The Economics of Co-Permitting

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Introduction

Traditionally, livestock growers have been responsible for managing manure and other waste products, appropriating any benefits (e.g., from use as fertilizer) and bearing any costs. The spread of contracting in livestock industries has raised questions about the appropriateness of this situation. It has been argued, for example, that integrators exert substantial operational control of contract livestock operations and should thus bear some responsibility for managing waste. It has also been argued that integrators have deep pockets allowing them to finance needed investments in waste management structures and equipment that individual growers cannot afford.

These arguments have led the US Environmental Protection Agency (EPA) and several states to propose regulations that would make integrators and growers jointly responsible for disposing of wastes from contract livestock operations. Growers and integrators alike have objected strenuously to these co-permitting proposals. Integrators argued that they should not be liable for the actions of growers, whom they characterized as independent businesses over whose day-to-day operations they exercise little control. Growers have expressed fears that co-permitting would give integrators more leverage in bargaining over contract terms, thereby limiting grower's ability to pass along compliance costs; that it would give integrators an excuse to interfere in growers' operations and to terminate contracts; and that it would tie growers to specific integrators by forcing them to invest in specific waste management facilities not used by others (Boessen et al.)

To date, there has been some rigorous analysis of the potential economic efficiency effects of proposals for joint responsibility for waste management in terms of economic efficiency but virtually none on potential impacts on the distribution of income between growers and integrators. Liability for pollution damage may be appropriate in some cases where integrators do not contribute to production but growers are judgement proof in the sense of being unable to pay the full cost of any environmental damage they may cause (Heyes; Pitchford 1995, 2001; Boyer and Laffont; Balkenborg; Shavell 1987, 1997). Both integrators and growers should bear some liability for pollution damage when integrators play an active role in production under conditions of double moral hazard in the sense that the inputs of both grower and integrator are non-contractible (Aggarwal and Lichtenberg).

This paper examines the efficiency and distributional implications of alternative forms of co-permitting, modeled generically as apportionment of liability for waste management between integrators and growers, in situations where production contracts feature conditions of single-sided moral hazard in which key inputs provided by growers (e.g., management) cannot be monitored or verified by integrators and in which integrators play an active role in production. We show that growers should be liable for less than the full marginal cost of environmental damage in order to counteract the adverse incentive effects of contracting. Integrators should also be liable for a share of environmental damage. In contrast to the grower, it can be optimal for the integrator to be liable for more than the full marginal cost of environmental damage. These results also carry over to the case where integrators play no active role in production.

The distributional effects of co-permitting are analyzed under the assumption that growers differ in terms of waste disposal costs but are otherwise identical. In the absence of regulation, waste disposal is assumed to be costless and hence irrelevant in contracting. When regulation is imposed, growers with high waste disposal costs are likely to lose existing contracts, regardless of how liability for waste disposal is apportioned. Regulations requiring co-permitting may allow integrators to acquire information about waste disposal costs and/or require integrator-specific investments in waste handling facilities, reducing their bargaining power. Thus, growers' fears about potential adverse effects of co-permitting regulations appear to have a sound basis.

A Model of of Livestock Waste Regulation

Let output of finished animals, q, be a concave function f(x,z) of inputs selected by the integrator (x) and by the grower (z). Let the social cost of environmental damage (equivalently, the cost of complying with an environmentally-determined waste management standard) be a convex function of those same inputs, h(x,z). Assume that x and z are complements in both production and environmental damage, e.g., higher quality animals grow faster and produce more manure under better management. This relationship is captured formally by assuming that the cross-partial derivatives f_{xz} and h_{xz} are positive. Let p, w, and v denote the respective prices of q, x, and z. Suppose also that output of finished animals and environmental damage are also both affected by stochastic factors, ε and η, respectively. To simplify matters, assume that both are additive, so that realized output of finished animals is $f(x,z)+\varepsilon$ and realized environmental damage is $h(x,z)+\eta$.[1]

[1] In this model, environmental damage can be reduced by lowering the usage levels of x and/or z; the cost of achieving reductions in environmental damage is a reduction in output and thus profit from livestock production. An alternative modeling approach would be to consider the use of inputs specifically devoted to waste management. The results obtained from such a model would be qualitatively equivalent to those derived from this formulation.

