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Utilizing Contingent Claims to Improve the Management of CAFOs

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We propose a market-based approach to reducing the environmental risk posed by concentrated animal feeding operations (CAFOs). The dual problems of hidden information and hidden action faced by policymakers are considered alongside the competing incentives faced by the CAFO manager in a multiple principal-agent setting. A new approach that uses insurance-like contracts is introduced by use of the specific example of a swine operation with a lagoon-based manure management system. Index-based contingent claims contracts in tandem with third-party auditing and waste hauling options are introduced as a complement to regulatory frameworks designed to reduce negative externalities from production.

Key Words: animal feeding operations, asymmetric information, environmental risk, insurance, public policy, regulation

JEL Classifications: D82, G22, L51, Q18, Q25, Q28

We introduce the idea of using market-based solutions along with regulations to reduce the environmental risk associated with animal feeding operations (AFOs). There is an emerging literature regarding how insurance underwriters, who are risk-sharing partners, might be more effective in changing behavior than government regulators (Freeman and Kunreuther 1996, 1997; Kunreuther, McNulty, and Kang 2002). This literature is motivated by the incentives to change the hidden information and hidden action that are at the core of success or failure in regulating industrial processes to control externalities.[1] This has been a major reason for recent changes in concentrated AFO (CAFO) regulations that require more information via Comprehensive Nutrient Management Plans (CNMPs). The

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[1] Hidden information and hidden action are the most specific terms to describe the particular sources of information asymmetry present. Every attempt is made to use the most specific language possible throughout. The more general terminology of adverse selection and moral hazard will only be used in the context of risk-management instrument design.

challenge in designing market-based solutions involves considering how to build on the existing regulatory frameworks. More fundamentally, the ideas presented here would use information from the regulatory requirements, science-based models, and third-party auditing to both mitigate and shift risk in the operation of CAFOs. The case of a hog operation with an anaerobic waste treatment lagoon will be used throughout this article for the illustration of key concepts. The broader application of these ideas to facilities with different waste management systems and species is addressed in the conclusion.

Background

Much attention has been devoted to AFOs in recent years as a result of industry concentration, accompanied by a change in production methods, higher observed levels of water pollution attributed to such operations (U.S. Environmental Protection Agency [EPA]), and several high-profile environmental accidents that have been widely reported in the media. An April 1993 *Cryptosporidium* outbreak in the Milwaukee drinking water system that was attributed to runoff from livestock waste on nearby dairy operations caused over 40 deaths and 370,000 illnesses (Terry). In 1995, the collapse of a wall at a 10,000-head swine operation in North Carolina resulted in the release of a volume of hog waste two times that of the Exxon Valdez oil spill—25 million gallons (Smothers). Hurricanes in North Carolina in 1996 and 1999 generated a great amount of publicity around large-scale hog confinement operations in that state (Kilborn) and intensified the national dialog about the risks of environmental release posed by such large scale livestock operations.

With greater public attention to this contentious issue, there has been increased regulation which has:

- defined different size classes with the largest such operations designated as CAFOs;
- required permitting under the National Pollutant Discharge Elimination System (NPDES) for operations on the basis of size or individual system characteristics;
- put in place design standards for waste management systems; and
- prescribed the adoption of best management practices (BMPs) for waste handling and utilization.

The most recently issued federal regulations are contained in the EPA's Final CAFO Rule (Final Rule)[2] and have increased the number of operations nationwide that fall under the requirements for a permit. A key aspect of the Final Rule designed to improve manure management was initiated under the Unified National Strategy for Animal Feeding Operations (U.S. Department of Agriculture [USDA] and EPA)[3] and requires operations to submit CNMPs by 2006.

The use of design standards, nutrient management planning, and mandatory permitting has effectively imposed new costs on operations; regulation has occurred in an attempt to force operations to internalize the cost of negative externalities generated through the production process. The EPA has estimated the total annual cost of the Final Rule to be about $335 million, inclusive of CAFO compliance expenditures and administrative costs to federal and state governments.[4] The implementation of federal CAFO regulations is accomplished through cooperative federalism in the states. Local implementation of CAFO regulations has been observed to vary widely from state to state and among livestock species within the same state (America's Clean Water Foundation). There may be multiple reasons for observed variation in regulatory stringency across different jurisdictions (Hellund), but public scrutiny motivated by localized environmental events is believed to be among the most significant factors in the case of CAFOs.

The use of the court system to force gov-

[2] 68 Federal Register 29: 7175–7274 (February 12, 2003) relating to 40 CFR Parts 9, 122, 123 and 412; became effective in April 2003.

[3] 66 Federal Register 9:2959–3145 (January 12, 2001) relating to 40 CFR Parts 122 and 412.

[4] 68 Federal Register 29:7242–7250 (February 12, 2003).

ernment regulatory action or to force firms to limit externalities has been very common since the inception of most environmental laws in this country (Naysnerski and Tietenberg) during the 1970s. Litigation has been increasingly used by individual citizens and environmental groups to force firms to mitigate environmental damages and alter their operations in ways that are consistent with laws and regulations governing CAFOs. Because agriculture has been largely exempt from the Clean Water Act, many legal actions taken over issues related to CAFOs have been under tort law. The results have been mixed, in terms of legal outcome, but the effects of the financial costs of this entrenched system of litigation and the highly contentious nature of interactions between producers and citizen groups using lawsuits to execute a "polluter pays" approach to controlling environmental externalities have been substantial.[5] As a result of the highly litigious nature of the interactions between citizen groups concerned about the environment and the livestock industry, the expected costs of litigation must be considered by CAFO managers in making production decisions. These costs include the expected value of a settlement as well as the costs of defense, which can be considerable (America's Clean Water Foundation).

