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University of Minnesota
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SESSION II: AGRICULTURAL POLICY AND SUSTAINABLE DEVELOPMENT - I

PAPER 4: SOME SPATIAL ASPECTS OF AN EXTERNALITY: THE CASE OF LIVESTOCK PRODUCTION FACILITIES

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Some spatial aspects of an externality: The case of livestock production facilities[*]

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Introduction

We were asked by the state legislature to examine the extent to which nearby feedlots might affect property value. Feedlot location is currently one of the hot topics in rural Minnesota. We can guarantee a crowd of 200 people on any night at any location, simply by announcing a public hearing on the siting of a new livestock facility. Among the many claims (for and against) that surface at such hearings is that a nearby feedlot will inevitably reduce the value of neighboring residential properties. The claim is sometimes backed by property appraisals, sometimes by simple assertion--but it is always made with vehemence!

In our report to the Legislature (Taff et al. 1996), we examined the interrelationships among residential property sales prices and nearby feedlots in two southwestern Minnesota counties. We found substantial support for such a link in the study area. That relationship was positive, not negative as we had expected. The effect was most pronounced for houses that are older, relatively lower in price, or located in small towns.

In this paper, I summarize the approach and discuss the findings of that research. I then sketch out what I hope will prove a fruitful set of further inquiries into the question of multiple disamenities and hedonic price estimation.

Much hedonic analysis looks at data clumped into "neighborhoods" or "vicinities," focused around a particular amenity or disamenity. (See, for example, the work reported in Palmquist et al., 1997 or in Abeles-Allison et al., 1990.) But how do we deal with the possibility that the disamenity, feedlots in this instance, may be multiple? Even my own work on wetland proximity considered only the single wetland closest to each property (Doss and Taff 1996).

Feedlots and house sales data

In our feedlot research, we linked observed sales prices to those properties' structural, location, and feedlot characteristics. The underlying data are 292 rural residential property sales in two Minnesota counties, plus certain features of all nearby feedlots greater than a certain threshold size. Because we knew the geographic location of each property and of each feedlot, we were able to measure the direction and distance of each

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feedlot from each house. We asserted that any feedlot more than three miles away was not influential.

We first calibrated a model that used only property and location characteristics to estimate sales prices. Then we systematically examined several feedlot characteristics, represented by what we called proximity indicators. If the addition of the feedlot did not "improve upon" the explanatory power of the basic model, in the sense that its t-value wasn't much greater than the critical level, then this variable was deemed not to influence nearby property values.

In Minnesota, all new and upgraded feedlots over 50 animal units in size require a state permit, issued by the Minnesota Pollution Control Agency. (Animal units are essentially standardized manure production measures. For example, a horse is 1 AU, a milk cow is 1.4, a breeder pig is 0.4, and a chicken is 0.01.) For the study, we examined the effects of only those feedlots larger than 500 AU. We thought that this size range, because it excludes many traditional dairy farms and swine facilities, more closely approximated the image that most people form in their minds when they hear the word "feedlot." Virtually no new facilities below that threshold have been built in the study area in recent years. For each feedlot, we identified the dominant animal type, the manure handling process, and the number of animal units for the entire facility.

Our housing data came from county assessor records and state property sales listings. We considered a property "residential" if the sale was so classified by the state: farmsteads are generally not included in this category. Nearly all the sales were for less than $50,000, and over a third were for less than $20,000. Somewhat less than half of the sales were for properties that had no feedlot within three miles, including over adjacent county lines. The majority of sales with nearby feedlots were associated with two or fewer feedlots. Figure 1 shows the distribution of the sales prices.