The Social Optimum

Socially efficient production is achieved by choosing usage levels of the inputs provided by the integrator and grower to maximize expected profit from livestock production less the expected cost of environmental damage, pf(x,z)-wx-vz-ch(x,z). The necessary conditions characterizing socially optimal use of each input are (letting subscripts denote derivatives),

(1) $$pf_x - w - h_x = 0$$

(2) $$pf_z - v - h_z = 0,$$

i.e., the value of the marginal product of each input (pf_j, j = x,z) equals the unit cost of the input less the marginal cost of the environmental damage it causes (equivalently, the marginal cost of meeting the waste management standard; in either case, h_j, j = x,z).

Production in Contracts with Single-Sided Moral Hazard

The model used in the preceding section is easily modified to incorporate the effects of contractual output sharing. Suppose that the grower's input z is non-contractible, being, for example, unobservable at reasonable cost or unverifiable if observed. Consider a situation in which the integrator acts as a Stackelberg leader, choosing contract terms and how much of her input to provide given knowledge of the grower's reaction to those contract terms. Assume the use of a linear contract that gives the grower a share of output β in addition to a fixed payment α. Let s and t be the shares of the social cost of environmental damage assigned exogenously by the regulator to the integrator and grower, respectively. The optimal contract in this case involves the integrator choosing x, α, β to maximize her expected income $(1-\beta)pf(x,z)-wx-sh(x,z)-\alpha$ subject to two constraints: (1) an incentive compatibility constraint specifying that the grower chooses z (conditional on x, α, β, and t) to maximize her expected income, z^c = argmax {α+βpf(x,z)-vz-th(x,z)} and (2) a participation constraint ensuring that the grower's income is no less than the income she could obtain outside of the contract, α+βpf(x,z)-vz-th(x,z) ≥ u_0.

The equilibrium levels of output sharing (β) and input provision (x and z) are determined simultaneously by the conditions

$$-f+[(1-\beta)pf_z-sh_z]\frac{\partial z^c}{\partial \beta}=0 \tag{3}$$

$$(1-\beta)pf_x-w-sh_x-[(1-\beta)pf_z-sh_z]\frac{\partial z^c}{\partial x}=0 \tag{4}$$

$$\beta pf_z-v-th_z=0 \tag{5}$$

$$\alpha+\beta pf(x,z)-vz-th(x,z)\geq u_0. \tag{6}$$

Condition (5) is the grower's incentive compatibility condition. It can be used to solve for z^c as a function of β and x and thus for the derivatives

$$\frac{\partial z^c}{\partial \beta}=\frac{pf_z}{th_{zz}-\beta pf_{zz}}\geq 0 \tag{7}$$

$$\frac{\partial z^c}{\partial x}=\frac{\beta pf_{xz}-th_{xz}}{th_{zz}-\beta pf_{zz}}>(=)(<)\ 0\ as\ \beta pf_{xz}-th_{xz}>(=)(<)\ 0\,. \tag{8}$$

The fixed payment α can be derived independently in accordance with a rule for sharing the total surplus generated by the industry based on the relative bargaining power of the grower and integrator (Muthoo). If the integrator has all the bargaining power, then the fixed portion of the grower's compensation α is set to ensure that the participation constraint (6) holds with equality.

To achieve a social optimum, conditions (4) and (5) must be equal to conditions (1) and (2), respectively. Equating condition (4) with condition (1) and condition (5) with condition (2) allows us to solve for the socially efficient shares of integrator and grower liability s* and t* conditional on the equilibrium output share β. (Solving these two equations simultaneously with condition (3) yields socially efficient integrator and grower liability together with the equilibrium output share.)

