Using Setback Requirements as an Economic Incentive to Reduce Livestock Waste Odors

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Abstract

This paper evaluates how much longer setback lengths associated with surface application must be to encourage soil injection of swine manure in Kentucky. Results indicate that proposed setback lengths do not encourage odor control via injection; the setback length associated with surface application must be substantially longer than that associated with injection.

Keywords: Confinement, Swine, Manure, Odor, Injection

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With increased concentration in the swine industry comes increased concern over surface and groundwater quality, air quality and the quality of rural life (Roka and Hoag, 1996; Letson and Gollehon, 1996; Palmquist et. al., 1997). With respect to air quality and the need to protect people, property, and natural areas from swine manure nutrients and odors, some states have turned to “separation” or “setback” provisions. These provisions require that swine production facilities or fields receiving swine manure be located a specified distance from neighbors, subdivisions, municipalities, public areas and surface water. The rational behind setback legislation is to allow sufficient room for the atmosphere to assimilate or diffuse noxious odors.

A second regulatory approach for improving air quality is to physically suppress noxious odors by incorporating swine manure into soil. With incorporation the manure is sealed in soil preventing (or, at least, slowing) the release of pungent odors into the atmosphere.

Unlike the nation, the State of Kentucky, since 1982, has experienced a decline in both the number of farms with pigs and the number of pigs grown (US Census of Agriculture). Nevertheless, some counties in the western half of the state (the primary agricultural region) are experiencing significant growth in the swine industry. Because of the growth in these counties and proposed investment in the region by other producers, the state of Kentucky is aggressively pursuing policies that address swine related manure nutrient management and odor concerns.

To address odor related concerns, Kentucky’s Natural Resources and Environmental Protection Cabinet (NREPC) is considering a number of setback requirements for large scale swine operations (one time capacity in excess of 420,000 pounds live weight). However, the
NREPC would like to differentiate the setback lengths such that there is an economic incentive to choose incorporation application of manure over surface application (a more odorous option relative to incorporation). Specifically, the setback length for surface application would be greater than that for incorporation. This paper mathematically defines the cost of manure management and uses this definition to estimate how much longer the setback length associated with surface application must be to encourage incorporation of swine manure. Given this empirical information, a set of proposed setback lengths will be evaluated to determine if they are incentive compatible.

The setback provisions being explored by the NREPC are unique because swine producers would be required to “control” all acreage receiving manure and all acreage within the setback. Control is defined as ownership or a long-term lease agreement. This is a critical departure from similar legislation in other states. Specifically, in most states, swine producers are allowed to apply manure to neighboring fields without formal legal agreements.

CONCEPTUAL FRAMEWORK AND EMPIRICAL MODEL

The empirical focus of this investigation is a large swine producer who is investigating the costs associated with locating in western Kentucky. It is assumed that the producer has not invested in land or production facilities; there are no expansion opportunities at current production sites. Furthermore, this producer is not currently producing crops or other agricultural commodities in the state. With respect to location choice, the producer is only constrained by the
availability of acreage suitable for receiving manure that is sufficiently large to comply with
Kentucky’s set back requirements. This analysis also assumes a land management strategy where
a swine production facility is centrally located within the land application area.

Meeting the objectives of this study requires estimating the marginal cost of land
acquisition and manure application for surface (irrigation) and incorporation (injection) manure
delivery systems. Conceptually, when the marginal cost of surface applying manure is equal to the
marginal cost of incorporating manure, the producer is indifferent between the two systems at that
level of swine production. Moving away from this point, the producer will choose the delivery
system that minimizes cost.

Given this theoretical basis, an empirical model of land acquisition and manure application
cost is developed. Using the empirical model, more specific information can be gained concerning
the degree to which the two setback requirements must differ if incorporation of manure is the
policy goal.

The total cost of manure management (TMC) is calculated using Equation 1. TMC is the
sum of the total land charge (TLC), the base charge (BC), and the additional mileage charge
(AMC). The TLC represents the cost of acquiring sufficient crop land for receiving manure stocks
and complying with the setback provisions (Fleming, 1998). The BC represents the cost of
hauling a quantity of manure and the AMC the variable cost of moving a quantity of manure a
given distance (Fleming et. al., 1998; Fleming, 1998).