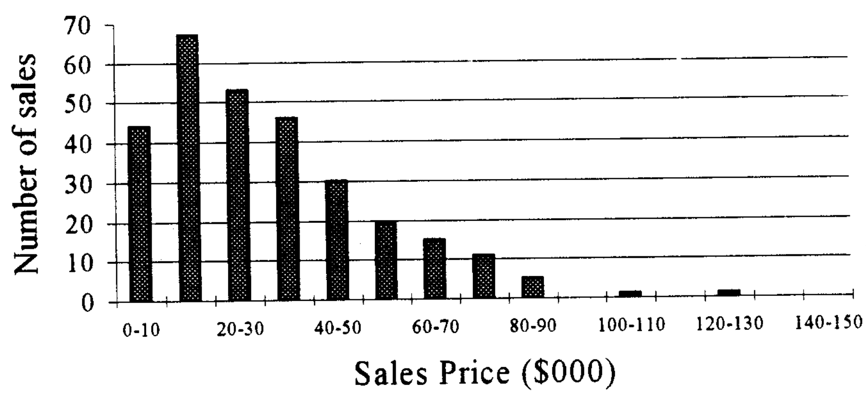
The basic property model

The first task was to explain as much of the observed variability in house prices as possible, using only available structural and location characteristics. Figure 2 shows the results of this "basic property model." All the independent variables are "statistically significant" in the traditional sense. The (rounded) transformations of the independent variables were those that made the joint distribution of those variables as close to normal as possible. The optimal Box-Cox transformation of the dependent variable, reported sales price, similarly made the residuals of the entire model as close as possible to a normal distribution. As it turns out, these transformations, while theoretically justified to reduce bias and variance, did not yield findings substantially different from what we would have come up with had we used a simple OLS model with no transformations of any sort.

The graph in Figure 3 is a "model checking plot" for the basic property model. It was generated by a forthcoming version of the R-code visual regression package introduced in

Cook and Weisberg (1994). Such plots permit permits us to visually inspect the "fit" of any proposed model. The straight lines are the mean and one standard deviation of the 0.5 LOWESS smoother for the fitted variable, and the other lines are from the same smoother for the observed data. The closer are the two sets of lines to each other, the better the model fits the data. There is no published protocol for judging when the two lines are "close," but one is under development.

Figure 1: Distribution of reported sales prices (n=292)



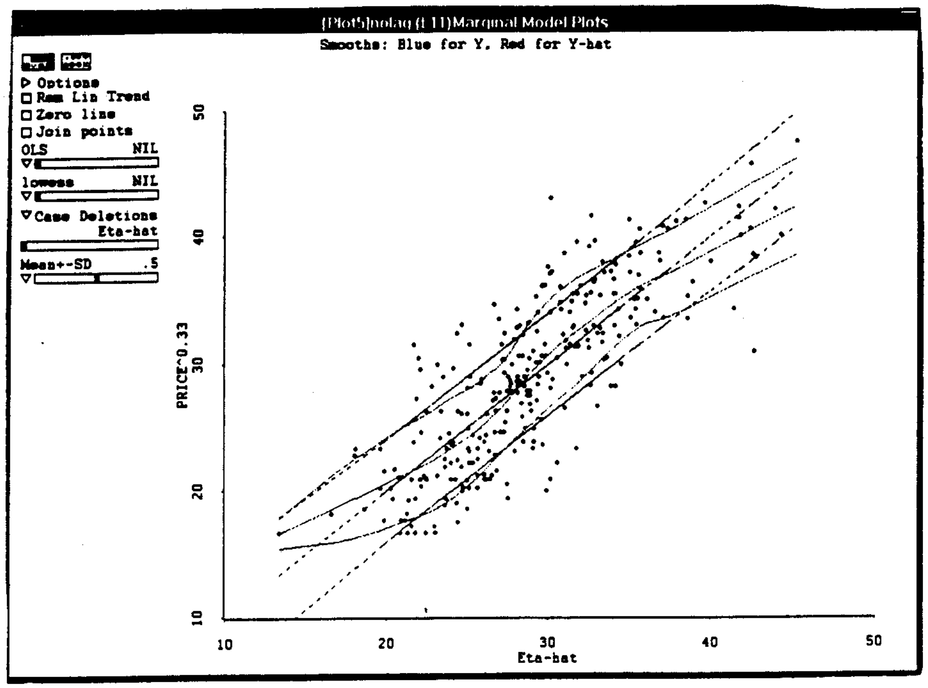
Source: Taff et al., 1996

Figure 2: Basic property model (cube root of price)

