

# The Relationship between Contracting and Livestock Waste Pollution

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This paper investigates factors and mechanisms that influence the relationship between contracting and animal waste pollution. The questions raised are whether contracting worsens livestock waste management problems and how to apportion the burden of regulation between the contracting parties in a socially optimal way. The paper shows that the potential linkages between contracting and animal waste depend on scale, specialization, and concentration of animal units, as well as on division of inputs and contract settlement rules. The long-run apportioning of an increase in costs of environmental compliance depends on the integrator's market power for grower services.

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Agricultural contracts are an integral part of the production and marketing of selected livestock commodities, such as broilers, turkeys, eggs, and hogs. The potential impact of livestock production on environmental quality has become a nationwide concern, particularly in areas with high concentrations of large-scale confined animal operation units, such as North Carolina and the Delmarva Peninsula. It is increasingly common for environmental advocacy groups to argue that contracting per se is a cause of environmental problems related to livestock production. Contracting increases the scale of livestock operations and simultaneously reduces opportunities for economies of scope in livestock utilization through increased specialization. An opposing view promulgated in corporate agriculture circles is that large, intensive livestock production units are, in fact, environmentally friendlier than small, family farms because they can afford technologically advanced waste management systems because of significant economies of scale.

The Clean Water Action Plan recognizes the importance of animal waste pollution as a cause of water quality problems. As of 2002, the U.S. Environmental Protection Agency (EPA) is proposing to revise and update two regulations that

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address the impacts of waste generated by concentrated animal feeding operations (CAFOs) on water quality. The National Pollutant Discharge Elimination System (NPDES) defines which operations are CAFOs and establishes permit requirements. The Effluent Limitations Guidelines for feedlots (beef, dairy, swine, and poultry) establish the technology-based effluent discharge standards for CAFOs. The EPA is proposing these revisions to address changes that have occurred in the livestock industries in the last 25 years. The environmental concerns addressed include ecological and human health effects. The public comment period on the proposed regulations ended July 31, 2001. The EPA plans to take final action by the end of 2002 (U.S. Environmental Protection Agency).

Two distinct characteristics of modern livestock production systems have potentially important environmental implications. The first is the shift to large-scale, intensive, specialized operations, the process often described as industrialization. There are two relevant issues here. One is the problem of different spatial allocation and land-use patterns that industrialization would bring compared with the traditional livestock production systems. The other is the issue of technological change in production and waste management practices adopted by large-scale animal operations compared with small, family farm units.

The second characteristic of the modern livestock industry is the shift from independent sole proprietorships that exchange inputs and outputs through open spot markets to farms, feed mills, and processors linked by production contracts, marketing agreements, or common ownership, the process known as vertical coordination. There are two important issues here as well. First, contracts have emerged as a form of vertical coordination in response to some form(s) of market failure. Hence, changing regulatory constraints may change the incentives on both sides of the contracts, possibly rendering the entire institutional structure inadequate. Second, the way contracts are written reflects a solution to a particular set of incentive problems. The nature of the relationship between an integrator and growers is plagued by numerous asymmetric information-type problems that contract provisions attempt to mitigate. The new set of regulatory constraints will require contract renegotiations, with welfare implications difficult to predict.

The economics literature on the relationship between agricultural production contracts and environmental pollution is virtually nonexistent, with only one paper found that explicitly deals with this issue. Preckel et al. analyze implications of contract design for nitrate-based environmental externalities generated by seed corn producers. They argue that contract insecurity, in which the probability of contract renewal depends on yield performance, distorts input use, causing an increase in nitrogen use by about 12%, resulting in a 17% increase in nitrate leaching. They advocate change in contracting practices calling for either awarding contracts by lottery or possibly modifying the contract payment function. The welfare implications of those ad hoc proposals have not been studied.

I want to accomplish two objectives in this paper. The first is to identify the factors and mechanisms that characterize the relationship between contracting and animal waste pollution. I address the question of whether contract operators have the same incentives to act as good stewards of the environment as independent farmers by intersecting the main findings from the literature on agricultural contracts with that on the economics of waste management. The second

objective is to analyze the potential impacts of anticipated waste management regulatory changes on the contractual relationship between integrator companies and contract growers and on the industry as a whole. I focus on policies frequently discussed in industry circles as having high probability of being adopted. Given that the precise nature of future changes in animal waste regulation is yet unknown, the discussion in this paper is based on two reasonable assumptions. First, the division of responsibilities for the removal and disposal of manure will be regulated toward some form of a shared responsibility between the integrators and the growers, and second, the cost of waste management would increase as a result of new regulation. Three issues dominate my presentation in the rest of the paper.

First, from the perspective of optimal contract design, shifting some responsibility for waste management from the growers to the integrator may cause significant changes in the contract structure and potentially in the entire industry organization. Instead of focusing only on providing incentives for growers to feed animals efficiently, the new generation of contracts will also need to provide incentives for the removal and the disposal of manure in an environmentally friendly manner. The notion that determining grower compensation based on objective performance measures for one task can be harmful for the integrator's interest if objective performance measures are not applied to other tasks may explain the tendency of employment contracts to utilize fixed wages (e.g., Holmstrom and Milgrom; Baker). This is because complex contracts involving pay-per-performance schemes may distort incentives to the point where paying workers fixed salaries may be the best available option. In a regulatory context, one might similarly conclude that the frequent tendency toward command and control regulation in place of incentives-based instruments, such as taxes and subsidies, may be caused by similar multitasking concerns (Slade).

Second, given that a significant proportion of livestock production is taking place under contracts,<sup>1</sup> the question of whether growers or integrators will ultimately carry the regulatory burden becomes critical in all future policy discussions and evaluations. Traditionally, the economics literature has addressed the question of a cost pass-through (CPT). The CPT describes the concept of regulatory compliance costs or other shocks occurring at one point in the production–marketing–consumption chain being passed through to later levels by means of higher prices. If an industry can pass on some of the cost of compliance to others, the impact of the regulation on the regulated industry will be reduced. Whereas the concept of CPT under a perfect competition assumption is reasonably straightforward, the realities of market concentration, regional trading, and vertical integration complicate the analysis considerably.<sup>2</sup>

The final question is the issue of liability for damages caused by accidental waste spills among the contract parties. The recent trend in U.S. environmental law has shown a tendency toward increased liability faced by lenders to so-called judgment-proof firms, that is, firms that can cause accidents and go bankrupt without having sufficient assets left to compensate the victims (Pitchford). Making parties who are involved in a project liable, although they have little direct means to prevent the accident from occurring, is known as vicarious liability (Sykes). From the perspective of this paper, an interesting question involves the conditions under which the vicarious liability of the integrator contracting the grow-out of

animals with judgment-proof growers can increase the incentives for accident prevention.

