Citizen Complaints, Regulatory Violations, and their Implications for Swine Operations in Illinois

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Abstract

In this paper, statistical and economic analyses are used in identifying, analyzing, and modeling the relationships among citizen complaints, swine production and community characteristics, EPA inspections, and regulatory violations. The primary results of this research include assessments of factors that affect citizen complaints and factors that affect the probability of regulatory violations. In addition, the analyses also provide statistical results of a comparison of the efficiencies of different types of site inspections in regulatory violation detection. Our results provide information valuable for understanding issues surrounding the development of the swine production industry and local communities.

Keywords: community, complaint, EPA, facility characteristics, inspection, regulation violation, swine.

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CITIZEN COMPLAINTS, REGULATORY VIOLATIONS, AND THEIR IMPLICATIONS FOR SWINE OPERATIONS IN ILLINOIS

Since 1979 the Illinois Environmental Protection Agency (EPA) has operated a livestock waste management program that provides for inspection of livestock production facilities throughout the state. Generally, Illinois EPA inspections are initiated either by citizen complaints or by random selection of facilities based on a regular schedule. Illinois EPA takes citizen complaints seriously and responds to each complaint by sending its agricultural engineer for site inspection promptly. Citizen complaints can be filed in written forms, by phone, or on the Agency's website. Concurrently, Illinois EPA data document that facility inspections are primarily prompted by citizen complaints.

Hogs are the third largest agricultural commodity in Illinois after corn and soybeans. Among all the livestock operations inspected during 1997-2001, swine facilities accounted for 62% of the total facilities inspected. Of inspected swine facilities, 59% were inspected as a response to citizen complaints. From 1997 through 2001, 157 Illinois swine facilities received odor complaints, 180 received water pollution complaints, and 81 received both odor and water pollution complaints (figure 1). Citizen complaints may indicate possible noncompliance with the environmental and livestock waste regulations, or indicate complainers' concerns over the potential impact of the facilities on their health and/or property values. Avoiding citizen complaints is vital to the sustainable development of swine production. This has become particularly important because of the rapid increase in size of swine operations and the geographic concentration of production over the past two decades. To date, a substantial amount of data have been accumulated from Illinois EPA site inspections regarding the characteristics and regulatory compliance status of operations along with other details. These data, obtained from all inspections (those as a result of complaints and those conducted on a regular schedule), represent a valuable source of information about factors that may cause citizen complaints and facility regulatory violations. The purpose of this paper is to explore relationships between facility characteristics, citizen complaints, and regulatory violations and suggest implications for the swine industry using the citizen complaint and Illinois EPA inspection data.

Background

There is a general dearth of formal research on the causes and implications of citizen complaints against swine as well as other livestock operations. In an earlier study Hardwick counted the number of livestock facilities in the United Kingdom that were causing justifiable odor complaints and found that among 1,820 pig, cattle, and poultry farms, 46% of the complaints were associated with manure land applications, 25% with building odors, and 19% with manure storage. Recently, Kliebenstein and Lorimor conducted a survey of Iowa pork producers and found that 21.7% of the 354 producers responding had received a complaint in the last five years (Messenger). Their preliminary results show that complaints were not necessarily related to farm size and that neighbors within 1/8 to 1/2 miles filed more complaints than those living further away. However, these findings were limited because they might be subject to potential response bias (e.g., producers who had received complaints might be more or less likely to respond to the survey than those with no complaints) and lacked adequate statistical evaluation.

Some economic studies of inspections and regulatory violations in other industries have been conducted (Feinstein, 1989; Helland; Smith). Feinstein (1989) constructed models to study the factors associated with regulatory noncompliance of U.S. nuclear power plants, the variation in detection rates among the Nuclear Regulatory Commission inspectors, and the relationship between undetected violations and abnormal occurrences. Helland used models similar to those proposed by Feinstein (1989) to examine the role of inspections in producing regulatory compliance and self-reporting under the Clean Water Act in the pulp and paper industry. Smith compared the productivities of two types of inspections (i.e., worker complaint initiated vs. generally scheduled inspections) conducted by the Occupational Safety and Health Administration (OSHA) and found that these two types of OSHA inspections were similarly productive in detecting safety violations in 1977-79. More recently, Eckert examined the effect of inspections and warnings to enforce environmental regulations at the petroleum storage sites in Manitoba, Canada using a two-stage-probit model. The author showed that though inspections deterred future violations, this effect is small.

The following sections are designed to answer the following questions: Are citizen complaints and regulatory violations related to production characteristics of swine facilities such as operating capacity and the type of manure storage? Are citizen complaints related to characteristics of the surrounding communities and its citizens such as education attainment, income level, and property values? Are complaint-initiated inspections as effective as regularly scheduled inspections in detecting air and water regulatory violations of the facilities and what are the implications of this analysis on the EPA's inspection resource allocation? What are some of the factors that may influence a producer's likelihood of having a regulatory violation?

