GLOBAL DEVELOPMENT AND ENVIRONMENT INSTITUTE

WORKING PAPER NO. 07-04

Living High on the Hog: Factory Farms, Federal Policy, and the Structural Transformation of Swine Production

Elanor Starmer and Timothy A. Wise

December 2007

Tufts University
Medford MA 02155, USA
http://ase.tufts.edu/gdae

Abstract

U.S. farm policy reforms in 1996 produced significant overproduction of supported crops, with prices falling to levels that were often below average farm production costs. Among the beneficiaries of the policy shift were the largest corporate purchasers of supported crops, as they saw a steady supply of low-priced inputs. Industrial livestock firms were among the most significant buyers of U.S. corn and soybeans, the main components of livestock feed. Filling an important gap in the literature, this paper estimates the savings to industrial hog operations between 1997 and 2005 from feed components priced at levels below their production costs. The savings are found to be significant. We also find that industrial hog companies benefited from weak federal regulation of environmental pollution from livestock operations. We estimate the costs to industrial hog firms of compliance with new environmental regulations regarding mitigation of surface-water contamination from excess manure concentrations. This cost is also found to be significant. We assess the implications of these findings for the continued consolidation and industrialization of the industry. We find that mid-sized diversified farms that grow their own feed may well be able to compete on cost with large-scale industrial operations if the latter pay full cost for their feed and have to pay for just one part of their externalized pollution costs.

Living High on the Hog:
Factory Farms, Federal Policy, and the Structural Transformation of Swine Production

Elanor Starmer and Timothy A. Wise[1]

Executive Summary

In the mid-1960s, a North Carolina high school teacher named Wendell Murphy decided to borrow $3,000 and open a feed mill. He soon realized something that diversified grain and livestock farmers had known for years: raising animals is a useful way to add value to relatively cheaper grain crops, particularly because livestock can be fed off the leavings after grains are harvested. Murphy had plenty of corn husks and other leftover organic matter sitting around his mill, so he built a pen, purchased a few hogs, and began to raise them (Stith, Warrick and Sill 1995). While the decision probably seemed an incidental one at the time, it was in fact revolutionary. By bringing hogs onto a feedlot rather than a farm, Murphy was pioneering a new, integrated system in which hogs are owned and raised not by farmers who feed them home-grown grains but by feed millers or meat packers who ship feed in from afar.

The structure of hog farming in the United States has changed dramatically since Murphy came on the scene. When Murphy opened his mill, 60% of all grain farmers in the United States also raised hogs. The animals not only added value to grain production but also had positive environmental benefits: they reduced the need for chemical fertilizers because rotational grazing or manure-spreading built up organic matter on the land. But between 1982 and 2002 the number of hog farms in the United States fell by 76%, while the number of hogs produced increased by 10%, to over 60 million animals (USDA/NASS 2006). By 2000, Murphy's company was the largest hog producer in the nation, owning some 6 million hogs across five states (Morris 2000). It has since been purchased by Smithfield, now the largest hog producer in the world (Hendrickson and Heffernan 2005).

The industry as a whole bears little resemblance to the diversified hog production system of old. It is an industrialized system built around what Minnesota analyst David Morris describes as, "a vision of a single farm with…tens of thousands of sows and hundreds of thousands of hogs in acres of climate-controlled buildings surrounding giant open-air manure lagoons that [hold] as much sewage as that of a large human city" (Morris 2000).

Confined animal feeding operations (CAFOs), sometimes called factory farms or industrial animal operations, are defined by the Environmental Protection Agency (EPA) as livestock operations that do not sustain their own crops or other animal feed and that

[1] Funding from the Tufts Institute of the Environment supported this research. The authors gratefully acknowledge the feedback of Professors Willie Lockeretz and Bill Moomaw on earlier drafts.

house more than 1,000 "animal units"—equivalent to 2,500 swine of 55 pounds or more (40 CFR 122.23 (b)(1)). Hog CAFOs in particular have been widely criticized in the environmental, public health, and toxics literature. Main concerns include nutrient runoff from manure, which leads to water and soil contamination; particulate matter air pollution; and overwhelming odor.

Supporters of the shift toward the CAFO model of livestock production argue that it is an inevitable result of market forces. The literature does provide evidence of some economic benefits associated with the kind of top-down, integrated meat production system of which CAFOs are a part, including better control along the supply chain and reduced transaction costs. We suggest here, however, that forces other than the invisible hand have helped drive the rapid growth in CAFOs over the last 25 years. In particular, commodity policies put in place between the mid-1970s and 1996 and lax environmental regulation of industrial livestock facilities have had the effect of reducing CAFOs' operating costs compared to those of smaller-scale, diversified operations. In this paper, we estimate those savings and their implications for CAFO competitiveness.

We begin by examining how recent changes to commodity policy have affected the price of feed, hog CAFOs' largest single variable cost. The 1996 Farm Bill, which ended an era of federal production and price controls for agricultural commodities and ushered in one in which commodity prices dropped below production costs, reduced feed costs for specialized livestock operations that buy their feed. As a result, these operations have seen lower operating costs on average than they would have if feed prices accurately reflected what the components cost to produce. We estimate these gains and find that after the passage of the 1996 Farm Bill, the average market price of hog feed was 26% lower than what the feed cost to produce. This decline brought operating costs for CAFOs down by 15%. The savings to CAFOs between 1997 and 2005 averaged $947 million per year, a 535% increase over the 1986-1996 period.

We then examine one of the many cited environmental externalities of CAFO production, estimating how much hog CAFO operating costs would increase if environmental regulations forced the operations to minimize surface-water contamination through more stringent manure management. Forcing industrial hog operations to internalize surface-water pollution costs would negatively affect operating costs for CAFOs, particularly relative to smaller-scale, diversified operations that apply manure to farmland at agronomic rates. Drawing on data provided in two academic studies that assess the cost of alternative manure-management strategies, we find that the use of alternative technologies and/or the acquisition of more land to reduce over-application of manure would raise CAFOs' operating costs by 2.4%-10.7%, depending on the strategy employed.

We conclude that in an economic climate of full-cost feed and with more stringent environmental regulation, CAFOs would see their operating costs rise by between 17.4% and 25.7%. According to USDA estimates, this could virtually eliminate the apparent cost advantage CAFOs have had over mid-sized diversified hog producers.

That new economic climate may be upon us now. The ethanol boom has sent corn and soybean prices near or above production costs, while new EPA regulations set to take effect target surface-water contamination from CAFOs. With these added costs, CAFOs may have difficulty out-competing mid-sized, diversified hog producers purely on cost. It may well be shown that CAFOs' apparent economies of scale have been less the result of efficiency than they are the result of government policies that have favored large-scale industrial animal production.

I. Background: The New Livestock Production Model

Like many players in the food and agriculture sector, livestock operations have become larger and more integrated in recent years. Agribusiness firms have taken control of all stages of the meat production process, from genetic breeding to feed-milling, to growing and processing the animals, to packaging and distributing the meat to stores across the nation and the world. Increasingly, this system is controlled by firms that contract out much of the production process to "growers" but ensure quality control by strictly regulating and monitoring the farmers with whom they hold production contracts.[2]

In the industrial model, production expenses are reduced through economies of scale, which spread fixed costs across a greater number of animal units, and through mechanization, which reduces labor costs. Animals in the industrial system are housed in massive climate-controlled "barns," often on grounds that look less like a farm than an industrial warehouse. Use of sub-therapeutic antibiotics and the maintenance of a sterile environment reduce animal loss despite confinement conditions. Strict control of breeding stock results in a proliferation of standardized animals whose feed efficiency produces the maximum amount of meat for the least cost.

Efficiency in the industrial livestock production model has been augmented by vertical integration in the industry—mergers, acquisitions, or other business relationships that tie meat production systems together from feed production through to processing and even retail distribution (see, for example, Henry and Raunikar 1960; Steedle 1986; Knoeber 1989; Bugos 1992; Aho 1999; Martinez 1999; Paul 1999; Tweeten 2001;

[2] A large body of literature addresses problems in contract agriculture, an issue that, while an important facet of modern hog production, is beyond the scope of this paper. Major concerns expressed in the literature include the erosion of spot markets when an excessive share of production value is under contract; the prevalence of production contracts and the presence of contracting firms on both the buying and selling sides of markets; risk-shifting from the integrator to the contract grower; and the inclusion of mandatory arbitration clauses or non-transparent language in production contracts. (Duffy, Ikerd, Kleibenstein et al. 1995; Hamilton 1995; Knoeber 1995; Plain 1997; Morrison 1998; Agricultural Marketing Service/USDA; Krebs 2000; Taylor 2002; Grimes 2003; Senate Agriculture Committee 2004; Constance 2005; ILSR 2006; National Campaign for Sustainable Agriculture (NCSA) 2006; WORC 2006). However, contracting is also associated with increased cost efficiency because contracts may facilitate the exchange of information or technology between integrators and growers (McBride and Key 2003).

MacDonald, Perry, Ahearn et al. 2004). Among the benefits to firms of a vertically integrated, industrialized system are reduced transaction costs; greater control of supply, quality, and price differentiation along the production chain; reduced volatility of spot markets; easier dissemination of new technology; and the perception of reduced risk by both the firm and the individual producers involved because of contract arrangements (Key 2005).