In what follows, I describe the main characteristics of contracting in animal agriculture, review the economics of animal waste management, and discuss different frameworks to analyze the impacts of contract regulation. I also address the problem of compliance cost incidence and discuss the liability issues, followed by conclusions and an outline for possible future research.

### **The Nature of Contracting in Animal Agriculture**

Almost one-third of the total value of production on U.S. farms is produced under contractual agreements (U.S. Department of Agriculture). The expanding role of contracting in total agricultural production is primarily the result of the increasingly sophisticated marketplace, where consumers are requiring a more uniform product supply and standardization in quality. Contracts are one vehicle through which food processors and marketers can rapidly respond to changes in consumer preferences.

The growth in contracts as a means of organizing agricultural production has been staggering. In 1969, only 156,400 farms, or about 6% of all farms, used production and/or marketing contracts. The value of production under contract totaled \$5.4 billion or nearly 12% of the total value of commodities sold. By 1993 11% of farms used production and/or marketing contracts and the total value of production under contract had increased almost nine times to \$47 billion or 32% of the total value of commodities sold. Most of the value of the contracted production was produced to fulfill marketing contracts. Only slightly over one-third of the contracted value was produced in conjunction with production contracts, where the contractor retains ownership of the commodity (U.S. Department of Agriculture).

Agricultural contracts can be classified into two broad groups: marketing and production contracts. *Marketing contract* refers to an agreement that sets a price or a pricing mechanism and an outlet for the commodity before harvest. Most management decisions remain with the growers since ownership is retained while the commodity is being produced. The farmer also assumes all risk of production but shares price risk with the contractor. Examples of marketing contracts are forward contracting and price setting after delivery based on a predetermined formula that considers grades and yields. *Production contracts* specify in detail production inputs supplied by the two parties, the quality and quantity of a particular commodity, and the remuneration mechanism for the grower. Because contractors control the volume of production and the practices used, they tend to dominate the terms of the contract. In addition, farmers themselves can be contractors. Oftentimes, a farmer will contract with another farmer to complete a stage of production in raising livestock. Various types of joint venture agreements between farmers and shippers/processors are also observed.

Livestock contracts are typical examples of production contracts. A production contract is an agreement between an integrator company and a farmer (grower) that binds the farmer to specific production practices. Livestock contracts have two main components: the division of responsibility for providing inputs, and the method used to determine grower's compensation. Growers provide land,

housing facilities, utilities (electricity and water), and labor, and are typically responsible for compliance with federal, state, and local environmental laws regarding disposal of dead animals and manure. They usually pay any charges imposed by a rendering plant or other dead animal disposal method. An integrator company provides animals to be grown to processing weight, feed, and medications and services of field men. Typically, the company also owns and operates hatcheries, feed mills, and a processing plant, and provides transportation of feed and live animals. Items like fuel or bedding can be the responsibility of either the integrator or the grower, or they can be shared. In some contracts, the integrator reimburses the growers for a percentage of the rendering plant costs but not for any costs associated with manure management (National Pork Producers Council). The integrator also decides on the volume of production both in terms of the rotations of flocks or batches on a given farm and the density of animals inside the house.

The various stages of animal production are typically covered by different contracts, and farmers generally specialize in the production of animals under one contract. For example, chicken production involves raising broiler breeder males and pullets, housing the mature breeding flock for the production of hatching eggs, and producing (growing-out) commercial broilers. Turkey production is mainly organized via contract production with a standard technological unit consisting of one brooder house and two finishing houses covered by one contract. Production technology is gradually changing towards separate (all-in, all-out) brooding and finishing operations. With this new management practice, the farmer specializes either in the brooding or finishing turkeys, and two stages of the production process are covered by separate contracts (Vukina).

The swine industry has the greatest variety of production contracts. Single production stage contracts (such as farrowing contracts), nursery contracts, and finishing contracts are the most frequently observed. Some integrators combine several production stages under one contract. These are known as farrow-to-finish contracts and the most recently introduced, wean-to-finish contracts.

Virtually all livestock production contracts are settled based on one of three compensation methods for growers. The first is a “base plus bonus” payment per pound of gain (live weight) transferred, where a bonus payment reflects some efficiency measure, such as feed conversion. The second compensation method is a “base payment per live animal transferred” with bonuses for efficiency. Bonuses for reduced death loss and uniformity are also common. A third compensation method popular in the upper Midwest for hog finishing contracts and wean-to-finish contracts involves paying the grower on a “per-pig space, per-year” basis (National Pork Producers Council). Most of the production contracts also have minimum guaranteed payment and disaster payment clauses. Neither one would apply if the grower were grossly negligent of production responsibilities.

The most widely used compensation schemes in the livestock sector are payments per pound of live weight delivered plus bonuses for efficiency. Most of the finishing contracts are based either on a tournament or some form of a fixed performance standard. In a tournament, the payment is determined by comparing the individual grower’s performance (e.g., the feed conversion ratio—the pounds of feed used to produce a pound of live weight) with the group average. For a below-average feed conversion (i.e., above-average performance), the grower

receives a positive amount over the base payment. If feed conversion is above average (i.e., below average performance), the grower receives a penalty.

A second type of grower remuneration is based on a fixed performance standard. Unlike a tournament where the benchmark for comparison is determined by a contest among growers, in a fixed performance standard, growers are competing against a predetermined constant feed conversion ratio.

The efficiency gains from contracting in the livestock sector have been substantial. Vukina explained the emergence of contracts with independent farmers in the poultry industry by the formation of economic circumstances that required adequate mechanisms to facilitate risk sharing (provision of insurance), technological progress and innovation dissemination, response to consumer demand for product reputation and uniform quality, and access to capital. At the same time, these four categories summarize the most important benefits that the widespread adoption of production contracts has generated.

The form of contracting used in the broiler industry (cardinal tournaments) shifts nearly all risk to the integrator, except for the small portion of the growers' idiosyncratic risk (Knoeber and Thurman). The likely explanation for the weak relation between price risk and broiler supply (Aradhyula and Holt) is not that price risk is small, but that all risk is shifted to large, sometimes publicly owned integrator companies who have small risk-bearing costs even though the risks themselves are rather large. The rapid technological change generated tremendous productivity gains resulting in a significant reduction in the cost of production that has been largely passed on to consumers via lower poultry meat prices. This increased productivity came about through disease control, development of genetically superior breeding stock, and innovations in animal nutrition. Contracting and vertical integration have given the poultry industry greater control over product volume and quality, which turned out to be especially important in meeting the needs of large food-away-from-home establishments and supermarket chains. The rapid expansion of the broiler industry was also facilitated by relatively easy and inexpensive access to capital through federally insured loans for construction of housing facilities. Grower provision of capital provided an efficient way for integrators to finance expansion, with a positive employment feedback to the growers.

