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People are willing to pay to locate in the countryside with small livestock operations.

The impact turns negative if the operation is too large or close to a residence.

More hog and sheep operations contribute negatively to property values.

More operations negatively influence the less expensive home prices.

Larger operations negatively influence more expensive home prices.

THE EFFECT OF LIVESTOCK INDUSTRY LOCATION ON RURAL RESIDENTIAL PROPERTY VALUES

Dooho Park, Andrew F. Seidl and Stephen P. Davies[1]

Introduction

The livestock industry creates jobs and income in, mostly rural, communities and can be an important engine of economic growth and development (e.g., Seidl and Weiler, 2000). Animal agriculture can also generate impacts beyond the boundaries of the farm, ranch, or feedlot, including flies, odor, water pollution, farm vehicle traffic, and noise, for example. The impact of these potential positive and negative economic effects increases with human interaction. Recent structural change within the livestock industry has heightened concerns about the industry's potential negative impacts.

In addition to the potential for water pollution, significant public attention has been directed toward offensive odors released from livestock operations (Palmquist et al., 1997). Farber (1998) discussed several perspectives from which to assess these effects, including the real or perceived health risks and environmental justice or civil rights. Assessing these social costs is complex and sometimes subjective. The odor from livestock operations can affect the quality of life of neighbors, the effect of which is difficult to evaluate objectively.

Odor may also influence more easily quantifiable aspects of human well being, and consumers may express their preferences for the negative environmental external effects of the livestock industry in the marketplace (Fisher et al., 1991). If livestock odor is undesirable, the presence, strength, duration, and type of odor should influence real estate values in the vicinity. Lower real estate values imply a lower residential tax base than would obtain in the absence of the odor. This implies that the failure to mitigate odor due to poor community planning or poor management practices results in fewer services and that a greater tax burden is imposed on the general populace by livestock

[1] Senior Researcher, Korean Institute of Construction Technology, Seoul, Korea; Associate Professor, Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO, 80523-1172; and Professor, Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO. Corresponding author, Andrew F. Seidl, T:(970) 491-7071. F:(970) 491-2067. E:Andrew.Seidl@colostate.edu.

producers. An alternative perspective is that by tolerating odor, residents are subsidizing livestock production by incurring a greater tax burden or fewer services than they would have in the absence of these odors.

Residential property prices implicitly contain all the characteristics of a house, such as house size, lot size, number of bedrooms and bathrooms, as well as community, neighborhood and environmental qualities. Therefore, housing price, determined by its traded value, reveals the consumers' willingness to pay for the bundle of housing attributes. A hedonic analysis allows us reveal the contribution of each of the components of the residential property to the market value.

The development effect of livestock operations should increase the demand for local housing while the odor effect should have a negative effect on demand. The net effect may be positive or negative and will depend upon a number of demographic and environmental factors as well as features of the housing market.

Previous Research

The hedonic pricing method (HPM) has received significant use since Lancaster (1966) and Ridker and Henning (1967). The method developed a theoretical framework and interpretation mainly to assess the value of environmental (dis)amenities (Griliches, 1971; Rosen, 1974; Nelson, 1978).

Despite extensive application of these techniques to a great variety of situations, there is very little empirical evidence related to the livestock industry. Rapid and substantial structural change in the hog industry, particularly due to the recent shift in the geographical concentration of large operations, has brought greater research focus on hogs in major hog states. Abeles-Allison and Conner (1990) estimated the residential property value of over 300 properties around 8 hog operations. They found that larger operations had more impact than smaller ones and that each additional hog decreased residential property values by $0.43 within 5 miles on average. However, the sample hog farm in this analysis received multiple odor complaints, thus it may have created a biased estimation that is not representative of the norm.

Research in North Carolina by Palmquist et al. (1997) is the only peer-reviewed study to date. They evaluated 237 rural residential properties in nine North Carolina counties within two miles of swine feedlots. They created an index[2] of hog manure production at different distances from the houses to estimate the differing impact on housing prices. They found a 4.75% ($2,889) drop within one-half mile from a 2,400 head swine operation. However, the impact decreased to 0.57% and 0.56% for one-half mile to 1 mile and 1-2 miles, respectively.