While the companion trends of industrialization and vertical integration have quickened pace in the last twenty years, they are by no means new phenomena. Indeed, both were present in the broiler chicken industry as early as the 1930s, as detailed in Constance (2002) and Starmer, Witteman and Wise (2006). The advent of industrialization, which reduced labor costs and increased feed efficiency, and vertical integration, which facilitated transactions between production stages and allowed for greater quality and supply control, were seen by many as a boon for the broiler companies involved. The industry saw its average feed efficiency double between 1945 and 1970, while labor productivity rose an annual average of 10.5% over the same period. Overall production costs dropped by nearly 90% between 1947 and 1999 (Aho 1999; MacDonald, Perry, Ahearn et al. 2004).

Pork and beef firms have followed the poultry example in recent years. The hog sub-sector in particular demonstrates high levels of vertical integration and industrialization. According to the USDA's Economic Research Service, the share of the U.S. hog inventory housed in facilities with 2,000 or more animals increased from 37% in 1994 to nearly 75% by 2002; in 2001, slightly more than half of the hog inventory was housed in facilities with 5,000 head or more, compared with about a third of the inventory in 1996 (McBride and Key 2003).[3]

However, evidence suggests that the economies of scale that favored industrialized poultry operations may not offer as many gains in the hog sector. In an analysis of USDA ARMS survey data from 1998, McBride and Key find that economies of scale are most evident between small (1-499 head) and medium (500-1,999 head) operations, leveling off as operations grow beyond 2,000 head. They find very little difference in production cost between large (2,000-4,999 head) and industrial (5,000 + head) operations. The authors also find that managerial ability "is probably as important as size economies in lowering the costs of hog production." They state, "There is substantial variation in production costs that cannot be attributed to size of operation. The distribution of costs by size of operation indicates that, despite higher average costs among small- and medium-sized operations, many of these operations can produce hogs at a cost that is competitive with larger operations" (McBride and Key 2003 p. iv).

[3] Notably, as the size of individual hog production facilities has grown, the market power of the top integrated hog firms has increased as well. According to Hendrickson and Heffernan (2005), four hog companies control nearly 50% of all hog production in the United States, and four control 64% of pork packing. Analysts note that concentration at these levels may affect smaller producers' access to markets, result in price discrimination, or raise prices for consumers (McBride and Key 2003; USDA/ERS 2003; Senate Agriculture Committee 2004).

Another notable difference between the broiler and hog sectors is the number of smaller hog operations still producing in the United States. The USDA reports that nearly all of the broilers produced in the United States are now done so under production contracts with vertically integrated firms using the industrial model of production (Hamilton 1995; Martinez 2002). However, more than 25% of hogs are still produced on operations with fewer than 2,000 head, and these small and mid-sized operations produced the majority of hogs as late as 1996 (McBride and Key 2003).

Thus, while it is clear that the industrial model offers efficiencies not available to very small hog operations, the benefits of industrial production over well-managed mid-sized diversified operations, which can make use of their own economies of scale, are less clear. Also demanding further inquiry is the issue of the costs that industrial hog facilities may externalize to rural communities, the environment, or public services.

As we demonstrate below, recent farm and environmental policies have tended to favor industrialized hog operations by reducing their costs relative to smaller diversified hog farms. In doing so, they have contributed to the separation of crop and livestock production and facilitated, if not encouraged, polluting practices such as the over-application of manure to land.

II. Commodity Policy, Low-cost Feed, and Hog Production

When the 1996 Farm Bill was passed, supporters and critics alike termed it the most significant shift in U.S. agricultural policy since the 1930s. The elimination of supply-control and price-stabilization programs put in place during the Depression—including land set-asides and grain reserves—brought acreage back into production, as did the introduction of greater planting flexibility. The 1996 bill also eliminated remaining price supports (Ray, De La Torre Ugarte and Tiller 2003). As discussed at length in Starmer, Witteman and Wise (2006), these policy changes provoked several important economic shifts in the period following the 1996 bill: declining commodity prices, increased production levels, rising input costs, and stagnant or declining net farm income.[4]

At the time the 1996 Farm Bill was authorized, market prices for most agricultural commodities were on an upswing due to increased domestic and export demand, fueling the calls for the federal government to get out of the supply-management business and allow U.S. farmers to freely compete with foreign producers (Abel and Earley 1994). Supporters of the reforms hoped that the new approach would allow producers to capture greater shares of the world market and would raise farm incomes. But the opposite proved to be true. Helped along by yield-increasing technology, the new policies ushered in a 28% rise in corn production and a 42% rise in soybean production between 1997 and

[4] The high corn prices seen in late 2006 and 2007 are an exception to this statement, to the extent that the $0.51/gallon federal subsidy to ethanol blenders encouraged investment in ethanol production and drove corn prices higher.

2005. In the same period, corn market prices dropped 32% while soybean prices dropped 21% (USDA/ERS 2005).[5] Average net farm income in the United States declined by an inflation-adjusted average of 15.5% between 1996 and 2005 (USDA/ERS 2005, and authors' calculations).

Congress addressed the resulting farm income crisis not through the reinstitution of production or price controls but through a series of emergency subsidies paid to farmers. These began in 1998 and were made more or less permanent in the 2002 Farm Bill. In the years since, 2007 notwithstanding, market prices for basic commodities such as corn and soybeans have often been lower than their costs of production and government spending on farm subsidies has soared.

Current farm policy is working for very few of its stakeholders. Despite record subsidy levels, farm income declined after the 1996 Farm Bill. Family farmers continue to exit the farm sector while the majority of remaining households supplement farm sales with income from off-farm jobs (USDA 2005). Abroad, chronically low world prices have driven many foreign farmers off their land (Watkins and Von Braun 2002; Oxfam 2003; Ritchie and Murphy 2003; Jones, El-Osta and Green 2006).

There is no shortage of proposals for how to fix the broken system. Some of the most vocal critics of U.S. farm policy claim that the draw of subsidies has driven farmers overproduce, leading to declining market prices for commodities (Oxfam 2003; Beattie 2005; Council of Economic Advisors 2006). This camp sees subsidies as the defining imperfection in U.S. agriculture policy and advocates their removal in order to restore a freer and fairer market in agriculture.

Others, including some academics and family-farm advocacy groups, point out that while subsidies have been a component of U.S. farm policy since the early 20th century, the hefty payments we see today were put into place only after prices fell and production soared in the late 1990s. Their analysis suggests that the price decline was due less to the institution of subsidies than to the replacement of production and price controls with a system that encourages production instead of limiting it, allows market prices to fall below production costs, and attempts to make up the shortfall with larger subsidy payments. They highlight deeper structural imperfections in agriculture that impede these markets from functioning correctly in the absence of government intervention. Individual farmers tend to produce more, not less, when prices fall, leading to a glut on the aggregate. Backed by recent modeling from the University of Tennessee (Ray, De La Torre Ugarte and Tiller 2003) and IFPRI (2003), they maintain that simply eliminating subsidies will not raise commodity prices markedly. Other policy instruments are needed to keep production in check and ensure fair returns to farmers (Ray, De La Torre Ugarte and Tiller 2003; National Family Farm Coalition 2007).

[5] We do not mean to suggest that farm policy reform was the sole factor behind price declines after 1996. Other factors, including the Asian financial crisis, clearly played a role. However, on balance, farm policy changes have been shown to have had a significant effect on commodity prices. See footnote 10 in Starmer, Witteman and Wise (2006).

Finally, many U.S. agribusiness groups and some domestic farm advocates have called for the maintenance of the status quo, arguing that subsidies are a necessary expense if the U.S. government hopes to maintain a vibrant farm sector despite low commodity prices (American Farm Bureau Federation 2006).

The debate over the price effect of subsidies has divided the farm advocacy community. It has also moved the focus off the major changes to farm policy that took place with the passage of the 1996 Farm Bill—among them, the elimination of remaining production and price control programs—and the impact of these changes on the agricultural supply chain, prices, and subsidy levels. Additionally, while there is a clear understanding in the literature of the groups that have been hurt by the recent policy changes, an extensive review of research dating back to 1960 presented in Starmer, Witteman and Wise (2006) found little research documenting the beneficiaries of today's policies. Filling this gap in the literature can contribute to clarity in agricultural policymaking.

This paper suggests that one of the major beneficiaries from recent changes to U.S. farm policy has been the industrialized livestock sector generally, and industrial hog operations in particular. Among some of the largest buyers of U.S. corn and soybeans, industrial hog operations spend some 60% of total operating costs on feed made largely of these two components (McBride and Key 2003). Below, we estimate the savings to the industry, in percentage and dollar terms, from feed produced from components that were available on the market at prices below their production costs. We are effectively comparing the industry's actual feed prices to what they would have been in a hypothetical environment in which market prices accurately reflected the costs of production. Following this analysis, we will turn to the question of environmental policy and pollution externalities. The implications of our findings are discussed in the final section of the paper.

Methodology and Data: Feed Prices and CAFO Production

In this paper, we focus on the hog sector, looking specifically at industrial hog operations that do not grow their own feed. Operations utilizing the kinds of production methods described as "industrial" above are often referred to as CAFOs, a term utilized by the EPA but not the USDA. In the USDA data, the closest proxy for the EPA definition of a CAFO is to consider the two largest USDA size categories: 2,000-4,999 head and 5,000 head and up. We will lump these two categories together for the purpose of this study and refer to the group as "industrial." The term CAFO will at times be used as a proxy.