Substantial benefits of vertical coordination via contracts with independent growers are visible in the hog industry as well. According to Key and McBride, contracting appears to be increasing the total factor productivity of the swine industry by 24%, resulting in 29% more output for a contract operator compared with an average independent farm. Contracting appears to raise productivity despite the fact that contract operations do not use more capital per unit of output or take on relatively more debt. The authors argue that higher productivity of contract operators may be due to a transfer of know-how from integrators to growers, especially concerning feed mixtures and feed timing, that results in better feed efficiency and lower labor costs. In addition, other inputs provided by the integrator, such as veterinary care and genetic selection, may be superior to those available to an independent producer, resulting in healthier animals and greater weight gain.

Despite unprecedented success of production contracts, recent years have been characterized by an increasing number of dissatisfied contract growers

and more concentrated efforts on both federal and state levels to place some legal constraints on the type of contracts integrators and growers can sign. The Producer Protection Act is advocated by 16 state attorneys general and a similar bill has been introduced by U.S. Senator Harkin.<sup>3</sup> Growers' complaints in the broiler sector focus primarily on tournament schemes. They are opposed to a system that bases payments on how well or how poorly their neighbors perform. In addition to concerns about the settlement process, growers have also complained about the genetic quality of animals they receive, the way that live animals and feed are weighed, and the length of time between flock/batches placements. They also complain about contract nonrenewal, contract terminations, requirements that facilities be modified or upgraded (excessively), their limited choice of integrators or their inability to change integrators, and alleged integrator reprisals for joining grower associations and for seeking redress of grievances.

The literature on the economic impact of integrator practices and procedures on contract growers and the need for government regulation of contracts is rather small. Lewin argued that by requiring growers to make large specific investments in housing facilities, integrators can increase grower incentives without increasing compensation, since the risk of losing the investment will increase growers' fears of low performance. Lewin concludes that grower complaints about excessive investments may be theoretically justified, especially in geographical regions where the integrator enjoys market power.

Analyzing the welfare effects of the regulatory proposal to ban tournaments and replace them with fixed performance standards, Tsoulouhas and Vukina (2001) showed that such a regulation, absent more specific rules, could actually be harmful to growers. Growers will be unequivocally better off only under a fairly complicated regulatory mechanism that includes the prescription regarding the slope coefficient of the bonus payment, the so-called piece rate. This improvement in grower welfare will invariably come at the expense of the integrator, and society may or may not be better off depending on the technology and preferences.

## **Economics of Animal Waste Management**

Pioneering work by Henry and Seagraves presented the basic economics of animal waste management more than 40 years ago. While addressing the economic aspects of broiler production density, they recognized potential environmental problems that may arise with the expansion of the industry. They noted that manure is a valuable by-product if it can be used to fertilize crops located near the livestock production facility. Because the marginal productivity of fertilizer drops towards zero as higher levels are applied, there are finite limits to the amounts that can be used profitably. Since manure is bulky relative to its fertilizer value, it is unprofitable to haul long distances. Therefore, if the available manure per acre of cropland in a given supply area exceeds the level of profitable application, its value should drop sharply.

### ***Manure Value***

The central task in most of the empirical literature on economics of animal waste is the determination of the manure shadow value under different scenarios. The

two most important factors that determine the net value of manure are its nutrient content (as a fertilizer or feed ingredient) and the distance it needs to travel before it can be used. The main problems in using manure are that nutrients in manure are diluted, they are mixed in relative proportions that are inappropriate for most plant and animal uses, and nutrient content in manure varies over time and with disposal practices. The low concentration of nutrients in manure means that the costs of storage, transportation, and application per pound of nutrient are high compared with commercial fertilizers or other feed ingredients. As an example, a ton of fresh swine manure may contain only 12 pounds (0.6%) total N, 9 pounds (0.45%)  $P_2O_5$ , and 9 pounds (0.45%)  $K_2O$  (Martin and Zering).

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

Finally, the nutrient availability in manure and its value depends on the waste management technology used by the livestock farm. For example, the value of manure treated in an anaerobic lagoon is greatly reduced because much of the nitrogen is lost to the atmosphere and much of the phosphate precipitates to the bottom of the lagoon. Hence, with anaerobic lagoons, the cost of delivering nutrients is always greater than the value of nutrients (Fleming, Babcock, and Wang).

The negative shadow value of the lagoon-based manure has been confirmed in other empirical studies as well. In frequently cited studies, Roka and Roka and Hoag developed a model of a prototypical swine finishing operation representative of North Carolina conditions where livestock management decisions and manure handling decisions are treated as a joint product. Using a mixed-integer-programming algorithm, they solve for optimal manure management decisions in a system that could simultaneously consider multiple management alternatives such as treatment, transportation, and crop type. A sensitivity analysis on herd size, crop type, crop yield, treatment type, and transportation distance yielded consistently negative manure value and found that it had no impact on live-weight decisions of market hogs. In addition, since the bulk of irrigation costs are fixed, manure production exhibited significant economies of scale. A 5,400-head operation experienced 10% lower costs of manure disposal than a 600-head operation.

In a complementary study of swine production conditions in Iowa, Fleming, Babcock, and Wang found that when slurry basins are used for storage, the cost of delivering manure nutrients can be less than the value of the nutrients. However, as herd size increases, marginal delivery costs eventually become greater than marginal benefits. The largest profit from slurry storage is earned for a herd size of 6,900 hogs when the facility is located in an area where only corn is grown (instead of typical corn–soybean rotation), basing manure applications on a P-standard and incorporating the manure into the soil. Using a P-standard rather than an N-standard forces a producer to apply manure to more

acres, but more of the potential value of the manure is captured because less excess nutrients are applied. Also, the benefits from conserving N through soil incorporation outweigh the additional costs of soil incorporation. As herd size increases, costs of following a P-standard rise faster than the costs of following an N-standard. Therefore, following an N-standard on continuous corn would eventually minimize net losses.

Despite the results showing slurry basins as the optimal manure storage technology for Iowa conditions, some Iowa hog producers still use anaerobic lagoons for several reasons. The first is that the amount of land available to actual farms for spreading manure is much more limited than is assumed in Fleming, Babcock, and Wang simulations. This, *ceteris paribus*, favors the use of the lagoon as the cost minimizing method of disposing of manure nutrients.<sup>4</sup> Second, as the number of hogs on a site increases, the cost disadvantage of a lagoon decreases. Hence, producers with a large concentration of hogs may choose an anaerobic lagoon to minimize losses from manure handling. Finally, certain types of swine operations work more efficiently with lagoon systems than with slurry basins. For example, modern farrowing facilities typically use lagoon effluent for flush water instead of fresh water. The production cost advantages in these facilities likely outweighs the disadvantages of higher manure delivery costs.