variable	coefficient	standard error	t-value
CONSTANT	-1156	152	-7.6
COUNTY (0/1)	2.2	0.5	4.4
TOWNSHIP (0/1)	7.5	0.9	8.7
BEDROOMS	0.8	0.3	2.5
RATIO (arcsine of square root)	9.4	2.2	4.3
BATHROOMS (inverse)	-4.4	1.1	-3.9
FOOTPRINT (cube root)	2.3	0.3	7.0
BUILT (log)	133.1	20.1	6.6
N= 292			
R2 = .66			
sigma-hat = 4.0			
F = 78.9			

Source: **Taff et al., 1996**

Figure 3: Model checking plot for basic property model



Adding in the feedlot proximity information

The model checking plot suggests that addition of additional information to the basic model might improve its explanatory power. Accordingly, we then assessed the implications of adding various feedlot variables. We created a set of proximity indicators, each of which encapsulated one of our basic research questions. Does size matter? Does distance matter? Does animal type matter? And so forth. A statistically significant parameter estimate on a proximity indicator was interpreted to mean that that particular feedlot characteristic does influence property values. Figure 4 defines and summarizes the indicators we used.

The impact of adding each of the indicators individually to the basic property model is summarized in Figure 5. As it turned out, all of the indicators "mattered," in that their individual estimated coefficients differed significantly from the zero null. Figure 6 is an "added variable plot" (AVP) from the R-code. It shows the relationship between a feedlot variable (NEARBY in this instance), adjusted for the effects of all the other independent variables in the model, against the fitted value of the price variable, again adjusted. The slope of the OLS line in the figure is the same as the estimated coefficient for that indicator in Figure 5.

We followed with an examination of the size of those property effects (they weren't small, see Figure 7) and an isolation of some of the major drivers of the results. In general, property values were most influenced by older, lower priced houses.

Figure 4: Proximity indicator definition and distribution

indicator	category levels	associated value	number of sales	meaning
NEARBY	0	no	138	Is there any feedlot within three miles?
	1	yes	154	
SWINE	0	no	160	Are there any swine feedlots within three miles?
	1	yes	132	
LAGOON	0	no	194	Are there any feedlots that use lagoons within three
	1	yes	98	miles?
DISTANCE	0	0 - 1	7	Miles to nearest feedlot of any type or size.
	1	1 - 2	97	
	2	2 - 3	50	
	3	3 +	138	
SIZE	0	0	138	Total number of animal units on all feedlots within
	1	1 - 1,000	34	three miles combined.
	2	1,000 - 10,000	102	
	3	10,000 +	18	
NUMBER	0	0	138	Total number of feedlots of any type or size within
	1	1 - 10	.147	three miles.
	2	10 +	7	
NORTHWEST	0	no	250	Are there any feedlots of any type or size located
	1	yes	42	northwest of the property within three miles?

Source: Taff et al., 1996

Figure 5: Proximity indicator coefficient estimates

indicator	estimate	standard error	t-value
NEARBY	1.9	0.5	3.8
SWINE	1.9	0.5	3.6
LAGOON	1.8	0.5	3.3
DISTANCE	-1.3	0.3	-4.8
SIZE	0.9	0.2	3.4
NUMBER	1.7	0.5	3.7
NORTHWEST	2.2	0.7	3.2