To consider the public policy problem that the government has attempted to solve through regulation, it is necessary to be mindful of the incentives and institutions involved in vertically integrated livestock production. Although the focus of this research is on designing more efficient solutions than relying solely on regulation, one must be mindful of the other principals that the economic agent—the CAFO manager—must respond to in day-to-day activities. Although some of these considerations are presented here, a more detailed, descriptive analysis is found in Skees, Black, and Gramig or Gramig.

In addition to the principal-agent interaction between the regulator and the CAFO, the firm manager is also accountable to the local community, the integrator that has a contract for delivery of livestock, the local Natural Resources Conservation Service office where CNMPs are filed, and any lending institution involved in capitalizing the construction and operation of a confined livestock operation. This diverse group of principals represents the competing interests present in the production and marketing of livestock products. When considering the regulatory problem faced by society and the specific principal-agent interaction between the regulatory agency and the firm, it should be clear that the CAFO remains an economic agent balancing competing incentives to keep a wide array of principals satisfied with the agent's performance. This is necessary for the CAFO to stay in business.

The economic and management decisions made by the producer are based on the expected economic values (either costs or revenues) of different actions. The regulatory problem is, from the perspective of the agent, one of the expected probability of getting caught and the particular penalty associated with different regulatory infractions. This introduces an important aspect of the public policy problem that is common to any form of regulation (or contract enforcement). As long as either the probability of detection or the magnitude of the penalty are perceived to be small, economic incentives are not sufficient for the agent to abide (at least in whole) by the particular regulation. This is an important problem for CAFO management, because of the multistage production and waste management process, a lack of monitoring infrastructure capable of handling non–point source pollution from agricultural runoff, and a number of other factors.[6] CAFO management has

[5] For a more thorough discussion of trends in litigation under federal law (includes the Clean Water Act, Resource Compensation and Recovery Act, and Racketeering Influenced and Corrupt Organizations Act), state law, and tort law against animal feeding operations, see Appendix M of the report by America's

[6] Vukina frames the balancing of objectives that are referred to in this research as the "multi-stage production and waste management process" in the context of Holmstrom and Milgrom's analysis of principal-agent

strong incentives not to get caught in any violation a first time because of the likelihood that, once caught, the scrutiny of the operation by regulators is increased. Additionally, it has been found that the severity of financial penalties for water quality enforcement actions taken against repeat offenders is greater than that for first-time offenders (Oljaca, Keeler, and Dorfman).

Public Policy Problem: Information Asymmetry and Site-Specific Factors

The problem that public policy has sought to solve through regulation has two key dimensions that lend themselves well to the contingent claims-based solutions that we propose. First, the problem of ensuring that management occurs consistent with regulations has principally been one of information asymmetry between society and the AFO. There are two types of information asymmetry present in the principal-agent relationship that exists between the government regulator and the AFO subject to regulation.

AFOs possess a great deal of private information about their operations, which prevents communities and environmental enforcement entities from efficiently limiting pollution through regulations or required BMPs. The most basic information that an AFO possesses and that regulators do not is the data required to determine whether or not an operation meets the criteria for an NPDES permit. Sorting operations into size classes for regulatory purposes is just one example of the considerable informational advantage that AFOs have had over those charged with regulating them. This may be stated as a hidden information problem according to the information economics literature; "adverse selection" is the common terminology in the insurance literature when referring to risk classification.

Hidden information also affects the design of regulation (design standards for waste management systems, required BMPs, etc.). Because the firm is presumed to have better information than the regulator about the costs of production and the nature of their production function (animal product and manure output are jointly produced), it is exceedingly difficult to adhere to the economic theory of regulation, which seeks to limit externalities to socially efficient levels. Although the social cost of externalities from a firm or an entire industry may be theoretically calculable, any difference between the social cost and the private costs borne by the firm likely cannot be determined by government regulators. The provision of a subvention to cover all or some portion of the cost of limiting externalities to socially efficient levels is clearly complicated by hidden information.

The other informational advantage that AFOs possess is the result of what is known as "hidden action" in information economics. This concept is referred to more generally as "moral hazard" in the insurance literature. The terminology used can be a source of confusion when one delves into the specifics of such a multifaceted problem. In an effort to use the most specific language possible, we will use the term "hidden action" when we are discussing the nature of the information problem. "Moral hazard" will only be used in the context of underwriting. Although hidden action is a source of moral hazard in insurance, it does not constitute fraud unless the terms of the contract are violated.

If one views regulation as a contractual relationship (albeit entered into coercively) between the principal and agent,[7] any actions taken by the agent that violate regulations constitute a breach of contract. It is the desire of the regulator to limit such violations, but, to the extent that certain firm activities are not verifiable (because of principal budget constraints, high transaction costs of measure-

same problem referred to here, only the issue raised in Vukina considers the concept of integrator-grower

[7] While referred to as being a "contract" entered into coercively, the regulatory "contract" is bilaterally determined through administrative rulemaking, and the industry has effectively altered proposed rules through lobbying between the filing of the proposed Final Rule and the final version as published. Integrator liability is one significant provision that was initially proposed

ment, etc.), hidden action is believed to be a persistent source of AFO externality. Hidden action is a common problem in environmental monitoring and enforcement and is of particular concern for continuing compliance aspects of AFO regulation.