Consider first the grower's share of liability (conditional on the equilibrium output share β):

(9) $$t^* = 1 - \frac{(1-\beta)pf_z}{h_z}.$$

It can be seen from condition (8) that the grower should be liable for less than the full social cost of environmental damage (if the grower were liable for the full social cost of environmental damage, her share t would equal 1). Instead, the grower should be liable for the full social cost of environmental damage less an adjustment factor $(1-\beta)pf_z/h_z$ designed to correct the distortion in her input provision due to the fact that she receives less than the full value of the marginal product of her input under her contract with the integrator.

The integrator's optimal share of liability for environmental damage is:

(10) $$s^* = \frac{(h_x - \beta pf_x)(th_{zz} - \beta pf_{zz}) - (1-\beta)pf_z(th_{xz} - \beta pf_{xz})}{h_x(th_{zz} - \beta pf_{zz}) - h_z(th_{xz} - \beta pf_{xz})},$$

which can also be written as

(10′) $$s^* = 1 - \frac{\dfrac{\beta pf_x}{h_x} - t\dfrac{h_z}{h_x}\dfrac{\partial z^c}{\partial x}}{1 + \dfrac{h_z}{h_x}\dfrac{\partial z^c}{\partial x}}.$$

As in the grower's case, the integrator's optimal share of liability for environmental damage is adjusted downward to accommodate the distortion in the provision of her input x due to output sharing. In the integrator's case, however, this adjustment takes into account both the direct effect of output sharing on the integrator (the term $\beta pf_x/h_x$) and the indirect effect of the integrator's choice of x on the grower's provision of her output z.

In contrast to the grower, it is possible that the integrator should be liable for more than the full social cost of environmental damage, i.e., that the grower's optimal share s* should exceed 1. A necessary condition for such an outcome is $-1 < \partial z^c/\partial x < 0$, the integrator's and grower's inputs are strategic substitutes (i.e., reductions in the usage level of the integrator's input x induce the grower to increase the use of her input z). In such cases, it is necessary to increase the integrator's liability enough so that decreases in environmental damage due to reductions in x more than make up for any increases in environmental damage due to increases in z caused by reductions in x. Note that a necessary condition for $\partial z^c/\partial x < 0$ is that $\beta pf_{xz} < th_{xz}$, a reduction in x lowers the grower's tax liability th_{xz} more than her compensation for production βpf_{xz}.

It can be seen from conditions (10) and (10′) that co-permitting can be desirable ($s^* > 0$) even when the integrator's actions have no effect at all on environmental damage ($h_x = h_{xz} = 0$). In that case,

$$s^* = 1 - \frac{\beta pf_x - th_z \dfrac{\partial z^c}{\partial x}}{1 + h_z \dfrac{\partial z^c}{\partial x}}$$

where $\partial z^c/\partial x > 0$. Intuitively, co-permitting in this case is due to the strategic interaction between the integrator's and grower's (Bulow, Geanakoplos, and Klemperer). As a result, the integrator needs to be made liable for a share of environmental damage in order to correct distortions in production due to moral hazard on the part of the grower.

Finally, adding up using conditions (9) and (10′), we find that the optimal liability for environmental damage imposed on the industry as a whole, s*+t* is

$$(11) \qquad s^* + t^* = 1 - \frac{\dfrac{\beta p f_x}{h_x} + \dfrac{(1-\beta) p f_z}{h_z}}{1 + \dfrac{h_z}{h_x}\dfrac{\partial z^c}{\partial x}}.$$

It is evident from equation (11) that s*+t* < 1 as long as the denominator of the fraction on the right hand side is greater than the numerator of that fraction. As long as that condition holds, the industry as a whole should be liable for less than the full extent of environmental damage.[2] In essence, the discount on liability for environmental damage serves to compensate for the effects of grower moral hazard in production.

In sum, then, when contracts for livestock production are designed to provide incentives for mitigating moral hazard in growers' provision of management effort, we can conclude the following with respect to liability for environmental damage:

1. In most circumstances, joint integrator/grower liability is necessary to achieve socially optimal production and waste management together.
2. In most circumstances, both the grower and the integrator should be liable for less than the full social cost of environmental damage.