### ***Size and Concentration***

The production and management of animal waste generates many potential external effects. Innes (1999) mentions three groups of externalities: (a) nutrient runoff and leaching from application of manure to cropland, (b) accidental spills and leaks from waste storage facilities, and (c) direct ambient air pollution from feedlots and storage facilities including odors and ammonia gases. The surveyed literature seems to indicate that the environmental impact of livestock production is largely independent of asset ownership and market organization but is mainly determined by production technology and the nature of environmental externalities. Therefore, our investigation of the links between contracting and waste management reduces to the investigation of the systematic differences in the size and the concentration of contract-based versus the independent livestock production units.

Innes (2000) shows that given the existing government standards for waste handling systems,<sup>5</sup> livestock producers have incentives to produce too many animals in operations that are either larger or more populated than is efficient, or both. This is because increased animal production raises environmental costs by increasing the size of potential waste spills, the level of excess manure application, and ambient pollution generally. Also, a given level of regional production could be achieved with smaller than efficient numbers of facilities.<sup>6</sup> When the government cannot directly regulate manure application, producers will always choose to spread more manure to nearby croplands than the exact substitution for chemical fertilizer would require. The degree of excess manure application rises with the size of an operation and with the proximity of the field to the storage facility. The intuition is that by applying manure on any given field, a farmer not only receives the nutrient benefits but also saves on the transportation costs

relative to applying the same manure on a more distant field. These results show that the use of animal waste as a fertilizer worsen nutrient runoff and leaching from croplands regardless of whether the livestock producer is a contract operator or an independent farmer.

A meaningful comparison between the sizes of the livestock production units owned by independent producers versus contract operators can only be done with hog production data because virtually all broilers and, to a large extent, turkeys are produced under contracts. Using the 1998 USDA Agricultural Resource Management Survey (ARMS) data, Key and McBride showed that contract hog growers produce on average over three times as much as independent producers and are much more likely to be in the larger-scale categories. While the impact of contracting on productivity appears to be sizeable, Key and McBride found that contracting did not have large scale-effects. In other words, contracting appears to be raising productivity for all size operations. This result suggests that greater productivity of contract operators is not a major force driving the increase in the scale of production of hog farms. On the other hand, production technology, which displays increasing returns to scale regardless of the ownership structure, does serve as a motive for increasing the size of the operation.

The difference between contract-based and independent production operations seems to be insignificant when it comes to industry concentration. Arguably, contract production would always result in high concentration of livestock production facilities in a given area. To minimize transportation costs, an integrator company would want its growers to be located close to the feed mill and processing plant. However, there is also a tendency for the independent livestock producers to concentrate in certain geographical areas due to significant agglomeration economies. Vukina and Wossink found an excellent example in the manure surplus regions in the Netherlands. The established network of feed mixers, slaughtering plants, specialized construction companies, extension specialists, veterinarians, and banking services geared around the specific needs of livestock producers, as well as the local availability of skilled labor, became an important factor of industry growth.

Even if industry concentration in a region dominated by contract producers is larger than in a region dominated by independents, in contrast to Innes (2000), one can argue that the high concentration of livestock facilities in a given geographical area is not necessarily inefficient. In a hedonic study of rural residential house sales in North Carolina, Palmquist, Roka, and Vukina showed that proximity to hog operations caused a statistically significant reduction in house prices of up to 9%. However, the negative effect on property values caused by constructing a new hog farm is felt more where the initial hog population is low. As an area becomes more saturated with hogs, both the dollar loss and the percentage price reduction from the addition of a new hog operation become smaller. For example, in an area with few hogs, building a 2,400-head finishing operation within one-half mile of a house reduces its value by over 8%. However, if the area already has a large number of hogs, adding the same operation within one-half mile of a house causes less than 0.3% reduction in value. These results suggest that social welfare would be enhanced by directing livestock industry expansion towards areas where concentration of animal units is already high rather than

trying to distribute future animal industry growth more evenly across the entire landscape.<sup>7</sup>

### **Contracts as Incentives Mechanisms**

Among the three groups of externalities that production and management of animal waste generates, nutrient runoff and leaching and air quality problems (ammonia emissions) are the most pervasive ones. For all of them, nutrient management plays a critical role. Nitrogen and phosphorus are the nutrients of greatest concern. The amount of nutrients that ends up deposited in the environment is directly related to the composition of animal feed. Tension in the production contract arises because the integrator owns the feed and decides about its composition, thus determining the nutrient content of the manure. Growers own the manure and are legally liable for its removal and disposal. In a frictionless economy, assuming that the nutrient content of feed and therefore of manure can be costlessly observed by the grower, the net benefits of nutrient application (or costs if the shadow price is negative) should be, in principle, incorporated into the payment schedule of a production contract. The Coase theorem<sup>8</sup> would suggest that, from an efficiency perspective, it matters little who bears responsibility for waste disposal and who decides on feed formulations.

One of the reasons the net costs or benefits of the nutrient application cannot be easily incorporated into the payment schedule of a production contract is that shadow value of the manure and its individual components depends on many exogenous factors. As mentioned earlier, most empirical studies on the economics of animal waste suggest that the majority of producers derive little or no economic benefit from applying manure to cropland. However, these results are not only spatially and scale sensitive, but also significantly dependent on the relative prices of agricultural commodities.<sup>9</sup> The shadow price of manure can also change in response to frequent changes and fine-tuning of the environmental regulatory policies and requirements. The change in the shadow value of the manure would require adjustment of the payment mechanism and other possible contract provisions through renegotiations. Frequent contract renegotiations impose substantial transaction costs on both parties and are highly impractical, so parties may seek alternative ways to regulate their relationships.