Association between facility characteristics and citizen complaints and regulatory violations

The characteristics of a livestock facility that are recorded in an Illinois EPA inspection include types of livestock raised or boarded, operating capacity in terms of the National Pollutant Discharge Elimination System (NPDES) defined animal units (AU)[1], types of livestock waste storage structures, number of lagoons or outside holding ponds, types of building structures (total confinement or others), and existence of a concrete settling basin. Specifically, Illinois EPA categorizes the operating capacities of livestock facilities into six groups, ranging from less than 50 to more than 7,000 AU. Since operations with a capacity of 1,000 or more AU are subject to more restrictive environmental and livestock waste management regulations, we regroup inspected swine facilities into two capacity categories: less than 1,000 AU or more than 1,000 AU. Similarly, based on the available inspection data, facilities are also divided into two categories using the following pairs of nominal variables: with at least one or with no lagoon/holding pond; consisting of total confinement buildings only or otherwise; with or without an open feedlot; and with or without a concrete settling basin. In addition to categorization based on these characteristics, facilities are also categorized by whether or not they are complained against and/or are in regulatory violation. Specifically, facilities are categorized according to whether they receive an odor complaint, a water pollution complaint, or either of these two complaints. Regulatory violations are distinguished by air emission violations, water pollution violations, and any regulatory violations.[2] The number of inspected swine facilities in terms of the above categorizations is shown in table 1.

We assume that facilities that are not complained against but inspected are chosen without regard to specific facility characteristics. This assumption is reasonable since in most cases the Illinois EPA inspectors do not have information about a facility's production characteristics prior to their visit to the facility regardless of whether the inspection is complaint-prompted or not. Statistical analysis of categorical data is used to assess the relationship between pairs of categorical variables, i.e., the relationship between the column variables such as facilities receiving an odor complaint or receiving no odor complaint and row variables such as operating capacity less than 1000 AU or greater than 1000 AU. The null hypothesis of no association between the row variable and the column variable is tested using various chi-square tests (Everitt; SAS Institute Inc.).[3] The hypotheses and their statistical test results are summarized in table 2, in which the lowest chi-square statistic and highest P value for each null hypothesis are reported. The statistical tests as well as other statistical analyses in this paper are all conducted using the SAS program Version 8.2.

Our results (table 2) show that operating capacity greater than 1,000 AU is statistically associated with more odor complaints ($\chi^2=21$, $P<0.001$) and more air emission violations ($\chi^2=10.74$, $P=0.001$). However, capacity less than 1,000 AU is associated with more water pollution complaints ($\chi^2=6.06$, $P=0.014$), more water regulatory violations ($\chi^2=19.89$, $P<0.001$), and more overall regulatory violations ($\chi^2=4.7$, $P<0.03$). Contrary to our intuition, outside lagoons/holding ponds are associated with fewer odor complaints ($\chi^2=4.83$, $P<0.028$), i.e., facilities with no outside lagoons/holding ponds are more likely to receive odor complaints. But we found no association ($P>0.05$) between waste storage type and other complaints/regulatory violations. Facilities with only total confinement buildings are associated with more odor complaints (χ^2=25.15, P<0.001) and more air emission violations (χ^2=3.94, P=0.047) but with fewer water complaints (χ^2=9.38, P=0.002) and fewer water regulatory violations (χ^2=64.93, P<0.001). When both odor and water pollution complaints and both air and water violations are considered, our results suggest that total confinement facilities lead to more citizen complaints (χ^2=3.85, P=0.05) while facilities other than total confinement result in more regulatory violations (χ^2=38.36, P<0.001). Facilities with open feedlots are associated with fewer odor complaints (χ^2=24.91, P<0.001) but more water pollution complaints (χ^2=11.13, P<0.001), more water pollution violations (χ^2=70.47, P<0.001), and more overall regulatory violations (χ^2=44.17, P<0.001). However, total confinement facilities are not significantly associated with more air emission violations or more overall citizen complaints. Finally, facilities with a concrete settling basin are associated with fewer odor complaints (χ^2=6.79, P=0.009) but more water and overall regulatory violations (χ^2=15.03, P<0.001; and χ^2=7.49, P=0.006, respectively).

Association between citizen complaints and community characteristics

Economic theory suggests that citizens are more likely to complain to the authorities about pollution when the expected benefits from agency action are likely to exceed the expected costs for their own investment of time and effort. According to Dasgupta and Wheeler, factors affecting citizen complaints in a region include pollution damage suffered by the individual, the individual's understanding of the problem (which is assumed to be a function of education), and the cost of a complaint (which is assumed to be a function of income). The relationship between citizen complaints and community characteristics is assessed using the county level data and an econometric model with the proportion of swine production facilities receiving complaints as the dependent variable. Among the independent variables, we include average swine operation scale, swine inventory intensity, and soil productivity rating to capture the pollution damage potential caused by swine production; proportion of residents with a high school diploma or higher to proxy education attainment of the residents in a county; and median household income in 2000. Other county characteristic variables such as distance to nearest city of a population over 50,000, rural-urban continuum code (Beale code), average farmland price, average home price, population density, and proportion of residents aged over 65 were also tried but eliminated in our analysis because of collinearity problems or showing little statistical significance. Table 3 describes the variables used in this study (for further description of these variables, see Huang et al.).