The second aspect of the public policy problem relates to the individualized nature of AFO structure and management. Not only is hidden information present in the classification of operations for permitting, but there are a number of site-specific factors that play a significant role in determining the environmental risk of a particular operation. Agronomic and hydrologic variables like soil type, slope of the land, and proximity to surface and groundwater resources must be considered. The type of waste management system (technology) used is important. For instance, both wet and dry manure storage systems exist, and there are several types of system configurations that can be used for wet or dry storage that have different implications for environmental risk when considering other site-specific and management variables. Weather is also an important factor to consider, and it can be a compounding variable when poor management or equipment failure occurs. All of these considerations contribute to the individualized nature of a public policy problem where regulatory rules cannot effectively address externalities from a very diverse set of sources. Given these limitations of regulation, a nonregulatory solution to the information and site-specific nature of the problem may complement the public efforts to control risk in CAFO management.

Proposed Solution

Society has attempted to limit externalities through what have become known as "command-and-control" methods, which have been a common approach to environmental policy in the United States. We described this approach above as a "polluter pays" model of regulation, because it seeks to extract the full cost of operation from the firm. Economists have called for greater efficiency in regulation nisms for the control of pollution. There is a rich literature discussing mechanisms for the more optimal performance of environmental policy.[8] We present a new proposal to address individual system risk and CAFO manager behavior, with the goal of increasing efficiency in achieving public policy objectives. *Reducing the risk of failure* is a key aspect of achieving these objectives. In the context of the present article, "failure" is defined as any breakdown in the waste handling system that results in documented damages to water resources, land resources, aquatic species, or wildlife habitat. In simple terms, a failure can occur in the form of a breach over the dam of a lagoon or as a result of the overapplication of manure to a crop or cropland. Assessing this risk can be complex.

One key aspect of the Final Rule presents a new opportunity to utilize market-based risk management instruments to address the dual problems of information asymmetry and the site-specific nature of environmental risk from CAFOs. The introduction of required CNMPs represents a considerable information concession on the part of livestock operators that has bearing on the hidden information problem for regulators and society. Because CNMPs are individually tailored to a specific operation, they contain the information necessary to evaluate site-specific environmental risk when they are analyzed in light of the biophysical interaction between the manmade waste management system and the natural system (watershed or ecosystem) where the CAFO is located.

Contingent Claims as an Alternative to Litigation and Regulation

The class of market-based solutions proposed here would use contingent claims markets to achieve the goals of public policy. Freeman and Kunreuther (1996, 1997) reviewed the relative transaction costs associated with an insurance solution versus litigation and tort. They compared the amount of claims settle-

[8] Stavins provides an excellent review of such in-

ments that went to remediation for an environmental problem (about 40%) versus the percentage of premium going to indemnity payments to fix an environmental problem (about 75%) and concluded that properly designed environmental insurance products should be more socially optimal than more litigation and regulation.

It can be argued that regulations and litigation are costly ways for society to address environmental externality problems (Gray; Hylton; Polinsky and Shavell; Trubek et al.; Viscusi 1983, 1998). Command-and-control regulation creates an adversarial relationship between the regulator and those being regulated. This adversarial relationship often results in mutual suspicion and distrust. Typically, the individual or firm being regulated will provide the regulator with no information beyond the absolute minimum required to satisfy the law. CAFO operators might respond more favorably to a risk-sharing partner than to a government regulator. As a result, a diligent insurance underwriter might be more effective than a government regulator in improving manure management and reducing the likelihood of system failures. If insurance solutions prevent litigation, then society could be made better off by lower costs associated with such solutions. Before developing this theme further, it is important to provide a primer on insurance, so that its principles are understood.

Background on Insurance

Keep in mind that, despite the premise that contingent claims might provide a more efficient solution than regulation or litigation, insurance solutions are not easy. Effective underwriting must be used to rectify information asymmetries that cause adverse selection and moral hazard. There are at least four keys to effective underwriting:

(1) Proper risk assessment procedures (engineering models like the one used in the present study are intended to serve as one mechanism to accomplish this task);
(2) Proper procedures to properly classify the risk of potential policyholders;
(3) Proper insurance policy designs that mitigate the opportunities for insureds to benefit from their superior information; and
(4) Good monitoring systems that allow for discovery of problems created when the insured changes their behavior in ways that increase their risk.

Items one and two are designed to address adverse selection (hidden information) by classifying risk *ex ante*. Items three and four are designed to address moral hazard (hidden action) with clear rules for the insurance and monitoring of the insured after the purchase. Noting these keys to effective underwriting, the goals for CAFO environmental insurance that are carried forward in the present article are to

(1) Provide insurance that will improve the incentives of farmers;
(2) Give strong preference to insurance concepts that would compensate farmers to mitigate the risk *ex ante* rather than those that would pay after a problem has occurred;
(3) Create incentives that couple the insurance with a stronger regulatory response for bad managers; and
(4) Make certain that the events that are being indemnified are well defined and can be measured.

For insurance to be developed and sold to animal producers to mitigate the risk of animal waste system failures, it will be important to create a market for such a product. In creating that market, it will be critical that the insurance policies offered to producers are affordable. Third-party audits could play an important part in this effort. If an insurance product could be created in which the premium were lowered for animal producers that voluntarily had third-party audits of their facilities for environmental compliance, the risks and premium rates would decline.

inspection of this kind is in the ability to distinguish between high-risk and low-risk parties (Kunreuther, McNulty, and Kang). A firm that allows auditors to inspect its facility can do this as a way of revealing its risk of failure. This is referred to as "signaling" in the information economics literature, and it subsequently reveals information necessary for insurance to be priced accordingly: higher for those who are operating at an elevated risk of release and lower for those who have reduced their risk. This signaling is also potentially important from a regulatory perspective, as will be discussed below.