[2] One would expect that condition to hold in all but pathological cases. A necessary condition for it not to hold is that the two inputs are strong strategic substitutes ($\partial z^c/\partial x < 0$ and quite large in absolute value). In that case, reductions in the integrator's provision of x due to liability for environmental damage can trigger increases in the grower's provision of z large enough to increase overall environmental damage. Liability for more than total environmental damage is needed to compensate for this pathology.

3. In most circumstances, the industry as a whole should be liable for less than the full social cost of environmental damage.

Note that the industry as a whole can be made liable for less than the full social cost of environmental damage by adopting a hybrid policy that combines full liability for the social cost of environmental damage with subsidies for waste management designed to mitigate the effects of grower moral hazard in production. Such a policy could utilize an ambient pollution tax along with waste management subsidies. Alternatively, it could impose co-permitting that required the industry as a whole to adopt measures resulting in socially efficient generation and disposal of livestock waste along with subsidies that reduce the cost of production to mitigate grower moral hazard.

Contracting over Waste Disposal Costs

The analysis in the preceding sections assumed that the degrees of liability for environmental damage faced by the integrator and grower were both exogenous, imposed by a regulatory body. It is more likely, however, that under co-permitting regulators would impose joint responsibility for meeting conditions of discharge permits (which generally take the form of following waste disposal procedures believed to provide adequate safeguards for environmental quality) without specifying how the costs of following those procedures should be split between contracting parties. Under co-permitting, therefore, the way in which the costs of meeting waste disposal standards are divided between integrator and grower will likely be negotiated as part of the terms of the contract in a manner similar to output sharing and fixed payment levels.

The arguments of the preceding sections can be applied straightforwardly to the co-permitting case where waste disposal cost sharing is determined endogenously as part of the contract terms. Let h(x,z) denote the cost of meeting a given regulatory waste disposal standard (instead of the social cost of environmental damage). Clearly the cost of waste disposal is influenced by the nutrient composition of that waste, which is in turn influenced by nutrition, breeding, and placements, all of which are controlled by the integrator. The cost of waste disposal is also clearly influenced by the grower's management and other actions. Thus, it makes sense to specify waste disposal cost as a function whose arguments include actions of both the integrator and grower.

First, ignore for a moment the implications of output sharing. Holmstrom's budget balancing proof clearly applies to waste disposal since meeting the regulatory standard is a form output and since the fact that many of the choices that influence the cost of waste disposal are unobservable and/or unverifiable, creating a free riding moral hazard problem. Thus, achieving a social optimum under co-permitting likely requires some form of waste management subsidies for both grower and integrator even in the absence of distortions induced by moral hazard in livestock production.

Next, consider the implications of moral hazard in livestock production due to the non-contractibility of the growers' management effort. As before, consider a linear contract. Let τ denote the share of waste management cost to be borne by the grower. The optimal contract in this case involves the integrator choosing x, α, β, and τ to maximize her expected income $(1-\beta)pf(x,z)-wx-(1-\tau)h(x,z)-\alpha$ subject to two constraints: (1) an incentive compatibility constraint specifying that the grower chooses z (conditional on x, α, β, and τ) to maximize her expected income, $z^c = \text{argmax } \{\alpha+\beta pf(x,z)-vz-\tau h(x,z)\}$ and (2) a participation constraint ensuring that the grower's income is no less than the income she could obtain outside of the contract, $\alpha+\beta pf(x,z)-vz-\tau h(x,z) \geq u_0$. The results of the analysis of the single moral hazard case indicate that such a contract cannot achieve a social optimum without (a) a waste management subsidy for the grower and (b) most likely a subsidy for the integrator (but possibly a penalty assessed in (unlikely) cases where the integrator's and grower's inputs are substitutes with a very large elasticity of substitution). It follows that contracts that divide the entire cost of meeting a waste disposal standard between the integrator and grower cannot achieve the social optimum without subsidies for both growers and integrators. In other words, co-permitting can be efficient only if it is supplemented with the appropriate waste management subsidies for both growers and integrators.