Table 4 shows that the three models of citizen complaints produce similar estimation results and all are statistically significant. In addition, the signs of the coefficients are, in general, as expected. Higher swine inventory intensity leads to higher percentage of swine facilities being complained against. This finding is consistent with our intuition that higher swine production intensity in terms of number of hogs per square mile may generate greater environmental pollution and hence a higher proportion of facilities being complained against. However, the estimated coefficient of the average swine operation scale bears a negative sign, suggesting that given the number of hogs in a county, more concentrated production may be associated with less overall environmental pollution at the county level and therefore lead to a lower proportion of facilities receiving citizen complaints. A plausible explanation for this finding is that most of the large operations are relatively new and rely on more advanced production technologies that are less offensive to citizens in the local communities.[4] Our results also show that higher soil productivity ratings are related to a higher proportion of facilities being complained against. Since soil productivity ratings are used to capture pollution damage potential arising from swine production, the higher the soil productivity, the higher the marginal pollution damage becomes. On the other hand, owners of land with higher soil productivity ratings have more incentive to protect their land that has higher values. Moreover, consistent with economic theory, a higher household income tends to cause a lower proportion of facilities being complained against because the opportunity cost of complaints is higher in high income counties. Finally, it is worth noting that the adjusted R^2s are low (less than 0.2) in all three estimated equations, suggesting that factors affecting citizen complaints are far more complicated than what we have modeled.

Efficiencies of complaint-initiated and regularly scheduled inspections in detecting regulatory violations

The usefulness of citizen complaints for regulatory enforcement agencies to allocate inspection resources is controversial (Smith; Dasgupta and Wheeler). One view is that complaints are undoubtedly a source of low-cost information, since pollution and regulatory violations of a facility are often apparent to their neighbors even if they are invisible to governmental agencies. The other is that complainers may lack sufficient information to distinguish between a nuisance and a true regulatory violation. In addition, some individuals or communities may have a higher propensity to complain than others, regardless of the objective situation. Therefore, if agencies respond to complaints, aggressive complainers may capture most of the available resources.

As noted earlier, the Illinois EPA is responsive to each complaint with a site inspection and complaint-initiated inspections compose a majority (59%) of the agency's swine facility inspections. In order to assess the relative efficiency of complaint-initiated and regularly scheduled inspections in violation detection, swine facility inspections are divided into odor complaint initiated, water pollution complaint initiated, both odor and water pollution initiated inspections, and regularly scheduled inspections. The efficiencies of these four types of inspections in detecting different regulatory violations are compared using the statistical analysis of categorical variables as described earlier. The specific regulatory violations that are examined and the related inspection data summary on which the analysis is based are shown in table 5. The related hypotheses and statistical test results are presented in table 6.

Our results show that compared with regularly scheduled inspections, odor complaint initiated inspections are more efficient in detecting air emissions violations but less efficient in detecting various water pollution related violations. On the other hand, water pollution initiated inspections are more efficient than regularly scheduled ones in detecting water quality standard violations, runoff control requirement violations, manure handling/storage requirement violations, and field application criteria violations. However, there is no statistical difference between a water complaint and a regular inspection in detecting an effluent standard violation and an air emission violation. Between regularly scheduled and those prompted by both odor and water pollution complaints, the latter show a higher efficiency in detecting air emission and field application criteria violations while there is no statistical difference between the two in detecting water quality standard, effluent standard, runoff control requirement, and manure handling/storage requirement violations. It appears that our results tend to support the view that inspections prompted by citizen complaints are more likely to identify facilities with violations than regularly scheduled visits, suggesting that the Illinois EPA has responded properly if the goal is to detect violations.

Factors affecting regulatory violations

According to the theory of rational crime (Becker), a profit-maximizing facility will violate an environmental regulation as long as the compliance cost exceeds the expected penalty of noncompliance. The basic premises of this theory help us to formulate appropriate variables to include in the analysis and interpret the results, even though one might argue that most swine producers, just like most citizens, generally abide by the existing laws and regulations. Following this theory, three factors influence a facility's regulatory violation: the cost of compliance, the cost of the penalty, and the likelihood of the penalty. However, such data are usually unavailable. In this analysis, a facility's production characteristics such as operating capacity and type of waste storage are used as a proxy for compliance cost because they are important determinants of this cost. The expected economic penalty of noncompliance for swine facilities in Illinois can be a fine and the cost of compliance.[5] Again, due to the lack of such data, we use community characteristics to proxy the expected economic penalty of a violation. This treatment is reasonable as inspections and the stringency of environmental enforcement are usually determined by the economic situation of the surrounding communities (Helland). Other factors that may contribute to noncompliance include the history of past violations and the difference in inspectors' ability to detect violations. Noncompliance history is important because often violations can only be corrected with a capital investment such as the installation of a new abatement technology (Helland). In our analysis, we use the number of on-site visits by EPA staff as a proxy for the violation history of a facility and we expect that past violations are positively related to current violations (Magat and Viscusi). It has been documented that inspectors may differ substantially in their detection of violations for various reasons (Feinstein, 1989). Inspectors not only determine whether or not a violation exists but also influence a facility's compliance behavior.[6] Hence, the probability of a violation can be modeled as a latent variable that is a function with the following form as suggested in the regulatory violation literature (Helland; Feintein, 1989):