Using the methodology in Starmer, Witteman and Wise (2006) and modifying the calculation to account for differences in the composition of broiler and hog feed,[6] we

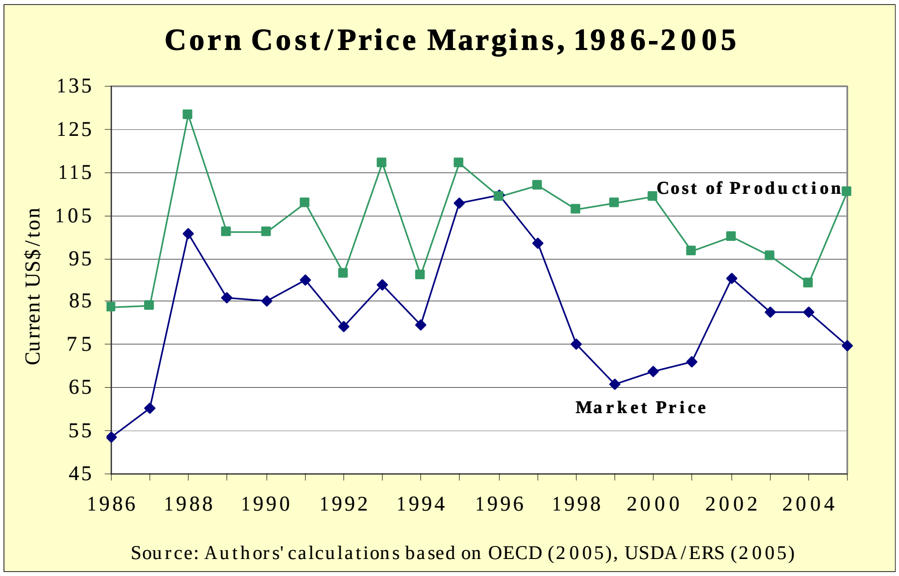
[6] Averaged across the life cycle, hog feed is a mixture of about 80% corn, 17% soybean meal, and 3% additional ingredients, generally including bone meal or protein supplements, vitamins, and minerals. Broiler feed, in contrast, is 60% corn and 25% soybean meal (Harvey 2006, personal communication).

calculate the discount that industrial hog operations gained from their ability to purchase below-cost corn and soybeans on the market. We then compare industrial hog farms' production costs without the feed discount with production costs for mid-sized hog operations that have not received such savings because they grow most of their own feed.[7]

Findings

The difference between the market price and the production cost of corn, which we term the cost/price margin, averaged 17% from 1986-96 and 21% from 1997-2005. The margin for soybeans averaged 5% in the first period and 15% in the second (see Figures 1 and 2). Starmer, Witteman and Wise found the latter change to be statistically significant.[8]

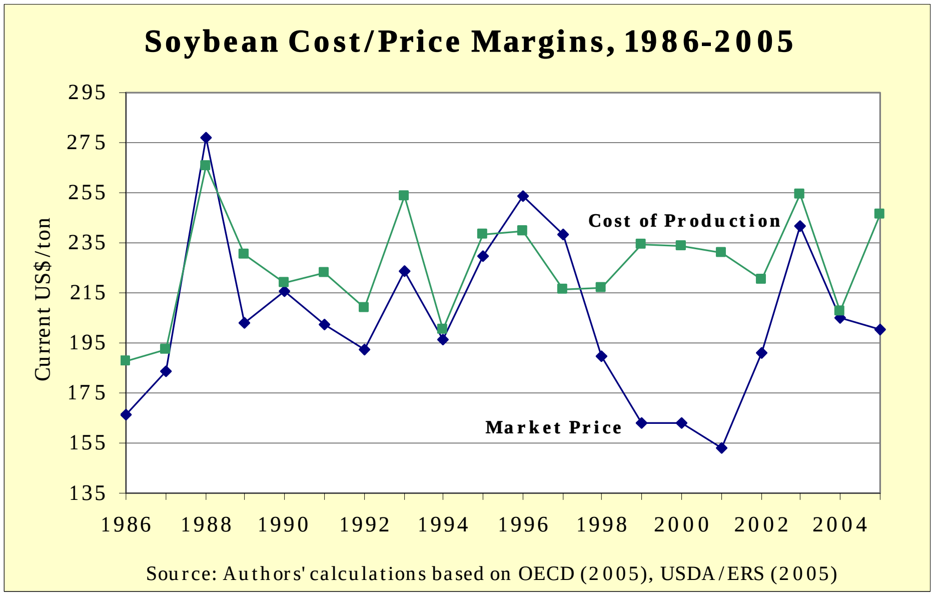
Figure 1: Corn Cost/Price Margins



[7] Small and mid-sized operations are far more diverse than industrial operations. According to ARMS survey data, hogs' share of total farm production value for small and medium operations is only 7 and 34 percent respectively. In contrast, large and industrial operations glean, respectively, 62% and 80% of farm production value from the sale of hogs. (McBride and Key 2003). These data suggest that large and industrial operations tend to raise hogs almost exclusively, while smaller operations will raise and sell crops and/or other livestock along with hogs. This conclusion is echoed in other research (see, for example, Boessen, Lawrence and Grimes 2004).

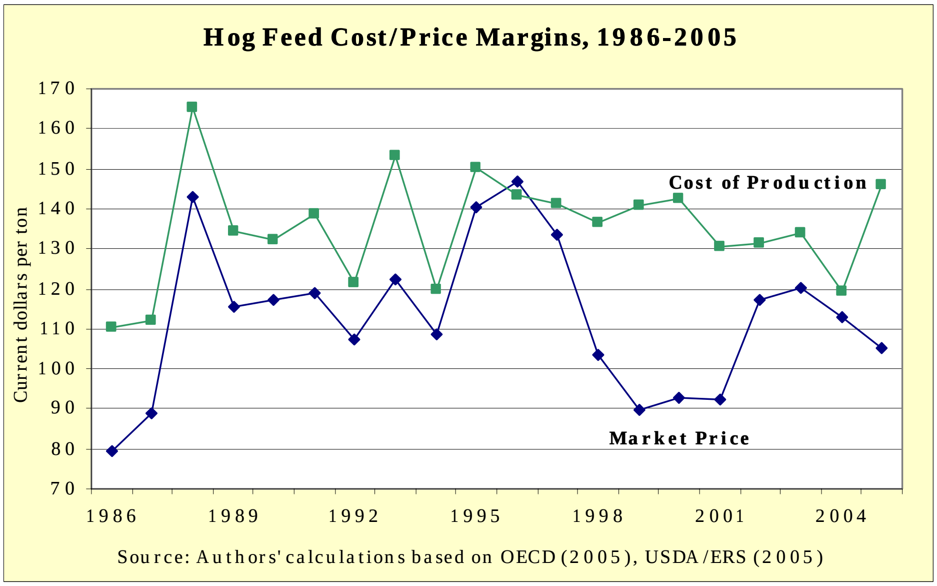
[8] Starmer, Witteman and Wise (2006) ran T-tests comparing cost-price margin data pre- and post-Farm Bill (1986-1996 and 1997-2005). They confirmed a statistically significant difference between the two periods for the soybean margins (t-stat = -2.06, p<.05) but not for corn (t-stat = -1.11, p = .1). The legitimacy of any t-test in this case is questionable given the small sample size.

Figure 2: Soybean Cost/Price Margins



Corn and soybeans account for more than 95% of the contents of commercial hog feed. As a result of their ability to purchase corn and soybeans on the market at a price below cost of production, industrial hog operations received, in effect, a discount on their feed from below-cost corn and soybeans. We estimate this discount to be 10% in the earlier period and 26% in the post-reform period, as illustrated in Figure 3.

Figure 3: Hog Feed Cost/Price Margins

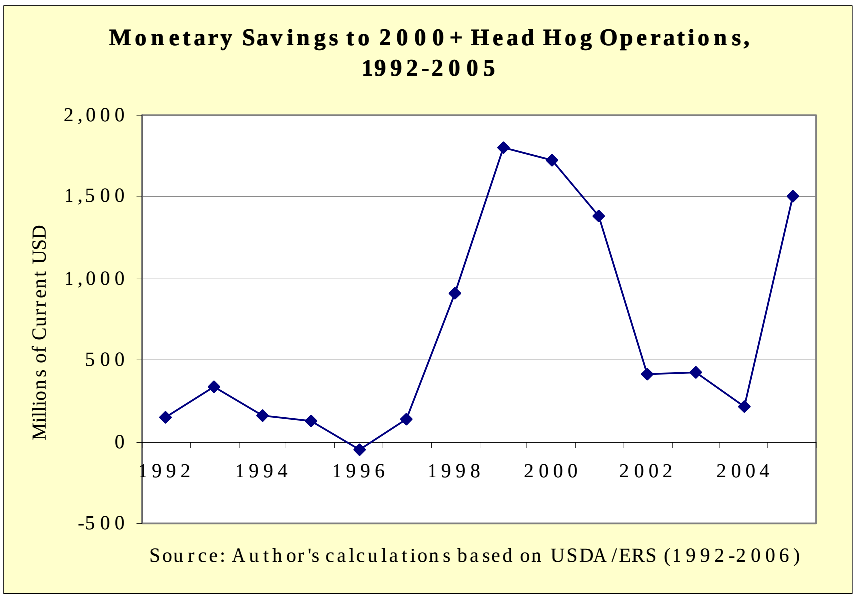


With feed costs representing 60% of operating costs, the 26% feed discount that the operations received on average between 1997 and 2005 translates into a 15%

reduction in firms' operating costs, worth an estimated $945 million per year over the nine-year period. By comparison, cost savings between 1986 and 1996 reduced operating costs by 6%.

