0.3	11046.0	121.1	0.4	10422.0	Persons/Sq. miles
House	25897.7	242	2021833	28756.6	273	2096121	Units
Hden	45.6	0.3	4731.5	50.5	0.3	4640.8	Units/Sq. miles
P2	172.1	0	122013.4	170.7	0	108618.1	-
H2	29.6	0	22387.0	31.0	0	21536.7	-

Empirical Results

After testing for structural change across the two time periods, this study finds that it is not suitable to pool the data. Therefore, this study estimates the supply equation and the selection equation in each period and compares those estimates in order to observe the change in behavior of hog operations between the two periods. In addition, with the same specification, this study compares the presence of CAFOs and tests the pollution haven hypothesis for each decade.

Tables 3a and 3b list the marginal effect results of the first-stage probit model, explaining the farm level decision to adopt the CAFO production system versus the small farm hog production system. The coefficients of the probit model, which are not shown here, are used to compute the inverse Mills ratio used in the two-stage procedure. Estimates from the first-stage procedure are used as starting values in the maximum likelihood estimation in the first-stage selection model. The models are significant and correctly predict 69.8% and 63.4% the farmer decision whether or not to adopt the CAFO hog production system in 1992 and 2002, respectively. Most variables have consistent coefficients that are statistically different from zero except for *Envreg* in the 1992 model and *Pt1* in the 2002 model, and their signs are consistent between the two periods except for *Costshr* variable. The marginal effect results indicate that for an average operation, an increase in housing density, property taxes, and square value of population density lessen the probability of the establishment of CAFOs, while an increase in population density and square value of housing density raise the likelihood of CAFOs. An increase in the environmental regulation index is more likely to broaden the probability that the hog operation will be concentrated. These results are consistent with the fact that all CAFOs have been broadly regulated by the Clean Water Act.

Table 3a. 1992 Marginal Effects of Probit Estimates: CAFO's Decision

Probit regression, reporting marginal effects	Number of obs	=	1320
	Wald chi2(7)	=	61.56
	Prob > chi2	=	0.0000
Log pseudolikelihood = -759.63841	Pseudo R2	=	0.0609

Dcafo	dF/dx	Robust Std. Error	z	P>(z)	x-bar	[95% C.I.]	
Envreg	.0045431	.006584	0.69	0.490	3.66515	-.008361	0.17448
Costshr*	.1055312	.0281105	3.56	0.000	.262879	.050436	.160627
P2r	-.0028175	.0009014	-3.17	0.002	172.143	-.004584	-.001051
H2r	.0154074	.0048849	3.20	0.001	29.5736	.005833	.024982
Pt1	-4.96e -07	2.16e -07	-2.31	0.021	46887.2	-9.2e -07	-7.4e -08
Pden	0.94725	.0016897	5.60	0.000	112.875	.006161	.012784
Hden	-.0224695	.0040099	-5.59	0.000	45.5865	-.030329	-.01461
obs. P	.6977273						
pred. P	.6976455 (at x-bar)						

*dF/dx is for discrete change of dummy variable from 0 to 1
z and P>(z) correspond to the test of the underlying coefficient being 0

Table 3b. 2002 Marginal Effects of Probit Estimates: CAFO's Decision

Probit regression, reporting marginal effects	Number of obs	=	1320
	Wald chi2(7)	=	127.51
	Prob > chi2	=	0.000
Log pseudolikelihood = -771.87996	Pseudo R2	=	0.1044

Dcafo	**df/dx**	**Robust Std. Error**	**z**	**P>(z)**	**x-bar**	**[95% C.I.]**	
Envreg	.0434366	.0076072	5.70	0.000	7.15985	0.28527	0.58346
Costshr	-.1645927	0.24399	-6.72	0.000	.673485	-.212414	-.116772
Pt1	-1.78e -07	3.37e -07	-0.53	0.597	.59004.7	-8.4e -07	4.8e -07
Pden	.0106023	.0018859	5.73	0.000	121.055	.006906	.014299
Hden	-.0246814	.0043712	-5.74	0.000	50.4503	-.033249	-.016114
P2r	-.0037833	.0013094	-2.95	0.003	170.731	-.00635	-.001217
H2r	.0192133	.0065832	2.98	0.003	31.0139	.006311	.032116
obs. P	.6409091						
pred. P	.6344448 (at x-bar)						

z and P>(z) correspond to the test of the underlying coefficient being 0

Table 4a. 1992 Selection Model Maximum Likelihood Estimate

Heckman selection model	Number of obs	=	1320
(regression model with sample selection)	Censored obs	=	399
	Uncensored obs	=	921
	Wald chi2(7)	=	446.70
Log pseudolikelihood = -11868.35	Prob > chi2	=	0.000