$$Y_j^* = \mathbf{X}\beta + u_j \tag{1}$$

$$Y_j = \begin{cases} 1\,(\textit{in violation}) & \textit{if } Y_j^* > 0 \\ 0\,(\textit{no violation}) & \textit{if } Y_j^* \leq 0 \end{cases}$$

where Y_j is the observed binary variable as defined above; **X** denotes an array of variables likely to affect the probability of a facility's regulatory compliance as discussed above; β is a vector of parameters to be estimated; u_j is a disturbance term representing unobservable facility and community characteristics and factors that affect the costs and benefits of compliance; and j is a subscript index for facility. Assuming that u_j is normally distributed, model (1) therefore becomes a probit model that can be estimated using conventional maximum likelihood techniques.[7]

In specification, facility characteristic variables include current operating capacity in terms of the NPDES defined animal units, number of outside lagoons/holding ponds, building type (total confinement or otherwise), and type of settling basin (concrete or otherwise). Feedlot type (open feedlot or otherwise) is omitted due to its high correlation coefficient (0.96) with building type. Community characteristic variables include distance to the nearest city over 50,000, rural-urban continuum code (Beale code), population density, annual household income, education attainment of the residents, swine inventory intensity, and average scale of swine operation.[8] Other variables include number of on-site visits by EPA staff, investigator, and year when violations occurred, hoping to capture the trend over time in facilities' compliance behavior. More detailed description of these variables is presented in table 7.

To alleviate concerns about statistical sampling issues that may arise from the inspection data, we divide the data into two categories: one consisting of all the facilities that have been complained against while the other consisting of all the facilities that have been inspected based on a regular schedule. The former represents a complete population of facilities being complained against while the latter is assumed to be a random sampling from a large population consisting of facilities that have not been complained against. The model is separately estimated for each of these two data sets. The estimation of the model is carried out using the SAS probit procedure and the results are presented in table 8.

Our results show that the probability of regulatory violations of a facility significantly depends on whom the EPA inspector is, consistent with the existing literature that an inspector's ability to detect a violation or her strictness in regulatory enforcement can substantially influence a facility's compliance behavior. The probability of violation might decrease over time but this decreasing trend is not statistically significant. As expected, the coefficient for number of visits by EPA staff is positive and significant, indicating that violations take time to correct.

Similar to our finding regarding the association between citizen complaints and operating capacities (see table 2), our results show that the probability of violations is independent of a facility's operating capacity. One may expect that larger operating capacity means higher compliance cost and hence higher violation probability. However, the literature on regulatory compliance also suggests that larger facilities may be more likely to be in compliance because of the lower cost per unit of emission removal when economies of scale in compliance exist (Gray and Deily). Therefore, the influence of operating capacity on compliance behavior is an empirical issue and we did not find evidence that the capacity of a facility would have an impact on the facility's probability of violation. Similarly, we did not find evidence that the number of lagoons/holding ponds would influence the probability of violation. However, we did find strong evidence that total confinement facilities tended to have a lower probability of violation in both study populations. This finding is not surprising since total confinement facilities are usually new and better equipped, suggesting that total confinement facilities may have a lower compliance cost. Also, this finding is in accordance with an earlier result that non total confinement facilities are associated with more regulatory violations (see table 2). Our results regarding the impact of concrete settling basin on the probability of violation are mixed: among the EPA selected facilities, a concrete settling basin tends to make violations less likely; while among the citizen complained facilities, a concrete settling basin may tend to make violations more likely (although this association is not statistically significant).

The community characteristics included in our analysis exhibit no statistically significant influence on the violation probability of the facilities inspected on a regular schedule. Among the facilities with citizen complaints, our results show that facilities located in counties with a higher swine inventory intensity also have a higher probability of violation. If we assume that community characteristics partially capture the expected penalty of violation, it is reasonable to argue that the expected violation penalty could be less severe in major hog producing counties than elsewhere. Another interesting finding among this category is that there is significant evidence that the income level of the communities does not affect the probability of violation. In general, our results show that a facility's compliance behavior is not obviously affected by community characteristics.

Conclusions

In this paper, statistical and economic analyses are used in identifying, analyzing, and modeling the relationships among citizen complaints, swine production and community characteristics, EPA inspections, and regulatory violations. The primary results of this research include assessments of factors that affect citizen complaints and factors that affect the probability of regulatory violations. In addition, the analyses also provide statistical results of a comparison of the efficiencies of different types of site inspections in regulatory violation detection. Our results provide information that helps better our understanding of the complicated issues concerning the development of the swine production industry and local communities. Our results are useful for swine producers and consultants to develop best management strategies that minimize citizen complaints and regulatory violations leading to improved sustainability and vitality of the swine industry. Our results can also be valuable in helping livestock production and environmental regulatory administrations to better use their management or enforcement resources.

