The Impact of Confined Animal Feeding Operations on Agricultural Land Values in Kansas

by

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Abstract

According to the United States Department of Agriculture's Economic Research Service (USDA ERS, 2018), land comprises greater than 80 percent of the assets in the farm sector. Because land makes up such a large majority of assets in the farm sector, changes in the value of agricultural land has a significant impact on all who have a stake in the farm sector.

Many previous studies have attempted to explain the variation in farmland values, but none have considered the possibility that confined animal feeding facilities (CAFOs) with a certain proximity of an agricultural land parcel may have an effect on the value of the land. Using agricultural land parcel sales data from the Kansas Department of Revenue Division of Property Valuation between the years of 2011 and 2017 and CAFO data provided by the Kansas Department of Agriculture, this study attempts to determine if a meaningful relationship exists between the sales price of Kansas agricultural parcels and the number of CAFOs within a given distance. This study found a positive relationship between the price per acre of agricultural land sales and CAFOs within 25 miles of the parcel sale on average between the years of 2011 and 2017, and a negative relationship between the sales price per acre of agricultural land and the number of CAFOs between 25 miles and 50 miles of the parcel sale.

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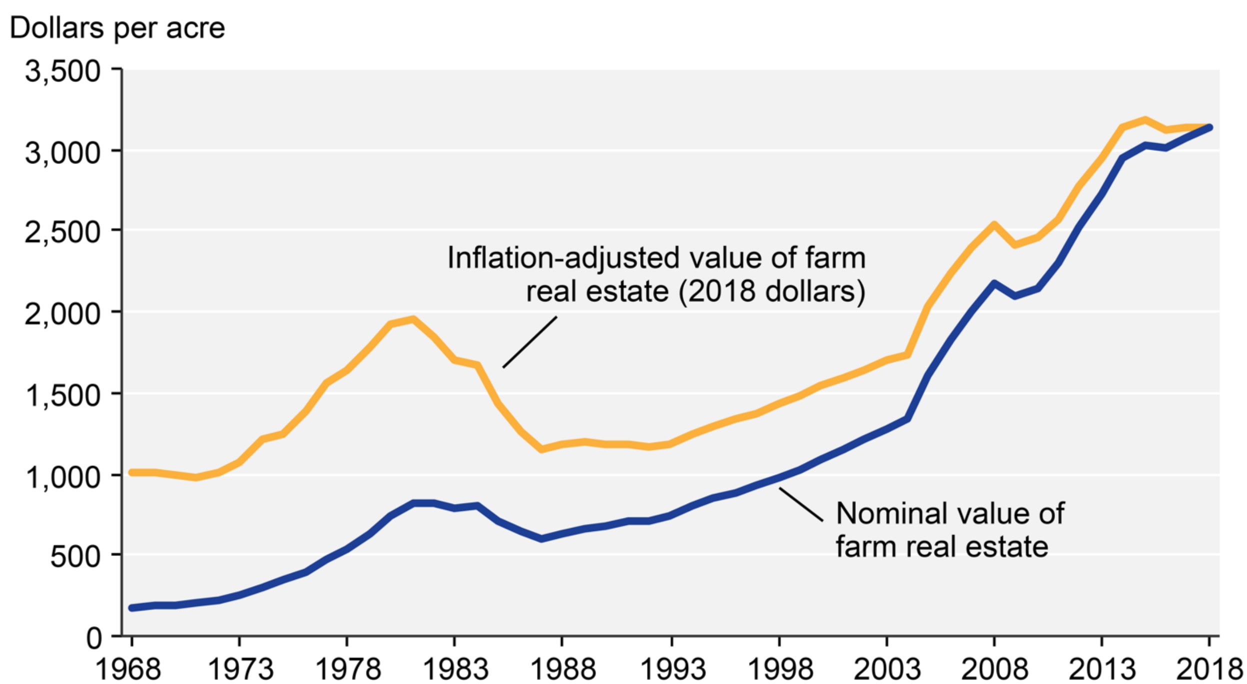
Chapter 1 - Introduction

The value of agricultural land has a significant impact on the agricultural economy. According to the USDA's Economic Research Service (ERS), farm real estate comprises over 80 percent of assets within the farm sector (USDA ERS, 2018). With farm real estate comprising such a large majority of farm sector assets, changes in the prices of agricultural land have significant impacts on the profitability of the farm sector as well as the net worth of land owners. Understanding the drivers behind agricultural land prices help operators, land owners, lenders, and many more participants in the farm sector to make better financial management decisions. Figure 1 shows changes in farmland values over the period of 1968 to 2018. Since the late 1980s, farmland values have been rising. With these rises in farmland values has come significant rises in the net worth of land owners.

Figure 1. Average U.S. Farmland Value by Year



Source: USDA ERS (2018)

Many previous studies have estimated the impacts of specific attributes of agricultural land parcels on their sales price per acre and several studies have estimated the impact of confined animal feeding operations (CAFOs) on rural-residential property values. In both cases, hedonic models have been used to measure the impact of specific attributes on the value of agricultural land or on rural-residential property.

