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by

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Public interest and concern about livestock waste management has been heightened by recent episodes of water contamination in the Chesapeake Bay and in the drinking water of Milwaukee, and huge spills from hog waste stores in Iowa and North Carolina. Simple facts on the volume of waste produced by confined animals, and the increasing numbers and concentration of these animals, illustrate the potential magnitude of the management and policy problem at hand. For example, the average adult hog produces three times the amount of waste as the average adult person—and the average adult milk cow produces twenty times this amount. For Iowa and North Carolina alone, this translates into handling a hog waste volume roughly equal to the sewage from one-third of the entire U.S. human population. And the magnitude of the problem is growing. Over a decade, U.S. hog production has risen 18 percent, while the number of production operations has fallen 72 percent (Glover). Similarly, cattle, dairy, and poultry industries have grown increasingly concentrated, with more large operations and more production in Oklahoma and Texas (for cattle); the West, Southwest, and Florida (for dairy); and Delmarva (for poultry).

Here, I offer some thoughts on how government policy can and should provide livestock producers with incentives to account for the environmental costs of their actions. The production and handling of livestock and their waste has many potential external effects that need to be considered when devising regulatory policy: nutrient runoff and/or leaching from application of manure to croplands; spills and/or leaks from animal waste stores; and ambient odors and gases from feeding operations. For some of these effects, the economist's simple answer—taxing the external effect so that producers pay the environmental cost of their practices and therefore act efficiently to protect the environment—is simply not feasible. In particular, tracing the environmental cost of nutrient pollution to individual livestock facilities is virtually impossible. To elicit producer behavior that efficiently accounts for environmental effects requires careful attention to both (1) the relationship between producer choices and environmental outcomes, and most importantly, (2) the choices that can be observed by the government at a reasonable cost. Only the latter choices should be the object of direct or economic regulation, a point that often appears to be lost in policy debate on livestock waste.

The previous article in this issue by Lovell and Kuch highlights this tendency. In fact, Lovell and Kuch's vision of livestock waste policy is almost Orwellian: a massive army of manure police patrolling a livestock producer's surrounding crop fields to watch and limit the operator's every manure application. And it doesn't stop there. Wherever manure goes, the police must follow—into the lives and fields of any poor farmer who is suckered into purchasing manure that the government wants to be moved long distances—at potentially exorbitant cost—to get away from the livestock facility. This policy of "a government agent in every field" is almost certainly too costly to be justified.

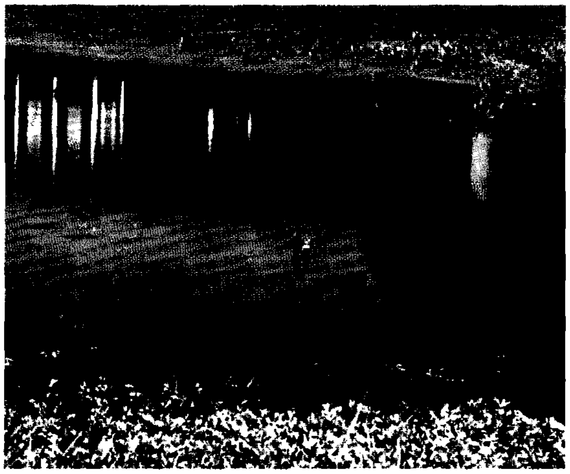
An alternative course takes for granted the livestock farmer's freedom to spread livestock waste on surrounding fields in accord with the economic incentives in place to do so. Of course, some limits on applications may be possible; for example, the Clean Water Act implicitly proscribes the dumping of so much waste on a farm field that the waste is being directly discharged into an adjacent stream (*Concerned Area Residents* v. *Southview Farm*, 2d Cir., 1994). However, field applications of livestock waste which do not directly discharge into surface waters—but may lead to nutrient runoff and leaching, just as can fertilizer applications—are an entirely different matter. As indicated by Frarey and Pratt, for example, "an almost insurmountable task faces any regulatory agency attempting to regulate polluted runoff from manure application fields through site inspection alone" because "the amount of solid or liquid manure applied to a field is virtually impossible to determine after application." That is to say, permanent in-field manure police would be required to enforce limits on per acre nutrient applications.