Notably, USDA production and expense data for the largest hog operations are not available before 1992. Prior to that year, the largest size category for which the USDA collected data was 1,999 hogs; 2,000+ head operations were included beginning in 1992, while 5,000+ head operations were not included in the data until 1996 (McBride and Key 2003). This fact alone illustrates the rapid and recent growth of large hog operations in the United States. We can therefore only estimate the cost savings to industrial operations for the periods 1992-6 and 1997-2005. Figure 4 illustrates this cost savings. Again, the savings here represent the difference between what industrial hog producers paid for feed and what they would have paid if the market price of feed equaled its cost of production.

Figure 4: Monetary Savings to 2000+ Head Hog Operations



As shown here, savings are low when corn and soybean prices rise, as happened in 1996 and again in 2002-2004 because of supply shocks from drought, pests, and global demand fluctuations. For the period after the 1996 Farm Bill, however, the average market price for both corn and soybeans was quite low compared to the previous ten-year period, so the average cost savings from purchasing feed on the market rather than growing it on site was quite high. Between 1992 and 1996, cost savings averaged $149 million per year. In the post-1996 Farm Bill period, savings averaged $945.3 million per year.

These estimates suggest that industrial hog operations gained considerably from policy changes in 1996 that fed overproduction and provoked lower feed-market prices. Indeed, average savings to the largest hog operations after 1996 exceeded average savings in the 1992-96 period by 535%.

These savings are not theoretical; they are real gains that accrued to a real group of companies with a membership that has been declining steadily as the livestock industry consolidates. Using basic market-share data, Wise and Starmer (2007) calculate the savings to the top four pork companies, which together controlled some 50% of the market in 2003:

Table 1.

Total Savings from Low Feed Prices, 1997-2005
Top Four Hog-Producing Companies

Company	Market Share*	Total Savings 97-'05**	Annual Savings 97-'05***
Smithfield	30%	$2.54 billion	$284 million
Premium Standard	8%	$680 million	$76 million
Seaboard Corp.	7.5%	$638 million	$71 million
Prestage	5%	$426 million	$47 million

*Constant 2003 market share
**Savings is equal to the difference between the market price of hog feed and feed priced at the full cost of production. Production costs based on USDA/ERS estimates of total economic costs of production for corn and soybean meal, the main components of hog feed. Between 1997 and 2005, hog feed was sold on the open market at an average of 26% below cost of production.
***Average annual savings over the 9-year period. Actual savings varied from year to year

Source: Starmer and Wise (2006), based on data from USDA/ERS 1996-2005

A Note on the Data: Land Values

The method for calculating the full cost of producing corn and soybeans has its limitations. As discussed at greater length in Starmer, Witteman and Wise (2006), existing literature raises concerns about the USDA estimates of agricultural land values in the United States (Weersink, Turvey, Clark et al. 1999; Ryan, Barnard and Collender 2001; Gardner 2002; Shaik, Helmers and Atwood 2005). While land values represent real costs to farmers—payments on mortgages, rental fees, taxes, and insurance—they are inflated by government payments. Starmer, Witteman and Wise (2006) adjust for the overvaluation of land due to subsidy payments by deflating the contribution of land values to operating costs by 20%, based on estimates in the literature. This reduces the cost-price margin for corn by an average of four percentage points between 1997 and 2005, from 23% to 19%. For soybeans, the margin shrinks by about six percentage points, from 15% to 9%.

Extrapolating these findings to industrial hog operations, we find that the adjustment shrinks the discount on feed costs by nine percentage points between 1997 and 2005, to 17%, and the discount on total operating costs by five percentage points, to

10%. The operations' monetary savings are reduced under this calculation adjustment by an average of $314 million annually, or 33%, to $632 million per year on average between 1997 and 2005.

With these adjustments, cost-price margins for corn and soybeans and industry savings are smaller, but certainly not inconsequential. The findings suggest that even if land values were deflated by policies that eliminated federal farm payments, production costs would still exceed market prices for corn and soybeans for most years, except those in which supply was particularly constrained.

Feeding the Factory Farm

The significance of these findings is clear. To the extent that federal farm policy has reduced the market prices for the main components of hog feed, it has reduced costs for operations that buy feed—specialized, industrialized operations. We calculate the cost savings to industrial operations at an average of $947 million per year between 1997 and 2005, or a total of $8.52 billion over the nine-year period. This discount was not available to smaller operations that grew their own feed. The availability of low-priced hog feed on the market may have contributed to a structural transformation in hog production, encouraging the growth of industrial operations by giving them a cost advantage over diversified competitors. These cost advantages may have had less to do with efficiency gains accruing to larger operations than with U.S. government policies that reduced corn and soybean prices below production costs.

Below, we consider a second way in which federal policy may have facilitated the growth of CAFOs: through lax environmental regulations that allow for the externalization of pollution costs. The discussion section will examine changing market and regulatory conditions affecting commodities and the environment and will consider the extent to which efficient diversified hog farmers may be able to better compete with CAFOs going forward.

III. The Externalized Costs of CAFO Pollution

In every way—within the barns and within the communities and regions where hogs are raised for meat—animal production in the United States has become more concentrated. In two North Carolina counties alone, the number of hogs raised has increased by 2 million since 1990. In these two counties, there were by 1997 an average of 2,185 hogs per square mile (Hubbell 1998). Between 1992 and 1997, three counties in northern Iowa experienced a nearly three-fold increase in the number of hogs—from 600,000 to over 1.6 million. The animals were concentrated on fewer and bigger farms, as the number of farms raising hogs in that region declined by almost 40% (Jackson, Keeney and Gilbert 2000).

Industrial livestock production concentrates more than just animals. It concentrates the environmental and health effects that emerge when a large number of animals are raised in a small area. Traditionally, nutrients taken in by animals in the form of feed have returned to the land in the form of manure fertilizer. But research suggests that CAFOs concentrate manure production on land areas that are too small to allow for agronomically acceptable manure application. As a result, manure must be stored in tank or lagoon systems, transported to neighboring land for application, or applied to surrounding CAFO land at rates that risk overloading the soil with nutrients. While there are many documented effects of poor manure management on CAFOs, [9] we focus here only on one category of problems, those associated with surface water pollution.

Research suggests that excess nutrients and surface water runoff are problems for many CAFOs. Ribaudo, Gollehon, Aillery et al. (2003) found that in 1997, farms with livestock controlled 73 million acres of cropland and permanent pasture. Based on the amount of manure that could be recovered from the operations and used as fertilizer, the authors estimated that land could assimilate only 40% of the available nitrogen (N) and 30% of the available phosphorus (P) in the manure. Large CAFOs, which made up only 2% of all livestock operations, were responsible for fully half of the nutrient excess. In areas where N or P levels are in excess of assimilative soil capacity, and in areas where manure application standards are weak or poorly enforced, humans and the environment may be at risk from the effects of nutrient loading and the presence of microbes such as E. Coli, antibiotic-resistant bacteria, and/or heavy metals in the soil or water (Cole 2000; Murray et al. 2003; Ribaudo, Gollehon and Aillery 2003; Osterberg 2004; Wallinga 2004).

Water contamination from hog and other industrial livestock facilities comes largely from two sources: excessive application of manure to land and leaching from waste storage systems. Lagoons, the most common method of manure storage, have a history of breaks and leaks that release liquid manure—sometimes millions of gallons at a time—into soil or surface water (Krider 1987; Huffman 1991; Westerman 1995; Cole 2000). One study found that over half of Iowa's 5,600 manure storage structures leaked at rates above legal limits (Osterberg 2004). Studies also suggest that CAFOs sometimes utilize legal loopholes or take advantage of lax enforcement to over-apply manure to available land (Jackson, Keeney and Gilbert 2000; Williams 2006).

These costs are environmental externalities from industrialized hog production. The costs – to human health, the environment, and quality of life – are not paid by the producers. Here we estimate the costs of one such externality by estimating the costs of mitigating CAFO surface-water pollution. We then can evaluate these costs as an additional benefit to industrialized hog operations compared to diversified farms that are managing their hog manure in agronomically efficient ways.

[9] The body of literature on air pollution, odor, and worker health effects from CAFOs is extensive; see, for example, (Donham 1990; Zuskin 1991; Zejda and Hurst 1993; Choudat 1994; Cole 2000; Wing and Wolf 2000; Legator 2001; Wallinga 2004).

Regulating CAFO Pollution

One way in which industries can be compelled to internalize some of the costs of their polluting activities is through government regulation. In the case of CAFOs, regulation can have important health and environmental effects as well as an impact on social equity. Pollution is often concentrated in vulnerable communities with little power to compel legislative change; Halverson (2000) notes that of the 15 top hog-producing counties in North Carolina, 14 rank in the bottom 50% of North Carolina's state family income ranking, and 13 have a 25% or higher African-American poverty rate.

By many accounts, the government has failed to fulfill its role with respect to CAFO pollution. The basic tenets of federal CAFO regulations were contained in a 1972 amendment to the Clean Water Act (CWA); the emphasis of the legislation was the protection of surface waters, not air or groundwater quality or soil health (Safley 2003). Pressure from community, environmental, and labor organizations succeeded in convincing Congress and the EPA to update the regulations governing CAFOs, and changes to the CWA were promulgated in 2003. CAFOs are now required to create a Comprehensive Nutrient Management Plan (CNMP), which must meet certain federal standards and must contain plans for storing and disposing of manure. Government funds through the Environmental Quality Incentives Program (EQIP) for improvement of manure management and disposal infrastructure at the facility are only available to operations that have created a CNMP (National Agricultural Law Center 2005).