	coef.	Robust Std. Error	z	P>(z)	[95% C.I.]	
HOG						
Price1	345.8701	100.0988	3.46	0.001	149.68	542.0602
Pmz1	2296.857	7119.634	0.32	0.747	-11657.37	16251.08
Feed1	.5042489	.2096977	2.40	0.016	.0932491	.9152488
Sub1	1.095332	.274964	3.98	0.000	.5564125	1.634252
Pt1	-.0634356	.022704	-2.79	0.005	-.1079346	-.0189366
Farm	333.9771	26.98635	12.38	0.000	281.0848	386.8693
Envreg	-2632.902	1159.198	-2.27	0.023	-4904.889	-360.9153
_cons	-61070.99	20568.71	-2.97	0.003	-101384.9	-20757.06
DCAFO						
Envreg	.007203	.0180538	0.40	0.690	-.0281817	.425877
Costshr	.0629648	.0658707	0.96	0.339	-.0661394	.1920691
Pt1	-3.38e -07	4.86e -07	-0.70	0.486	-1.29e -06	6.14e -07
Pden	.0169188	.0036095	4.69	0.000	.0098444	.0239933
Hden	-.0410076	.0084667	-4.84	0.000	-.057602	-.00244131
P2r	-.0054686	.0015414	-3.55	0.000	-.0084897	-.0024474
H2r	.0300389	.0083959	3.58	0.000	.0135833	.0464945
_cons	.2949835	.0687587	4.29	0.000	.160219	.4297481
/athrho	2.086815	.1961788	10.64	0.000	1.702312	2.471318
/insigma	11.02872	.1996223	55.25	0.000	10.63746	11.41997
rho	.9696744	.0117181			.9356974	.9858296
sigma	6168.42	12300.41			41666.96	91123.29
lambda	59749.8	12528.95			35193.52	84306.09

Wald test of indep. eqns. (rho=0): chi(2)=113.15 Prob>chi2=0.000

The maximum likelihood estimates of the 1992 and 2002 treatment effect selection models are presented in Tables 4a and 5a, respectively. Based on the Wald test, the sample selection corrections are needed in both models, supporting this study framework in both years. The estimated coefficients in the bottom half of Tables 4a and 5a correspond to the selection equation, and are mostly consistent in sign with the results of the probit model in Tables 3a and 3b, but more efficient. In addition, the standard errors presented in Tables 4a and 5a are the robust standard errors.

Selection Equation

In terms of environmental regulations (*Envreg and Costshr*), the estimated parameters show that regulations have no effect on producer decisions in 1992, while *Envreg* increases the probability that a CAFO is sited in a particular county in 2002. Urbanization variables (*Pden*, *Hden*, *P2r*, and *H2r*) affect significantly the producer decision among study periods. Property taxes parameters (*Pt1*) are not statistically significant in either year. This means that property taxes are not the main criteria to the decisions of being CAFOs.

The positive sign of *Envreg* in Tables 3a, 3b, 4a, and 5a gives consistent information that stringent environmental regulations do not deter the hog producer decisions to be concentrated feeding operations, but support. At the federal level, CAFOs have been regulated based on the Clean Water Act, and odor from the operations is not included. At the state and/or county level, it may be the case that environmental regulations probably are not stringent, not fully implemented, and/or offer exemptions to hog operations.

Tables 4b and 5b show the predicted probabilities of being CAFOs and their marginal effects. The predicted probabilities for the 1992 and 2002 models overall are 62.1% and 53.4%, respectively. When all variables are held at their means, an additional index value of *Envreg*

Table 4b. 1992 Marginal Effects on the Probability of Being CAFO's

Marginal effects after Heckman y = Pr (Dcafo) (predict, psel)
= .62148545

Variable	dy/dx	Std. Error	z	P>(z)	[95% C.I]		X
Envreg	.0027393	.00685	0.40	0.689	-.010687	.016165	3.66515
Costshr	.0238289	.0246	0.97	0.333	-.024385	.072043	.262879
Pt1	-1.29e -07	.00000	-0.70	0.485	-4.9e -07	2.3e -07	46887.2
Pden	.0064342	.00131	4.90	0.000	.00386	.009008	112.875
Hden	-.0155951	.00308	-5.07	0.000	-.021624	-.009566	45.5865
P2r	-.0020797	.00058	-3.62	0.000	-.003207	-.000953	172.143
H2r	.0114237	.00313	3.65	0.000	.005286	.017561	29.5736

*dy/dx is for discrete change of dummy variable from 0 to 1

Table 4c. 1992 Marginal Effects of Regression Equation

Marginal effects after Heckman y = E [Hog*|Pr (Dcafo)] (predict, y expected)
= 32140.939