In a working paper, Taff et al. (1996) expanded the North Carolina study by obtaining the exact location of properties and feedlots in Minnesota so that they could measure the direction and distance of each livestock operation to each house. The results showed that houses closer to feedlots appear to have sold for more than would have been expected based on knowledge of the characteristics of the house alone. It could be argued that the development effect outweighed any potential odor effect in this case, or that some omitted variable (i.e., the construction of a casino nearby) was driving the unexpected changes.

Recently, Rabotygov (2002) revisited North Carolina hog operations in his Master's thesis. The results show that hog production influences property values in both directions. Large-scale hog operations, especially when they are geographically concentrated, generate more income and beneficially impact housing values. However, he also found that more hog inventory decreased residential property values after a fashion.

We expect that the regional and local impact of the livestock industry on residential property values will depend on not only the distance to livestock operations, the size and species of these operations, but also the value of other nearby housing units (neighborhood effects). This spatial interdependence has been recognized in some research areas, especially in regional economics, but never in an assessment of livestock industry impacts.

[2] The manure index, which represents potential environmental damage, is based on the accumulated effect of hog operations by distance: $MAN = NMAN0 + \gamma_1 * NMAN1 + \gamma_2 * NMAN2$, where *NMAN0*, *NMAN1* and *NMAN2* are manure (tons) per year for each distance ring, and γ1 and γ2 are the estimated weights.

Observing the similarity of homes within modern residential subdivisions, it is not particularly surprising that neighborhood effects might be observed.

Objectives and Hypotheses

This study has four specific objectives. First, we hope to find whether neighborhood effects (spatial correlation) can be revealed in the rural residential housing market. Secondly, we hope to reveal whether the impacts of livestock operations on residential property values differ by the size, number and species of the operation. Thirdly, we intend to examine the degree to which proximity to the operation affects housing prices. Finally, we hope to examine the differential effect of livestock operations on a price stratified housing market in order to provide information about potential development effects distinct from odor effects.

It is hypothesized that the effects of livestock operations on residential property values will diminish with distance from the operation. The second hypothesis is that greater livestock inventory will have a greater effect and the third hypothesis is that more operations, i.e. a given inventory is less concentrated, will have less effect than fewer operations. The final hypothesis is that the more expensive end of the housing market will have a more pronounced negative effect of proximity to livestock operations than the less expensive end of the market, since it can be expected that countervailing positive development (job proximity) effects will be concentrated at the less expensive end of the local housing market.

Data

A total of 3,354 residential housing sales data were collected over three years (1999-2001). Housing sales data were provided by Weld County (Colorado) Assessor's Office and processed using GIS to get spatial information. The essential characteristics of housing units and the neighborhood were collected, which included age of house, number of bedrooms, number of bathrooms, square feet of heated area (building size), lot size and house sales price. The proximity to major highways, population density, school budgets and student/teachers ratio represent potential neighborhood influences. However, since the spatial boundaries of this study lie within a single county, the available secondary neighborhood information does not vary substantially within the study region.

Features of the livestock operations near each rural residential sale were collected to estimate a social cost of the livestock sector. There were 184 livestock operations included in this analysis. Within the sample, 72 dairy farms, 59 beef cattle operations including feedlots, 25 hog operations and 28 poultry and others species (20 chicken + turkey and 8 sheep) were found.

We drew three rings from each housing unit. The radii of the three rings were: 0 to 1mile, 1 to 2 miles and 2 to 3 miles, in keeping with published accounts. Within each mile radius, we collected the number, size and species of operations for every single housing unit. The number of animals was converted to an animal unit basis, based on the EPA's norms[3]. All the variables and descriptive statistics are reported in Table 1.

Like all desirable attributes, the willingness to pay for superior air quality should increase with income. Unfortunately, county housing sales data do not include individual household income of the purchaser. From a policy perspective, it is important to verify whether the impacts of livestock operations differ by residence location. Housing markets are commonly clustered by price and the impacts of livestock operations of the same size on less expensive residential neighborhoods may not be the same as in more expensive areas. Therefore, instead of using household income, we assert that higher household incomes should be strongly correlated with higher priced home purchases.

By dividing the dataset among less expensive, "average," and more expensively priced houses, we can proxy the effect of income on revealed preferences to live near livestock operations. The mean value of residential properties in this sample was approximately $175,000. Upon examination of the data, we establish the less expensive housing price group as less than $150,000, the medium price as more than $150,000 but less than $200,000, and the more expensive price group as over $200,000 (Table 2).