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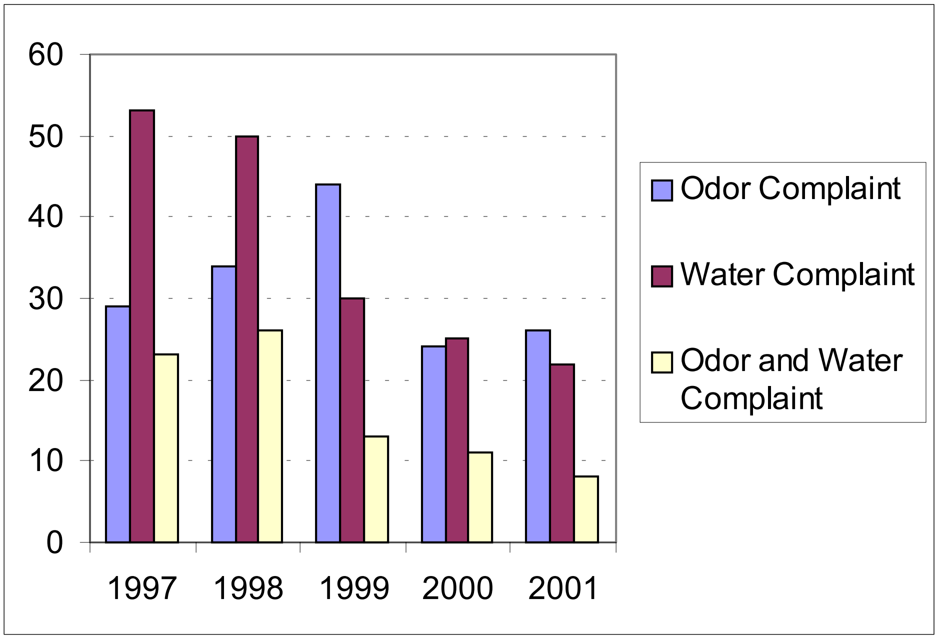

Figure 1 Number of swine facilities receiving citizen complaints in Illinois, 1997-2001.

Table 1. Categorization of inspected swine facilities in Illinois, 1997-2001

Facility characteristics		Odor complaint	No odor complaint	Total	In air violation	Not in air violation	Total
Operating capacity	<1000 AU	152	377	529	72	457	529
	>1000 AU	86	94	180	44	136	180
	Total	238	471	709	116	593	709
Waste storage type	Lagoon/pond	119	279	398	67	331	398
	No lagoon/pond	119	194	313	49	264	313
	Total	238	473	711	116	595	711
Building type	Total confinement	160	222	382	72	309	381
	Non total confine	78	250	328	43	285	328
	Total	238	472	710	115	594	709
Feedlot type	Open feedlot	73	240	313	41	272	313
	No open feedlot	164	232	396	74	322	396
	Total	237	472	709	115	594	709
Settling basin type	Concrete	11	51	62	9	53	62
	Non concrete	227	422	649	107	542	649
	Total	238	473	711	116	595	711
Facility characteristics		Water complaint	No water complaint	Total	In water violation	Not in water violation	Total
Operating capacity	<1000 AU	209	320	529	274	255	529
	>1000 AU	52	128	180	58	122	180
	Total	261	448	709	332	377	709
Waste storage type	Lagoon/pond	142	256	398	192	206	398
	No lagoon/pond	119	194	313	140	173	313
	Total	261	450	711	332	379	711
Building type	Total confinement	121	261	382	124	257	381
	Non total confine	140	187	327	207	121	328
	Total	261	448	709	331	378	709
Feedlot type	Open feedlot	137	176	313	202	111	313
	No open feedlot	124	272	396	129	267	396
	Total	261	448	709	331	378	709
Settling basin type	Concrete	28	34	62	44	18	62
	Non concrete	233	416	649	288	361	649
	Total	261	450	711	332	379	711
Facility characteristics		Any complaint	No complaint	Total	In any violation	Not in any violation	Total
Operating capacity	<1000 AU	303	226	529	324	205	529
	>1000 AU	115	65	180	93	87	180
	Total	418	291	709	417	292	709
Waste storage type	Lagoon/pond	222	176	398	239	159	398
	No lagoon/pond	196	117	313	178	135	313
	Total	418	293	711	417	294	711
Building type	Total confinement	238	144	382	182	199	381
	Non total confine	179	148	327	233	95	328
	Total	417	292	709	415	294	709
Feedlot type	Open feedlot	173	140	313	227	86	313
	No open feedlot	244	152	396	188	208	396
	Total	417	292	709	415	294	709
Settling basin type	Concrete	33	29	62	47	15	62
	Non concrete	385	264	649	370	279	649
	Total	418	293	711	417	294	711

Table 2. Hypotheses and statistical test results regarding the association between facility characteristics and citizen complaints and regulatory violations