Variable	dy/dx	Std. Error	z	P>(z)	[95% C.I.]		X
Price1	214.9532	63.863	3.37	0.001	89.7848	340.122	100.6
Pmz1	1427.463	4427.9	0.32	0.747	-7250.98	10105.9	2.43485
Feed1	.3133834	.12733	2.46	0.014	0.63812	.562955	9512.43
Sub1	.680733	.16408	4.15	0.000	.359146	1.00232	7276.73
Pt1	-.0389958	.01311	-2.98	0.003	-.064686	-.013305	46887.2
Farm	207.5619	20.336	10.21	0.000	167.704	247.42	106.88
Envreg	-1645.436	686.34	-2.40	0.017	-2990.64	-300.228	3.66515
Costshr*	-100.4883	147.82	-0.68	0.497	-390.205	189.228	.262879
Pden	-21.43486	32.17	-0.67	0.505	-84.487	41.6173	112.875
Hden	51.9535	78.048	0.67	0.506	-101.18	204.925	45.5865
P2r	6.928248	10.384	0.67	0.505	-13.4243	27.2808	172.143
H2r	-38.05698	57.051	-0.67	0.505	-149.876	73.7616	29.5736

*dy/dx is for discrete change of dummy variable from 0 to 1

in the 2002 model increases the probability of being CAFOs by .044.

Hog Supply Equation

The estimated parameters of the 1992 model follow the study expectations (Table 4a). Although the *Pmz* has a positive sign, it is not statistically significant. Property taxes have a negative tiny effect to the hog supply equation. The pollution haven hypothesis is supported with the 1992 model with a negative sign of *Envreg*. An increase in environmental stringency index in a particular location will lower the number of hogs in that location; however, it will increase the chances of the presence of CAFOs.[5] This is not surprising because CAFOs are the operations that have new technology, including waste management plans and facilities.

The predicted hog supply, given the probability of the presence of CAFOs, is about 32,140 animal units in a county (Table 4c). The marginal effects on the hog supply show that a unit increase in the hog price will increase the hog supply by 214 animal units. An additional average farm will increase the hog supply by 207 animal units. An additional environmental regulations index will decrease the hog supply in a particular county by 1,645 animal units which is consistent to the pollution haven hypothesis. Urbanization variables, on average, do not affect the supply of hogs.

For the 2002 model, the significant parameters are consistent with the 1992 model results except for the *Envreg*. The positive sign of *Envreg* does not support the pollution haven hypothesis. Instead, this is evidence of the Porter Hypothesis that environmental regulations promote competitiveness (Levinson, Forthcoming). In fact, it could be the case that environmental costs are measured and understood; therefore, firms have innovation-based solutions (Porter and van der Linde, 1995). Since the federal environmental regulations concerning hog operations were operational in both 1992 and 2002,[6] it is possible that all CAFOs have already adopted the appropriate technology in order to meet those regulation requirements. In this case, *Envreg* not only increases the probability of being CAFOs but also increases the number of hogs in the county.[7] The marginal effects in Table 5c show that, given the probability of the presence of CAFOs, an additional environmental regulations index will increase supply of hogs in a particular county by 6,860 animal units. The conclusion here is also consistent with the findings of Weersink and Eveland (2006). They find that "Instead of locating to reduce environmental compliance costs as suggested by the pollution haven hypothesis, barns are being built largely where the livestock sector is concentrated suggesting the existence of agglomeration economies."

Table 5a. 2002 Selection Model Maximum Likelihood Estimate

Heckman selection model	Number of obs =	1320
(regression model with sample selection)	Censored obs =	399
	Uncensored obs =	921
	Wald chi2(7) =	446.70
Log pseudolikelihood=-11868.35	Prob > chi2 =	0.000

	Coef.	Robust Std. Err	z	P>(z)	[95% C.I.]	
HOG						
Price1	64.08264	42.02616	1.52	0.127	-18.28712	146.4524
Pmz1	4744.284	1171.88	0.40	0.687	-18328.18	27816.75
Feed1	.6678473	.1728373	3.86	0.000	.3290924	1.006602
Sub1	1.062579	02998487	3.54	0.000	.4748868	1.650272
Pt1	-.1138807	.0413708	-2.75	0.006	-.194966	-.0327953
Farm	797.6608	91.61118	8.71	0.000	618.1032	977.2154
Envreg	14857.69	2193.031	6.77	0.000	10559.43	19155.95
_cons	-176949.9	42515.11	-4.16	0.000	-260278	-93621.81
DCAFO						
Envreg	.1112601	.0168942	6.59	0.000	.078148	.1443722
Costshr	-.0260755	.0303527	-0.86	0.390	-.0855657	.0334148
Pt1	8.03e -08	5.38e -07	0.15	0.881	-9.74e -07	1.13e -06
Pden	.0141442	.0032763	4.32	0.000	.0077228	.0205656
Hden	-.0328132	.007829	-4.19	0.000	-.0481577	-.0174687
P2r	-.0053142	.0012991	-4.09	0.000	-.0078603	-.0027681
H2r	.0260795	.0071489	3.65	0.000	.012068	.040091
_cons	-.6551218	.1263364	-5.19	0.000	-.9027366	-.4075069
/athrho	2.602695	1599737	16.27	0.000	2.289152	2.916237
/insigma	11.7252	.1686766	69.51	0.000	11.3946	12.0558
rho	.9890861	.0034728			.9796643	.9941555
sigma	123648.3	20856.57			88840.34	172094
lambda	122298.8	20862.48			81409.05	163188.5