### ***A Standard Agency Theory Approach***

The asymmetric information nature of the livestock contracting and waste management problems is perhaps the most important reason for the failure of the negotiated settlement to produce a socially desirable outcome. Since the interests of growers and integrators are not in unison, an integrator offering a contract needs to align the incentives to induce growers to act in the company's interest. The problem is magnified by the fact that the integrator (principal) cannot directly observe the grower's (agent's) action (effort) and the outcome (output) is influenced by immeasurable effects of random factors (such as weather).<sup>10</sup>

The conflict of interest between the contracting parties arises because the agent's effort contributes to increased output—the same output that the principal's income positively depends on. Therefore, the principal wants the agent to work

hard. But the effort generates disutility to the agent who has a tendency to work less hard than the principal would like. Because of imperfect information on the agent's effort, the principal cannot specify and enforce the desired level of effort. In addition, because of the stochastic nature of the production process, the principal cannot verify whether the agent's shirking or the unfavorable state of nature causes a bad outcome. Making the agent's income dependent on the consequences of his effort mitigates the nonalignment of work incentives. However, this design makes the agent's income variable as a consequence of the presence of random shocks that influence the outcome. Hence, the result of the agent's effort would depend not only on his own actions, but also on uncertain factors beyond his control. Being risk averse, the agent prefers a certain income to an uncertain income. The optimal contract needs to strike a balance between providing incentives for the agent to exert effort and alleviating his exposure to risk.

As mentioned before, the payment mechanism in most of the livestock contracts combines the existing division of production responsibilities with a piece rate and some type of a relative performance bonus. The literature on agricultural contracts has shown that when it comes to efficient utilization of standard inputs (such as conversion of feed into pounds of live animal weight), such relative compensation schemes solve the moral hazard problem of both the agents and the principal (Tsoulouhas). In fact, absent bankruptcy concerns, a two-part piece-rate tournament provides a linear approximation of the optimal incentive scheme when agents are homogeneous in their abilities (Tsoulouhas and Vukina, 1999). With heterogeneous agents whose abilities can be observed by the principal, a menu of individualized contracts is optimal. The fact that individualized contracts are rarely observed is most likely the consequence of sizeable screening, administrative, and other transaction costs (Levy and Vukina). The currently observed payment mechanisms are unlikely to be optimal after contemplated regulatory changes take effect because different kinds of moral hazard problems would emerge over and above those already inherent in efficient animal fattening practices.

The intensity and bias of the moral hazard would depend on the division of responsibility for waste disposal because monitoring the nutrient content of feed and manure disposal is costly and imperfect. Each party cannot observe the effort exerted by the other. Also, some companies may perceive the exact feed formulations as trade secrets, and may be unwilling to disclose them publicly, fearing competition.

There are two ways the integrator can impact the nutrient content of manure through changing feed formulations. First, substituting synthetic amino acids for crude proteins (corn, soybeans) in animal feed can reduce the nitrogen content in manure up to 20% (Ferket et al.). The cost-efficiency of feed formulation is highly dependent on relative prices of competing inputs. When prices of corn and soybeans are high, replacing crude proteins with synthetic ones may be profitable. When prices of feed grains are low, absent any regulatory or other incentives, the feed rations will be based on crude proteins with high nitrogen in manure.

Second, changing animal diet can also reduce phosphorus pollution. Phytic acid constitutes approximately 65–75% of the total phosphorus in corn and soybeans. However, the problem is that phytic acid phosphorus cannot be digested by monogastric animals (pigs, poultry) and is excreted in manure. Therefore,

producers add inorganic phosphorus to diets to meet nutritional requirements of these animals. One way to increase the availability of phytic acid phosphorus is to add phytase to the ration to convert phytic acid into inorganic phosphorus. When phytase is added to the diets, inorganic phosphorus supplementation can be reduced 30–50% and still maintain optimal performance. The rations based on phytase are \$2–3 per ton more expensive than the regular inorganic phosphorus diets (Ferket et al.). While the use of phytase in animal rations benefits society by reducing phosphorus pollution, the cost is exclusively borne by the integrators. When responsibility for waste disposal remains with the growers, absent other incentives or regulation, the integrator will have limited incentives to mix the feed using environmentally friendly formulations.

While the integrator determines the feed composition and the type of waste management technology (slurry basin, lagoon, etc.) utilized, the growers can control nutrient pollution from animal waste by implementing environmentally friendly management practices. For example, reduced tillage, cover crops, and buffer strips can appreciably reduce phosphorus inputs to surface waters. If the waste disposal responsibility lies with the integrator, growers will have limited incentives to use best management practices that reduce nutrient runoff and leaching. Consequently, the contracts will have to be changed to accommodate the new circumstances.

Bontems, Dubois, and Vukina studied the problem of optimal regulation of private production contracts with environmental externality using generic policy instrument (tax/subsidy). They modeled a trilateral relationship between the regulator (EPA), the principal (integrator), and the agents (growers) with the technology characterized by a joint production of output (live animal weight) and pollution (waste). They found that in this three-tier hierarchy involving either a single-sided or a double-sided moral hazard problem, the principle of equivalence across regulatory schemes generally holds. In both situations, regardless of the tax legal incidence, for a given amount of tax revenue, the regulator can obtain the same outcome. The only task is to determine the optimal total tax revenue in each state, because any sharing of the tax burden between the principal and the agent would result in the same optimal solution. The results provide an important extension of earlier work by Segerson and Tietenberg, who studied the structure of penalties in a three-tier hierarchy under risk neutrality for all parties and moral hazard on the agent's side. They showed that the efficient outcome can be reached by imposing a penalty on either party.

### ***Multitasking***

In light of new regulation potentially forcing integrators to accept part or all responsibility for waste management, designing a new incentive-compatible contract may be so complicated that companies may seek alternative ways to organize their livestock production. The potential problem can be best explained by understanding that the standard agency theory considers only the agent's incentive to exert a single-dimensional effort. However, the production of animals involves at least two distinct types of effort, one related to the job of fattening the animals and the other related to manure management. Compensation schemes often

have unintended consequences resulting from agents changing their actions in ways privately beneficial to them, but harmful to their employers. Therefore, a potential cost of the pay-for-performance schemes is not only that they impose risk on agents, but also that the agents can “game” the evaluation procedure to their advantage (Prendergast). This arises because many jobs are too complex for all their aspects to be contracted over. Consequently, an agent could focus too much on the tasks covered by the explicit contracts at the expense of those not included. This type of distortion has become known in the literature as “multitasking” (Holmstrom and Milgrom). For example, if the integrator offers a higher return for feeding animals efficiently than for spraying the lagoon effluent according to the agronomic rates, the grower will allocate all his effort to reducing the feed conversion ratio, assuming that the cost of effort is the same for both tasks. This would happen even if the integrator would prefer that a grower allocate time to both tasks. To induce the agent to allocate time to both activities, the same incentives must be offered, even if this is not otherwise optimal. As a result, multitasking imposes constraints on the trade-off between risk and incentives.