[3] Beef cattle are 1AU, each dairy cow is 1.4AU, each hog is 0.4AU, chicken is 0.01, turkey, 0.02, sheep, 0.1 etc.

Table 1: Variables and Descriptive Statistics of Analysis for the General Model

Variables	Description	Units	Min	Max	Mean	Std Dev
Hp	housing sale prices	$1,000	53.00	880.00	175.80	69.97
Yr	age of house	years	1.00	82.00	11.62	16.56
Bed	# of bedroom	#	0.58	6.00	2.97	0.58
Bath	# of bathroom	#	0.00	6.00	2.24	0.71
Prox	proximity to highway	mile	0.00	6.20	1.87	1.41
Bdsize	building size	sq ft	468	8336	1541.98	606.56
Lotsize	lot size	acres	0.03	14.65	0.42	1.25
Beef1	# of operations w/in 1 mile	#	0.00	3.00	0.25	0.55
Beef2	# of operations 1-2 miles away	#	0.00	9.00	0.91	1.18
Beef3	# of operations 2-3 miles away	#	0.00	13.00	1.58	2.12
BeefAU1	AUs per operation w/in 1 mile	1000AU	0.00	10.00	0.33	1.01
BeefAU2	AUs per operation 1-2 miles away	1000AU	0.00	27.75	1.36	2.47
BeefAU3	AUs per operation 2-3 miles away	1000AU	0.00	100.00	2.87	5.69
Hog2	# of operations w/in 2 miles	#	0.00	2.00	0.19	0.40
Hog3	# of operations 2-3 miles away	#	0.00	3.00	0.22	0.42
HogAU2	AUs per operation w/in 2 miles	1000AU	0.00	1.27	0.19	0.44
HogAU3	AUs per operation 2-3 miles away	1000AU	0.00	1.60	0.14	0.35
Chicken2	# of operations w/in 2 miles	#	0.00	3.00	0.16	0.42
Chicken3	# of operations 2-3 miles away	#	0.00	2.00	0.34	0.61
ChickenAU2	AUs per operation w/in 2 miles	1000AU	0.00	24.10	0.43	2.39
ChickenAU3	AUs per operation 2-3 miles away	1000AU	0.00	24.10	0.35	1.51
Sheep2	# of operations w/in 2 miles	#	0.00	2.00	0.07	0.28
Sheep3	# of operations 2-3 miles away	#	0.00	3.00	0.11	0.39
SheepAU2	AUs per operation w/in 2 miles	1000AU	0.00	7.00	0.14	0.66
SheepAU3	AUs per operation 2-3 miles away	1000AU	0.00	7.00	0.15	0.56

Table 2 presents the summary descriptive information for each of these three groups and illustrates the statistical distinctions of housing characteristics among the three residential property price categories, providing justification for the tripartite market segmentation. The age of the house is significantly different across the three-price categories, with age decreasing as price increases. The number of bedrooms, bathrooms, house size and lot size all increase as price category increases. Less expensive price category properties are significantly closer to the highway on average than medium and more expensive category homes. However, the medium and relatively expensive homes do not differ significantly in their average distance to the highway (Table 2).

Model

The empirical model in this analysis is generality specified as follows:

$$log(Home\ sale\ price_i) = f(HC_i, AnimalUnits_i, Animal\ Operations_i)$$

The *HC* variables are five common housing characteristics including age, number of bathrooms and others described earlier, and the distance to a major highway. Livestock inventories can change in two ways; the number of operations can increase (decrease) or the number of animals on each existing operation can increase (decrease). Two livestock-related sources of data were used to derive a number of additional variables in order to understand the influence of livestock inventories on residential property values; animal units by species and operations within a particular distance of a property. Thus, Sheep3 reflects the number of sheep operations found between two and three miles of a housing sale. The number of animal units within each radius is divided by the number of operations found there to derive the average size operation by species within a particular distance from a residential property sale. Thus, BeefAU2 refers to the average number of beef cattle animal units per operation found between one and two miles from a housing sale, while HogAU3 would show the average number of hog animal units found between two and three miles of a sale.