Wald test of indep. eqns. (rho=0): chi(2)=264.70 Prob>chi2=0.000

Table 5b. 2002 Marginal Effects on the Probability of Being CAFOs

Marginal effects after Heckman y = Pr (dcafo) (predict, psel)
= .53465327

Variable	dy/dx	Std. Error	z	P>(z)	[95% C.I.]		X
Envreg	.0442188	.00669	6.60	0.000	.031097	.057341	7.15985
Costshr	-.0103633	.01206	-0.86	0.390	-.03401	.013283	.673485
Pt1	3.19e -08	.00000	0.15	0.881	-3.9e -07	4.5e -07	59004.7
Pden	.0056214	.00129	4.35	0.000	.003089	.008154	121.055
Hden	-.0130412	.00309	-4.22	0.000	-019092	-.00699	50.4503
P2r	-.0021121	.00051	-4.12	0.000	-.003118	-.001106	170.731
H2r	.0103649	.00282	3.67	0.000	.004833	.015897	31.0139

*dy/dx is for discrete change of dummy variable from 0 to 1

Table 5c. 2002 Marginal Effects on Regression Equation

Marginal effects after Heckman y = E [hog*|Pr (dcafo)] (predict, y expected)
= 41199.799

variable	dy/dx	Std. Error	z	P>(z)	[95% C.I]		X
Price1	34.262	22.321	1.53	0.125	-9.48727	78.0113	73.1577
Pmz1	2536.547	6273.6	0.40	0.686	-9759.55	14832.6	2.32231
Feed1	.3570668	.08912	4.01	0.000	.182396	.531737	8717.39
Sub1	.5681115	.1586	3.58	0.000	.257267	.878957	9477.53
Pt1	-.0616687	.02284	-2.70	0.007	-.106439	-.016899	59004.7
Farm	426.472	50.574	8.43	0.000	327.348	525.596	39.9167
Envreg	6860.843	904.3	7.59	0.000	5088.46	8633.23	7.15985
Costshr	253.7866	309.4	0.82	0.412	-352.627	860.2	.673485
Pden	-137.6619	58.138	-2.37	0.018	-125.611	-23.713	121.055
Hden	319.3639	137.15	2.33	0.020	50.5551	588.173	50.4503
P2r	51.72209	22.897	2.26	0.024	6.84558	96.5986	170.731
H2r	-253.8257	117.08	-2.17	0.030	-483.307	-24.3441	31.0139

*dy/dx is for discrete change of dummy variable from 0 to 1

Conclusion

The transformation of the structure of the US hog industry from the crop-hog farm to CAFOs is the result of profit maximization. The expansion of CAFOs is the result of new technology adoption, production contracts, and the externalization of costs to society. This study assesses the probability of the presence of CAFOs in a given county and tests the pollution haven hypothesis by using county-level data in the 15 most significant hog-producing states.

With the treatment effect selection model in each period of study, the selection procedure reduces the chances of an omitted variable bias. In addition, the selection equations confirm the adoption of CAFOs in order to determine the supply of hogs. The first-stage probit model estimates and the selection equation estimates for both periods are consistent in that the stringency of environmental regulations increases the likelihood of confinement hog production.

The observed differences in the pollution haven hypothesis between the two periods in hog supply equations have at least two possible interpretations. First, hog farmers suffer from the environmental regulations and thus they seek out hog havens; however, adopting the new technology to meet environmental requirements is more likely to be current practice rather than seeking another less stringent area and exploiting neighbors in a new area. Second, it is possible that environmental regulations are not fully implemented, mostly in the areas where local revenue comes from the farm. This study finds that there is no evidence regarding the trade-off between the pollution haven hypothesis and resource abundance. Therefore, a good explanation for the expansion of hog production is derived from the conventional idea of profit maximization. It cannot be denied that for the first stage of production, operations may seek out hog havens. Environmental regulations are put into effect after people suffer and make complaints. In response to new environmental regulations, hog operations will then adopt new technologies obtained through the production contract and/or government supports in order to meet the new requirements. Environmental compliance costs favor production in large operations.

Endnotes (Appendix)

[1] Hog operations will be called CAFOs when they have an inventory of more than 1,000 animal units, which generally is equal to 2,500 head of hogs.

[2] CAFO implies lower transportation costs associated with input delivery and product pickup. In addition, large production units imply lower fixed cost per unit hog herd. Key and McBride (2003) state that CAFOs have lower fixed cost associated with transportation, screening and search for potential contractees, negotiation of contracts, and monitoring behavior for breech of contract.

[3] CAFOs have been regulated since 1974 under the Clean Water Act. Although federal CAFO regulations were strengthened in 2003, these regulations do not require control of potential air emissions from CAFOs.