A number of insurance alternatives can be considered for CAFOs. At one end of the spectrum is the complete contract, which would indemnify the farmer for any environmental problem that might be created by manure. At the other end of the spectrum, one can consider something much simpler, which would pay only on the basis of excess rainfall that might create manure management problems. There are several alternatives that fall somewhere between these two extremes. As shall be explained, the alternatives are likely more practical. The example of a swine operation with a lagoon-based waste storage system will be used as a case to consider different potential risk-sharing arrangements.

By this point, it should be clear that offering insurance for any environmental problem that is created by a CAFO would be problematic. The asymmetric information regarding the management of the operation would unquestionably be plagued by adverse selection and moral hazard problems. Offering this type of insurance would be extremely difficult because of the problems associated with developing expected losses that drive premium rates. Every policy would need to be rated for premiums on the basis of the location and the proximity to natural resources that could be damaged when there is overtopping from the lagoon, leakage from the lagoon, spills during application, or overapplication. The scope of things that could go wrong would be very large, and many of the potential problems would be linked directly to management. An open-ended contract that would pay for damages has the potential to encourage bad management and increase the environmental risk if the policy were offered without third-party inspections. Even with third-party audits, there are many things that can go wrong and would not be considered insurable. For example, a bad motor causing a spill would generally be excluded from most insurance policies of this nature (any equipment failure is generally excluded).

The complexity of writing a clear traditional liability policy that would include all of the necessary exclusions makes it unlikely that such policies will emerge. No insurance provider would want to offer this insurance if the policy language could not be written in a clear fashion. Litigation over confusion in what is insured and what is not can be quite expensive in both time and direct financial resources. Nonetheless, certain "acts of God" may be insured at some level under certain conditions. This is more likely true if these events can be well defined and if they do not carry the burden of being highly correlated.

A Base Model for Index-Based Insurance

Given that certain problems with manure management are caused or compounded by extreme rainfall or chronic rainfall events, the simplest contract for managing environmental risk by CAFOs may be rainfall insurance contracts. Rainfall insurance contracts could be used to indemnify CAFOs when there is excess rain and a high likelihood that the lagoon levels will be high. These indemnity payments could be used to pay fines and/or compensate for lost income from not being allowed to feed animals during the winter months.[9] CAFO op-

[9] A common consequence of violating management guidelines required under federal or local environmental regulations that is imposed by integrators on CAFO operators producing animals under contract is to withhold feeder pigs for a single cycle in annual production as punishment for failing to adhere to required BMPs. One example of this is when lagoon storage levels exceed the minimum reserve capacity required to contain rainfall events. This is referred to as emergency storm storage, or, alternatively as "freeboard" or "slack capacity." This and other incentives in the multiple principal-agent relationship surrounding CAFO operators are discussed in much greater detail in Skees, Black, and Gramig.

erators would be less likely to risk causing environmental damage by improper spraying if insurance indemnities compensated for lost production (Martin, Barnett, and Coble). Still, the use of rainfall insurance contracts would be more in the class of a derivative product, in that the direct link to the event and the damage may or may not be clearly established.

To design effective derivative products that would serve as insurance, there must be a strong correlation between the event (excess or chronic rainfall) and the damage. To provide an example of how such a product might work, consider the following scenario. If it is determined that rainfall amounts in excess of 10 inches over a 3-day period place manure systems at added risk, one could write an insurance-like contract that would make direct payments for amounts in excess of this level. The payments could be set at specific levels for every one-tenth of an inch above 10 inches. One can also envision that an upper limit on the payments would be established by the writer of this contract. For example, once rain during the period exceeds 20 inches, there would be no more payment. The maximum payout or liability could be set at $1 million.

In the language of derivatives, the 10-inch rainfall measurement is called the strike or trigger, the one-tenth of an inch payment increment is called a tick, and the $1 million maximum liability is called the limit. Between 10 and 20 inches there are 100 ticks [(20 − 10) × 10]. The value of a payment for each tick is determined by maximum liability divided by the total number of ticks [$1,000,000/100], in this case $10,000. Thus, if the rainfall measurement is 11.2 inches, the payment will be based on 12 ticks [(11.2 − 10) × 10]. At $10,000 per tick, the payment would be $120,000 [12 × $10,000]. This payment would be made regardless of whether there is a problem with the manure lagoon.

The premium rating for this rainfall insurance contract would be relatively straightforward, because it is based on the history of rainfall events in excess of 10 inches over a 3-day period for the specific locale. The key questions for the farmer are what strike to select and what limit (liability) makes sense on the basis of risk exposure for an individual operation? The premium payments are based on the premium rate multiplied by the liability. Thus, if the premium rate for this policy were 3%, the farmer would pay $30,000 ($1,000,000 × 0.03).

The advantage of this type of insurance is that there is no adverse selection problem because of the nature of a rainfall contract, and resources are provided to prevent moral hazard.[10] Neither the CAFO manager nor the underwriter can control the amount of rain that falls from the sky, and both the CAFO and the underwriter have access to equivalent information about historic rainfall. Furthermore, it is entirely up to the farmer to determine the exposure and what liability is purchased. One can envision providing advice to a farmer faced with this choice. The question, "What do you think would be the worse-case scenario if your lagoon failed and most of the manure went into a nearby stream?" is certainly a starting point. The worse-case scenario, being mindful of the storm discharge exemption provided for in federal regulation, would be the basis for selecting the liability.