Co-Permitting and the Distribution of Income between Integrators and Growers

Growers' opposition to co-permitting appears to be motivated primarily by fears that it would redistribute income in a manner unfavorable to them. For example, growers' negative comments on EPA's proposed co-permitting regulation all concerned potential adverse distributional effects such as decreased grower leverage in bargaining over contract terms, greater integrator interference in growers' operations, and potential termination of contracts (Boessen et al.). Of course, it is to be expected that the imposition of regulation by itself will have some adverse effects on growers' (and industry) financial returns from contract livestock production. It is important to separate the effects of imposing regulation per se from those of co-permitting. This section considers these effects in turn.

Impacts of Imposing Regulation on an Unregulated Industry

Imposing regulations that force livestock producers to dispose of wastes in a manner that reduces negative environmental impacts (lowers the social cost of environmental damage) will generally lower the income of the livestock production industry as a whole and growers in particular. It is a truism that regulation will be costly: If the most profitable (or least costly) means of disposing of livestock waste caused no damage to the environment, there would be no need to impose regulation to protect environmental quality; thus, the need for regulation is by itself evidence that regulation will be costly. The additional costs imposed by regulation need not be completely, or even largely, financial. The primary impact of regulation may be to require growers to exert more management effort and expend more of their own labor, both of which largely involve implicit costs rather than explicit monetary expenditures. For example, a recent study by Lichtenberg, Parker, and Lynch found that poultry litter applied to cropland as a fertilizer substitute should be a profitable by-product of poultry production on the Delmarva Peninsula, even with transportation costs, application costs, and restrictions on application rates due to environmental regulations taken into account. They argued that the main impediment to the profitability of using poultry litter this way was the lack of a marketing infrastructure and the consequent costliness (in terms of time and hassle) of arranging trades through individual barter arrangements.

The fact that regulation will be costly to at least some growers implies that imposing regulation on an unregulated livestock production industry will lead to the termination of some existing contracts, regardless of the relative bargaining power of growers vis-à-vis integrators and regardless of whether co-permitting is imposed. Suppose for example that some growers have profitable ways to dispose of livestock waste (for example, using it as a fertilizer substitute on their own fields or selling it to neighboring crop producers) while others find waste disposal costly. In the absence of regulation, the maximum cost of waste disposal is zero. If the market for contracts is efficient, all those for whom waste disposal is profitable will be awarded contracts. If the production capacity of those growers is less than integrators' demand, some growers for whom waste disposal is costly will also be awarded contracts. Contract awards to this latter group will be made without regard to potential disposal costs, however. Once regulation is imposed, growers for whom waste disposal is profitable will retain contracts but some growers for whom waste disposal is costly will lose contracts to growers with lower disposal costs (or will opt out of contract livestock production because it is no longer profitable once disposal costs are internalized). In other words, contract terminations can result from the imposition of regulation alone.

A formal model may help make this point more clearly. To simplify the analysis, assume that integrators do not play an active role in production and that growers differ in terms of their variable costs of disposing of livestock wastes in a manner that meets regulatory standards, denoted c, but are identical otherwise. Production contracts feature output sharing to mitigate the effects of (one-sided) moral hazard due to the non-contractibility of grower management effort, as before. The participation constraint in this case is $\alpha+\beta pf(x_0,z^c)-vz^c-c \geq u_0$, where x_0 is a fixed level of integrator inputs and z^c is the grower's optimal input choice under the terms of the contract, specifically the output share β. The cost of waste disposal c is negative for growers with profitable disposal options. For growers for whom waste disposal is costly, the cost of waste disposal is equal to min{0,c} in the absence of regulation and positive ($c > 0$) otherwise. Let G(c) be the number of growers with disposal cost no greater than c.