[4] For example, the state of Iowa prohibits the use of spray irrigation techniques and requires that an extensive waste-management plan be submitted for state approval before the operation may begin production (Metcalfe, 2000b). With respect to air quality and the need to protect people, property, and natural areas from swine manure odors, some states, (for example, Iowa and North Carolina) have implemented "separation" or "setback" provisions (Fleming, 1999).

[5] In 1992, there were only 10,770 CAFO farms, while the total number of farms was 141,081 farms or 7.63%.

[6] In 2003, EPA announced its plans to regulate the CAFOs with more stringent regulations. In addition, since March 2007, EPA no longer exempts large livestock farms from the requirement of reporting emissions of ammonia and various other air pollutants.

[7] In 2002, there were about 11,333 CAFOs, while the total number of farms was 52,690 or 21.5%.

References (Appendix)

Aillery M, Gollehon N, Johansson R, Kaplan J, Key N, Ribaudo M (2005). *Managing Manure to Improve Air and Water Quality*. Economic Research Service, US Department of Agriculture, p 66.

Boehlje M (1992). Alternative Models of Structural Change in Agriculture and Related Industries. *Agribusiness* 8(3): 219–231.

Census, US (1990). United States Census 1990.

Census, US (1992). 1992 Census of Governments.

Census, US (2000). United States Census 2000.

Census, US (2002). 2002 Census of Governments.

Copeland J (1994). *Environmental Laws Impacting [State] Livestock Producers*. National Center for Agricultural Law Research and Information, Fayetteville, Arizona.

Dean JM, Lovely ME, Wang H (2004). *Foreign Direct Investment and Pollution Havens: Evaluating the Evidence from China.* Office of Economics, US International Trade Commission.

Drabenstott M (1998). This Little Piggy Went to Market: Will the New Pork Industry Call the Heartland Home? *Federal Reserve Bank of Kansas City Economic Review* 83(3): 79–97.

Fleming RA (1999). The Economic Impact of Setback Requirements on Land Application of Manure. *Land Economics* 75: 579–591.

Greene WH (2000). *Econometric Analysis.* Prentice-Hall, Upper Saddle River, New Jersey.

Hurt C (1994). Industrialization in the Pork Industry. *Choices: The Magazine of Food, Farm & Resource Issues* 9: 9.

Isik M (2004). Environmental Regulation and the Spatial Structure of the US Dairy Sector. *American Journal of Agricultural Economics* 86(4): 949–962.

Key N, McBride W (2003). Production Contracts and Productivity in the US Hog Sector. *American Journal of Agricultural Economics* 85(1): 121–133.

Kliebenstein JB, Lawrence JD (1995). Contracting and Vertical Coordination in the United States Pork Industry. *American Journal of Agricultural Economics* 77: 1213–1218.

Levinson A, Forthcoming, Pollution Haven Hypothesis, *New Palgrave Dictionary of Economics*.

Martin LL, Zering KD (1997). Relationships between Industrialized Agriculture and Environmental Consequences: The Case of Vertical Coordination in Broilers and Hogs. *Journal of Agricultural and Applied Economics* 29(1): 45–56.

McBride WD, Key N (2003). *Economic and Structural Relationships in US Hog Production*. Agricultural Economic Report No. 818, Resource Economics Division, Economic Research Service, US Department of Agriculture.

Metcalf M (2000a). *Environmental Regulation and Implications for the US Hog and Pork Industries*. PhD Thesis, North Carolina State University.

Metcalfe M (2000b). State Legislation Regulating Animal Manure Management. *Review of Agricultural Economics* 22: 519–532.

Mo Y, Abdalla CW (1998). *Analysis of Swine Industry Expansion in the US: The Effect of Environmental Regulation*. Department of Agricultural Economics and Rural Sociology, Pennslyvania State University.

NACPTF (1998). National Survey of Animal Confinement Policies. National Animal Confinement Policy Task Force, Washington, DC.

Park D, Seidl A, Davies S (2002). Environmental Policy and Industry Location: The Case of the US Livestock Industry. *Review of Regional Studies,* 32(2): 293–307.

Porter ME, van der Linde C (1995). Toward a New Conception of the Environment-Competitiveness Relationship. *Journal of Economic Perspectives* 9(4): 97–118.

Rhodes VJ (1995). The Industrialization of Hog Production. *Review of Agricultural Economics* 17: 107–118.

Sullivan J, Vasavada U, Smith M (2000). *Environmental Regulation and Location of Hog Production. In: Agricultural Outlook*.

USBEA (2007). Farm Income and Expenses.

USDA-NASS (2008). Agricultural Statistics Data Base.

USDA (1992). 1992 Census of Agriculture.

USDA (2002). 2002 Census of Agriculture.

Weersink A and Eveland C (2006). The Siting of Livestock Facilities and Environmental Regulations. *Canadian Journal of Agricultural Economics* 54(1): 159–173.