Starting with the seminal papers of Holmstrom and Milgrom and Baker, economists have increasingly speculated that the existence of multitasking concerns may partly explain the tendency of employment contracts to use fixed wages rather than pay-for-performance schemes. This argument could be extended to the problem of integrator/grower shared responsibility for animal waste management. Once waste management becomes the responsibility of the integrators, they would have to contract with growers based on some type of waste management performance measure. For the most part, the measure would be different and independent of feed conversion ratio or other similar cost efficiency measures. Also, the waste management job is probably too complex for all aspects to be contracted. Instead of offering rather complicated contracts, which growers can possibly game to their advantage, the integrators may be tempted to offer simple wage contracts. Notice, however, that this type of remuneration changes the nature of the relationship dramatically and brings it substantially closer to the model of vertical integration via company-owned livestock farms that employ wage labor.

Finally, some of the multitasking problems may be solved through the ownership of assets (Prendergast, footnote 24). For example, a worker employed on piece rate may not take due care of the machinery because the incentives are simply to produce as much as possible in a given interval of time. In contrast, an agent who owns his machinery has better incentives to exercise proper care and would allocate his time to both production and maintenance. Notice that in the context of integrator-grower relations, the ownership of assets solution to the multitasking problem is similar in spirit to transferring the responsibility for waste management back to the grower.

### **The Incidence of Regulatory Compliance Costs**

Regardless of the final version of the new EPA livestock waste management regulation, it is safe to assume that new CAFO rules will increase the cost of producing livestock. Independent of the federal government, states are also considering new initiatives to regulate the concentrated livestock production

facilities within their jurisdiction. For example, North Carolina signed an agreement with Smithfield Foods, Inc., and Premium Standard Farms to provide resources for the development of “environmentally superior technologies” to traditional lagoon/spray field systems for treating swine waste. It is not known which of the alternative technologies will show the most promise; however, it is almost certain that the new technology will be more costly to implement than the traditional lagoon and spray field. If mandated by law, the implementation of alternative waste management technologies could have significant negative effects on the ability of the swine industry to compete successfully in increasingly open domestic and foreign markets.

The degree of cost pass-through is an important assumption in the analysis of the welfare consequences of government regulation. If an industry can pass on some of the cost of compliance to producers or consumers, the impact on the directly regulated industry will be reduced. Much of the empirical research in this area has tried to quantify the extent of packer/processor control in the livestock sectors, notably in the beef industry. Because of the high level of market concentration in this industry, there is concern that beef packing firms could exercise market power in the purchase of finished cattle by keeping cattle prices below competitive levels. In addition to oligopsony issues, cattle producers have expressed concerns about packer-owned feedlots and captive supplies (Azzam and Anderson). If any of these issues substantially affect finished cattle prices, they will affect the cost pass-through. The idea is that if meat packers can force the price of live animals below the perfectly competitive price, then producers will have little opportunity to pass on costs of regulatory compliance.

The organization structure of livestock production is characterized by independent producers, vertically integrated firms with company-owned production facilities, and vertically integrated firms with production contracts with independent farmers. The issues related to the farm-level price formation in livestock industries dominated by production contracts, such as broilers or turkeys, are different from those in the industries dominated by independent producers, such as the beef sector. One important difference is that the payment per pound of live weight that a contract grower receives does not reflect the marginal cost of producing a pound of meat. Instead, it represents only the compensation for production factors that contract growers provide (housing, utilities, labor). Of course, these payments can also reflect a degree of market power of the integrator on the market for growers’ services. Also, the contract-based price received by growers is *de facto* net of the risk premium that farmers are implicitly paying to the integrator for income volatility insurance. As mentioned earlier, all production contracts transfer significant aggregate risk from growers to integrators, a phenomenon that is entirely absent when goods are exchanged via regular market transactions.

Figuring out the distribution of regulatory costs in the hog industry will surely prove even more difficult because of the parallel existence of spot markets and production contracts. Kliebenstein and Lawrence characterize the pork industry in transition, with the shift from the beef to the broiler production model occurring at different rates in different regions of the country. Old production areas (Iowa) tend to function with spot markets while newer production areas (North Carolina) tend to use contract production. This dichotomy creates problems, as spot markets

are getting thinner and risk seems to be shifting from those with contracts to those without them. The increasing share of the production contracts between integrators and independent growers, as well as the integrator-owned farms in the overall supply of live hogs, can be perceived as deteriorating competition and price discovery in the swine industry. The phenomenon is quite similar to the effect of increasing captive supplies in the beef sector. The argument is that, as captive supplies replace independent swine production and provide a substantial portion of packers' needs, the price received by independent producers must necessarily go down (see Perry). Alternatively, spot market prices may be depressed because of higher transaction costs, product variability, and poor quality, regardless of whether market power is exercised or not (Paarlberg et al.).

Aside from the standard market power issues well documented in Azzam and Anderson, the degree of CPT in a vertically integrated industry using production contracts with independent farmers is likely to depend on the market power of the integrator on the market for growers. The large national companies (Smithfield Foods, Tyson, etc.) that run their businesses through smaller profit centers spread throughout the country dominate livestock contract production. Different areas are characterized by different levels of competition for growers. In some areas companies have difficulties signing up enough growers; in others growers have no feasible opportunity to defect and seek contracts with other companies.

In situations where an integrator has a substantial monopsony power in the market for growers, it is reasonable to observe contracts where growers earn zero expected rents. The CPT solution in this kind of market structure may show that regardless of how the regulatory burden is initially levied, the cost of compliance always ends up being borne by the integrator. This is because the growers' participation constraints were binding even before the new regulation was imposed (i.e., they are making exactly their reservation wage), so growers would not accept contracts offering worse terms.<sup>11</sup> However, assuming that contracts between the firm and the agents can be optimally revised following a change in the regulatory structure, all regulatory schemes would generate essentially identical results (Bontems, Dubois, and Vukina).

## **Liability**

Another possibility for providing incentives to livestock producers to act like good stewards of the environment is to make them liable for the actual damage they cause rather than regulating them *ex ante*. The liability arises under the common law of private and public nuisance and is enforceable through courts. The theoretical literature dealing with liability as a policy instrument descends mainly from the Coase theorem, and its main focus is on the efficiency properties of liability schemes and their comparison to explicit government intervention of the classical Pigovian sort. Under certain assumptions (small number of both polluters and damaged parties and negligible transaction costs) the liability approaches have been shown to be roughly equivalent in efficiency properties and superior to Pigovian taxes when behavior of agents is not cooperative (see Bohm and Russell).

The liability system may be a desirable way to approach problems for which information is scarce and expensive. An example of this is accidental waste spills

from large-scale confined animal operations, which occur quite rarely.<sup>12</sup> In such circumstances a designation of liability with the payment guaranteed by a performance bond or insurance policy could be appealing. However, the choice of a liability approach suffers from some serious disadvantages. Unless some special process of enforcement was designed up front, damaged parties would still suffer real damage, have to hire lawyers, and go to court to claim their entitlements and they would have to prove the connection between their damages and the act of the responsible party (Bohm and Russell).