The simple economics of manure application

Economists have studied the incentives that livestock operators have to spread manure (Schnitkey and Miranda) and the policy tools that might be used to augment these incentives, as well as improve the nutrient properties of the manure being spread (Innes). The core of these analyses is this: Because transporting manure to distant lands is generally too costly (Wastenberger and Letson), operators spread manure on surrounding fields. They do so in response to two forces. First, manure substitutes for the use of chemical fertilizers in providing nutrients to crops. Second, manure is cosrly to deliver to crop fields, and increasingly costly as the distance from the waste store to the field rises. This second force implies that operators will apply more manure close to the facility than far from the facility, because the marginal cost of manure delivery is lower. However, as a farmer applies more manure to a given field, the marginal nutrient benefits that are derived from the application (in crop production) are lower. Thus, in general, the operator does not want to dump all of his waste as close to his facility as possible; rather, he will only apply manure until the additional cost of delivering to a more distant field is offset by the higher marginal nutrient benefits of the more distant application.

The crucial question, from the environmental point of view, is this: Does the livestock operator want to apply more manure than just substitutes for chemical fertilizer that would otherwise be used? That is, is the manure application excessive in that it increases the total amount of nutrients being applied and thereby causes more nutrient pollution than would otherwise occur? The answer is yes: Everywhere that an operator applies manure (except on the boundary of the application region), he or she will want to apply excessively—and increasingly so on fields that are closer to the facility. The reason is that, by applying manure on a given field—rather than a more distant field—a livestock farmer not only reaps the nutrient benefits of the application but also saves the transport costs on the more distant application. This extra benefit implies that the farmer will want to apply more manure nutrients than he or she would otherwise want to apply in chemical fertilizers that only yield the benefit of supplying crop nutrients. As a result, the use of manure can be expected to worsen nutrient runoff and leaching from croplands.

Of course, as with any theory, this argument abstracrs from some realities. For example, manure may affect not only polluting runoff and leaching from cropfields by affecting the total level of nutrient applications to these lands. Manure application may potentially yield runoff that is more damaging to the environment than chemical fertilizer, for two reasons: (1) because manure can contain weed seeds, its application may prompt increased use of herbicides; and (2) manure can contain harmful biological pathogens that are absent in chemical fertilizers. On the other hand, by increasing water retention in soils, manure may deliver its nutrients with less leaching and runoff than would an equivalent amount of



chemical fertilizer. This tendency is offset by farmers' need to apply more water when they use manure in order to leach out harmful salts (Glover). However, if the need for irrigation water is increasingly great as more manure is applied, there will be an added cost to applying excessive amounts of manure—and, hence, less incentive to do so.

Despite these caveats, the conclusion described here—that there is a positive relationship between livestock and per acre farm nutrient applications—has found empirical support in recent academic work (see Navin and Innes). And its logic is rather compelling: Even when a livestock operator's fertilizer costs are "small" relative to other costs of producrion and crop cultivation, the operaror will want to dispose of animal waste at least cost—or maximum benefit—by trading off the crop nutrient benefits of manure with its costs of application.

Regulating manure spreading

In view of the incentives that operators otherwise face to apply manure excessively, the government may want to embrace policies that reduce these incentives and thereby reduce the extent of nutrient pollution. For example, some economists have proposed market interventions that may raise the demand for manure and thereby deter its wasteful use in excess applications. One possible form for such intervention is a chemical fertilizer tax (CEA); another is a manure subsidy (Bosch and Napit). The extent of excess nutrient applications may also be affected by other observable objects of regulation, including the technology by which manure is transported to the fields, the (pre-application) waste treatment technology, and the mix of crops cultivated on farm acreage surrounding livestock operations. Let us consider each of these topics in turn.

Fertilizer taxes. By raising chemical fertilizer prices, a fertilizer tax raises the opportunity cost of excess manure applications, those applications for which fertilizer substitution benefits are low. Excess manure applications are thereby deterred (Innes). In particular, the tax prompts the facility to lower the extent of excess application close to the facility, where applications are greatest and marginal substitution benefits are smallest, by shifting manure to more distant farmland where applications are smallest and substitution benefits are greatest. Consider, for example, the operator's choice between applying an extra pound of manure at two alternate locations: (1) close to the facility; and (2) at the edge of the farm, where no manure is yet applied. At the farm's edge, every extra nutrient delivered by the manure translates into that much less chemical fertilizer that the operator needs to purchase; when the chemical fertilizer price goes up in tandem with the tax, the value of this fertilizer substitution also goes up. Close to the facility, however, the operator is already applying manure excessively and using no chemical fertilizer; here, the extra manure yields value in directly providing additional crop nutrients, rather than substituting for other fertilizers. Clearly, this value is not tied to the price of chemical fertilizer. A fertilizer tax thus leaves the value of "close" applications unchanged, and thereby raises the operator's incentive to apply manure at the farm's edge.