Table 2: Descriptive statistics of stratified housing market, by sales price category

		<$150,000		$150,000- $200,000		>$250,000	
Variables	Units	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Hp	$1,000	123.6	19.8	170.83	14.24	267.70	78.16
Yr	years	18.5[a]	20.3	7.82[b]	12.06	6.00[c]	10.40
Bed	#	2.8[a]	0.5	3.01[b]	0.50	3.22[c]	0.63
Bath	#	1.8[a]	0.6	2.35[b]	0.58	2.76[c]	0.67
Prox	mile	1.4[a]	1.1	2.19[b]	1.55	2.20[b]	1.43
Bdsize	sq ft	1192.4[a]	303.7	1490.72[b]	353.32	2183.43[c]	744.35
Lotsize	acres	0.2[a]	0.2	0.30[b]	1.52	0.94[c]	1.59
Beef1	#	0.3	0.6	0.25	0.49	0.25	0.51
Beef2	#	0.9	1.2	0.87	1.16	1.01	1.11
Beef3	#	1.5	1.8	1.70	2.52	1.57	1.99
BeefAU1	1000AU	0.4	1.2	0.27	0.77	0.34	0.92
BeefAU2	1000AU	1.1	1.9	1.64	2.73	1.43	2.79
BeefAU3	1000AU	3.3	7.5	2.22	3.47	3.11	4.72
Hog2	#	0.1	0.3	0.23	0.42	0.25	0.44
Hog3	#	0.2	0.4	0.21	0.41	0.21	0.42
HogAU2	1000AU	0.1	0.2	0.26	0.50	0.29	0.53
HogAU#	1000AU	0.1	0.3	0.16	0.38	0.11	0.29
Chicken2	#	0.1	0.4	0.14	0.37	0.24	0.48
Chicken3	#	0.4	0.7	0.35	0.58	0.18	0.46
ChickenAU2	1000AU	0.6	3.0	0.22	1.42	0.39	2.46
ChickenAU3	1000AU	0.3	1.1	0.22	1.24	0.56	2.26
Sheep2	#	0.1	0.3	0.04	0.20	0.08	0.34
Sheep3	#	0.1	0.3	0.15	0.46	0.09	0.39
SheepAU2	1000AU	0.2	0.5	0.07	0.40	0.20	1.06
SheepAU3	1000AU	0.1	0.5	0.19	0.55	0.14	0.68

Note: [a,b,c] denote statistically distinct groups at $p<0.05$ or better. This is based on pair-wise comparison of the calculated mean values in each of the three property value subcategories. t_{lm}, t_{lh} and t_{mh} indicate t-stats between low and medium, low and high and medium and high priced groups, respectively.

Size and location data were collected for beef cattle, dairy, chicken, turkey and hog operations. Preliminary analysis revealed sufficient rural residential sales within one mile of beef and dairy operations to run the models. However, there were insufficient rural residential real estate sales near chicken and turkey operations. As a result, chicken and turkey farms were combined to form a category called "poultry," and, additionally, the final models had 0-2 miles as the closest potential impact zone rather than our original intent to model influences from within a mile. Moreover, no significant differences in housing prices were observed in beef cattle versus dairy operations, providing preliminary evidence that species may matter more than operation type. As a result, beef cattle and dairy operations were combined into one category representing cattle.

In addition to the general model analysis, the dataset was segregated into three housing price ranges to see if different impacts exist by price category. This analysis permits different coefficients on animal units for all three housing price groups, thereby allowing us to investigate the income effect of willingness to pay for the same property attribute.

Results

General results

The results can be illustratively depicted in terms of a one-unit change in each of the independent variables. From the mean residential sale value of $175,800, the housing value depreciates by $703 with each year of age. By adding one more bedroom, the housing price increases by $3,164, and one more bathroom is worth

$13,536 on average. One hundred square feet of living space is worth $380, while adding one acre to the lot size increases housing value by $4,219.[4]

As expected, across all species the effect of more operations or larger average size operations becomes weaker and less statistically significant with increasing distance from the residential property sold. However, the direction of the effect was not uniform across species. For example, an additional beef cattle or dairy operation in proximity to a residence correlates positively with sale prices, while an additional hog or sheep operation is negatively related to proximal residential sale prices. An additional beef or dairy operation (Beef1) within a mile of a residential property increases the sale price of that property by 5.4% ($9,493).

The effect of more poultry operations is positive within two miles and mildly negative within two to three miles of a residence, potentially pointing to a development effect or some data issues. The impact of an additional hog operation (Hog2) within two miles reduces the housing value by 23%, while an additional sheep operation (Sheep2) within two miles reduces housing values by more than 38%, and 24% from two to three miles (Sheep3) away. While beef and dairy operations are almost evenly distributed throughout the entire study area, most hog and sheep operations are located in the north side of the county. Therefore, these results may pick up some strictly localized negative externalities. In addition, the average number of operations within each successive one mile radius is around 0.2 for hogs and about half that for sheep. As a result, a one unit increase represents an enormous, though technically "marginal," and potentially unlikely change in the variable, leading us to these somewhat unbelievably large marginal effects.