These types of contracts are most attractive in their simplest form, because they have very low administrative costs and address adverse selection and moral hazard concerns. The problem with the contract is that it is difficult to match the losses and the payments. It would be best used for truly catastrophic levels of rain that everyone knows will put the system under risk. However, given that there are exemptions for the 25 year 24-hour storm or the

[10] Improper disposal of manure (hidden action) could result from an indemnity being paid to the insured under a rainfall contract despite the intent that indemnities be used to mitigate the risk. For instance, the economic incentive to overapply manure when a storage lagoon is under stress from excess rainfall, given the perceived probability of detection or likelihood of a fine, may be considerable, because the firm receives an indemnity and minimizes the cost of reducing manure/wastewater storage levels in this scenario. Although this outcome may not satisfy the environmental objective of public policy, it does not violate the terms of the rainfall-based contingent claims contract and therefore does not constitute fraud in insurance terminology.

100 year 24-hour storm (depending on the species and age of the operation), the incentives for the farmer to purchase these contracts might be limited.

Index Insurance Based on Model Results for Well-Managed CAFOs

An insurance concept that falls in between the two extreme cases already discussed would pay on the basis of engineering model results. The manure system model developed by Considine and Burns for a report to the USDA Risk Management Agency (America's Clean Water Foundation) provides a unique opportunity to design an index-type insurance policy. The index would be calibrated to model results. The model uses an engineering approach to measure inflow and outflows for the total system, given the size of the manure holding facility, number of animals, agronomic system, the management plan, and weather events. The lagoon system storage level becomes the important output variable that affords the opportunity to offer a special insurance product that would be free of adverse selection and moral hazard.

As long as the manager follows the total management plan (the CNMP discussed above), model estimates of the system storage level will serve well as an index of potential challenges to the system. When the storage level approaches or exceeds the capacity of the system, there are at least three possible outcomes: (1) the lagoon will overtop, resulting in a manure spill; (2) the manager will overapply manure to control lagoon levels; or (3) the manager will develop new solutions to properly remove the manure, including the possibility of trucking the manure to a new location. Obviously, the latter solution is the preferred choice for society and, hopefully, for the producer. The degree to which storage level estimates exceed the capacity of the system should be directly related to the problems that will result from any one of the three outcomes above. The index would pay once the estimate of the water level from the model exceeds a specified level (recall that we call this the strike or trigger level) for a specific date. Furthermore, payments would be a direct function of model lagoon level estimates. Thus, as the water level exceeds the trigger level, the payments would increase in a similar manner as in the rainfall insurance contract explained above.

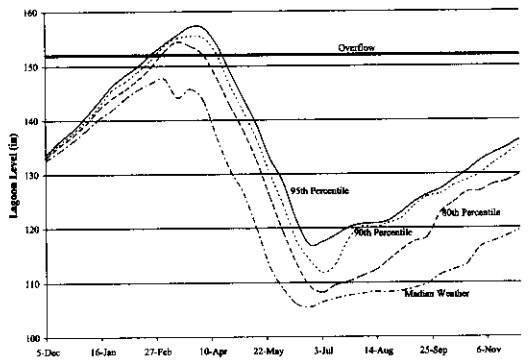

Figure 1. Model Results for a 10,000-Head Anaerobic Lagoon Swine Operation in North Carolina

An example should help clarify how this index would work. Figure 1 presents actual model results for a representative system in North Carolina. The lagoon overflow level is 152 inches. The system needs to be managed in such a fashion that the storage level will have nearly a zero probability of exceeding this level. The CNMP will be used to make certain that the system is properly managed. Third-party auditors would have access to the CNMP and be able to use that input to model the manure levels given the weather in the past 50 years. The model results presented in Figure 1 allow one to see what the lagoon levels would be, given the initial conditions, for the median and 80th, 90th, and 95th percentiles. As can be seen, the system is at considerable risk. There is in excess of a 20% chance that this system will exceed its capacity during the winter months. This is for illustrative purposes only.

The model demonstrates that the BMP involves getting the water level to 106 inches once the planting season is complete, on June 1. Under average weather conditions, the system will accumulate water slowly through the summer, because some dewatering is possible and sunlight and temperature result in evapo-

ration. Given average weather, the system would build up to about 146 inches over the winter and into early spring. On about March 15, dewatering can occur. Concerns arise as to when rain and/or lack of sunshine place extra stress on the system. The model can be monitored in early January by inputting the actual weather events. There should be ample warning when the system is being stressed and the likelihood of exceeding the capacity increases to unacceptable levels.

The contract would allow the farmer to obtain indemnity payments as the system approaches stress levels. For example, let us say that the farmer purchases a contract that would begin making payments any time the model water levels exceed 146 inches during the month of January. Again, the payment structure would be similar to the rainfall insurance contract. For example, one-half inch could be used as the tick. The payment schedule could be set at $1,000 for each tick above 146 inches in the model results during the month of January. The third-party auditor would be required to visit the farm when these thresholds are crossed in the model. At that point, the auditor would work closely with the farmer to determine how to mitigate the risk and prevent overtopping or the overapplication of manure. Funds from the insurance could be used to mitigate the risk. This could involve trucking the manure away, cutting back on the number of animals in the system, or gaining access to neighbors' fields to apply manure there. The third-party auditor would work with the farmer to determine the best mitigation plan given the indemnity payments. Should the mitigation plan not be sufficient and a problem still emerges, it is likely that regulators will be much more forgiving of these farmers than those who have problems but who have not attempted to mitigate the emerging problem.