Endnotes

[1] CAFOs have been regulated since 1974 under the Clean Water Act. Although CAFO regulations were strengthened in 2003, these regulations do not require control of potential air emissions from CAFOs.

[2] For example, the state of Iowa prohibits the use of spray irrigation techniques and also requires an extensive waste management plan to be submitted for state approval before the operation may begin production (Metcalfe, 2000). With respect to air quality and the need to protect people, property, and natural areas from swine manure odors, some states (for example, Iowa and North Carolina) have turned to "separation" or "setback" provisions (Fleming, 1999).

[3] The (economic) hog cycle refers to the peaks and troughs in hog inventories over time, while the biological hog cycle refers to the biological time lags involved in hog production.

[4] Nonetheless, there may be some overlap in enterprise type; for example, farrow-to-finish operators may sell or buy feeder pigs if their feed production is smaller or larger than their own production needs.

[5] In the 1980s, the industry began to change, and nontraditional hog states became important producers of pigs. North Carolina went from the bottom of the list of hog producers to second behind Iowa. In addition to changes in the transportation sector, changes in technology, disease control, concentration on genetics, and improved control of feed rations contributed to the ability of nontraditional hog states to compete.

[6] The Consumer Expenditure Survey (CE) collected for the Bureau of Labor Statistics by the Census Bureau provides information on the buying habits of American consumers, including data on their expenditures, income, and consumer unit (families and single consumers) characteristics.

[7] All definitions of these approaches can be found at http://www.ers.usda.gov/Data/CostsAndReturns/methods.htm.

[8] A unit of weight measurement created by US merchants in the late 1800s. A hundredweight is equal to exactly 100 pounds.

[9] Fixed Costs: Costs that will occur regardless of the level of production each year. They generally include such things as depreciation, repairs, taxes, and insurance on facilities, breeding livestock, and livestock equipment and facilities. Annual depreciation and other fixed costs of ownership are assumed to be a percentage of the original value. Variable Costs: Costs that vary according to the level of production. Interest is calculated on feed and other variable costs for one-half the production period.

[10] Starmer, Witterman, and Wise (2006) created an estimate of the full cost of producing corn and soybeans and compared it to the price of the crop on local markets to find the cost-price margin. The authors then estimated the amount broiler companies save by being able to purchase feed at a price below production costs. Unlike the broiler industry, the hog industry utilizes a different feed mixture. Therefore, the expenditure saved by being able to purchase feed at a price below production cost is different from that in the broiler industry (Starmer and Wise, 2006).

[11] See Lobao (2000) and Stofferahn (2006) for a discussion and analysis of the positive and negative externalities of hog production.

[12] Since WWII, the dominant Western capitalist economic system has shifted from operating on Keynesian demand side assumptions to the neoclassical assumptions of the supply side economics that gained ascendancy in the 1980s under the influence of Thatcher in the United Kingdom and Reagan in the United States. The operation of the food system is not independent of the social context, within which it operates. Perception about costs and how they are allocated are shaped by the social context. Social policy in any one period of time reflects the current social context, including the distribution of power among the members of society. Another factor in shaping social policy is the historical context within which it operates.

As a part of the social context, the intellectual climate shapes the intellectual constructs that are available for understanding the nature of the industrialized food system. The process of raising questions about the nature of industrialized food production, in and of itself, helps push the limits of available intellectual constructs that can be used to identify and deal with the impacts of a globalized, industrialized food system by encouraging the creation and identification of additional conceptual frameworks that can be used to enrich our understanding of the taxonomy of social and economic systems.

[13] The current intellectual climate provides a three-element taxonomy for economic systems—the communist system; the socialist system; and the neoclassical capitalist economic system. On the face of it, those stark choices must be seen as caricatures that deny the complexity of the day-to-day operation of the social and economic system within which we live. In raising questions about the nature of the industrialized farm animal production system, this study challenges conventional wisdom and forces the researchers to expand the available intellectual constructs that can be brought to bear in the creation of a food production system that ultimately serves the biological, social, and economic needs of a human population that lives within an interdependent ecological system.

[14] For instance, in the case of EM (effective microorganism) technology, the application of these biological agents only in the pits have been able to lower the numbers for both ammonia and hydrogen sulfide levels to 3–5 ppm. When combined with application through a fogging system, the levels can be brought to zero. However, the EM technology is relatively expensive in terms of labor cost and EM cost. For example, a CAFO with 2,500 heads generating 550,000 gallons of manure has to apply about 20–26 gallons of EM cost, or about $1,250 per cycle. However, including the additional labor hours will cost the producers more. With the fogging system, the cost of applying EM will be higher.

[15] Tim Pringle, PE, is a civil engineer with McGill Associates, Sevierville, Tennessee. He designs municipal and industrial wastewater treatment facilities.

References (Main report)

Abeles-Allison LC (1992). Structural Changes in the Hog/Pork Subsector: Coordinating Roles of Livestock Farmer Cooperatives. Michigan State University.