One of the important goals of liability law is to provide the potential injurers with proper incentives to take adequate care in their actions. However, making firms liable for damages they cause fails to achieve a socially efficient outcome if the firm lacks resources to pay. In other words, injurers may sometimes cause damages in excess of their resources. This is what has been labeled in the literature as the *judgment proof* problem (Shavell) or the problem of the *disappearing defendant* (Summers). These authors suggested that the potential insolvency can cause a reduction in care levels under strict liability because firms care only about the costs that they might actually have to pay. Second, wealthier firms or individuals may take greater care than poorer ones because they have more to lose and are less likely to escape paying damages through bankruptcy.<sup>13</sup> Translated into the context of livestock production contracts, facing increasingly stringent environmental regulation, growers are exposed to substantial risks of large penalties for environmentally hazardous disposal practices and especially catastrophic waste spills. Because growers generally have limited assets, the likelihood of bankruptcy is much larger for them than for the integrators, which are large, sometimes publicly owned companies. Ignoring externalities associated with animal waste, the observed contracts should be efficient in the sense of maximizing joint integrator plus grower surplus. This explains why the existing contracts specify the contract growers as solely responsible for waste management and disposal. The internalization of animal waste externalities may require different allocation of liabilities for waste handling than that currently observed. This is the question that I will try to answer in this section.

A substantial increase in the number of environmental clean-up cases during the 1980s coupled with an increase in the entry rate of small judgment-proof firms into hazardous sectors (Ringleb and Wiggins) has stimulated interesting literature on vicarious liability. The results from this literature could be extended to other cases of vicarious liability, such as the integrator-grower relationship. Instead of being a lender, the principal can be an integrator company and the owner of the judgment-proof firm can be an independent contract operator. The early literature on judgment-proof firms has produced contradictory results. For example, Pitchford has argued that the incentives for accident prevention of a small judgment-proof firm may actually be reduced if the lender's assets are used to pay for liabilities that the firm cannot afford. On the other hand, Hayes and Boyer and Laffont have suggested that lender liability would increase the incentives for accident prevention. The solution to this apparent contradiction is found in Balkenborg, who claims that the distribution of bargaining power between the lender and the owner of the firm is the key to the puzzle.

Making the lender liable for the damage caused by the owner of the firm can have two effects. First, it may induce the lender to provide stronger financial

incentives for the owner to take better care. Second, in order to be compensated for the risk of high liabilities, the lender may demand higher interest payments when no accident occurs, thereby reducing the owner's gain from accident prevention. Balkenborg shows that the first effect is decisive when the lender has high bargaining power and can extract a high share of the surplus from the financed project. On the other hand, if the lending market is close to perfectly competitive, the second effect dominates and Pitchford's results continue to hold. From the social welfare point of view, it is never optimal to set a joint and strict liability<sup>14</sup> so high that the deep pockets of the lender are employed if the bargaining power of the lender is low. Contrary to that, for high bargaining power of the lender, the optimal joint liability employs deep pockets of the lender and may in fact be punitive (i.e., exceed the actual damage costs).

The implications of these results for the vertically integrated livestock sector that contracts the production of live animals with small independent farmers are straightforward. In geographical areas where the market for growers is fairly competitive such that the integrator's bargaining power is rather low, making integrators liable for environmental damages caused by the growers is not theoretically justifiable. On the other hand, if the integrator is the only game in town and the probability of growers defecting to another integrator is low, making integrators liable for environmental damages caused by the growers may be socially optimal. This result is especially important in light of the newly proposed CAFO regulations, which envision both the integrator and the grower being jointly co-permitted for the operation of any intensive livestock facility.

## Conclusions

The policy discussions about the potential linkages between contracting and livestock waste problems have been focused on two sets of issues. One set relates to the emergence of livestock waste as a major environmental problem that requires urgent regulatory intervention. Implicit in this debate is the notion that animal waste-related environmental problems have been caused or exacerbated by the organizational structure of the livestock industry, notably its high degree of vertical integration via production contracts with independent farmers. Another set of issues relates to the design of regulatory policies that could be implemented given the existing organizational structures of various livestock industries. As far as the emergence of animal waste as a major environmental problem is considered, the central objective of this paper is to try to answer the question of whether contracting worsens livestock waste management problems and if yes, then how and to what degree? When it comes to designing an appropriate regulatory regime, the paper focuses on the question of how to apportion the burden of regulation among the contracting parties in a socially optimal way.

The evidence about the potential linkages between contracting and animal waste management problems presented in the paper fits into four categories: (1) scale, (2) specialization, (3) concentration, and (4) division of inputs and contract settlement.

1. While the impact of contracting on productivity is sizeable, contracting does not appear to have large-scale effects. This result suggests that the increased

productivity of contract operators is not a major force driving the increase in the scale of production of hog farms. On the other hand, the production technology, which displays increasing returns to scale regardless of the ownership structure, does serve as a motive for increasing the size of both independent and contract operations. Also, large is not necessarily bad. Again, because of significant economies of scale, this time in waste management, intensive livestock production units could, in fact, be environmentally friendlier than small, family farms because they can make technologically advanced waste management systems economically feasible.

2. It is true that contracting creates more specialized animal production operations, thereby breaking the tradition of joint production of crops and livestock that characterizes traditional independent family farms. However, the joint production of crops and livestock may not necessarily be friendlier than specialized production. Farmers tend to apply livestock manure in excess of the amount that would require just substitution of the chemical fertilizer. By applying manure on any given field, they not only receive the nutrient benefits of that application but also save on the transportation costs relative to applying the same manure on more distant fields. This result shows that the use of manure can be expected to worsen nutrient runoff and leaching from croplands regardless of whether the livestock producer is a contract operator or an independent farmer.
3. Contract production results in high concentration of livestock production facilities in a few geographic areas. However, there is also a tendency for the independent livestock producers to concentrate in certain geographical areas because of significant agglomeration economies. The established network of feed mixers, slaughtering plants, specialized construction companies, extension specialists, veterinarians, and banking services geared around the specific needs of livestock producers as well as the local availability of skilled labor could become important factors of industry growth in certain regions. However, concentration is not necessarily bad either. An empirical estimate of environmental damages caused by the proximity of large-scale hog operations suggests that social welfare would be enhanced by directing the industry expansion towards areas where the concentration of animal units is already high, rather than distributing the future animal industry growth more evenly across the landscape.
4. The amount of nutrients from animal waste deposited in the environment is directly related to the composition of animal feed. The tension in the contract arises from the fact that integrators determine the nutrient content of manure through decisions about genetic makeup of animals and their feed rations, but growers own the manure and are legally liable for its removal and disposal. Given the fact that monitoring the nutrient content of feed and manure is costly and imperfect and each party cannot observe the effort exerted by the other, the net benefits (cost) of nutrient application may fail to get incorporated into the payment schedule of a production contract. Therefore, the question of the division of responsibilities for providing inputs in livestock production and the resultant payment schemes used to settle the contracts becomes important for purposes of optimal contract design.