Facility characteristics	Odor complaints		Air emission violations	
	Hypothesis	χ^2 and P value	Hypothesis	χ^2 and P value
Operating capacity	H_0: no association H_1: larger capacity, ***more*** complaints	$\chi^2 = 21.00$ $P < 0.001$	H_0: No association H_1: larger capacity, ***more*** violations	$\chi^2 = 10.74$ $P = 0.001$
Waste storage type	H_0: no association H_1: no lagoons/ponds, ***more*** complaints	$\chi^2 = 4.83$ $P = 0.028$	H_0: no association H_1: lagoon/ponds, **more** violations	$\chi^2 = 0.10$ $P = 0.749$
Building type	H_0: no association H_1: total confinement, ***more*** complaints	$\chi^2 = 25.15$ $P < 0.001$	H_0: no association H_1: total confinement, ***more*** violations	$\chi^2 = 3.93$ $P = 0.047$
Feedlot type	H_0: no association H_1: no open feedlot, ***more*** complaints	$\chi^2 = 24.91$ $P < 0.001$	H_0: no association H_1: no open feedlot, ***more*** violations	$\chi^2 = 3.62$ $P = 0.057$
Settling basin type	H_0: no association H_1: non concrete, ***more*** complaints	$\chi^2 = 6.79$ $P = 0.009$	H_0: no association H_1: non concrete, ***more*** violations	$\chi^2 = 0.05$ $P = 0.825$
Facility characteristics	Water pollution complaints		Water regulatory violations	
	Hypothesis	χ^2 and P value	Hypothesis	χ^2 and P value
Operating capacity	H_0: no association H_1: smaller capacity, ***more*** complaints	$\chi^2 = 6.06$ $P = 0.014$	H_0: No association H_1: smaller capacity, ***more*** violations	$\chi^2 = 19.89$ $P < 0.001$
Waste storage type	H_0: no association H_1: no lagoons/ponds, ***more*** complaints	$\chi^2 = 0.32$ $P = 0.573$	H_0: no association H_1: lagoon/ponds, ***more*** violations	$\chi^2 = 0.73$ $P = 0.392$
Building type	H_0: no association H_1: non confinement, ***more*** complaints	$\chi^2 = 9.38$ $P = 0.002$	H_0: no association H_1: non confinement, ***more*** violations	$\chi^2 = 64.93$ $P < 0.001$
Feedlot type	H_0: no association H_1: open feedlot, more complaints	$\chi^2 = 11.13$ $P < 0.001$	H_0: no association H_1: open feedlot, more violations	$\chi^2 = 70.47$ $P < 0.001$
Settling basin type	H_0: no association H_1: non concrete, ***more*** complaints	$\chi^2 = 1.71$ $P = 0.191$	H_0: no association H_1: concrete, ***more*** violations	$\chi^2 = 15.03$ $P < 0.001$
Facility characteristics	Odor and/or water complaints		Any regulatory violations	
	Hypothesis	χ^2 and P value	Hypothesis	χ^2 and P value
Operating capacity	H_0: no association H_1: larger capacity, ***more*** complaints	$\chi^2 = 2.16$ $P = 0.142$	H_0: No association H_1: smaller capacity, ***more*** violations	$\chi^2 = 4.70$ $P = 0.030$
Waste storage type	H_0: no association H_1: no lagoons/ponds, ***more*** complaints	$\chi^2 = 3.11$ $P = 0.078$	H_0: no association H_1: lagoon/ponds, ***more*** violations	$\chi^2 = 0.61$ $P = 0.436$
Building type	H_0: no association H_1: total confinement, ***more*** complaints	$\chi^2 = 3.85$ $P = 0.050$	H_0: no association H_1: non confinement, ***more*** violations	$\chi^2 = 38.36$ $P < 0.001$
Feedlot type	H_0: no association H_1: no open feedlot, ***more*** complaints	$\chi^2 = 2.65$ $P =0.104$	H_0: no association H_1: open feedlot, ***more*** violations	$\chi^2 = 44.17$ $P < 0.001$
Settling basin type	H_0: no association H_1: non concrete, ***more*** complaints	$\chi^2 = 0.63$ $P = 0.427$	H_0: no association H_1: concrete, ***more*** violations	$\chi^2 = 7.49$ $P = 0.006$

Table 3. County characteristic variable definitions, sources, and summary statistics

Variable	Mean value	Standard deviation	Definition	Source
Comrate	5.64	5.16	Percentage of swine facilities receiving either a water pollution or/and an odor complaint, %.	Illinois EPA and 1997 Census of Agricultural.
Wcomrate	3.63	3.43	Percentage of swine facilities receiving a water pollution complaint, %.	Illinois EPA and 1997 Census of Agricultural.
Ocomrate	3.14	3.87	Percentage of swine facilities receiving an odor complaint, %.	Illinois EPA and 1997 Census of Agricultural.
SII	68.74	63.79	Swine inventory intensity, hogs/mile^2.	Illinois Department of Agriculture.
ASOS	599.44	380.83	Average swine operation scale, hogs/operation.	1997 Census of Agricultural.
SPR	72.39	14.21	Soil productivity ratings, ranging from 5 to 100 based on the relative ability of soils to grow crops.	Illinois Farm Business Farm Management Association.
Income	38775	8736	Median household income, $.	2000 Census of Population.

Table 4. Complaints and county characteristics model estimation results

Independent variable	Dependent variable		
	log(Comrate)	log(Wcomrate)	log(Ocomrate)
Intercept	44.29** (2.29)	48.40** (2.28)	21.70 (0.75)
log(SII)	2.34*** (4.41)	2.29*** (3.91)	1.32* (1.67)
log(ASOS)	-2.21** (-2.48)	-1.67* (-1.70)	-0.45 (-0.34)
log(SPR)	4.22** (2.05)	3.40 (1.50)	6.80** (2.22)
log(Income)	-5.45** (-2.58)	-5.88** (-2.53)	-5.26* (-1.67)
# of observations	95	95	95
F statistic	6.62***	5.70***	2.48**
Adjusted R^2	0.19	0.17	0.06

t statistics are shown in parentheses below estimated coefficients.