An increase in the average size of a beef cattle or dairy operation in close proximity to residential properties decreases the value of the sale, while increases in the average size of sheep or hog operations correlates positively with proximal residential property values. If the average size beef or dairy operation located within a mile of a residential property (BeefAU1) increases by one unit (1,000 AU), housing values decrease by 1.4% ($2,461). An identical change, but located 2-3 miles from the residence (BeefAU3), has a much smaller predicted impact (0.2%, or $352) on sale prices. The effect of larger average size poultry operations is negative within two miles of a residential property and positive if located from two to three miles from the sale.

Some of these results are counter to expectations and beg explanation. While practically all commercial sheep, hog, poultry and dairy operations are confinement operations, some beef cattle enterprises are more properly viewed as ranches. More nearby beef cattle ranches may imply more of the natural amenities drawing people to the region including rural lifestyles, open space and pastoral landscapes. As the number of beef cattle per operation increases, so does the likelihood that the operation is a confinement operation, or feedlot, characterized by more concentrated potential negative externalities (e.g., flies, odor, dust, truck traffic) and fewer positive spillovers (e.g., pastoral landscapes). In all species, as average size of operation increases it becomes more likely that direct employment, or development, effects will be created by the operation and less likely that the operation employs only "family" labor. The results of this general approach may encourage such hypothesizing. Unfortunately, the mixed signals generated by these estimates provide little in the way of solid conclusions regarding the strength of the negative versus the positive influence of livestock operations on nearby residential sale prices. Since it is likely that these effects could vary by housing price, as housing dynamics could differ by income levels, this issue is addressed in the next section.

Results by operation size

The spatial hedonic model was re-estimated for three housing price strata in order to attempt to provide insights into potential differences in development versus odor effects across income groups. While housing purchases are not exactly income, a reasonable argument can be made they can provide a useful proxy for household income. Since housing is one of the major purchases a family makes, the distribution of home purchases reflects, to some degree, the distribution of income.

[4]The North Carolina study (Palmquist et, al) showed $29 for one more square foot, $7,500 for one more bathroom and $3,000 for lot size, based on a mean housing value of $73,132.

The model divided into three price categories revealed a good statistical fit for the less expensive end of the housing market, a poor statistical fit for the average price residences in the sample, and an excellent fit for the more expensive end of the market. That is, the lower and higher ends of the market were most responsive to the measured variables. Discussion of the results within and across housing price categories provides interesting insights into the role of livestock in the local residential property market.

Where significant in both markets, the number of nearby livestock operations was consistently of opposite influence on less expensive versus more expensive residential sales. Beef, dairy, hogs and poultry operations all correlated positively with higher end residential sales, while sheep operations were negatively related to more expensive residential sales. On the contrary, hog and poultry operations negatively influenced the lower end of the market and sheep operations were positively correlated with less expensive home prices. One more hog operation decreases housing values by 9.6% ($11,877) within two miles and 9.8% ($12,112) within two to three miles. One additional poultry operation decreases housing values by 4.21% ($5,203) within two miles and 1.67% ($2.064) within three miles in this housing price category. The number of beef and dairy operations had little influence on the less expensive housing market.

The influence of average operation size is similarly contrary in the two market segments. The average size hog operation is positively related to the price of less expensive homes and negatively related to more expensive homes. The positive impact of larger hog operations for the low price group may be driven by the employment effect. For the more expensive market segment, a 23% ($58,894) decrease within two miles and 21% ($56,217) within three miles is predicted as another 1,000 AUs of hogs are added per operation. The average size of poultry and sheep operations is uncorrelated to the less expensive market segment. The more expensive housing market segment prices are positively related to poultry operation size and negatively correlated with sheep operation size. The impact of an additional 1,000 AUs per poultry operation is relatively smaller than for hogs. Within a one to two mile radius around a high-priced home sale, there is 1.98% ($5,300) decrease in sale price and a 1.53% ($4,095) decrease if the poultry operation is located between two and three miles. Only eight sheep operations were used in the analysis, so the results may not be reliable due to the lack of information.