Clearly, for such a system to work, the farmer has to trust the model. The model will only be useful if the farmer supplies good information with regard to the CNMP. When the actual system levels deviate from the model results, the third-party auditor will attempt to determine what caused these differences. There are several possible explanations: (1) the weather measures at the nearby station do not match precisely what happened at the lagoon[11]; (2) the farmer overapplied waste material on the farm; or (3) the model needs to be recalibrated.

There are several advantages associated with this insurance contract:

(1) Limited opportunity for adverse selection and moral hazard.
(2) Relatively low administrative cost.
(3) When coupled with the CNMP and the third-party auditor, there is significantly more information available.
(4) The opportunity is present to give an early warning signal of an emerging problem and make payments that can be used to mitigate the risk.
(5) The adaptive learning of the entire system with model results and fully priced insurance contracts should improve the management of the system and lower the risk of failure significantly.
(6) The initial lagoon levels will influence the pricing of the insurance in such a fashion that the farmer may have incentives to mitigate the risk early (e.g., if the differences in premium will at least pay for trucking the manure away before initiating the contingent claims contract, then there is an incentive to do this when the initial levels are high; however, there may also be an incentive to inappropriately lower lagoon levels initially).

With this system, the focus is on preventing a problem rather than providing compensation after the problem occurs; thus, the need to understand that potential local environmental losses are reduced. Nonetheless, the policy could be designed in such a fashion that, beyond certain levels, there is another policy altogether that would fully recognize that overtopping and environmental damage has occurred.

[11] This is referred to as basis risk. Backup low-cost instruments could be placed at the lagoon if there is a discrepancy. This already happens for frost insurance in California but more as a monitoring function.

Incorporating Hauling Options for Ex Ante Solutions

Given the model results index insurance, any number of companion products could be sold jointly with the base product. This product removes much of the correlated risk problem and opens the door for some tailored products. For example, an insurance company could consider writing specific perils that might involve random events that are not tied to the model results. The third-party audit gives much more information. This might then allow for an equipment failure rider to accompany the base model index insurance. Furthermore, extreme rainfall events could also be added as additional riders onto the base product.

The search for good insurance contracts has focused on contracts that potentially mitigate the frequency and severity of manure system failure and transfer a portion of the financial risk if a failure occurs. Regulators are particularly interested in contracts that potentially mitigate failures and ensure that resources are used to limit or pay for damage when a failure occurs.

Among the more creative ideas to emerge from a recent study completed for the USDA Risk Management Agency (America's Clean Water Foundation) is the concept of contracts that would result in hauling waste in such a way as to prevent or at least significantly reduce the chances of overtopping or overapplying manure. By incorporating waste hauling into the risk management portfolio for a CAFO, an additional aspect of the production system is incorporated. Hidden action in land application, or, more generally, waste utilization, is a significant regulatory hurdle that presents many challenges because BMPs are not verifiable.

The information asymmetry in this aspect of the production process was previously considered by Innes, Centner and Mullen, and Skees, Black, and Gramig. In addition, Gramig considered the notion of substitution among offenses (Smigel cited in Becker) from the economics of crime literature and applied this to the economic decision making of a CAFO subject to environmental regulation. Following from Becker's seminal work on the economics of crime, all of this work assumes that economic agents act on the basis of their assessment of the realistic probability of detection (alternatively referred to as the "credibility of the regulatory threat") associated with different actions or stages in the waste management system.

To illustrate this concept, the modeling examples developed earlier for the 10,000-head North Carolina lagoon system are used. For the purpose of illustration, the threshold volume is specified as being the total holding capacity of the system, but one could just as easily specify in the contract the removal of any volume that encroaches into the emergency storm storage, or "freeboard."

Table 1 depicts the percentiles of waste volume exceeding storage capacity if the system starts on October 1 with 12 inches in storage above the treatment volume.[12] Excess waste is not observed until the 95th percentile; or, to put it another way, there is a 5% chance of a potential failure. The challenge is to define a contract to reduce the chances of failure.

One approach would be to begin hauling waste if a signal appears that there is a good chance of system failure. That is, to push the percentiles at which failures occur to higher levels and the volume of excess waste to much lower volumes—preferably, zero. To implement such a program, an insurance provider could engage in a wide array of services for the CAFO manager. The provider could have contracts with a trucking firm that would guarantee access to trucks when the model results signal a problem. The multiple service provider could do the following:

(1) Offer a guarantee to prevent overflow by hauling excess or predicted excess manure/wastewater to a publicly owned treat-

[12] Treatment volume refers to the portion of the lagoon below a certain depth where a great deal of biological activity goes on to break down waste and to store heavy metals and other materials that remain within the manure storage unit. This volume represents a level below which the system is never drained for application purposes.

Table 1. Probability of Overflow, Quantity, and Cost of Disposal Estimates Over 12 Months Starting with 12 Inches of Working Volume on October 1

Percentile[a]	Excess Waste Volume (Ft^3)[a]	1,000 Gal[b]	Trucking Cost[c]
95%	31,816	238	$10,204
96%	50,906	381	$16,335
97%	65,259	488	$20,923
98%	70,141	525	$22,509
Average	4,630	35	$1,501
Max Since 1970	79,905	598	$25,639

Source: America's Clean Water Foundation, risk model results, modified January 2004.
[a] Values are output from the engineering model for a North Carolina swine operation.
[b] Gallon conversions from cubic feet are rounded to the nearest thousand.
[c] Trucking costs are calculated on the basis of $5.25/6,000 gal/loaded mile. The average haul is assumed to be 25 miles. A tipping fee is set at $21/1,000 gal.

ment works (POTW) for treating human sanitary waste or other disposal site (land application site, commercial composting, etc.).