Let Q be the integrator's demand for total output, for example, the level of throughput that minimizes the total cost of operating the processing plant (if the average cost of processing is U-shaped and the integrator is a price-taker in the market for processed products, then this level maximizes processing profit). The number of growers receiving contracts in this case will be $Q/f(x_0,z^c)$. Suppose that each grower's cost of waste disposal is private information (i.e., unknown to the integrator) but that the market for contracts is competitive. In the absence of regulation, contracts will be awarded to all growers with negative disposal costs and to some growers with positive disposal costs. The integrator will be indifferent to the grower's disposal cost since the fixed payment needed to induce participation will be independent of the disposal cost. When regulation is imposed, however, integrators are no longer indifferent to waste disposal costs since the fixed payment needed to induce participation will rise to ensure that the marginal grower awarded a contract is compensated adequately for the cost of regulation. Thus, contracts will be awarded to the growers with the lowest disposal costs up to the point needed to ensure total processing throughput Q. The marginal grower awarded a production contract will have disposal cost c* defined by $G(c^*) = Q/f(x_0,z^c)$ or $c^* = G^{-1}(Q/f(x_0,z^c))$. If integrators offer a uniform contract to all growers, the fixed portion of the grower's compensation α will be set to ensure an output level Q and will thus be

(12) $$\alpha = u_0 + c^* + vz^c - \beta f(x_0, z^c).$$

Three conclusions can be drawn from condition (12). First, growers with waste disposal costs greater than c* will either find their contract terminated or will voluntarily exit the industry because contract livestock production is no longer more profitable than alternative occupations (which pay u_0). In other words, contract terminations can result from the imposition of regulation by itself and is thus not necessarily attributable to co-permitting. Second, growers for whom waste disposal is profitable will earn additional rent from the imposition of regulation when integrators offer uniform contract terms to all growers. Prior to regulation, they earned profit from waste utilization equal to c; after regulation they earn c*-c, benefiting from the fact that the cost of waste disposal of the marginal grower is passed on to the integrator. Thus, when contract terms are uniform, some growers may actually gain from the imposition of environmental regulations imposing waste disposal standards that are costly at the margin but that do not involve co-permitting.

In the analysis of the preceding paragraphs, all the costs of meeting regulatory standards for livestock waste disposal are passed on from growers to integrators. The reason that integrators bear all the cost is that their demand for processing throughput was assumed to be perfectly inelastic. It is possible, for course, that increases in the acquisition cost of finished livestock would lower the efficient scale of operation of the processing plant. Such an effect is easily incorporated into the model by letting processing demand Q be a function of waste disposal cost Q(c) such that $Q_c < 0$.[3] The marginal contract award in such a case would be made to a grower with disposal cost c** defined implicitly by $G(c^{**}) = Q(c^{**})/f(x_0,z^c)$. Incorporating this specification into the model would not change any of the qualitative conclusions as long as c** > 0, regulation remains costly at the margin. The number of contract terminations and/or voluntary exits

[3] The integrator's average payment per unit of finished livestock is $\alpha/f(x_0,z^c)+\beta$, which can be written (after substituting for the equilibrium fixed payment α) as $(u_0+c^{**}+vz^c)/f(x_0,z^c)$, an increasing function of the waste disposal cost of the marginal grower, c*. Since demand for throughput is downward sloping in price, an increase in c* reduces the equilibrium quantity of processing throughput $Q(c^{**}) \equiv Q((u_0+c^{**}+vz^c)/f(x_0,z^c))$.

would be larger and the rent earned by growers for whom waste disposal is profitable would be smaller than in the case of inelastic processing demand.