Increases in the average size beef and dairy operation are negatively correlated with the less expensive residential housing market and is inconsistent over distance in the more expensive market segment. A marginal increase (1,000 AUs) in beef or dairy cattle per operation within one to two miles is associated with a 0.59% ($729) reduction in mean housing value in the less expensive market segment, while from two to three miles there is a 0.2% ($247) reduction. However, the effect was positive but insignificant within one mile, potentially explained that the development effect neutralized the odor effect in the less expensive housing market.

Incremental impacts

The discussion above gives the impact on housing price from a one unit change in an independent variable. However, a one unit change may be unrealistically large to be considered “marginal” for many of these independent variables. For example, if the mean value is 0.1 hog operations within one to two miles, a 100% increase in the mean value is only 0.2 operations. Therefore, a one-unit increase may not be a realistic assumption, as it implies a 1,000% increase in the average number of hog operations locating near houses in this sample. Alternatively, elasticities can provide a proportionate change based on the mean values in the dataset (Table 3).

This view of the results reveals that the low price-housing group has less negative impact from livestock operation odors than the high price-housing group. The animal units of beef and dairy and the number of hog operations within two and three miles have a negative impact on sales in the lower priced homes. For 1% increases in beef and dairy animal units per operation, there is a decrease in the low price housing value by 0.0063% ($7.79) within two miles and 0.0068% ($8.40) within three miles on average (Table 3).

Table 3: Housing price damages of the less expensive and more expensive income/housing price categories, elasticities

	Less than $150,000 Mean HP = $123,585			More than $200,000 Mean HP = $267,704		
Variables	Elasticity	Mean	$Impact	Elasticity	Mean	$Impact
BeefAU1	-	-	-	-0.012	0.3412	-32.12
BeefAU2	-0.0063	1.066	-7.79	-	-	-
BeefAU3	-0.0068	3.307	-8.40	-	-	-
Hog2	-0.0918	0.119	-113.45	-	-	-
Hog3	-0.1154	0.236	-142.62	-	-	-
HogAU2	-	-	-	-0.066	0.2895	-176.7
HogAU3	-	-	-	-0.023	0.1058	-61.6
Chicken2	-	-	-	-0.034	0.3919	-91.0
ChickenAU2	-	-	-	-0.008	0.0752	-21.42
ChickenAU3	-	-	-	-0.009	0.0934	-24.09
Sheep2	-	-	-	-0.454	0.0752	-1,215.38
Sheep3	-	-	-	-0.146	0.0934	-390.85

The impact of the number of hog operations is much bigger than for beef and dairy operations. A 1% increase in hog operations from its mean[5] decreases housing prices by 0.09% ($113.45) within two miles and 0.11% ($142.62) within three miles. Contrary to expectations, the impacts by distance to the operation do not decrease for the low price group.

The negative impact by distance on the high priced group is clearer than for the low priced group. Each housing unit has 341 AUs per beef and dairy operation within one mile on average. The 1% increase from the mean reduces the housing value of a high-priced home by 0.012% ($32.12). It also means that there is a $26,466 [6] total reduction of housing value to society due to the 1% increment. The impact of beef and dairy operations outside of one mile away was not significant. The larger the size of hog operations within two miles, the higher the impact, and it is more than five times greater than beef and dairy. With a 1% increment of AUs per operation from its mean, high-end rural residential real estate values decrease by 0.066% ($176.70), or a $145,600 negative impact on the high end housing stock. A detectable impact remains at two miles, decreasing values by of 0.023% ($61.60), creating an additional $50,758 drain on high end housing values. Therefore, the total negative impact of a 1% increase in hog operation size within two miles of more expensive homes in Weld County would be almost $200,000 in lost taxable value for the county.

The number of poultry operations within two miles decreases housing values by 0.034% with a 1% increase from the mean, but again there is no significant impact after two miles. The impact of poultry AUs per operation does not show a decreasing trend over three miles. Rather, the effect is quite similar over the measured distance, measuring 0.008% ($21.42) and 0.009% ($24.09) within the two and three miles distance, respectively, for a total negative impact of $37,500 due to the change. The number of sheep operations within two miles has the highest negative impact, 0.45% ($1,215.38), decreasing to 0.14% ($390) within three miles, for a total estimated negative impact of more than $1.3 million were the number of sheep operations relatively near the higher end rural residences in Weld County increased incrementally.