With respect to the components of Equation 1, La is the amortized per acre price of land,
QM is gallons of raw manure and added water for lagoon treatment, NM is the quantity (pounds) of
nitrogen in a gallon of delivered manure (after storage losses), NC is the inverse of the quantity
(pounds) of nitrogen needed by a crop on a per acre basis, and H is swine production in 1,000 pounds live weight. The product of the proportion of cropland, \( \alpha \), the proportion of suitable cropland, \( \beta \), and the proportion of crop acres where manure is accepted, \( \gamma \), is called the suitability coefficient (Fleming et. al., 1998). Its purpose is to inflate required acreage to account for areas where manure cannot be applied. The remaining parameters in Equation 3 include \( r_s \), the setback distance measured in feet, \( c \), a constant representing \( \pi \) divided by 43,560, \( r_B \), the unit cost of hauling manure, and \( \theta \), the slope of the unit mileage charge schedule (Fleming, 1998).

\[
TMC = TLC + BC + AMC \\
= L \alpha \left( Q_M N_M N_C H + 2 r_S \left( \frac{Q_M N_M N_C H C}{\alpha \beta \gamma} \right)^{\frac{1}{2}} + C r_S^2 \right) + r_B Q_M H + \theta \left( \frac{Q_M H}{5,280} \right)^{\frac{2}{3}} \left( \frac{N_M N_C}{C \alpha \beta \gamma} \right)
\]

Equation 1 is the general formulation of TMC. In fact, TMC will vary by method of manure application (as reflected in differences in \( N_M \), \( r_B \) and \( r_S \)) and by the crop to which manure is applied (\( N_C \)). Given Equation 1 and assuming no difference in crop, the marginal cost of manure management using surface application and incorporation can be calculated. Comparing these marginal costs is useful when trying to determine if a specific set of setback lengths will result in adaptation of incorporation. But more importantly, these marginal costs can be used to determine the relationship between the setback lengths for surface application and incorporation of manure. This is accomplished by setting the marginal cost of surface application equal to the marginal cost of incorporation and solving for one of the setback lengths (either \( r_S,S \) or \( r_S,I \); see Equation 2).
Equation 2 shows that the setback length associated with surface application of manure \( r_{s,s} \) is a linear function of the setback length associated with incorporation of manure \( r_{s,i} \) and that the difference between the two setback lengths varies by the level of swine production. For the marginal costs of surface application and incorporation to be the same, \( r_{s,s} \) must be greater than \( r_{s,i} \) at all levels of swine production. For \( r_{s,s} \) to equal \( r_{s,i} \), \( N_{M,i} \) must equal \( N_{M,S} \) and \( r_{B,I} \) must equal \( r_{B,S} \). Specifically, the setback lengths will be equal only when the nutrients delivered in swine manure and the cost of delivering those nutrients are the same for the two application systems.

**RESULTS**

Relevant parameter values for Western Kentucky are reported in Table 1. Additional information concerning these parameters is provided by Fleming (1998). In this investigation, the suitability coefficient (the product \( \alpha \beta \gamma \) in Equations 1 and 2) is assumed to be 1. Specifically, all the acreage purchased for land application of manure is available and suitable for application.

Solution values for \( \lambda(H)_0 \) and \( \lambda_1 \) from Equation 2 are calculated for three crop scenarios.
(continuous soybeans; corn, soybeans, wheat and bermuda grass in rotation; and continuous bermuda grass) and 3 levels of production (0.42, 5.04, and 10.08 million pounds of annual live weight).

### Table 1. Parameter values and solutions to Equation 2 at three levels of swine production.

<table>
<thead>
<tr>
<th>Equation Parameters</th>
<th>Soybeans</th>
<th>Mixed Crops</th>
<th>Bermuda grass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface</td>
<td>Inject</td>
<td>Surface</td>
</tr>
<tr>
<td>(Q_M N_M N_C) (Ac./1,000 lbs)</td>
<td>0.57</td>
<td>0.94</td>
<td>0.28</td>
</tr>
<tr>
<td>(Q_M) (Gallons/1,000 lbs)</td>
<td>8,422</td>
<td>8,422</td>
<td>8,422</td>
</tr>
<tr>
<td>(L_a) ($/Ac.)</td>
<td>92.74</td>
<td>92.74</td>
<td>92.74</td>
</tr>
<tr>
<td>(r_b) ($/Gal.)</td>
<td>0.0057</td>
<td>0.0071</td>
<td>0.0057</td>
</tr>
<tr>
<td>(\theta)</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
</tr>
</tbody>
</table>

**Solution Values**

The slope term: \(\lambda_1\)

- Soybeans: 1.2842
- Mixed Crops: 1.2956
- Bermuda grass: 1.291

**Annual Production**

<table>
<thead>
<tr>
<th>1,000 lbs live weight</th>
<th>(\lambda(H)_0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>420</td>
<td>1,679.05</td>
</tr>
<tr>
<td></td>
<td>1,512.31</td>
</tr>
<tr>
<td></td>
<td>1,485.51</td>
</tr>
<tr>
<td>5,040</td>
<td>9,237.43</td>
</tr>
<tr>
<td></td>
<td>7,745.29</td>
</tr>
<tr>
<td></td>
<td>6,758.06</td>
</tr>
<tr>
<td>10,080</td>
<td>18,341.62</td>
</tr>
<tr>
<td></td>
<td>14,820.48</td>
</tr>
<tr>
<td></td>
<td>12,044.46</td>
</tr>
</tbody>
</table>

1) Corn, Soybeans, Wheat and Bermuda grass.
2) The constant C is 0.0000721.
3) To convert to head, divide by the average weight. For finished hogs divide by 168.