Because the nutrient runoff from manure applications—and the environmental costs of this runoff—rise with the extent of excess application, the "evening out" of applications leads to reduced levels of runoff and environmental damage. A positive fertilizer tax can thus make facilities act as if they face some of the environmental costs of their manure applications, and increase economic welfare as a resulr.

Manure subsidies. Some manure is amenable, in principle, to cost-effective off-farm marketing. Dry poultry litter is a possible example (Bosch and Napit); liquid waste is generally not. For marketable manure, the government may want to subsidize sales. Assuming that marketed manure is not overapplied (relative to chemical fertilizer alternatives), such a subsidy may potentially reduce rates of excess manure application by prompting increased off-farm manure sales and thereby reducing the amount of manure that any given operator applies to his own surrounding fields.

Regulating irrigation. Producers with liquid waste have two transport alternatives (see, for example, Roka): (1) hauling and spreading, using a tractor and "honey wagon"; and (2) installing an irrigation system that pumps and pipes the slurry to the fields. An irrigation system yields lower marginal costs of delivering manure to more distant locations (within the confines of the system) at the cost of a higher initial capital investment. By lowering marginal costs of transporting manure, an irrigation system reduces private operators' incentive to spread manure close to the facility. As with a fertilizer tax, the resulting "evening out" of applications reduces the extent of nutrient runoff and attendant environmental damage.

When the value of these environmental benefits exceeds the cost of installing irrigation, economic efficiency can potentially be enhanced by government policies which promote the use of irrigation systems, whether with regulatory mandates or cost-sharing incentive programs. Clearly, the environmental benefits of irrigation will be larger when the societal costs of a facility's excess manure applications (and, hence, the marginal benefits of reducing these excesses) are also large. This is true, for example, when a facility is larger and therefore has greater rates of excess manure application.

Crop selection mandates. In principle, the government could mandate that livestock operators plant a conservation crop that has a high nutrient uptake. Although the higher uptake of the substitute crop directly reduces the residual (nonabsorbed) manure nutrients that can be washed into rivers, streams, and groundwater, a conservation crop mandate can also have an offsetting environmental cost: the conservation crop reduces the opportunity cost of manure application by reducing its benefits in substituting for fertilizer. With reduced substitution benefits, more manure will be applied close to the facility, which will worsen nutrient runoff. In the extreme, when there are no substitution benefits of manure, producers would like to dump all of their manure as close to the facility as possible.

Regulating waste treatment. Producers make decisions on the design of their waste handling systems that affect the nutrient content of their manure. In North Carolina, for example, the predominant treatment system used by hog producers is a single-stage anaerobic lagoon, the size of which determines the level of "treatment," or nutrient loss (Roka). Other (less costly) waste-handling systems provide lower levels of nutrient loss. By lowering the nutrient content in manure, "treatment" of waste directly reduces the nutrient runoff from a given amount of manure waste and a given manure spreading policy. However, there may be an offsetting environmental cost of treatment: With reduced nutrient content, manure again has less value in substituting for fertilizer. Moreover, when treatment is achieved with increased lagoon volume, it increases the "gross waste" volume of material that must be applied to fields, per unit of animal waste, and thereby raises costs of transporting a unit of treated waste. Both effects give producers less incentive to transport manure to more distant locations at which substitution benefits can be realized; they thereby favor more concentrated applications close to a facility.

Despite these offsetting environmental effects, it is likely that some increased treatment—beyond its privately optimal level—will reduce environmental damage from a livestock operation. In principle, government regulation of the treatment level could then increase economic efficiency. An optimal treatment standard will depend upon the size of facilities. In particular, the nutrient-reducing environmental benefits of treatment are likely to rise when levels of excess manure application are greater, as they are when facilities are larger (all things equal). If so—or if there are economies of scale in treatment—an optimal treatment standard will be higher for larger facilities.

All of these remedies—fertilizer taxes, manure subsidies, and regulation of irrigation, waste treatment, and/or the planting of conservation crops—may have merit in reducing the environmental costs of manure spreading. However, they do not correct market incentives for the overall organization—and level—of livestock production to account for its environmental costs. I now turn to this topic.