This reduction in residential values has clear implications for county and school district tax receipts. Any reduction in tax revenues from residences due to livestock operation externalities should be considered in view of

[5] The total number of low price housing units is 1,337 and mean hog operations within two miles is 0.119 per housing unit. Thus, there are approximately 135 houses that have a hog operation within two miles. Unfortunately, it is not possible to infer how many operations will be added with a 1% increase from the mean. If an operation is going to locate in a high density residential area, the mean of number of operations within a certain distance will be higher than that of low density housing area.

[6] $32.12 reduction for each house of high price group and the total number of houses is 824.

commercial or industrial tax revenues from the livestock industry, the cost and feasibility of odor mitigation technologies or management, and the relative demand for services among competing or complementary land uses in considering local land use planning and development options. For example, a 1% increase in AUs per beef operation implies a $26,466 reduction in the value of the high end housing stock and the total average property tax burden in the state of Colorado is about 80 mills. As a result, $2,117 in residential property taxes would be lost to the county due the externalities associated with beef production on high end homes from a 1% increase in the average size of nearby beef or dairy operations. A 1% increase in the number of nearby sheep operations would cost Weld County $106,000 in unrealized potential tax revenues from higher priced rural residences. This can be considered a subsidy to the livestock industry or an additional tax burden suffered by homeowners in order to provide their county public services.

Table 4 reproduces the elasticities from earlier presentations and reports impacts on housing prices and tax revenues given one-percent increases in the respective independent variables. It is constructed to permit a comparison of effects of both added numbers as well as the size of an operation; as in any location decision, there are both of these at work. There are instances when both effects are positive, or when the size effect is opposite to the effects of added numbers of livestock firms. For example, looking at the impacts on low-income housing, if the number of beef and dairy firms within two miles of a house increases by one percent, there is an increase of $35.47 in the value of the house, of $0.35 in tax revenues to the county, and of $1.67 to coffers of the school district.

It is easiest to assume that a one-percent change in size also occurs, as the livestock facility that is added has some size impact also. In that case, it is necessary to deduct $7.78 from the added value to the house, and $0.17 and $0.37 from county and school district taxes, so the net effect is a combination of increased numbers within a certain radius also with varied size. Within a two- to three-mile radius, the location of a beef operation has no effect, but increased size does cause a decline in the value of a house by $8.40 without any benefit (or cost) from increased numbers of livestock businesses, as that effect is insignificant.

The greatest negative impact on low-income housing comes from the location of hog operations within two to three miles of a particular house. In that case, raising the average number of hog operations by one percent will cause a decline in housing value of $142.62, and bring with it decreased tax revenues to the county of $3.14 and of $6.70 to the school district. This decline is not as great because of an opposite effect from the increased size, which adds $26.82 to the value of a house and adds $0.59 and $1.26 to tax revenues in the county and school district. The net effect is a decline of $115.80 in housing value and almost $8.00 in tax effects.

As expected, the range of effects on the highest income category is much higher also. With the exception of sheep operations, the location of any livestock firm near a highly valued house raises its value and tax revenues to the county and school district. The caveat is that the size of the operation should not grow by more than about four percent for each one-percent gain in numbers. The largest, positive effect of increasing hog operations within a radius of one to two miles by one percent is $631.79 in housing value and $43.71 in tax revenues. The largest negative effect comes from sheep operations that locate within two miles, which creates a decline in housing values of $1,215 less $82.99 and also high tax losses. However, given the few sheep facilities found in the data, this needs to be seen as an anomaly. Interestingly, both size and numbers effects from beef are positive within one to two miles (and are, on balance, positive across all three radii).

In sum, if a beef firm is located next to a house in Weld County, it is increasing the value of that house and the tax revenues to the county. Hog businesses raise the value of high income housing substantially but hurt the value of low-income houses, as do poultry facilities. These results need very much to be seen in light of several points. First, the average number of firms is very low for both high and low-income housing. Therefore, positive values can easily be attributed to rural lifestyle amenities, but these might reverse themselves rapidly with higher concentrations of feeding facilities, or the new locations of a very larger operation, especially in hogs. Secondly, small livestock businesses are not a growing sector of the agricultural economy, so these results should be seen more as indications that these firms do not hurt rural lifestyles, and in fact appear to be a positive effect on housing values and tax revenues in this sample. The implication is that the governments should not impose

policies that prematurely drive smaller livestock facilities into extinction. While these numbers are in many respects modest, they can lead to considerable impacts in aggregate.