Even allowing for reductions in throughput demand, it remains the case that all of the remaining growers' costs of meeting regulatory waste disposal standards will be passed to integrators by means of the increase in the fixed portion of the grower's compensation needed to ensure participation, α. The underlying reason why integrators pay the full cost of waste disposal—and some additional rent—is because disposal costs are growers' private information. Furthermore, it seems unlikely to be feasible for integrators to develop contractual mechanisms that would allow them to avoid those costs. Auctioning off contracts by having growers bid on the fixed payment α is unlikely to result in an equilibrium in which all growers bid their true reservation price, $u_0+c+vz^c-\beta f(x_0,z^c)$ because it will typically be easy for growers to exchange information, if not collude outright. One would expect the outcome of such auctions to be a single price equal to c* (or c**). Nonlinear pricing schemes are unlikely to be workable, either, because there tends to be little correlation between observable variations in outcomes (e.g., total production of finished animals or total manure generated) and disposal cost.

The preceding analysis also assumed that all of the costs of meeting regulatory standards for livestock waste disposal were variable. It is possible, however, that meeting these regulatory standards would require some investment in waste handling facilities and equipment. The fixed costs arising from such investments (e.g., loan repayments) must be met whether or not the grower continues producing livestock under contract, unless the grower is able to sell all of the facilities for their full value. If growers cannot recoup those investments when they cease contract livestock production, their earnings from alternative occupations will be lower by the amount of their fixed cost obligations. Thus, if waste handling capital is non-salable (e.g., because the industry shrinks in size in a given region), growers will not be able to pass their fixed cost obligations on to integrators. Specifically, let k denote the grower's annual fixed payments for irrecoverable investments in waste handling facilities and equipment. (For simplicity, assume that all growers' investments are the same.) The net annual earnings of a grower in an alternative occupation will be u_0-k. The fixed payment guaranteed to the grower will thus be

(13) $$\alpha = u_0 - k + c^* + vz^c - \beta f(x_0, z^c),$$

i.e., reduced by an amount equal to the annual irrecoverable fixed cost.

Impacts of Co-Permitting

Co-permitting gives integrators a direct interest in waste disposal. As a result, integrators would likely alter the terms of production contracts to protect themselves against legal (and financial) liability for failure to meet waste disposal regulations. One possibility would be to include in production contracts terms that explicitly define growers' duties for waste disposal. Another possibility would be for integrators to take ownership of livestock waste and oversee its disposal directly. The former would likely result in a redistribution of income from growers to integrators. The latter would likely not alter the distribution of income between growers and integrators unless integrators have opportunities for waste disposal that are not available to growers either individually or collectively.

Giving integrators legal authority over waste disposal can result in a transfer of income from growers to integrators in two distinct ways. First, incorporating waste management provisions into production contracts could reveal growers' private information about disposal costs, which could in turn allow integrators to appropriate any gains from waste disposal and ensure that growers paid all waste disposal costs. Second, imposing specific waste disposal requirements could limit growers' ability to change integrators by increasing the cost of making such a transition.

Consider first the question of information provision. One eminently reasonable way for integrators to show regulators that they had taken verifiable and enforceable steps to ensure compliance with waste management regulations would be to require growers to submit detailed waste disposal plans conforming to regulatory standards as a condition of being awarded a contract, with the proviso that failure to follow those regulatory standards would result in financial penalties and/or the loss of future contracts. Since waste management regulations typically impose due diligence requirements rather than strict liability for damages incurred, such a procedure could absolve integrators of legal liability by allowing them to demonstrate that they had taken adequate precautionary measures. Such a process could, however, reveal to integrators each grower's private information about waste disposal costs. With that information in their possession, integrators could bargain individually with each grower over the size of the fixed payment needed to ensure the grower's participation. Since integrators likely have most, if not all the bargaining power, the result of such negotiations would likely be individual payment guarantees allowing the integrator to capture most, if not all, of the surplus generated in the production of finished animals. If the integrator had all the bargaining power, for instance, the fixed payment for a grower with waste disposal cost c would be

(14) $$\alpha(c) = u_0 + c + vz^c - \beta f(x_0, z^c)\,.$$

The integrator would appropriate all profits from waste disposal (c < 0) and would force growers with positive waste disposal costs (c > 0) to pay the full amount of those costs.