*Significant at the 0.1 level.

**Significant at the 0.05 level.

***Significant at the 0.01 level.

Table 5. Efficiency in identifying violations by inspection type in Illinois, 1997-2001[a]

Type of regulatory violation	Odor complaint initiated inspection	Water complaint initiated inspection	Odor and water pollution complaint initiated inspection	Regularly scheduled inspection
Water quality standards (subtitle C)	7 (4.5%)	60 (33.3%)	19 (23.5%)	47 (16.0%)
Effluent standards (subtitle C)	5 (3.2%)	34 (18.9%)	14 (17.3%)	47 (16.0%)
Air emissions (9a)	77 (49.0%)	3 (0.6%)	36 (44.4%)	3 (1.0%)
Runoff control requirements (501.403)	11 (7.0%)	66 (36.7%)	18 (22.2%)	61 (20.8%)
Handling/storage requirements (501.404)	20 (12.7%)	96 (53.3%)	23 (28.4%)	79 (27.0%)
Field application criteria	25 (15.9%)	24 (13.3%)	22 (27.2)	4 (1.4%)
No violations	61(38.9%)	42(23.3%)	22(27.2%)	168(57.3%)
Number of facilities inspected	157	180	81	293

[a] Figures in the table are numbers of violations and their percentage in parentheses.

Table 6. Hypotheses and statistical test results of the efficiency of inspections in violation detection

Type of regulatory violation	Odor complaint vs. regular inspections		Water complaint vs. regular inspections		Odor & waster complaint vs. regular inspections	
	Hypothesis	χ^2 & P value	Hypothesis	χ^2 & P value	Hypothesis	χ^2 & P value
Water quality standards (subtitle C)	H_0: no difference H_1: regular ***more*** efficient.	$\chi^2=11.91$ $P<0.001$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=18.07$ $P<0.001$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=1.92$ $P=0.17$
Effluent standards (subtitle C)	H_0: no difference H_1: regular ***more*** efficient.	$\chi^2=15.30$ $P<0.001$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=0.45$ $P=0.50$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=0.01$ $P=0.92$
Air emissions (9a)	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=158$ $P<0.001$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=0.03$ $P=0.85$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=105$ $P<0.001$
Runoff control requirements (501.403)	H_0: no difference H_1: regular ***more*** efficient.	$\chi^2=13.50$ $P<0.001$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=13.46$ $P<0.001$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=0.01$ $P=0.90$
Handling/storage requirements (501.404)	H_0: no difference H_1: regular ***more*** efficient.	$\chi^2=11.24$ $P<0.001$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=32.14$ $P<0.001$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=0.01$ $P=0.91$
Field application criteria	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=33.56$ $P<0.001$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=26.57$ $P<0.001$	H_0: no difference H_1: regular ***less*** efficient.	$\chi^2=51.75$ $P<0.001$

Table 7. Variable definitions, sources, and summary statistics for violation model

Variable	Mean value	Standard deviation	Definition	Source
Violation	0.59	0.49	Dummy variable, 1 for detecting at least a violation and 0 for none.	Illinois EPA.
Invest1	0.21	0.41	Dummy variable, 1 for inspection by investigator 1 and 0 otherwise.	Illinois EPA.
Invest2	0.16	0.36	Dummy variable, 1 for inspection by investigator 2 and 0 otherwise.	Illinois EPA.
Invest3	0.19	0.40	Dummy variable, 1 for inspection by investigator 3 and 0 otherwise.	Illinois EPA.
Invest4	0.12	0.33	Dummy variable, 1 for inspection by investigator 4 and 0 otherwise.	Illinois EPA.
Invest5	0.12	0.33	Dummy variable, 1 for inspection by investigator 5 and 0 otherwise.	Illinois EPA.
Invest5	0.19	0.40	Dummy variable, 1 for inspection by investigator 6 and 0 otherwise.	Illinois EPA.
visit	1.67	1.57	Number of on-site visits by EPA staff during the current calendar year.	Illinois EPA.
Capacity	1227	1430	Current operating capacity, AU.	Illinois EPA.
Lagoon	1.03	1.41	Number of outside lagoons/holding ponds.	Illinois EPA.
Building	0.54	0.50	Dummy variable, 1 for total confinement and 0 otherwise.	Illinois EPA.
Basin	0.09	0.28	Dummy variable, 1 for concrete settling basin and 0 otherwise.	Illinois EPA.
SII	68.74	63.79	Swine inventory intensity at the county level, hogs/mile^2.	Illinois Department of Agriculture.
ASOS	599.44	380.83	Average swine operation scale at the county level, hogs/operation.	1997 Census of Agricultural.
Popdens	68.50	76.98	Population density at the county level, residents/mile^2.	2000 Census of Population.
Income	38775	8736	Median household income of the county, $.	2000 Census of Population.
Highsch	81.52	4.26	Proxy for education attainment, percentage of residents with a high school education or above, %.	2000 Census of Population.
SPR	72.39	14.21	Soil productivity ratings, ranging from 5 to 100 based on the relative ability of soils to grow crops.	Illinois Farm Business Farm Management Association.
Distance	52.20	28.30	Distance from a county's centroid to city over 50,000, mile.	Authors' computation using ArcView GIS.
Beale	5.45	2.04	Rural-urban continuum code (Beale code), value between 0 and 9.	Economic Research Service (ERS), USDA.