The spatial arrangement of livestock operations

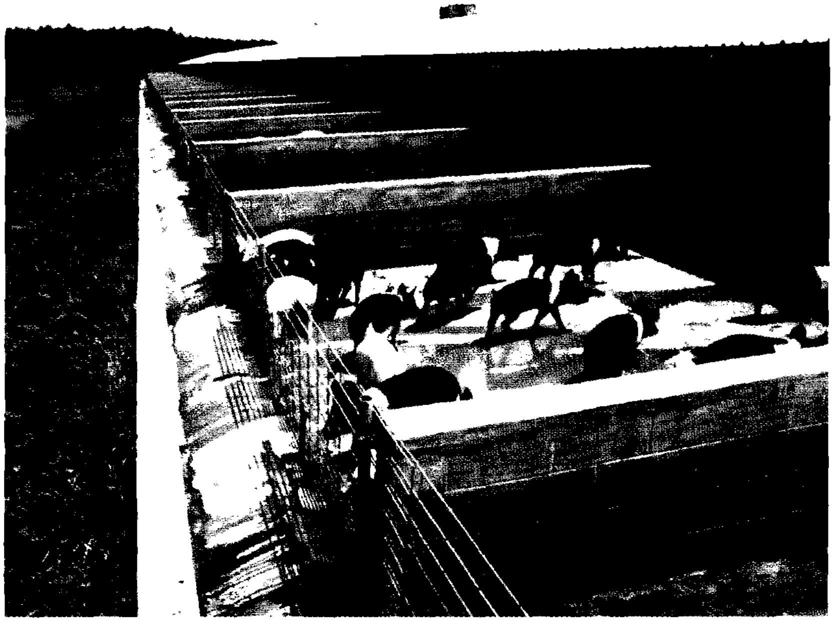
Environmental costs of livestock production, even when reduced due to regulation, are typically not paid by livestock operators themselves. Regulation may reduce nutrient pollution, but rarely will it tax producers for the harm that they cause. Citing regulations may limit the adverse effect of odors, pests, and gases from livestock feeding operations but again may not confront producers with remaining external costs. Government standards on waste storage may limit the frequency and extent of waste spills, but they may not always assess full liability for harm from spills that occur nonetheless. Because these social costs of livestock production are not paid by private actors, too much production can be expected to occur. Moreover, the spatial arrangement of production need not reflect its true costs and benefits: livestock facilities may tend to be more concentrated or less concentrated than they would be if the environmental costs and benefits of concentration were taken into account.

The question of whether there are environmental benefits or costs of concentration is important and one which cannot be resolved conceptually. On one hand, waste spills are more concentrated when production is more concentrated; if larger spills are more damaging at the margin (because the assimilative capacity of the local environment is taxed more heavily), then more concentrated spills will be more harmful, giving rise to an external diseconomy of concentration. Odors, on the other hand, may perhaps be less harmful when concentrated, reflecting the notion that "once there is a smell, marginal smells don't add much cost"; if so, there will be an external economy of concentration. Of course, this is an empirical issue; concentrated smells may alternatively be more harmful if "small smells aren't too bad but larger ones are horrible."

There is a similar ambiguity when it comes to effects of concentration on manure nutrient applications. On one hand, larger facilities have more manure to spread and will therefore apply more excessively than will smaller facilities; on the other hand, larger facilities will spread manure on more distant lands which absorb some manure as a substitute for chemical fertilizer. If the second ("farm expansion") effect is strong enough, average excess manure applications can fall when production becomes more concentrated. However, environmental damages from excess applications will rise with increased concentration if either the "expansion effect" is small *or* marginal nutrient runoff rises sufficiently rapidly with levels of excess nutrient applications. In the latter case, manure applications will give rise to an external diseconomy of concentration.

Finally, all of these comparisons have fixed the waste handling technology in the "other things being equal" background. However, larger facilities may be advantageous if there are economies of scale in the technologies that can deliver environmental benefits, including irrigation systems and improved waste storage/treatment systems.

Now, you ask, what does all this have to do with public policy toward livestock production? What it says is this: Even if it were politically fea-



sible, simply taxing livestock in order to confront producers with the external cost of increased production is unlikely to do the trick in promoting an efficient spatial organization of production. Additional spatial restrictions or incentives will be needed to elicit both efficient levels of production and an efficient spatial arrangement—producing a given level of output with facilities that are of efficient size and number and location.