As part of the CNMP, CAFO operators must detail plans for proper land application of manure and meet certain effluent limitation guidelines. The plan must ensure minimal N and P runoff by detailing application rates, application methods, and the potential for runoff from the site. CAFO operators are required to document manure application and retain the documents to allow for EPA oversight (40 CFR 122.23).

Critics of the 2003 reforms argue that the new regulations leave many important gaps unfilled. Like the 1972 law, the new regulations do not focus on groundwater or air pollution. EPA may lack the money or staff needed to properly enforce the regulations. And after environmental groups won a 2005 lawsuit to strengthen the CNMP provisions, the EPA extended the deadline for operators to submit CNMPs until 2007 (EPA 2005). This action delayed the benefits of more stringent regulation.

Notably, there is evidence to suggest that regulations, if strictly enforced, can significantly reduce pollution levels. Keplinger and Hauck (2006) and Innes (2000) find that when the government cannot regulate manure application rates, producers will apply manure to land at levels that exceed agronomic health, leading to increased runoff from croplands. Innes suggests that the government regulate livestock facility size and entry in addition to regulating manure application, since environmental costs tend to fall as animal production becomes more dispersed.

Estimating the Cost of Internalizing Manure Pollution

If weak or laxly enforced federal regulations allow CAFOs to externalize many of the pollution costs associated with their production, then communities and the public sector are indirectly subsidizing CAFOs by paying to clean up CAFO pollution and/or shouldering the costs of human health impacts. New, more stringent regulations could presumably eliminate that indirect subsidy, at least as it applies to surface-water pollution. How much has lax regulation been worth to CAFOs, and how might their operating costs be affected in a new regulatory environment?

Two studies examine the extra cost to industrial hog operations of improved manure management. Cochran, Rudek and Whittle (2000) estimate the cost of implementing various technology-based strategies for controlling hog manure in North Carolina. The strategies were chosen by North Carolina State University researchers following a 1999 proposal by Governor Jim Hunt to replace lagoons with more effective waste-management systems within ten years. The strategies offered would be used to modify or replace open-air lagoons to reduce nutrient escape and water contamination. The researchers estimate the cost of the traditional lagoon/sprayfield system used by most North Carolina producers to be $3.72 per finished hog. Cochran et al. estimate that the use of new technologies would add an additional $2.39 to $5.21 per finished hog to the cost of production for North Carolina CAFOs, depending on the type of technology employed. The cost of each technology is detailed in Table 1.

While the Cochran et al. study focused only on North Carolina CAFOs, research suggests that these alternative manure management strategies would be applicable to CAFOs elsewhere. McBride and Key (2003) provide data on the types of manure management technologies currently used by CAFOs in different USDA resource regions. Sixty-six percent of Heartland (Midwest) CAFOs use lagoons, while 34% use pits or tanks. The ability to add on alternative technologies to existing pit or tank systems is not addressed in the Cochran study, but the 66% of Heartland CAFOs using lagoon and sprayfield systems would likely see costs similar to those outlined above. In the Southern Seaboard, which includes North Carolina, almost 100% of CAFOs use lagoons. Only 1% move manure off the operation, implying that the others either store it or spread it on their own land (McBride and Key 2003).

The second study, conducted by Ribaudo, Cattaneo and Agapoff (2004), assesses the cost to large CAFOs of compliance with agronomic N and P standards for manure application. As noted earlier, the new regulations contain specific instructions regarding land application of manure. Large CAFOs must meet effluent limitation guidelines that specify a reduction in surface water N and P runoff. The authors estimate the cost to large hog CAFOs in four different areas of the country—Mid-Atlantic, South, West, and Midwest—of meeting the new standards.

They find that 82% of large hog operations in the United States do not have enough land to meet the N standard, and 96% do not have enough land to meet the P standard. They then compare the net cost of meeting N and P application standards—

taking account of the cost of meeting the standards and the value of the fertilizer offset—to the total baseline production costs for various sized operations. The authors assume that most CAFOs would be forced to transport manure off the operation to cropland in the region. Compliance with the N standard would increase operating costs for large CAFOs in the mid-Atlantic, South, and West by between 2 and 3%. Due largely to their proximity to cropland, most large CAFOs in the Midwest were found to be meeting the N standard already. Meeting the P standard, which requires more land, would raise operating costs for CAFOs in the mid-Atlantic, South and West by between 4% and 5.5%. In the Midwest, it increases CAFO costs by 1%.

Cost Estimates for Alternative Management Strategies

In its new regulations, the EPA did not lay out the specific steps producers must take to meet the new standards, but relied instead on more general best practices guidelines. Given the flexibility available to producers, it is reasonable to assume that if current regulations are enforced, they might choose to utilize either alternative technologies such as those outlined in Cochran et al., or meet N and P standards by increasing the amount of land to which they apply manure, as in the Ribaudo et al. model. How would the adoption of these new manure management strategies affect CAFO operating costs?

To answer this question, we use an estimate of average operating costs for 2,000 + head hog operations of $39.87/cwt (authors' calculations based on McBride and Key 2003) and simply add the additional costs calculated by Cochran et al. and Ribaudo et al. to this number. The resulting estimates provide a range of new costs per cwt depending on the type of strategy employed. It is reasonable to assume that some operations may choose or be forced to adopt both technological and land-acquisition solutions in order to meet new standards. Therefore, we have also provided a range for new operating costs based on the adoption of more than one strategy.

Existing literature suggests that operators will have a more difficult time meeting the P standard than the N standard because it requires a greater amount of land. Since meeting both standards is required by the EPA but costs will be driven by the more rigorous P standard, we will refer only to the P standard here.

If CAFOs adopted one or more of the strategies proposed by Cochran et al. or Ribaudo et al., the operating costs to the firm would increase by at least 2.4% and as much as 10.7%. The lower bound represents the additional cost to the firm of building an ambient digester, the least expensive alternative technology, onto an already existing lagoon. The upper bound represents the cost of constructing an upflow biofiltration system, the most expensive of the alternative technologies proposed, and also expanding available land for manure application in order to meet the P standard.

It is worth reiterating that the employment of alternative manure-management strategies to meet surface-water regulations would help address groundwater contamination and may also have the added effect of reducing air pollution or odor depending on the kind of strategy employed. However, policies that forced CAFOs to internalize the other costs that they currently shift to outside parties would most likely affect CAFO operating costs to a greater extent than calculated here. In other words, the increase in operating costs presented here does not represent the full financial impact of regulations that adequately protected workers, community members, and the environment from CAFO pollution. Cost estimates for the different strategies are presented in Table 2.

Table 2

Costs to Hog CAFOs from the Adoption of Improved Waste Management Technology

Technology Adopted	Added Cost/Cwt.	Cost of Production/Cwt.	% Change in Operating Costs
Baseline- none	---	$39.87	---
Technological Alternatives:			
Ambient Digester	$0.96	$40.83	2.4%
Solids Ecoreactor	$1.15	$41.02	2.9%
Complete mix digester	$1.20	$41.07	3.0%
Upflow biofiltration system	$2.08	$41.95	5.2%
Meeting P standard	$1.59-$2.19	$41.46-42.06	4%-5.6%
Tech. alt. + P standard	$2.55-$4.27	$42.42-$44.14	6.4%-10.7%

Sources: Authors' calculations based on Cochran et al. (2000), McBride and Key (2003), and Ribaudo et al. (2004).

IV. Recalculating CAFO Competitiveness

We have determined that industrial hog operations received a discount from low-priced feed that averaged 15% of operating costs over the period 1997-2005. The data discussed above suggest that lax environmental regulations have offset anywhere from 2.4% to 10.7% of operating costs. Taken together, the current policy environment has reduced CAFO operating costs by a total of between 17.4% and 25.7%, as illustrated in Table 3.

Table 3

Costs to Hog CAFOs of Full-Cost Feed and Environmental Compliance

	Cost/cwt.	% increase
Current CAFO cost of production	$39.87	---
Full-cost feed	$5.98	15%
Environmental compliance (surface water)	$0.96 - $4.26	2% - 11%
Adjusted cost of production	$46.81 - $50.11	17% - 26%

Source: Authors' calculations based on Cochran et al. (2000) and Ribaudo et al. (2004).

These figures suggest that hog CAFOs have received a significant discount on their production costs over the last decade. This discount is a direct result of the structure of federal commodity and environmental policies that have favored a certain kind of hog operation—specialized, industrialized firms that depend on cheap commercial feed and generate large quantities of waste. Those same policies have, in turn, discouraged smaller scale, diversified hog farms that grow their own feed and apply manure at agronomic rates to farmland.

Our findings suggest that without these discounts, hog CAFOs may struggle to be cost-competitive with mid-sized, diversified operations. Experts in the field agree that it is difficult to make generalizations about cost efficiency based on operation size. Management differences seem to account for the bulk of the discrepancy between average operating costs for medium, large, and industrial hog operations (McBride and Key 2003; Boessen, Lawrence and Grimes 2004). McBride and Key (2003) estimate that nationally, 19% of small hog operations currently produce at $40/cwt or less, and 40% of medium operations produce at $40/cwt or less. An estimated 55% of large and industrial operations produce at $40/cwt or less. Put another way, nearly half of mid-sized operations are already cost-competitive with efficient CAFOs, even with the disadvantages they face from government policies that reduce feed prices and fail to demand environmental compliance. If CAFOs' operating costs rose, efficient mid-sized producers could be in an even better position to capture market share.