Aillery M, Gollehon N, Johansson R, Kaplan J, Key N, Ribaudo M (2005). *Managing Manure to Improve Air and Water Quality*. Economic Research Service, US Department of Agriculture, p 66.

American Society of Agricultural Engineers (2003). *Swine Housing II: Proceedings of the 2nd International Symposium: October 12–15, 2003, Raleigh, North Carolina.* American Society of Agricultural Engineers: St. Joseph, Michigan.

Beghin, John and Mark Metcalfe (1998). *Environmental Regulation and Competitiveness in the Hog Industry*. ISU Economics Working Paper #NDN0011. http://www.econ.iastate.edu/research/webpapers/NDN0011.pdf.

BLS (2007). Consumer Expenditure Survey.

Broadway R, Wildasin D (1984). *Public Sector Economics*, 2nd edn. Little Brown: Boston, Massachusetts.

Brum MC, Harmon JD, Honeyman MS, Kleibenstein JB, Lonergan SM, Morrison R, Richard T (2004). Hoop Barns for Grow-Finish Swine. *Agricultural Engineers Digest* 41.

Brum, MC, Harmon JD, Honeyman MS, Kleibenstein JB, Lonergan SM, Morrison R, Richard T (2007 revised edition). Hoop Barns for Grow-Finish, *Agricultural Engineers Digest AED 41*, Ames, Iowa: Midwest Plan Service.

Coase R (1960). The Problem of Social Cost. *Journal of Law and Economics* 3: 1–23.

Davis CG, Lin B-H (2005). Factors Affecting US Pork Consumption. In: *Electronic Outlook Report from the Economic Research Service*. Economic Research Service/USDA.

Ellis S, Lawrence JD, Edwards W, Johanns AM. *Ag Decision Maker, Livestock Enterprise Budgets for Iowa*, Page 6, Iowa State University, University Extension. http://www.extension.iastate.edu/agdm/livestock/html/b1-21.html.

EPA (2003). Animal Agriculture: Concentrated Animal Feeding Operations—Livestock Operation Inspection. Assurance OoEaC, (ed).

ERS (2006). Hog. In: *Briefing Room*. United States Department of Agriculture.

Fleming RA (1999). The Economic Impact of Setback Requirements on Land Application of Manure. *Land Economics* 75: 579–591.

Grannis J, Seidle A (1998). Swine Industry Economics. *Agricultural Resource Policy Report* ARPR 98: 1–5.

Guan TY, Holley RA (2003). Pathogen Survival in Swine Manure Environments and Transmission of Human Enteric Illness—A Review. *Journal of Environmental Quality* 32: 383–392.

Herriges JA, Secchi S, Babcock BA (2003). Living with Hogs in Iowa: The Impact of Livestock Facilities on Rural Residential Property Values. Iowa State University, Department of Economics, Staff General Research Papers.

Holden PJ, Ensminger ME (2006). *Swine Science*, 7th edn. Pearson Prentice Hall: Upper Saddle River, New Jersey, p 359.

Hurt C (1994). Industrialization in the Pork Industry. *Choices: The Magazine of Food, Farm & Resource Issues* 9: 9.

Kephart KB, Greaser GL, Harper JK, Moore LH (2004). Swine Production. In: *Agricultural Alternatives*.

Key N, McBride W (2003). Production Contracts and Productivity in the US Hog Sector. *American Journal of Agricultural Economics* 85: 121–133.

Kliebenstein JB, Lawrence JD (1995). Contracting and Vertical Coordination in the United States Pork Industry. *American Journal of Agricultural Economics* 77: 1213–1218.

Lobao L, Kraybill DS (2005). The Emerging Roles of County Governments in Metropolitan and Nonmetropolitan Areas: Findings from a National Survey. *Economic Development Quarterly* 19: 245–259.

Lobao LM (2000). Industrialized Farming and Its Relationship to Community Well-Being: Report Prepared for the State of South Dakota, Office of the Attorney General. The Ohio State University: Columbus.

Lyford C, Hicks T (2001). The Environment and Pork Production: The Oklahoma Industry at a Crossroads. *Review of Agricultural Economics* 23.

McBride WD, Key N (2003). Economic and Structural Relationships in US Hog Production. (AER 818) Resource Economics Division, Economic Research Service, US Department of Agriculture. http://www.ers.usda.gov/publications/AER 818/.

Mellon MG, Benbrook C, Benbrook KL, (2001). *Hogging It: Estimates of Antimicrobial Abuse in Livestock*. Union of Concerned Scientists: Cambridge, Massachussetts.

Metcalfe M (2000). State Legislation Regulating Animal Manure Management. *Review of Agricultural Economics* 22: 519–532.

Mikesell, Robert E, Kenneth B Kephart, and Charles W Abdulla (2004). Overview of Social Issues Related to the Swine Industry. University of Illinois Extension: Illiniois SOWM (Swine Odor and Waste Management) papers. http://www.livestocktrail.uiuc.edu/sowm/paperDisplay.cfm?ContentID=6504.