Source: Taff et al., 1996

Figure 6: Added Variable Plot for NEARBY indicator

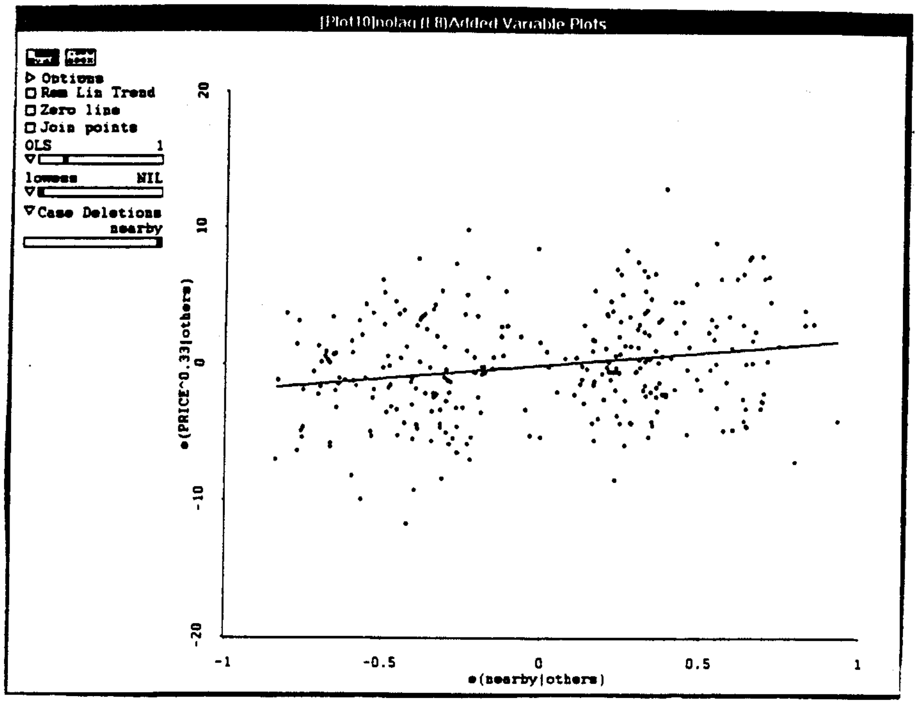


Figure 7: Change in property prices due to change in proximity indicator

indicator	categories	estimated coefficient	percent change (at 25% / 75%)	price change (at 25% / 75%)
NEARBY	no, yes	1.9	8.2 / 5.6	1,150 / 2,450
SWINE	no, yes	1.9	8.2 / 5.6	1,150 / 2,450
LAGOON	no, yes	1.8	7.7 / 5.3	1,100 / 2,300
DISTANCE	0-1, 1-2, 2-3, 3+	-1.3	-5.6 / -3.8	-800 / -1,650
SIZE	0, 1-1000, 1000-10000, 10000+	0.9	3.9 / 2.6	550 / 1,150
NUMBER	0, 0-10, 10+	1.7	7.3 / 5.0	1,000 / 2,200
NORTHWEST	no, yes	2.2	9.4 / 6.5	1,300 / 2,850

Source: Taff et al., 1996

Reactions

We had to admit that these positive findings surprised us. We were expecting modest *negative* effects at most. Nor would we have been shocked to find no statistically significant effects whatsoever, given the large level of "noise" common in rural property market data. The positive direction of the relationship has caused a stir. That is not what feedlot opponents wanted to hear!

Of course we knew when we started our research into this politically explosive area that there was no way that any of our results would be "correct," no matter what they turned out to be. But these results don't even make economic sense, at least in terms of conventional externality theory. And besides, our findings are not what many local officials really wanted us to come up with. They didn't want us to prove or disprove that feedlots are bad neighbors--they already have formed their own opinions on that, whatever our scholarly findings might turn out to be.

What local officials say they'd really want is for us to tell them how far away from houses any new feedlots should be located so that they won't diminish property values. They want our economic studies to tell them how far to draw buffers around feedlots (to exclude houses) or around houses (to exclude feedlots). This is altogether a different task than we set out for ourselves in the first study.