Integrators could also increase their leverage over growers by specifying that growers invest in integrator-specific waste handling facilities and equipment. The annual payments for such investments would be irrecoverable if a grower switched from one integrator to another utilizing a different set of waste handling facilities and equipment. Waste handling contract specifications could be used in this manner to limit grower mobility and thus competition between integrators for growers, increasing integrators' bargaining power relative to growers'. As noted earlier, these irrecoverable fixed annual payments would also lower the fixed payment guarantee needed to ensure adequate grower participation.

In contrast, integrators would seem to stand to gain little or nothing by taking title to (or physical possession of) livestock waste unless they have opportunities for disposal that are more profitable (or less costly) than those available to growers individually or collectively. The amount of waste generated by each grower is unlikely to be correlated with disposal cost (or profit), so monitoring it would not allow integrators' to devise nonlinear pricing mechanisms allowing them to appropriate profits from disposal (or ensure that growers pay any costs). Taking possession of livestock waste is unlikely to reveal growers' private information about disposal costs, either. It could, however, be advantageous for integrators to contract for possession of livestock waste as well as finished livestock output under certain conditions. For example, if the transaction costs involved in finding the most profitable/least cost disposal options are decreasing in the volume of waste handled, waste disposal could be less costly for integrators than growers. Alternatively, integrators might be able to utilize economies of scale in some means of disposal. One possible example is the Perdue/AgriRecycle venture on the Delmarva Peninsula that pelletizes poultry litter to sell as a component of fertilizer formulated for precision agriculture. Perdue's control over placements gives it the ability to coordinate (and ensure) deliveries of poultry litter at a lower cost than individual growers or than an outside firm. It remains to be seen whether this venture will remain profitable, however.

Conclusions

This examines the efficiency of co-permitting and to its likely impacts on the distribution of income between integrators and growers. We model co-permitting as a general form of joint liability for environmental damage from livestock waste imposed on both integrators and growers. We show that joint liability for environmental damage offers a means of correcting distortions caused by moral hazard at the same time as it addresses environmental concerns—whether or not the integrator plays an active role in production. We also show that, in most circumstances, (1) joint integrator/grower liability is necessary to achieve socially optimal production and waste management together; (2) both the grower and the integrator should be liable for less than the full social cost of environmental damage; and (3) the industry as a whole should be liable for less than the full social cost of environmental damage.

Note that the industry as a whole can be made liable for less than the full social cost of environmental damage by adopting a hybrid policy that combines full liability for the social cost of environmental damage with subsidies for waste management designed to mitigate the effects of grower moral hazard in production. Such a policy could utilize an ambient pollution tax along with waste management subsidies. Alternatively, it could impose co-permitting that required the industry as a whole to adopt measures resulting in socially efficient generation and disposal of livestock waste along with subsidies that reduce the cost of production to mitigate grower moral hazard.

Grower testimony regarding EPA's proposed CAFO regulation expressed fears that co-permitting would have adverse effects on growers relative to integrators. Economic theory suggests that those fears have a basis: Co-permitting is likely to result in a redistribution of income from growers to integrators. Regulation is likely to create opportunities for growers pass all of the costs of complying with waste management regulations and for some growers to earn additional rent due to their possession of private information about waste disposal costs. Co-permitting could allow integrators to uncover that information, which would in turn allow them to force growers to bear all the costs of complying with waste management regulations and to appropriate all profits from waste disposal. Co-permitting could also provide means for integrators to tie growers more tightly by making it more costly for growers to switch integrators.

The analyses presented here were simplified in a number of important ways. Growers were assumed to be identical. In reality, they are likely to differ in terms of management ability, creating problems of hidden information in production that would likely be addressed in contract terms and would thus influence the desirability of joint liability for environmental damage from livestock waste and the appropriate form of policies for addressing that damage. Production contracts were assumed to be linear, with incentive payments based on total output. Many livestock production contracts feature tournament compensation schemes in which incentive payments are based on relative productivity, e.g., higher than average feed conversion efficiency (Knoeber). Further research would be needed to assess the implications of these factors on the efficiency and distributional impacts of co-permitting.

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