Table 4: Impact of incremental changes in livestock inventory or operations on housing price and county tax revenues

	Low Value Rural Residential Property House Price $123,585				High Value Rural Residential Property House Price $267,704			
	Elasticity	$ Impact	County tax revenue impact	School district revenue impact	Elasticity	$ Impact	County tax revenue impact	School district revenue impact
Beef1	Ns	0	0	0	0.063	168.65	3.72	7.92
Beef2	0.029	35.47	0.78	1.67	0.029	77.63	1.71	3.65
Beef3	Ns	0	0	0	0.027	72.28	1.59	3.40
BeefAU1	Ns	0	0	0	-0.012	-32.12	-0.71	-1.51
BeefAU2	-0.006	-7.79	-0.17	-0.37	0.007	18.74	0.41	0.88
BeefAU3	-0.007	-8.40	-0.19	-0.39	ns	0	0	0
Hog2	-0.092	-113.45	-2.50	-5.33	0.302	808.47	17.82	37.98
Hog3	-0.115	-142.62	-3.14	-6.70	0.158	422.97	9.32	19.87
HogAU2	0.010	11.86	0.26	0.56	-0.066	-176.68	-3.89	-8.30
HogAU3	0.022	26.82	0.59	1.26	-0.023	-61.57	-1.36	-2.89
Chicken2	Ns	0	0	0	0.034	91.02	2.01	4.28
Chicken3	-0.020	-24.22	-0.53	-1.14	0.024	64.25	1.42	3.02
ChickenAU2	Ns	0	0	0	-0.008	-21.42	-0.47	-1.01
ChickenAU3	Ns	0	0	0	-0.009	-24.09	-0.53	-1.13
Sheep2	Ns	0	0	0	-0.454	-1215.38	-26.79	-57.09
Sheep3	0.107	132.36	2.92	6.22	-0.146	-390.85	-8.61	-18.36
SheepAU2	Ns	0	0	0	0.031	82.99	1.83	3.90
SheepAU3	Ns	0	0	0	0.011	29.45	0.65	1.38

Notes: ns = not significant; 1999-2001 Weld county property tax = 22.1 mills; 2000 Local school district property tax = 46.974 mills

Concluding Remarks and Future Directions

The hedonic price technique allows us to quantify the monetary impacts of the livestock industry on surrounding property values. We quantified the property price impact of 199 livestock operations for 3,355 housing sales from 1999 to 2001 in Weld County, Colorado. From the results of the general model, the estimated relationships generally followed expectations with impacts decreasing and become less statistically significant with increasing distance from the residential property. Beef and dairy operations, which are quite traditional in the region, seem to create a positive rural lifestyle amenity effect up to a point. People are willing to pay to locate in the countryside with small, diversified or unconcentrated livestock operations. However, the net impact of livestock operations on rural residential sales turns to negative if the gets too large and especially close to a residence. More hog and sheep operations contribute negatively to property values and the poultry industry shows mixed impacts.

The segmented regression results, based on three housing price strata as a proxy for income, give slightly different housing demand patterns. Generally speaking, the results of the less expensive end of the housing market

were opposite those of the more expensive end of the market. The less expensive the house, the more negative the impact of another operation, and the higher the housing value, the more negative the impact of larger operation sizes.

It is not easy to detect the interaction and relationship between the housing market and the location of the livestock industry. The results were not fully consistent with the hypotheses, even though several interesting features have been revealed. From a policy perspective, it is important to know the marginal impact a new operation might have. It would be worthwhile to estimate the marginal impact of additional animal units of a particular species in a specific area. Clearly, it would be of use to explore the fiscal impacts of odor mitigation technologies or of different residential development options as well. Although it is not currently possible to fully simulate these potential effects, future analysis should be conducted with such goals in mind.

Though not perfectly conclusive, our results provide insight into understanding the potential external social costs of the livestock sector on rural residential development. We can clearly conclude that both size (or concentration) and species matter. Policy makers may incorporate this social cost in the regional planning to minimize the negative external and maximize the development effect. Moreover, the efficacy of odor mitigating technologies and local policies could be evaluated relative to anticipated tax revenue collection increases from their adoption. Therefore, local officials and private individuals should carefully consider the location and characteristics of new residential properties and animal operations alike.

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