Without precisely knowing the nature of the future changes in the regulation of animal waste that may emerge, the discussion in the paper is based on two assumptions: first, that the division of responsibilities for the removal and disposal of manure will be regulated toward some form of a shared responsibility between the integrators and the growers, and second, that the cost of waste management, as a result of new regulation, would increase. The conclusions reached in this paper belong to three larger groups of regulatory issues: (1) contract regulation, (2) regulatory compliance cost incidence, and (3) liability.

1. In light of substantial multitasking problems, the regulation toward some form of shared responsibility between the integrators and growers for manure disposal may render the currently used relative performance, piece-rate remuneration schemes obsolete. It is conceivable that rather than switching to fixed wage contracts as a method of rewarding their growers, integrator companies may gradually change their organization structure towards more company-owned farms. Such an important shift in the industry structure away from contracting may have dire implications for local rural communities in many parts of the country. Especially strong impact could be felt in the Southeast, where many small, family farms heavily depend on the supplemental income from contract poultry operations.
2. The incidence of anticipated increases in environmental compliance cost may depend on the market power of the integrator on the market for grower services. In markets with absolute monopsony power of the integrator, the increased cost of environmental regulation is likely to be borne by the integrator. However, when contracts are allowed to adjust optimally to changes in regulation, all regulatory schemes turn out to be welfare equivalent.
3. The concept of shared responsibility for accidental waste spills between the integrator and growers may or may not be welfare enhancing depending on the relative bargaining power of the integrator on the market for growers. In geographical areas where the competition for growers is fairly fierce, making integrators liable for environmental damages caused by the growers may not be theoretically justifiable. On the other hand, if the integrator is the only game in town and the probability of growers defecting to another integrator is low, making integrators liable for environmental damages caused by the growers may be socially optimal.

Finally, one has to admit that a lot of unanswered questions remain about how regulation should be imposed and how it will affect contract structure and organization of livestock industries. If the public policy in this area is to receive sufficient scientific guidance, it is essential that more research be conducted in three areas: the optimal regulation of production contracts with environmental externalities, the incidence of regulation compliance costs, and the optimal allocation of liability for accidental catastrophic waste spills. As several of the results may critically depend on the degree of market power of the integrator in the market for growers, the development of the methodology and the empirical estimation of the degree of integrators' oligopsony power may be especially important. The cooperation between academia, the livestock industries, and both federal and state agencies

may prove to be essential, because the empirical data for these types of analyses is rather difficult to obtain.

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## Endnotes

<sup>1</sup>It has been estimated that well over 90% of broilers and 32% of hogs are currently produced under contracts (U.S. Department of Agriculture).

<sup>2</sup>Much of the empirical research in this area has tried to quantify the extent of packer/processor control in the livestock sectors. If meat packers can force the price of live animals below the perfectly competitive price, then producers have little opportunity to pass on the costs of regulatory compliance. For an extensive economic history and review of the empirical evidence, see Azzam and Anderson.

<sup>3</sup>Full text of the proposed legislation is available on the Iowa Attorney General website: <http://www.state.ia.us/government/ag>. For an overview of the history of attempts to regulate contracts, see Tsoulouhas and Vukina (2001).

<sup>4</sup>Gollehon et al. have shown that confined livestock and poultry farms produced over 1.2 million tons of recoverable nitrogen and 0.7 million ton of recoverable phosphorus in 1997. Most farms (78% for N and 69% for P) have adequate land on which it is physically feasible to apply the produced manure at agronomic rates. Still, manure produced on those operations that cannot fully absorb it at agronomic rates accounts for over 60% of manure nitrogen and 70% of manure phosphorus.

<sup>5</sup>The Clean Water Act is the major federal law affecting manure management on animal operations, under which the National Pollutant Discharge Elimination System (NPDES) program covers animal feeding operations meeting certain criteria. For an overview of current regulations under NPDES, see Gollehon et al.

<sup>6</sup>Notice that this result is valid only if the increased production dispersion (decreased concentration) causes the environmental costs to decrease. This will be true under the assumptions that manure applications of larger facilities cause more per-unit environmental damage than those of smaller facilities, and that ambient external costs of livestock operations are convex. Frequently, those assumptions are not likely to hold.

<sup>7</sup>As pointed out by an anonymous referee, this result hinges on the assumption that property values fully reflect the external cost of livestock waste pollution. Any information asymmetries or the complete lack of scientific information about long-run effects of waste pollution would prevent these effects from being capitalized on in the property values.

<sup>8</sup>For a nice summary of criticisms of the Coase Theorem, see Cooter.

<sup>9</sup>The same is true for the shadow price of carcasses. The prices that rendering plants pay livestock producers for mortality disposal vary dramatically (and can be negative) and are negatively correlated to the prices of other proteins, such as soymeal and fishmeal.

<sup>10</sup>For surveys of the principal-agent literature, see Hart and Holmstrom and Levinthal.

<sup>11</sup>There is something to be said about the possibility of integrator's postcontractual opportunism of another kind. Realizing that a grower (tied down with the ownership of large relationship-specific investments) has nowhere to go, the integrator may change the contracts and offer worse payment than in the original contract. In the dynamic context, however, the integrator's reputation problem could alleviate the hold-up problem.

<sup>12</sup>In June 1995, after 21 inches of rain had fallen over a 3-week period, the dike impounding an above-ground lagoon near Jacksonville, North Carolina, broke, spilling more than 20 million gallons of sewage into the New River and causing a massive fish kill. Four other hog lagoons and a poultry lagoon experienced spills that summer. In response to those events, the governor ordered the inspection of all lagoons in the state. Among more than 4,000 lagoons inspected, 2.8% were found to have illegal discharge devices and 10% had lesser problems such as eroded banks or insufficient freeboards. One producer had no spraying field, but was discharging effluent into a swamp (Martin and Zering).

<sup>13</sup>Beard has actually shown that for the case of risk-neutral injurer, both of those conjectures are not completely general. Depending on the circumstances, the injurer can also take too much care and his care levels are not generally increasing in wealth.

<sup>14</sup>A *joint and strict liability* rule requires the owner and the lender jointly to pay the liability if an accident occurs.

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