The solution values reported in Table 1 can be interpreted as follows. At 420,000 pounds of production and with manure applications to soybeans, if the setback length for incorporation
(r_{S,1}) is zero, then the setback length for surface application (r_{S,S}) has to be 1,679 feet for the producer to be indifferent between the two application methods (the marginal cost of the two application methods is the same). If r_{S,S} is less than 1,679 feet, then surface application is the preferred application method (it is least cost). And for every one foot increase in r_{S,1}, r_{S,S} has to be increased 1.28 feet to equate marginal cost. Hence, at 5.04 million pounds of production with manure applications to corn, soybeans, wheat, and bermuda grass in rotation, if r_{S,1} is 500 feet, then r_{S,S} must exceed 8,393 feet for incorporation to be the preferred manure application method.

Table 1 also shows that switching crop production to a crop that poorly utilizes nitrogen (like soybeans) favors surface application (a longer r_{S,S} is needed to equate marginal cost) while switching to a crop that is an intensive utilizer of nitrogen (like bermuda grass) favors incorporation. As an efficient user of nitrogen, less acreage is required to spread manure on bermuda grass. This cost savings allows soil incorporation to be the preferred manure management strategy at shorter setback lengths for surface application (r_{S,S}). But, as shown later, this result depends on the cost of land acquisition. Increasing production (moving from 0.42 to 10.08 million pounds) favors surface application of manure.

While not reported in Table 1, the sensitivity of model results to changes in key parameters was evaluated. In general, at any level of production, results are least sensitive to changes in crop mix. Using the mixed crop scenario, the sensitivity of model results to changes in the difference in required acreage (Q_{MN_{M,I}N_C} - Q_{MN_{M,S}N_C}) and the difference in manure delivery cost (r_{B,1} - r_{B,S}) is also measured. At an output level of 420,000 pounds, with r_{S,1} set to zero, and with a difference in required acreage of 0.19 acres per 1,000 pounds, marginal costs are equal when r_{S,S} is 1,512 feet (Table 1). If, instead, Q_{MN_{M,I}N_C} is equal to Q_{MN_{M,S}N_C}, then r_{S,S} is 447 feet.
Hence, at 420,000 pounds of output, there is a 56-foot increase in the setback length for surface application for every 0.01 acre increase in the difference in required acreage. At 10.08 million pounds of production, the marginal costs of manure management by surface application and incorporation are equal if the setback length for surface application \((r_{S,S})\) is increased 665 for every 0.01 acre increase in the difference in required acreage.

Model results are less sensitive to changes in the difference in manure delivery cost. Specifically, at 420,000 pounds of output, there is a 41-foot increase in the setback length for surface application for every $0.0001 increase in the difference in manure delivery cost. At 10.08 million pounds of production, the marginal costs of manure management by surface application and incorporation are equal if the setback length for surface application is increased 203 for every $0.0001 increase in the difference in manure delivery cost.

Model results are also sensitive to the assumed value of land \((L_a)\). Again, according to the proposed state regulations considered here, Kentucky swine producers would be required to control (i.e., own or have an easement on) not only the acreage to which manure is applied, but also the acreage required to meet setback obligations. This requirement significantly increases land holdings and costs associated with manure management. Large swine operations are, generally, in the business of raising hogs, not crops. Hence, it is expected that purchased acreage within the setback will be rented to crop farmers to capture the productive value of the land. Thus, the amortized land charge \((L_a)\) reported in Table 1 is the difference between the amortized purchase price ($175.24 per acre per year) and the rental value of crop acreage (5.5% of market value or $82.50 per acre per year), specifically, $92.74 per acre per year. This is also assumed to
be the price a swine producer would have to pay to obtain a manure and (or) setback easement on neighboring crop acreage.

Actual out-of-pocket land costs could be $32 (irrigation) to $39 (injection) lower if manure nutrients are accounted for in the rental arrangement (Fleming et. al., 1998). And in most states where setback legislation does not require legal control over acreage, acreage purchases (La) are zero. In this case, the decision to surface apply or incorporate manure is based on which method minimized manure delivery cost (BC + AMC in Equation 1; Fleming et. al., 1998). Hence, the impact that changes in La has on setback length is important (Table 2).