Would the elimination of these discounts slow the demise of mid-sized diversified hog farms? After all, evidence suggests that most mid-sized operations grow their own feed and do not have the kinds of manure management problems seen in CAFOs. A 2004 study conducted by researchers at Iowa State University and the University of Missouri of 1,198 randomly selected Iowa pork producers found that 84% of mid-sized hog operations grew feed corn, while 80% grew soybeans. Seventy percent reported that they milled and prepared their own feed (Boessen, Lawrence and Grimes 2004). Evidence also suggests that incidents of nutrient loading are far less common on mid-sized hog operations than in CAFOs. Ribaudo, Cattaneo and Agapoff (2004), in a detailed assessment of the costs of meeting N and P standards for different size operations, conclude that most mid-sized livestock operations have enough land to currently meet nutrient management best practices for both N and P.

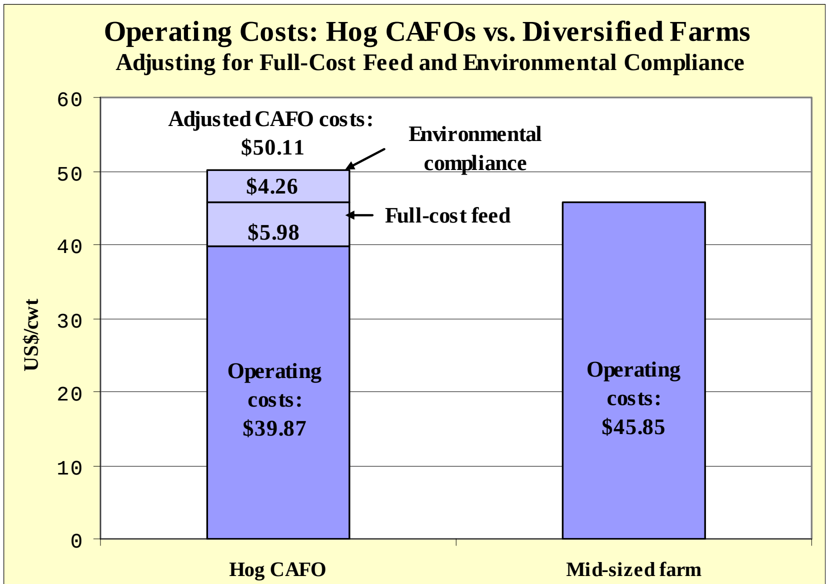
One study does attempt to break down cost performance by operation size. In an examination of ARMS survey data, McBride and Key find that in 1998, hog operations with more than 2,000 head had operating costs between 11% and 15% lower than mid-sized operations with inventories of 500-1,999 head (McBride and Key 2003).

We have determined that if the feed discount were eliminated, production costs for 2,000+ head operations would increase by 15%. That rise, according to the data presented by McBride and Key, would virtually eliminate CAFOs' production cost advantage over medium-sized operations that grow their own feed. Operating costs for medium-sized, diversified hog operations could become as much as 4% lower than costs for CAFOs.

If CAFOs were forced to comply with nutrient management standards for surface water, they would see production costs rise by an additional 2.4% to 10.7%. The environmental costs alone do not eliminate CAFOs' cost advantage over farms that apply manure at agronomic rates; CAFOs would still have costs anywhere from 0.3% to 12.6% lower than those of mid-sized operations, depending on the alternative strategy employed.

But taken together, eliminating the feed and environmental discounts makes mid-sized diversified hog farms competitive with hog CAFOs, as Figure 5 shows. Operating costs for hog CAFOs were $39.87/cwt in 1998, $5.98/cwt below the estimate for mid-sized farms of $45.85/cwt. Add to CAFOs the added costs of full-priced feed—15%, or roughly $5.98/cwt – and the costs of addressing surface water pollution (between $0.96 and $4.26/cwt), and mid-sized farms show a cost advantage of as much as $4.26/cwt over CAFOs.

Figure 5



Data from 1998 ARMS survey, McBride and Key (2003). CAFO cost adjustments for full-cost feed and costs of surface-water pollution control from improved manure management strategies (upper-bound estimate in range $.96-$4.26). Mid-sized farms have no added costs.

Discussion

It is important to note one area in which this presentation of relative competitiveness oversimplifies the issue. If feed market prices rose until they were equal with production costs, the feed discount to CAFOs would be eliminated, but so too would some of the subsidies to diversified farmer/feeders that are tied to low market prices, such as counter-cyclical and loan deficiency payments. Would diversified farmers' loss of subsidy income tip the balance back in favor of CAFOs, which do not receive these direct subsidies?

Evidence suggests that government payments have not generally been sufficient to make up the gap between low prices and higher costs. According to an analysis by Ray, de la Torre Ugarte and Tiller (2003), even with subsidies added to market income, farmers' returns to corn were still 6% below cost of production in 2000 and only 1% above cost of production in 2001. Returns to soybeans were 9% below cost of production in 2000 and 11% below cost of production in 2001.

Applying these estimates to our calculations of relative competitiveness, if CAFOs lost their feed discount and diversified farms lost all subsidies, CAFOs would still operate with costs between 3% and 7% lower than mid-sized operations. Of course, farmers would not lose direct payments under the current farm programs, since those payments are not tied to prices, so the continued receipt of direct payments could make mid-sized operations cost-competitive. Additionally, the removal of CAFOs' surface-water pollution externality would raise CAFO costs further and tip the balance back toward mid-sized operations.

The enduring finding is that U.S. policy appears to have helped fuel the rise of hog CAFOs by lowering feed prices and allowing them to externalize the costs of pollution. In a different political and regulatory environment, mid-sized, diversified hog operations could compete with CAFOs on cost.

Interestingly, the hog industry may now be entering just such an economic and regulatory environment. The new market for corn-based ethanol has driven corn prices above production costs, while soybean prices have climbed with the shift of soybean acreage into corn. On the regulatory side, the EPA-mandated grace period for CAFOs to comply with Clean Water Act regulations by completing CNMPs that include a plan for dealing with surface-water contamination expires in 2007. Our estimates suggest that such regulations could raise hog CAFOs' operating costs by 2.4%-10.7% if they are properly enforced. Together, these changes could alter the cost structure for hog CAFOs.

According to the most widely cited production and price projections (FAPRI 1999-2006), corn prices are expected to be above production costs for the next five years, while soybean prices should be close to production costs. Applying our model for estimating the impact on hog feed prices to these projections, we estimate that the price of hog feed should reach production cost as early as 2008. For the period 2008-2011, prices would exceed costs by about 3%. This would represent an increase of about 29% in hog CAFO feed costs, and 17% in total operating costs, over their average costs in the 1997-2005 period.

This scenario presents an unprecedented opportunity for new research examining whether the elimination of the feed-price discount slows or reverses the trend away from diversified crop-livestock farms and toward industrialized, specialized animal production. Diversified operations that grow their own feed crops and raise hogs may begin to make greater economic sense and may even come to out-compete industrial operations on cost. Such an outcome becomes even more likely with the scheduled EPA enforcement of manure regulations on surface water.

Industrial livestock companies have been vocal about their concerns over rising feed prices. Their fears are warranted. Our findings suggest that if current trends continue, the rise in the price of feed could raise CAFOs' operating costs significantly. Stricter environmental regulations could raise costs further. Such changes could significantly impact the structure of hog farming in the United States, slowing the trend toward large confinement operations. Further research is needed to assess how these changes affect the relative competitiveness of CAFOs and smaller-scale, diversified hog operations.

V. Conclusion

As noted at the start of this paper, CAFOs benefit from efficiencies that go far beyond simply producing at a lower cost. Some are innate to the model, including improved supply control in vertically integrated firms, uniformity of product, and production volume. Others appear to be a result of market imperfections—for example, analysts note that the over-proliferation of production contracts has put roadblocks in the way of smaller operations seeking market access.

This paper has shown that below-cost feed and lax environmental standards have contributed to CAFOs' apparent competitive advantages over diversified hog farms, allowing CAFOs to avoid or externalize the true costs of their production. New market conditions have at least temporarily eliminated the feed discount, and new environmental regulations may do the same for surface-water contamination. If they do, researchers may be able to evaluate the real efficiencies of various models of hog production. It may well be shown that CAFOs' apparent economies of scale have been less the result of inherent efficiencies than they are the result of government policies that have favored large-scale industrial animal production.

Elanor Starmer is a Research Fellow and Timothy A. Wise is Deputy Director of the Global Development and Environment Institute at Tufts University. Inquiries can be directed to tim.wise@tufts.edu.

REFERENCES

Abel, D. and Earley (1994). Large-Scale Land Idling Has Retarded Growth of U.S. Agriculture. Alexandria, VA, National Grain and Feed Foundation.

Agricultural Marketing Service/USDA (1999). Contracting in Agriculture: Making the Right Decision. Washington, DC, USDA.

Aho, P. (1999). The Economics of the US Chicken Meat Industry, American Soybean Association.

American Farm Bureau Federation (2006). AFBF Outlines 2007 Farm Spending Priorities. Farm Bureau News. **54**.

Beattie, A. (2005). U.S Faces Fresh Challenge on Farm Subsidies. Financial Times**:** 21.

Boessen, C., J. Lawrence and G. Grimes (2004). Production and Marketing Characteristics of U.S. Pork Producers- 2003. Ames, IA, Iowa State University.

Bugos, G. (1992). "Intellectual Property Protection in the American Chicken Breeding Industry." Business History Review **66**(Spring 1992): 127-168.