A different approach to spatial effects

Have we really made complete use of the data on hand? I don't think so. I think we might be able to so manipulate the data so as to give local officials more of what they say they really want to know.

If we knew more about the externality itself--odor, say--we could calculate an "odor decay function" that showed us how far we needed to keep houses and feedlots apart, given feedlot size, prevailing winds, etc. Unfortunately, odor turns out to be extremely difficult to model scientifically. We know it's there, but because smells are really complexes of many chemicals, there exists no "sniff-o-meter" and no accepted method to calibrate odor nuisance levels.

Because we can't calibrate buffer distances using an odor-effects function, I propose to turn instead to using a proxy--a *value-effects function*. The basic idea is to first estimate a hedonic price equation linking property value and feedlot characteristics (including size, distance, and direction); then use that equation to calibrate a relationship between feedlot distance and size, given feedlot direction; and then use that relationship to array various minimal-effects contours around any house.

Let me elaborate a bit on each stage of this process, illustrating it with the data from our earlier study. Please remember that this is research in progress, so don't hold me exactly to what I'm about to say. I'm about to chart a general course, not detail a complete map.

Our task would be simpler if there were only one feedlot in the vicinity of each house in the data set. Then we could easily estimate both distance and direction effects with simple variables. Given multiple-feedlot data, one approach would be to use information only on the closest feedlot to each house. But when there are several feedlots in the vicinity, the estimation procedure must be changed. Furthermore, the closest feedlot variable makes no use of either direction or feedlot size information. Some sort of weighting scheme seems to be indicated. But what sort of weighting?

A new set of proximity variables

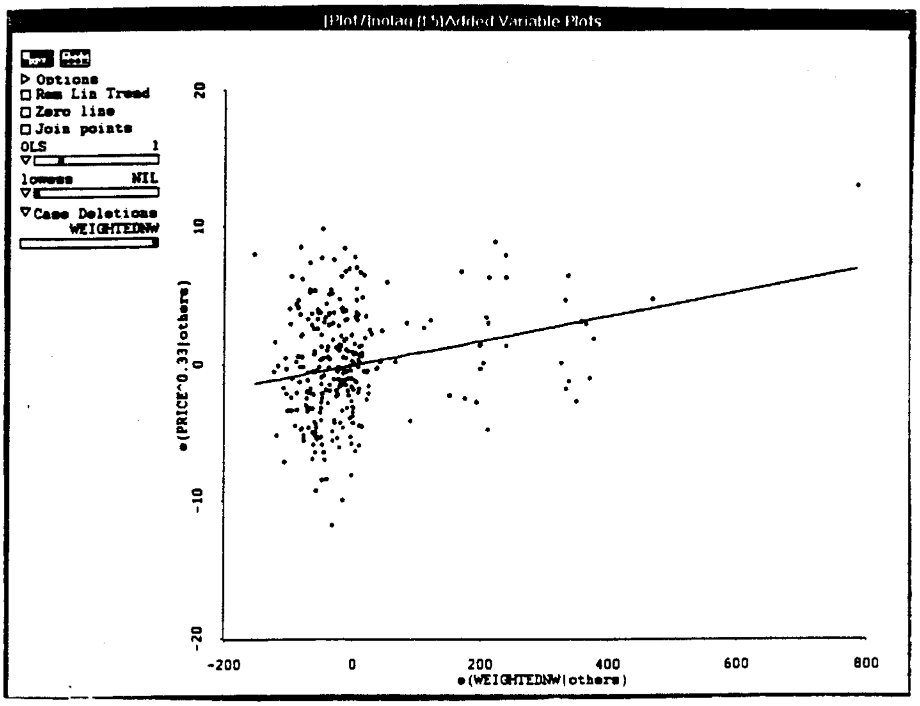
We have several relevant data at hand: for each house we know the size, distance, and direction of each feedlot located within a three-mile radius. Consider a variable that is the sum of all animal units in all feedlots located in a single quadrant from each house, the northwest say. If there are no feedlots to the northwest, the variable takes the value zero.