NPPC (2007a). International Trade.

NPPC (2007b). Today's US Pork Industry.

Palmquist RB, Roka FM, Vukina T (1997). Hog Operations, Environmental Effects, and Residential Property Values. *Land Economics* 73: 114–124.

Pitcher P, Springer S (1997). Swine Biology Overview.

Ray DE (2004). Agricultural Policy for the Twenty-First Century and the Legacy of the Wallaces. In: *The John Pesek Colloquium on Sustainable Agriculture*. Henry A. Wallace Endowed Chair for Sustainable Agriculture: Ames, Iowa.

Rhodes VJ (1995). The Industrialization of Hog Production. *Review of Agricultural Economics* 17: 107–118.

Ribaudo M, Cattaneo A, Agapoff J (2004). Cost of Meeting Manure Nutrient Application Standards in Hog Production: The Roles of EQIP and Fertilizer Offsets. *Review of Agricultural Economics* 26: 430–444.

Roe B, Irwin EG, Sharp JS (2002). Pigs in Space: Modeling the Spatial Structure of Hog Production in Traditional and Nontraditional Production Regions. *American Journal of Agricultural Economics* 84: 259–278.

Salvador, Ricardo J (Undated). *The Septic Tank Is Getting Full.* Iowa Writers' Circle for Sustainable Agriculture: Ames, Iowa.

Starmer E, Witterman A, Wise TA (2006). Feeding the Factory Farm: Implicit Subsidies to the Broiler Chicken Industry. Global Development and Environment Institute, pp 1–54.

Stofferahn CW (2006). Industrialized Farming and Its Relationship to Community Well-Being: An Update of a 2000 Report by Linda Lobao. Report Prepared for the State of South Dakota, Office of the Attorney General. Department of Sociology, The University of North Dakota: Grand Forks, North Dakota.

Sullivan J, Vasavada U, Smith M (2000). *Environmental Regulation and Location of Hog Production. In: Agricultural Outlook.*

United States Department of Agriculture, Economic Research Service, *Agricultural Outlook Tables*, Table 17. http://www.ers.usda.gov/publications/agoutlook/aotables/ and United States Department of Agriculture, Economic Research Service, *Data Sets, Commodity Costs and Returns: US and Regional Cost and Return Data.* http://www.ers.usda.gov/data/costsandreturns/testpick.htm. Year by year imputed Subsidies were computed from the data in these two sources.

United States Department of Agriculture, Economic Research Service, Livestock Marketing Information Center, *Retail Scanner Prices for Meat*. http://www.retail-lmic.info/CD/default.asp?ERSTab=3.

United States Department of Agriculture, Economic Research Service, "Data Sets, Commodity Costs and Returns: US and Regional Cost and Return Data." http://www.ers.usda.gov/data/costsandreturns/testpick.htm.

United States Department of Labor, Bureau of Labor Statistics, *Consumer Expenditures Survey, 2005* Table 3, column 1. http://www.bls.gov/cex/2005/Standard/age.pdf.

United States Department of Agriculture, National Agricultural Statistics Service. *Quick Stats* (Agricultural Statistics Data Base). http://www.nass.usda.gov/. Rank calculations and percent of US inventory by study authors from the USDA, NASS data.

USDA (2002). 2002 Census of Agriculture.

USDA (2007). Agricultural Resource Management Survey (ARMS).

USDA (2008). Production, Supply and Distribution Online.

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PCIFAP Staff

Robert P. Martin
Executive Director

Ralph Loglisci
Communications Director

Paul Wolfe
Policy Analyst

Emily A. McVey, PhD
Science Director

Lisa Bertelson
Research Associate

The Commission gratefully acknowledges the contribution of Dr. Amira Roess during her tenure as Science Director with the Commission.

Report Authors

Harwood D. Schaffer
Research Associate II
Agricultural Policy Analysis Center
Department of Agricultural Economics
Institute of Agriculture
The University of Tennessee

Pracha Koonnathamdee
Graduate Research Assistant
Agricultural Policy Analysis Center
Department of Agricultural Economics
Institute of Agriculture
The University of Tennessee

Daryll E. Ray, PhD
Professor
Agricultural Policy Analysis Center
Department of Agricultural Economics
Institute of Agriculture
The University of Tennessee

Peer Reviewers

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Constance L. Falk, PhD
Professor
Department of Agricultural Economics
and Agricultural Business
New Mexico State University

Roman Keeney, PhD
Assistant Professor
Department of Agricultural Economics
Purdue University

Elanor Starmer
Research Assistant
Global Development and Environment Institute (GDAE)
Tufts University

Timothy A. Wise
Deputy Director
Global Development and Environment Institute (GDAE)
Tufts University

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INDUSTRIAL FARM
ANIMAL PRODUCTION