Table 2. Sensitivity of setback length (the constant parameter \( \lambda(H) \) in feet) to changes in land acquisition cost (La).

<table>
<thead>
<tr>
<th>La ($/Acre)</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47,202.14</td>
<td>60,747.01</td>
<td>442,887.4</td>
</tr>
<tr>
<td>5</td>
<td>10,386.69</td>
<td>12,842.70</td>
<td>90,979.15</td>
</tr>
<tr>
<td>10</td>
<td>5,784.75</td>
<td>6,854.66</td>
<td>46,990.62</td>
</tr>
<tr>
<td>15</td>
<td>4,250.78</td>
<td>4,858.65</td>
<td>32,327.77</td>
</tr>
<tr>
<td>25</td>
<td>3,023.60</td>
<td>3,261.84</td>
<td>20,597.49</td>
</tr>
<tr>
<td>35</td>
<td>2,497.66</td>
<td>2,577.49</td>
<td>15,570.23</td>
</tr>
<tr>
<td>50</td>
<td>2,103.21</td>
<td>2,064.23</td>
<td>11,799.79</td>
</tr>
<tr>
<td>100</td>
<td>1,643.02</td>
<td>1,465.43</td>
<td>7,400.93</td>
</tr>
<tr>
<td>150</td>
<td>1,489.62</td>
<td>1,265.83</td>
<td>5,934.65</td>
</tr>
</tbody>
</table>

A - 420,000 pounds of production with manure applications to soybeans.  
B - 420,000 pounds of production with manure applications to a mixed crop rotation.  
C - 5,040,000 pounds of production with manure applications to a mixed crop rotation.
Table 2 shows that decreasing land acquisition costs favor surface application of swine manure. Specifically, as the cost of acquiring acreage decreases the difference in setback length that is needed to encourage incorporation increases. Conversely, increasing land acquisition costs favor incorporation. But the relationship between land cost and setback length is hyperbolic. Hence, there is a range where increasing land costs no longer favor incorporation.

With lower land acquisition costs, switching to a crop rotation that better utilizes nitrogen (fewer acres are needed to receive swine manure) favors surface application (compare columns A and B, Table 1). However, at higher land prices, we find the result reported in Table 1, specifically, switching to a crop that better utilizes nitrogen favors incorporation of manure (the respective functions for the two crop types cross between $35 and $50 per acre). Hence, at lower land prices, the savings associated with less acreage needed for manure spreading are not sufficient to justify incorporation, the more expensive manure management option. Finally, increasing swine production will favor surface application regardless of land acquisition cost (compare columns B and C, Table 2). And this result was shown in Table 1. However, at lower land acquisition costs, the advantage of surface application with increased production is large.

**CONCLUSIONS AND POLICY IMPLICATIONS**

Using the empirical model developed in this investigation, it is shown that swine producers will prefer incorporation of swine manure only if the setback length associated with surface application is sufficiently larger than that associated with incorporation. The results of this investigation show, for the conditions imposed, that the setback length for surface application of
Swine manure must exceed the setback length for incorporation by, at least, 1,485 feet if incorporation is to be the least cost manure management strategy. The required difference in setback length does depend on one’s chosen level of swine production and on the crop mix to which manure is applied. It also depends on the cost of acquiring land. With factory style swine production and with manure applications to a crop that is a relatively inefficient utilizer of nitrogen, the difference in setback length needed to promote incorporation will exceed 3 miles.

To protect property and natural areas from swine manure nutrients and odors, Kentucky’s NREPC, proposed a set of setback lengths for production facilities and manure application fields. Furthermore, to improve air quality near manure application areas, the NREPC differentiated the setback lengths such that the required setback length for surface application exceeded the required setback length for incorporation. For example, surface-applied manure application fields are required to be 1,500 feet from down stream surface waters while incorporated manure application fields are only required to be setback 750 feet. And this (750 feet) is the greatest difference in setback across all the proposed setbacks. What the results of this study show is that the differences between the proposed setback lengths for surface application and incorporation are not sufficient to encourage incorporation. Specifically, the NREPC’s proposed setback lengths are not incentive compatible. The setback lengths are not sufficiently different to provide an economic incentive to adapt incorporation as a manure management strategy.

Incorporating swine manure into crop acreage is expensive relative to surface application. The unit cost of incorporation is higher and injecting requires more crop acreage for land application. These higher costs make necessary large differences in setback lengths if incorporation is to be encouraged through implementation of setback provisions. It is possible
that the setback lengths suggested by this model are so great that they cease to be politically feasible. And this study does not account for many of the extra costs associated with incorporation including damage to standing crops, impaction, increased manure storage and more restrictive time constraints. Given the results of this investigation, other economic incentives that encourage incorporation of swine manure should be explored.

REFERENCES