Add this variable into the basic property model and inspect its estimated coefficients. For the Minnesota data set, this yields a coefficient estimate of 0.0022 (t=3.0), which is both significant and positive, as were nearly all the other indicators in that study. But pretend for now, in the interests of illustration, that this perverse result was inverted. Pretend that the relationship is significant and *negative* (consistent with prior expectations), that each new animal unit added to the northwest of the average house *reduces* the transformed price variable by 0.0022.

Even this variable does not make use of distance information. Consider next a weighting that discounts the effect of each feedlot the farther it is from the house. Then aggregate this weighted animal unit count for the quadrant, as before. The previous, unweighted, variable is equivalent to an assertion that relative distance doesn't matter, only proximity, in the sense that anything less than three miles bothers people equally, and anything more than three miles away doesn't bother them at all. An alternative is a linear decay function that varies between 1.0 at the house and 0.0 three miles away. For the southwest Minnesota data, this distance-weighted aggregate animal unit count for the northwest quadrant was 0.0009 (t=4.2). Figure 8 is the AVP for this variable.

Again, pretend for now that these results are inverted, that the true estimated coefficient for the distance weighted variable is really -0.0009. We now have a variable for a hedonic price function that links price to feedlot size, distance, and (one, for now) direction. Let's use this estimate to further the process.

Figure 8: Average Variable Plot for northwest-quadrant distance-weighted aggregate animal unit variable



To draw buffers around a house we need to first state a minimum value-effect, a constraint that any new feedlot siting will not be allowed to exceed. (This is obviously a decision better left to politicians than to economists.) For example, we might assert that no feedlot should be located where it would reduce an existing house's value by more than 1%. It is a simple process then to calculate the weighted variable measure (call it NWAU) necessary to keep within this constraint:

$$0.01 * \text{PRICE} > .0009 * \text{NWAU},$$

or

$$\max(\text{NWAU}) = (0.1 * 29.0) / (.0009) = 322$$

at the mean of the transformed response variable. In this example, it would become the law that the distance-weighted animal count in the northwest quadrant should not exceed 322 animal units.