Choudat, D., M. Goehen, et al. (1994). "Respiratory symptoms and bronchial reactivity among pig and dairy farmers." Scand J Work Environ Health **20**: 48-54.

Cochran, K., J. Rudek and D. Whittle (2000). Dollars and Sense: An Economic Analysis of Alternative Hog Waste Management Technologies. Washington, DC, Environmental Defense.

Cole, D., L. Todd, and S. Wing (2000). "Concentrated Swine Feeding Operations and Public Health: A Review of Occupational and Community Health Effects." Environmental Health Perspectives **108**(8): 685-699.

Constance, D. (2002). "Globalization, Broiler Production, and Community Controversy in East Texas." Southern Rural Sociology **18**(2): 31-55.

Constance, D., and R. Tulnstra (2005). "Corporate Chickens and Community Conflict in East Texas: Growers' and Neighbors' Views on the Impacts of Industrial Broiler Production." Culture and Agriculture **27**(1): 45-60.

Council of Economic Advisors (2006). Economic Report of the President. Washington, DC, Council of Economic Advisors.

Donham, K. J. (1990). "Health effects from work in swine confinement buildings." American Journal of Industrial Medicine 4:17-26.

Duffy, M., J. Ikerd, J. Kleibenstein, D. Keeney and J. Lawrence (1995). Economic Development. Understanding the Impacts of Large-Scale Swine Production: Proceedings from an Interdisciplinary Scientific Workshop, Des Moines, Iowa.

EPA (2005). Summary of the Second Circuit’s Decision in the CAFO Litigation. Washington, DC, USEPA.

FAPRI (1999-2006). FAPRI Agricultural Outlook Archive. Food and Agricultural Policy Research Institute, Iowa State University and the University of Missouri-Columbia.

Gardner, B. (2002). U.S. Commodity Policies and Land Prices. Government Policy and Farmland Markets. Washington D.C., USDA-ERS.

Grimes, G., and R. Plain (2003). 2003 Hog Marketing Contract Study. University of Missouri and National Pork Producers Council.

Halverson, M. (2000). The price we pay for corporate hogs. Minneapolis, MN, Institute for Agriculture and Trade Policy.

Hamilton, N. D. (1995). "A Farmer's Legal Guide to Production Contracts." Farm Journal **174**.

Harvey, D. (2006). Broiler production costs. E. Starmer**:** Phone communication.

Hendrickson, M. and W. Heffernan (2005). Concentration of Agricultural Markets. Columbia, MO, Department of Rural Sociology, University of Missouri.

Henry, W. R. and R. Raunikar (1960). "Integration in Practice: The Broiler Case." Journal of Farm Economics **42**(5): 1265-1274.

Hubbell, B., and R. Welsh (1998). "An examination of trends in geographic concentration in U.S. hog production, 1974–96." Journal of Agricultural and Applied Economics **30**: 285-299.

Huffman, R. L., and P. Westerman (1991). Seepage and Electromagnetic Terrain Conductivity Around New Swine Lagoons. Meeting of the American Society of Agricultuural Engineers, Albuquerque, NM.

ILSR (2006). New Rules Project. Minneapolis, MN, Institute for Local Self-Reliance.

Innes, R. (2000). "The Economics of Livestock Waste and its Regulation." American Journal of Agricultural Economics **82**: 97-117.

International Food Policy Research Institute (2003). Impact of Alternative Agricultural Trade Policies on Developing Countries. Washington, DC, IFPRI.

Jackson, L. L., D. R. Keeney and E. M. Gilbert (2000). "Swine Manure Management Plans in North-Central Iowa: Nutrient Loading and Policy Implications." Journal of Soil and Water Conservation **55**(2).

Jones, C., H. El-Osta and R. Green (2006). Economic Well-Being of Farm Households. Washington, DC, USDA.

Keplinger, K. and L. Hauck (2006). "The Economics of Manure Utilization: Model and Application." Journal of Agricultural and Resource Economics **31**(2): 414-440.

Key, N. (2005). "How Much do Farmers Value their Independence?" Agricultural Economics **33**(1): 117.

Knoeber, C. R. (1989). "A Real Game of Chicken: Contracts, Tournaments, and the Production of Broilers." Journal of Law, Economics, and Organzations **5**: 271-292.

Knoeber, C. R., and W.N. Thurman (1995). "'Don't Count Your Chickens….': Risk and Risk Shifting in the Broiler Industry." American Journal of Agricultural Economics **77**(August 1995): 486-96.

Krebs, A. V. (2000). "Editorial." Agribusiness Examiner **86**.

Krider, J. (1987). Assessing Animal Waste Systems' Impacts on Groundwater: Occurrences and Potential Problems. Rural Groundwater Contamination. F. M. D'Itri, and L.G. Wolfson. Chelsea, MI, Lewis Publishers, Inc.**:** 115-128.

Legator, M. S., et al. (2001). "Health Effects from Chronic Low-Level Exposure to Hydrogen Sulfide." Archives of Environmental Health **56**(2): 123-131.

MacDonald, J., J. Perry, M. Ahearn, D. Banker, W. Chambers, C. Dimitri, N. Key, N. Nelson and L. Southard (2004). Contracts, Markets, and Prices: Organizing the Production and Use of Agricultural Commodities. Washington, DC, USDA.

Martinez, S. W. (1999). Vertical Coordination in the Pork and Broiler Industries: Implications for Pork and Chicken Products USDA/ERS. Washington, DC, USDA.

Martinez, S. W. (2002). Vertical Coordination of Marketing Systems: Lessons From the

Poultry, Egg, and Pork Industries. Washington, DC, USDA/ERS.
McBride, W. and N. Key (2003). Economic and Structural Relationships in US Hog Production. Washington, DC, USDA/ERS.
Morris, D. (2000). Hogging the Market. Minneapolis, Institute for Local Self-Reliance.
Morrison, J. M. (1998). The poultry industry: A view of the swine industry's future. Pigs, Profits and Rural Communities. K. M. Thu, and E. P. Durrenburger. Albany, State University of New York Press**:** 145–154.
Murray et al. (2003). Benefits of Adopting Environmentally Superior Swine Waste Management Technologies in North Carolina: An Environmental and Economic Assessment. Research Triangle Park, NC, RTI International.
National Agricultural Law Center (2005). Animal Feeding Operations: An Overview.
National Campaign for Sustainable Agriculture (NCSA) (2006). Sign-on letter.
National Family Farm Coalition (2007). Food from Family Farms Act. Washington, DC, NFFC.
Osterberg, D., and David Wallinga (2004). "Addressing Externalities from Swine Production to Reduce Public Health and Environmental Impacts." American Journal of Public Health **94**(10): 1703-1709.
Oxfam (2003). Dumping Without Borders: How U.S. Agricultural Policies are Destroying the Livelihoods of Mexican Corn Farmers, Oxfam International.
Paul, C. M. (1999). "Production Structure and Trends in the U.S. Meat and Poultry Products Industries." Journal of Agricultural and Resource Economics **24**(2): 281-298.
Plain, R. (1997). Changing Structure of the Hog Industry. Professional Swine Producers Symposium, Lansing, MI.
Ray, D., D. De La Torre Ugarte and K. Tiller (2003). Rethinking US Agricultural Policy: Changing Course to Secure Farmer Livelihoods Worldwide, Agricultural Policy Analysis Center, University of Tennesee.
Ribaudo, M., A. Cattaneo and J. Agapoff (2004). "Cost of Meeting Manure Nutrient Application Standards in Hog Production: The Roles of EQIP and Fertilizer Offsets." Review of Agricultural Economics **26**(4): 430-444.
Ribaudo, M., N. Gollehon and M. Aillery, et al. (2003). Manure Management for Water Quality: Costs to Animal Feeding Operations of Applying Manure Nutrients to Land. Washington, DC, USDA/ERS.
Ritchie, M. and S. Murphy, et al. (2003). United States Dumping on World Agricultural Markets. Minneapolis, MN, Institute for Agriculture and Trade Policy.
Ryan, J., C. Barnard and R. Collender (2001). Government Payments to Farmers Contribute to Rising Land Values. Agricultural Outlook, USDA/ERS. **4**.
Safley, L. M. (2003). Getting My Barn Built: An Update on Regulations from a U.S. Perspective. Banff Pork Seminars, Banff, BC.
Senate Agriculture Committee (2004). Economic Concentration and Structural Change In the Food and Agriculture Sector: Trends, Consequences and Policy Options. Democratic Staff Committee on Agriculture Nutrition and Forestry, Government Printing Office.
Shaik, S., G. A. Helmers and J. A. Atwood (2005). "The Evolution of Farm Programs and Their Contribution to Agricultural Land Values." American Journal of Agricultural Economics **87**(5): 1190-1197.

Starmer, E., A. Witteman and T. A. Wise (2006). Feeding the Factory Farm: Implicit Subsidies to the Broiler Industry. Medford, MA, Global Development and Environment Institute.

Steedle, L. (1986). "Measuring Productivity in an Integrated Poultry Operation." Journal of Accountancy **161**(6): 142.

Stith, P., J. Warrick and M. Sill (1995). Murphy's Law. The News and Observer. Raleigh, NC.

Taylor, C. R. (2002). Restoring Economic Health to Contract Poultry Production. Agricultural and Resource Policy Forum, Auburn University.

Tweeten, L. G., and C.B. Flora (2001). Vertical Coordination of Agriculture in Farming-Dependent Region. Council for Agricultural Science and Technology. Ames, IA.

USDA (2005). Structure and Finances of U.S. Farms: 2005 Family Farm Report. Washington, DC, USDA.