Table 8. Facility regulatory violation model estimation results

Independent variable	Dependent variable: probability of violation	
	Citizen complained facilities	EPA selected facilities
Intercept	-5.6671** (6.02)	-11.7456*** (14.12)
Investigator 2	-0.9825*** (7.05)	-2.2526*** (30.59)
Investigator 3	-1.6653*** (13.57)	-1.7908*** (11.77)
Investigator 4	-1.4779*** (15.94)	-0.8780** (4.89)
Investigator 5	-1.3251*** (12.70)	-3.1280*** (25.22)
Investigator 6	-1.0877*** (9.83)	-1.1588*** (10.44)
Year	-0.0955 (2.29)	-0.0282 (0.14)
Visit (number of EPA staff visits)	0.2140*** (7.16)	0.8671*** (24.31)
Capacity (current operating capacity)	-0.0000 (0.84)	-0.0000 (0.16)
Lagoon (number of lagoons/holding ponds)	0.0802 (1.57)	-0.0521 (0.47)
Building (total confinement)	-0.3698** (4.79)	-0.7947*** (12.88)
Basin (concrete settling basin)	0.5307 (1.94)	-0.6042* (2.86)
SII (swine inventory intensity)	0.0059*** (7.18)	-0.0015 (0.36)
ASOS (average swine operation scale)	-0.0007 (2.65)	0.0008 (2.35)
Popdens (population density)	0.0009 (0.41)	0.0015 (0.43)
Income (median household income)	0.0000** (3.99)	-0.0000 (1.06)
Highsch (percentage of residents of high school education or plus)	-0.0166 (0.55)	0.0200 (0.27)
SPR (soil productivity rating)	-0.0011 (0.01)	0.0003 (0.00)
Distance (distance to city over 50,000)	0.0023 (0.28)	0.0064 (0.88)
Beale (Rural-urban continuum code)	0.0989 (2.21)	0.0452 (0.28)
Log Likelihood	-205.63	-110.17
Number of observations	417	290

Chi-square statistics are shown in parentheses below estimated coefficients.

*Significant at the 0.1 level.

**Significant at the 0.05 level.

***Significant at the 0.01 level.

Endnote

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[1] "Animal unit" is a term defined by the regulations to reflect pollution equivalents among the different animal types. Animal unit varies according to animal type and one animal is usually not equal to one animal unit. For instance, one slaughter/feeder steer is equal to 1.0 AU while a market hog weighing over 55 pounds is equal to only 0.4 AU, suggesting that one steer and 2.5 market hogs generate about the same amount of pollution.

[2] A facility is cited for an air emission violation if one or more atmospheric contaminants exceed the standards (quantity) adopted by Illinois EPA under the Environmental Protection Act during inspection. When a facility is cited for a water pollution violation, one or more of the following violations occur: water quality standards, effluent standards, runoff control requirements, waste handling/ storage requirements, manure field application criteria, NPDES permit provisions, and no NPDES permit. In addition to air and water pollution violations, any violations also include other regulatory violations such as new facility location.

[3] The chi-square test statistics used in this analysis include the Pearson chi-square, the likelihood chi-square, the continuity-adjusted chi-square, and Mantel-Haenszel chi-square. All these test statistics were computed using the SAS FREQ procedure and produced qualitatively identical results in our analysis.

[4] Coincidently, in a separate study of Illinois farmland values, Huang et al. find that Illinois farmland prices are negatively associated with swine inventory intensity but positively related to the average swine operation scale using aggregate county level data. Both results indicate that more concentrated swine production might be more environmentally friendly from a macro perspective.

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[5] If it is a first time violation and not of a serious nature, the facility will be asked to take measures to stop the violation and prevent future violations. This may require a capital investment by the facility. Yet many times the situation can be corrected with managerial changes only. If it is a continuing violation problem or a violation of a serious nature (e.g., fish kill), the matter will be referred to the Illinois Attorney General's Office for an enforcement action. In this case, the Illinois EPA can suggest a civil fine in addition to any damage assessment due to the destruction of aquatic species. The Attorney General's Office can use the suggestion or change it.

[6] Another reason for including the investigator variable is that violation detection data are censored since no data on undetected violations exist (Feinstein, 1990). Empirical studies using such censored data without appropriate corrections may produce biased results. The inclusion of the inspector variable can partially correct for this potential bias.

[7] The disturbance term u_j was also assumed to be logistically distributed and model (1) hence became a logit model and was estimated using the SAS logistic procedure. Our results show that both models produce qualitatively identical estimates.

[8] Land price and house price are excluded because of their high correlation coefficients with household income (0.73 and 0.90, respectively).