(2) Choose to reduce the risk of overflow by slowly removing liquid given a model signal calibrated to the site. Those signals would suggest that a significant risk of waste system failure is emerging.

(3) Or, in lieu of hauling manure away immediately, wait for more evidence of potential system failure to act.

(4) Or, in lieu of hauling manure, negotiate a compensation or business-interruption payment that would require the CAFO manager to cease production or reduce the number of animals until the manure levels return to acceptable risk levels.

Adaptive management that accurately gauges the need for removal and the subsequent effective deployment of trucking services to implement timely removal would influence profit for the service provider.

The advantage of pairing the concept of an insurance policy based on the model results with the hauling option contract is that this combination truly does address the risk problem using mitigation. Equally important, under some conditions, the cost of hauling may exceed the indemnity payments that would be required to get the CAFO operator to cease production and stop generating manure. Making such payments, in lieu of hauling, would be equivalent to offering business interruption insurance to the CAFO and maintains the flexibility of achieving least cost risk management solutions.

One possible way to structure such an arrangement is presented. A trucking firm would sell options to a CAFO (independently or via an underwriter) to haul manure away during times of excess stress. The model results would be used to forecast periods when manure storage systems would be placed under undue stress. Given the CNMPs and third-party audits, one can envision a trucking firm offering insurance that would give the CAFO manager an option to employ trucking services to haul. The trucking firm would be legally required to haul away certain amounts of effluent when the model results demonstrate that a system is under stress. The trucking firm could determine when to haul away the effluent. A rational decision process would use the model results early on to signal that some hauling is needed because of expected manure management problems based on historic weather information and initial lagoon levels. Staging the hauling by removing some manure volume early on would be more economical and less alarming to the community (i.e., having a large number of trucks moving on country roads at the same time would likely attract the attention of the community).

There are two steps in calculating the cost of such a contract. First, determine the cost of

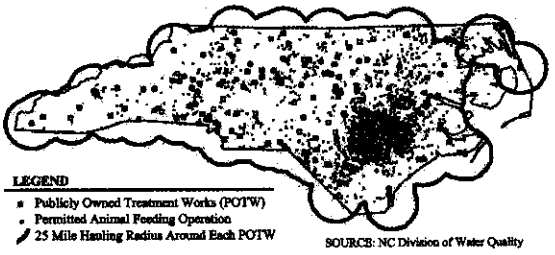

Figure 2. Spatial Illustration of the Overlap between Animal Feeding Operations and Wastewater Treatment Facilities in North Carolina

the trucking and tipping fee.[13] Second, assess the probability weighted average cost—determine the cost per gallon (cubic foot) multiplied by the probability of alternative excess waste volumes hauled. The probabilities for the case example presented here are given in Table 1. Estimated tipping fees at a POTW are $21/1,000 gallons (7.48 gallons/cubic foot). Trucking fees ranging from $2.50 to $3.50 per loaded mile for 6,000-gallon capacity trucks that would meet system requirements were observed with the lower end of the range for contracts that resulted in running at near capacity. In the case here, these would be option contracts that would be infrequently called into play; thus, a price of $5.25 per loaded mile was used. In many areas, trucks are routinely used to haul similar materials, so this fleet would not bear the full load; hence, $5.25 per loaded mile is a plausible provisional estimate.

Figure 2 shows the location of POTWs and permitted AFOs in North Carolina,[14] superimposed over a set of interconnected circles with a 25-mile radius. This mapping demonstrates that more than 98% of the AFOs in North Carolina are located within 25 miles of a POTW.[15] Thus, the cost for a 6,000-gallon load is approximately $260, or 4.3 cents per gallon. The average excess waste reported in Table 1 is 4,630 cubic feet (34,634 gallons), which gives a pure insurance premium before loading of $1,501, or $0.15/pig capacity. The premiums go up significantly if the system starts with a larger working volume or if the number of pigs per 1,000 cubic feet of storage capacity is higher. Keep in mind that the pure premium would be risk loaded to compensate for a number of uncertainties for the insurance provider. Thus, the loaded premium—the price that the insured actually pays—might be as much as twice the pure premium (the expected cost of the policy to the insurer). However, even at $0.30/pig, these costs are quite reasonable and should offer an excellent opportunity for protection.

Extensions and Obstacles to Implementation

The model that we have developed to use derivative instruments for environmental risk management represents a considerable departure from the way in which environmental policy has been approached in the United States to date. There are several extensions for the index-based contingent claims products proposed that have bearing on both private-sector risk management and public policy and environmental enforcement from a societal perspective. Several of these considerations are presented below.

Moving Toward Complete Contracts: The Hazard Analysis and Critical Control Point (HACCP) Model

As the regulation of CAFOs has escalated over the period from 1974 to 2003, policy has embraced a very individualized approach with

[13] POTWs generally charge for dumping effluent into their treatment systems. These charges are referred to as tipping fees.

[14] These data are from the North Carolina Division of Water Quality, Water Quality Section, for permitted animal feeding operations in August 2001 and for POTWs processing greater than 1 million gallons/day as of December 2003.

[15] The 25-mile radii used on the GIS map of North Carolina are drawn "as the crow flies" and therefore do not account for actual road miles from AFO to POTW. For the purpose of calculating the loaded road miles and estimating the cost of hauling excess storage volumes, 25-mile distances were used in Table 1 because of the good spatial coverage provided.