USDA/ERS (2003). Food Price Spread briefing room.

USDA/ERS (2005). Historic and Recent Costs and Returns. Washington, DC, U.S. Department of Agriculture.

USDA/NASS (2006). 2002 Census of Agriculture and Historical Highlights. Washington, DC, USDA.

Wallinga, D. (2004). Concentrated Animal Feeding Operations: Health Risks from Water Pollution. Minneapolis, Institute for Agriculture and Trade Policy.

Wallinga, D., MD (2004). Concentrated Animal Feeding Operations: Health Risks from Air Pollution. Minneapolis, MN, Institute for Agriculture and Trade Policy.

Watkins, K. and J. Von Braun (2002). Time to Stop Dumping on the World's Poor. Washington, DC, International Food Policy Research Institute.

Weersink, A., C. Turvey, S. Clark and R. Sarkar (1999). "The Effect of Agricultural Policy on Farmland Values." Land Economics **73**(3): 425-439.

Westerman, P., R.L. Huffman, and J. Feng (1995). "Swine Lagoon Seepage in Sandy Soil." Trans American Society of Agricultural Engineers **38**: 1749-1760.

Williams, H. (2006). "Fighting Corporate Swine." Politics and Society **34**(3): 369-398.

Wing, S. and S. Wolf (2000). "Intensive Livestock Operations, Health, and Quality of Life among Eastern North Carolina Residents." Environmental Health Perspectives **108**: 235-238.

Wise, T. A. and E. Starmer (2007). Industrial Livestock Companies' Gains from Low Feed Prices, 1997-2005. Medford, MA, Global Development and Environment Institute.

WORC (2006). Testimony before the House Committee on Agriculture. Field Hearing of the House Committee on Agriculture, Wall, South Dakota, Western Organization of Resource Councils.

Zejda, J. and T. Hurst (1993). "Respiratory health of swine producers: focus on young workers." Chest **103**: 702-709.

Zuskin, E., B. Kanceljak, et al. (1991). "Immunological and respiratory findings in swine workers." Environmental Res **56**: 120-130.

The Global Development And Environment Institute (GDAE) is a research institute at Tufts University dedicated to promoting a better understanding of how societies can pursue their economic goals in an environmentally and socially sustainable manner. GDAE pursues its mission through original research, policy work, publication projects, curriculum development, conferences, and other activities. The "GDAE Working Papers" series presents substantive work-in-progress by GDAE-affiliated researchers. We welcome your comments, either by e-mail directly to the author or to G-DAE, Tufts University, 44 Teele Ave., Medford, MA 02155 USA; tel: 617-627-3530; fax: 617-627-2409; e-mail: gdae@tufts.edu; website: http://ase.tufts.edu/gdae.

Papers in this Series:

00-01 Still Dead After All These Years: Interpreting the Failure of General Equilibrium Theory (Frank Ackerman, November 1999)
00-02 Economics in Context: The Need for a New Textbook (Neva R. Goodwin, Oleg I. Ananyin, Frank Ackerman and Thomas E. Weisskopf, February 1997)
00-03 Trade Liberalization and Pollution Intensive Industries in Developing Countries: A Partial Equilibrium Approach (Kevin Gallagher and Frank Ackerman, January 2000)
00-04 Basic Principles of Sustainable Development (Jonathan M. Harris, June 2000)
00-05 Getting the Prices Wrong: The Limits of Market-Based Environmental Policy (Frank Ackerman and Kevin Gallagher, September 2000)
00-06 Telling Other Stories: Heterodox Critiques of Neoclassical Micro Principles Texts (Steve Cohn, August 2000)
00-07 Trade Liberalization and Industrial Pollution in Mexico: Lessons for the FTAA (Kevin Gallagher, October 2000) *(Paper withdrawn- see www.ase.tufts.edu/gdae/ for details)*
00-08 Waste in the Inner City: Asset or Assault? (Frank Ackerman and Sumreen Mirza, June 2000)
01-01 Civil Economy and Civilized Economics: Essentials for Sustainable Development (Neva Goodwin, January 2001)
01-02 Mixed Signals: Market Incentives, Recycling and the Price Spike of 1995. (Frank Ackerman and Kevin Gallagher, January 2001)
01-03 Community Control in a Global Economy: Lessons from Mexico's Economic Integration Process (Tim Wise and Eliza Waters, February 2001)
01-04 Agriculture in a Global Perspective (Jonathan M. Harris, March 2001)
01-05 Better Principles: New Approaches to Teaching Introductory Economics (Neva R. Goodwin and Jonathan M. Harris, March 2001)
01-06 The $6.1 Million Question (Frank Ackerman and Lisa Heinzerling, April 2002)
01-07 Dirt is in the Eye of the Beholder: The World Bank Air Pollution Intensities for Mexico (Francisco Aguayo, Kevin P. Gallagher, and Ana Citlalic González, July 2001)
01-08 Is NACEC a Model Trade and Environment Institution? Lessons from Mexican Industry (Kevin P. Gallagher, October 2001)
01-09 Macroeconomic Policy and Sustainability (Jonathan M. Harris, July 2001)

02-01 Economic Analysis in Environmental Reviews of Trade Agreements: Assessing the North American Experience. (Kevin Gallagher, Frank Ackerman, Luke Ney, April 2002)

03-01 Read My Lips: More New Tax Cuts—The Distributional Impacts of Repealing Dividend Taxation (Brian Roach, February 2003)

03-02 Macroeconomics for the 21st Century (Neva R. Goodwin, February 2003)

03-03 Reconciling Growth and the Environment (Jonathan M. Harris and Neva R. Goodwin, March 2003)

03-04 Current Economic Conditions in Myanmar and Options for Sustainable Growth (David Dapice, May 2003)

03-05 Economic Reform, Energy, and Development: The Case of Mexican Manufacturing (Francisco Aguayo and Kevin P. Gallagher, July 2003)

03-06 Free Trade, Corn, and the Environment: Environmental Impacts of US-Mexico Corn Trade Under NAFTA

03-07 Five Kinds of Capital: Useful Concepts for Sustainable Development (Neva R. Goodwin, September 2003)

03-08 International Trade and Air Pollution: The Economic Costs of Air Emissions from Waterborne Commerce Vessels in the United States (Kevin P. Gallagher and Robin Taylor, September 2003)

03-09 Costs of Preventable Childhood Illness: The Price We Pay for Pollution (Rachel Massey and Frank Ackerman, September 2003)

03-10 Progressive and Regressive Taxation in the United States: Who's Really Paying (and Not Paying) their Fair Share? (Brian Roach, October 2003)

03-11 Clocks, Creation, and Clarity: Insights on Ethics and Economics from a Feminist Perspective (Julie A. Nelson, October 2003)

04-01 Beyond Small-Is-Beautiful: A Buddhist and Feminist Analysis of Ethics and Business (Julie A. Nelson, January 2004)

04-02 The Paradox of Agricultural Subsidies: Measurement Issues, Agricultural Dumping, and Policy Reform (Timothy A. Wise, February 2004)

04-03 Is Economics a Natural Science? (Julie Nelson, March 2004)

05-01 The Shrinking Gains from Trade: A Critical Assessment of Doha Round Projections (Frank Ackerman, October 2005)

05-02 Understanding the Farm Problem: Six Common Errors in Presenting Farm Statistics (Timothy A. Wise, March 2005)

05-03 Securing Social Security: Sensitivity to Economic Assumptions and Analysis of Policy Options (Brian Roach and Frank Ackerman, May 2005)

05-04 Rationality and Humanity: A View from Feminist Economics (Julie A. Nelson, May 2005)

05-05 Teaching Ecological and Feminist Economics in the Principles Course (Julie A. Nelson and Neva Goodwin, June 2005)

05-06 Policy Space for Development in the WTO and Beyond: The Case of Intellectual Property Rights (Ken Shadlen, November 2005)

05-07 Identifying the Real Winners from U.S. Agricultural Policies (Timothy A. Wise, December 2005)

06-01 The Missing Links between Foreign Investment and Development: Lessons from Costa Rica and Mexico (Eva A. Paus and Kevin P. Gallagher, February 2006)

06-02 The Unbearable Lightness of Regulatory Costs (Frank Ackerman, February 2006)

06-03 Feeding the Factory Farm: Implicit Subsidies to the Broiler Chicken Industry (Elanor Starmer, Aimee Witteman and Timothy A. Wise, June 2006)

06-04 Ethics and International Debt: A View from Feminist Economics (Julie A. Nelson, August 2006)

06-05 Can Climate Change Save Lives? (Frank Ackerman and Elizabeth Stanton, September 2006)

06-06 European Chemical Policy and the United States: The Impacts of REACH (Frank Ackerman, Elizabeth Stanton and Rachel Massey, September 2006)

06-07 The Economics of Inaction on Climate Change: A Sensitivity Analysis (Frank Ackerman and Ian J. Finlayson, October 2006)

07-01 Policy Space for Mexican Maize: Protecting Agro-biodiversity by Promoting Rural Livelihoods (Timothy A. Wise, February 2007)

07-02 Declining Poverty in Latin America? A Critical Analysis of New Estimates by International Institutions (Ann Helwege and Melissa B.L. Birch, September 2007)

07-03 Economists, Value Judgments, and Climate Change: A View From Feminist Economics (Julie A. Nelson, October 2007)

07-04 Living High on the Hog: Factory Farms, Federal Policy, and the Structural Transformation of Swine Production (Elanor Starmer and Timothy A. Wise, December 2007)