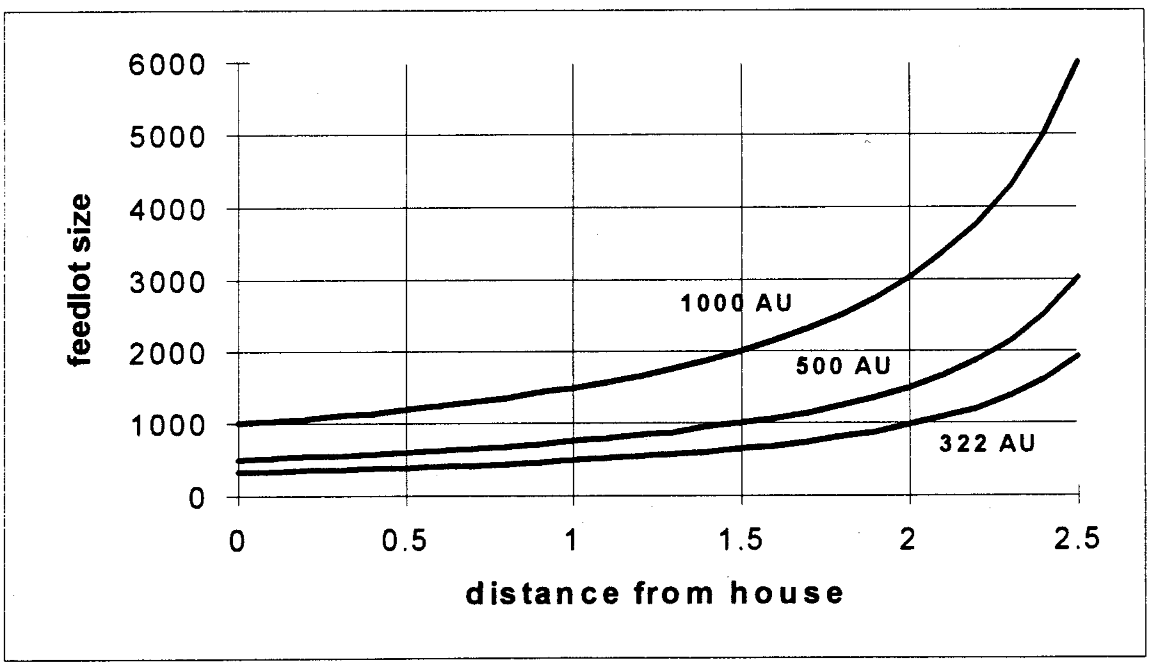
Mapping the constraint set

Knowing this constraint, we can now calculate the set of distance/direction measures that result in this count--and no more. Figure 9 shows how we might do this for the linear decay function just developed. The size limit for each distance is calculated as:

$$\max(SIZE) = (322) / ((3\text{-}DISTANCE) / 3)$$

Any combination of size and distance falling within the relevant constraint contour would be permitted under the proposed ordinance. I've added for comparison the contours for hypothetical value-effects constraints that lead to 500 and 1,000 weighted AU limits.