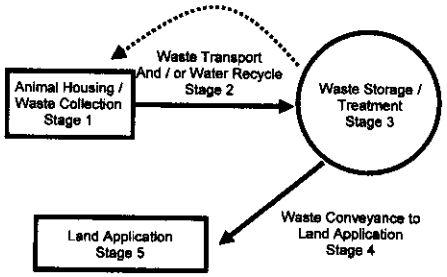

Figure 3. Five-Point HACCP Conceptual Model

site-specific facility design, permit, and nutrient management plans. This approach treats CAFOs like other industrial facilities, where negative externalities generated by the production process are the focus of regulations and facilities not adhering to regulations are subject to sanctions. Recognizing the similarities between traditional industrial activities and AFOs allows one to envision imposing a HACCP-type[16] program that would involve inspections of the critical control points where something could go wrong as waste moves through the entire management system. As depicted in Figure 3, there are five discrete stages in the entire production process that take place at any AFO that combine to create risks for society. At most, the contingent claims arrangements discussed thus far address risks in only two of these five stages. Even the hybrid-model index with hauling option described above only addresses system failures at stages three and five, related to lagoon management and land application. If the goal of using market mechanisms to manage risk and shift a share of regulatory functions to third-party auditors is to be fully realized, a more complete or total management system is required to address failures that can occur at any stage in the production process.

Implementing more complete contracts based on a HACCP-like model poses many questions related to firm profitability considerations and added transaction costs for the firm. If policy makers consider public support for the implementation of this type of system, a cost-benefit analysis framework needs to be used to evaluate the efficiency considerations from both a regulated firm and societal perspective. The movement to a HACCP system with private third-party auditors will require significant changes in the current regulatory structure if underwriters are to take over a share of the functions that have been traditionally delegated to state regulatory agencies through cooperative federalism. This revised arrangement could provide for more effective targeting of efforts by such agencies while simultaneously mitigating risks posed by CAFOs, *ex ante*; thus, achieving the goals of more traditional command-and-control approaches by using more flexible market instruments to address externality problems.

Linking the Base Insurance Product to Public Policy

Incentives may be needed to induce farmers to purchase the base product that would pay for emerging problems that are revealed from risk model results. Because this policy minimizes perverse incentives,[17] it may be appropriate to provide some base government support. Justification for government support is based on the recognition that the government has limited resources and expertise to address the environmental and health risks posed by animal agriculture. To the extent that contingent claims can satisfy policy goals that seek to curtail negative externalities from AFOs in a more cost-efficient and flexible manner than traditional regulatory approaches, insurance may provide a preferred solution. For example, the government could consider the following: (1) continuing to pay for a portion of the implementation costs of the CNMP with Environmental Quality Incentives Program cost-

[16] HACCP systems are customized systems for different types of industrial processes that involve extensive, regular inspection of all of the links in the production process where failures may occur. Coupling HACCP with insurance was previously proposed by Skees, Botts, and Zeuli for recall insurance as a food safety measure.

[17] Note that the potential incentive to improperly lower lagoon levels to reduce your premium before entering the contract remains.

share funding; (2) paying for the third-party auditor; (3) supporting, running, and improving the engineering/weather model developed for risk assessment; and (4) providing enough subsidy for the insurance product that the farmer would not pay more than the expected value of the indemnities. All of these considerations need more evaluation regarding the costs and benefits. In return for this type of support in a base insurance product, the farmers would provide full access to their records and farms to auditors. This is a significant concession from the farmer that should improve the overall management of CAFOs.

Once again, farmers who decide not to participate in this system (either audits alone or coupled with insurance) would be subject to increased scrutiny from the regulators, just as Kunreuther, McNulty, and Kang explained. Those operations that have undergone audits will seek to make this known to the regulator (and the community), to differentiate themselves from other facilities and demonstrate efforts at BMPs. This signaling on the part of the firm may be helpful in targeting regulatory inspections for budget-constrained public agencies. In the longer term, there might be few farmers who do not purchase insurance products that would help them manage and mitigate risk before an environmental problem emerged.

Conclusions

The case that we have discussed has focused on swine as an example of the insurance concepts proposed. The same framework can be applied to other species and types of manure storage systems. A comparison of a variety of swine, poultry, and cattle systems in different geographical locations by America's Clean Water Foundation demonstrates the broad applicability of the proposed class of risk-management instruments. Further research to investigate the sensitivity of the engineering model to changes in weather and management variables is needed, along with a more detailed analysis of transaction costs and policy afford- about the nature of continued public support for this product can be considered.

A major goal of public policy is to modify the behavior of the individual CAFO manager in such a fashion that the risk of failure is reduced. Many of the market-oriented solutions proposed in the literature (effluent/pollution charge systems and tradable emissions permits) are considered to be less desirable because they address aggregate behavior and are impaired by information asymmetry. Contingent claims contracts that provide incentives for individual underwriting and monitoring are deemed to be the most appropriate for focusing on individual behavior. However, as was clearly discussed above, such contracts must be carefully designed such that one does not create moral hazard or attract only the most risky (adverse selection). If these problems are not controlled, the risk can actually increase for the individual operation. The most attractive solutions involve using index-based contracts that would be free of adverse selection and moral hazard. To the extent that a broader range of coverage is offered—using insurance-like products—there is a clear role for third-party auditors. Finally, solutions that combine many of the principles from market-based solutions are most desirable, particularly if the combination of a contingent claims contract and a risk-mitigation strategy such as hauling can be achieved.

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