Consider, for example, the following "scale regulation": No more than a given number of animals (say A) may be located on a given number of acres (say N). If N is large, this regulation limits a facility's size to A/N animals per acre. Alternately, if N is small, the regulation directly limits facility size to A. If increased concentration is environmentally harmful—so that livestock production will tend to be more concentrated than is efficient—then this regulation can be designed to yield an efficient outcome in a homogeneous farming region. By limiting regionwide animal inventories to the per acre maximum (A/N) times the available regionwide farm acreage, the scale regulation can curb incentives for overproduction. The direct limit on facility size, in turn, can curb market incentives to concentrate production more than is efficient, with facilities that are too large. Efficient spatial arrangements can thus be induced by efficiently limiting both facility size (by choice of A) and per acre regionwide production (by choice of N).

However, if increased concentration is environmentally beneficial—so that livestock production will tend to be less concentrated than is efficient—then the "scale regulation" can only work to limit output (with the per acre restriction) and not to prompt the more concentrated production that is favored by environmental considerations. In this case, of course, mandating waste handling technologies that exhibit economies of scale—and making these mandates apply to all operators—can work against facilities that are otherwise too small to reap the environmental benefits of size.

The efficiency of overall production incentives is not only important in its own right; it is also important to consider when evaluating other policies that are intended to reduce the environmental costs of livestock operations. For example, incentives for overproduction may be worsened by policies such as fertilizer taxes and manure subsidies that raise the value of manure and thereby raise the value of the animals that produce it. A similar problem can arise with government cost-sharing programs for irrigation and/or waste treatment investments. Only if such policies are combined with appropriate production restraints—such as the "scale regulation" discussed above—can their environmental benefits be reaped without the long-run cost of greater overproduction.

Federalism and federal policy

So far, I have ignored the issue of the appropriate locus of regulation: Should the federal government be in charge, or should the regulation of livestock waste be left to the states? This issue, of course, is generic, raising the general question of when and what federal environmental protection is warranted.

Cross-boundary problems are typically thought to motivate federal intervention, for one state may have little incentive to protect the environment of another. (Some economists argue that interstate compacts are an alternative approach to addressing such problems.) In the livestock context, for example, spills and leaks from waste stores can threaten interstate waters and thus merit federal regulation under the Clean Water Act. Currently, the federal government requires larger facilities to prevent spills from rain events that are less severe than a twenty-four-hour, twenty-five-year storm (the highest level of rainfall over twenty-four hours that is expected once every twenty-five years). However, larger facilities have larger spills and leaks, which typically cause larger marginal and total environmental damages. The benefits of higher levels of spill protection—that is, protection from more severe storm events—is thus greater when facilities are bigger. Yet, the federal standard has not risen as facilities have become larger and has not been sufficiently flexible to impose efficiently different onuses on facilities of different size and different locations. Also lacking in the regulatory tool kit has been the certain imposition of liability for spill damages, which can provide operators with incentives to design their waste stores and handling practices in order to reduce the risk of spills, leaks, and uncomfortable effects from their operations.

In general, heterogeneity in environmental and production conditions argues for more local regulation, and this is why siting restrictions and other regulations of scale have been the domain of state and local governments. However, there is a continuing and vibrant debate surrounding the economic merits of "leveling the playing field" with federal environmental protections (see Braden and Proost for example).

A call for review of the current regime

Overall I have argued here against a "manure Gestapo" approach to livestock regulation—the stationing of federal agents in every field to monitor and limit the nutrient applications of livestock operators on surrounding croplands. Instead, I suggest that government policy should seek to provide livestock operators with improved incentives for manure application and avoid the astronomical regulatory costs of the "Gestapo" approach. To provide these incentives—and to achieve other environmentally beneficial changes in livestock production and waste management—government policy should focus on observable choices that affect environmental outcomes. Among these observables are chemical fertilizer prices (which can be raised by taxes in order to prompt greater economy in the use of manure), prices of marketed manure, the manure transport technology used by livestock operators, the waste treatment system, and the scale and location of production operations. In sum, I argue for a review of the current regulatory regime that is short on scale regulation, producer liability, flexible standards for prevention of spills from waste stores, and policy measures that can provide firms with optimal incentives, rather than unenforceable directives, for environmentally friendly manure management. ■

■ For more information

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Note: *AJAE* is the *American Journal of Agricultural Economics*, *JOA* is the *Journal of Agribusiness*, *AFR* is *Agricultural Finance Review*, *ARER* is the *Agricultural and Resource Economics Review*, and *JARE* is the *Journal of Agricultural and Resource Economics*.