Figure 9: Feedlot size / distance isoquants for maximum value-effect

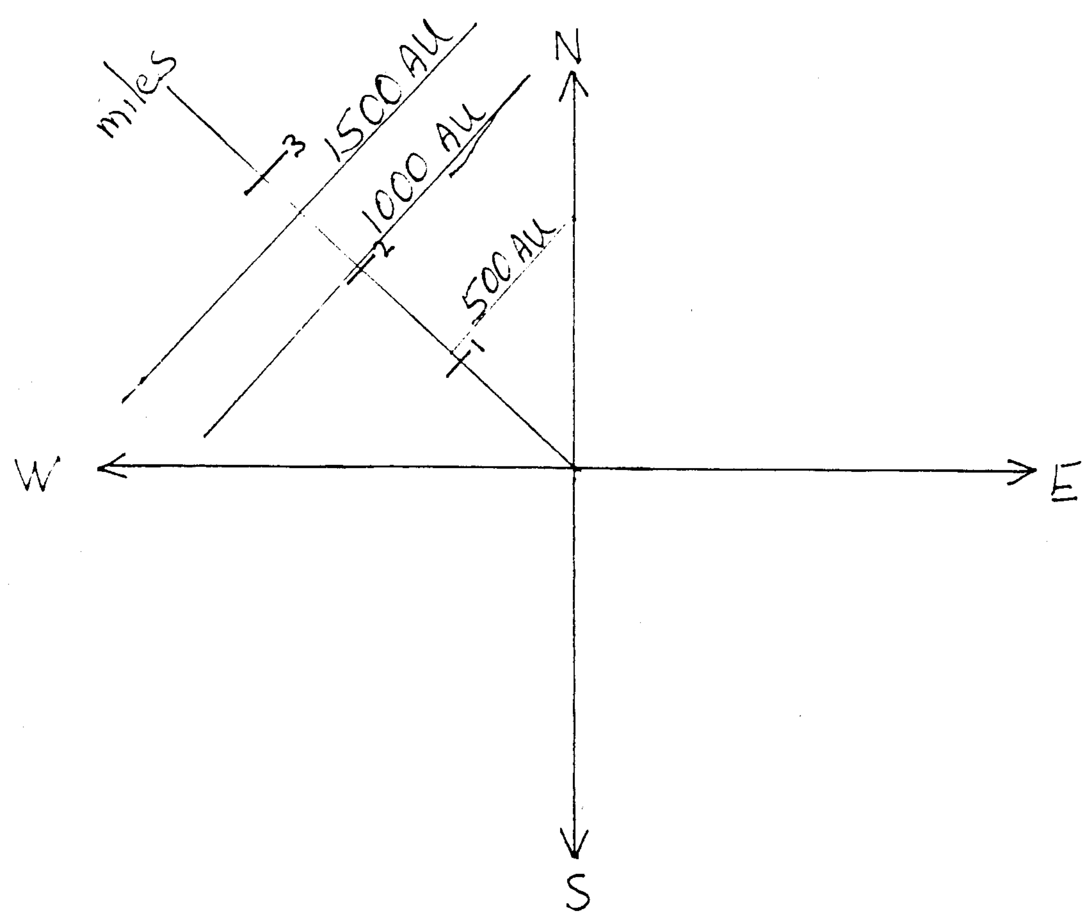


Finally, this set of iso-effect lines can be transposed to geographic space, blending distance and direction. This is a straightforward mapping of a given isoquant from Figure 9 into Figure 10. For a given distance-weighted animal unit limit (which in turn was derived from a required maximum value effect level), we can determine--for the quadrant that the hedonic equation was estimated for--a series of buffer distances, each associated with a proposed feedlot of a given size:

min(DISTANCE) = 3 - ((3*322) / SIZE)

For the 322 AU limit, the minimum distance is of course zero, by definition. The chart shows buffers that feedlots of 500, 1000, and 1500 AU would have to conform to in order not to exceed the .01 value-effect limit. The buffer distances in each quadrant might be different, because of different wind patterns. I've calculated those only for the northwest. Those for the other quadrants are unknown at this point. One could conceivably calculate such buffers for directional sectors smaller than quadrants.

Figure 10: Buffer distances by feedlot size to conform to maximum value-effects constraint



A siting decision for a feedlot would have reference to Figure 10 to see how far from a house that feedlot should be. If there were feedlots already located in place around that house, their existing effects could be factored in prior to the new decision if one argued that cumulative effects mattered. However, any value effects from existing feedlots should already be capitalized into the observed sales prices of the sample properties. A stronger economic argument can be made, I think, for assessing only the marginal effects of new feedlots.

Conclusion

I've outlined a procedure that transposes observed economic activity into a series of buffer distances that can support feedlot location regulations. Interestingly, at least one county in Minnesota has already created such a contingent buffer ordinance. I'm not sure where their limits came from (feedlots between 1-2 thousand AU, for example, must be a mile or more from a house), but I do know that they're not using the procedure I've just proposed--yet.

Geographical information systems that provide increasingly detailed location information about a variety of economic activities have led to a flurry of activity in the field of spatial statistics, but not much yet in spatial economics. (There remain, of course, the traditional rent gradient models of land economics, some Hotelling models in industrial organization, and several location models in economic geography.) The present policy question, involving the siting of multiple disamenities, is a logical candidate for further work in this emerging body of theory and practice.

Sources

Abeles-Allison, M. and L. J. Connor. 1990. *An Analysis of Local Benefits and Costs of Michigan Hog Operations Experiencing Environmental Conflicts.* **Agricultural Economics Report Number 536.** Michigan State University. June.

Cook, R.D. and S. Weisberg. 1994. **An Introduction to Regression Graphics**. John Wiley, New York.

Doss, C.R. and S.J. Taff. 1996. *The Influence of Wetland Type and Wetland Proximity on Residential Property Values.* **Journal of Agricultural and Resource Economics**. Forthcoming.

Palmquist, R.B., F.M. Roka, and T. Vukina. 1997. *Hog Operations, Environmental Effects, and Residential Property Values.* **Land Economics**. Forthcoming, February.

Taff, S.J., D.G. Tiffany, and S. Weisberg. 1996. *Measured Effects of Feedlots on Residential Property Values in Minnesota: A Report to the Legislature.* Staff Paper P96-12, Department of Applied Economics, University of Minnesota. June.