Confined animal feeding operations have been found to have a negative effect on rural-residential housing values. The odor and increased road traffic are two reasons cited for this negative effect. Recently, Smithfield Foods was required to pay $473.5 million in damages to rural-residential property owners surrounding three of their farms in North Carolina because of the nuisance created by their farms (CBS, 2018). While the effects of CAFOs on rural-residential property values is documented, whether a relationship between agricultural land values and the location of CAFOs exists has yet to be discerned.

There has yet to be a study to take into consideration the effects of CAFOs on agricultural land values. The main objective of this study is to evaluate the relationship between CAFOs and agricultural land values. Additionally, this thesis will explore other factors that impact land values such as physical characteristics of agricultural parcels and the economy.

This study uses data on farmland sales and CAFOs in Kansas for the years 2011 through 2017 to determine if a relationship exists between CAFOs and the sales price per acre of agricultural land parcels using ordinary least squares regression. While land values and the sales price per acre of land can be interpreted as different things, this study will use these terms interchangeably.

The organization of this thesis is the following: Chapter 2 will be a review of previous literature on hedonic modeling related to property valuation. Chapter 3 will be an explanation of the methodology and empirical models used by this study. Data and sources of the data used by this thesis are discussed in Chapter 4. Chapter 5 will be a presentation and discussion of the results from this study. Chapter 6 will provide conclusions and future research.

Chapter 2 - Literature Review

This chapter serves as a review of the valuation techniques used by previous studies. Many previous studies have used hedonic models to explain the variance in agricultural land prices. Hedonic modeling is used in land valuation to explain the price differences between heterogenous parcels of land using the characteristics of those parcels. This study will use a hedonic model to attempt to explain the variance in the sales price per acre of agricultural parcels.

Previous Studies Using Hedonic Models

The most frequently cited and seminal work on hedonic modeling is the work by Rosen (1974). Rosen found that price differences are the equalizing factor between two goods with different observed characteristics. To gain the effects of differing product characteristics on prices, Rosen developed the hedonic model which follows the general form $p(z) = p(Z_1, \ldots, Z_n)$ where p(z) is the price of the good as function of a vector of its characteristics, z, and each z_i is a different characteristic of that good. The partial derivative with respect to each characteristic, z_i, provides the marginal value for each characteristic of the good.

Taylor and Brester (2005) studied the impact of noncash income transfers from the U.S. government to sugar producers on land values in Montana using a hedonic discounted net present value model. They theorized the price per acre of land to be dependent on the county, expected cash receipts, population density of the county, size of the parcel, size of the parcel squared, the quality-adjusted price of sugar beets, an interaction term of the quality-adjusted price of sugar beets and the parcel's county, and a dummy variable for each year of the study. Taylor and Brester found a positive and statistically significant relationship between price per acre and the quality-adjusted price of sugar beets, expected cash receipts, and population density of the county. Also, they found a negative and statistically significant relationship between size of the parcel and price per acre.

In a recent study by Sudbeck (2018), he examined the impact of land quality on the price of agricultural land in Kansas. Sudbeck modeled logged average agricultural land prices per acre as a function of the logged dependent variable lagged one period, percentage by weight of organic material in the soil, net farm income, quarterly S&P 500, 30-year fixed-rate mortgage rates, and low-quality land sales as a percent of total sales. He found positive relationships between the average price per acre and the lagged price per acre, net farm income, and the S&P 500. Negative relationships were found between the percentage of low-quality land of total sales and the logged average price per acre.

Pendell (2013) evaluated agricultural land prices in Kansas as a function of fixed-rate interest rates, acres in the parcel, acres in the parcel squared, population of the county were the parcel was located, population of the county where the parcel was located squared, an urban location index, crop reporting district, percent of acres that were irrigated, percent of acres that were native grass, percent of the acres that were tame grass, and the Kansas Farm Management Associations (KFMA) reported net farm income reported. Pendell found negative relationships between the log of price per acre and interest rate and the size of the parcel. Also, positive relationships were found between the log of price per acre and the population of the county where the parcel was located, an urban location index, and net farm income. Irrigated acres were found to increase the price per acre relative to dryland acres, and acres of pasture were found to decrease the price per acre relative to dryland acres.

Herriges et al. (2005) applied the hedonic framework to rural-residential housing values to determine the effect of livestock facilities on housing prices. Herriges et al. determined housing prices as a function of lot size, year of sale, age of the house, living area minus additions, total area of additions, whether the home was air conditioned or not, number of bathrooms, number of decks or enclosed porches, number of fire places, whether there was an attached or detached garage, distance to the nearest large town, distance to the nearest high school, population density and median income of the township, and controls for livestock facilities. To capture the effects of livestock facilities around the housing sale, explanatory variables were added to account for distance and size of the nearest livestock facility, number of livestock facilities within one, three, and ten miles of the housing sale, and dummy variables to account for the effects of prevailing winds by indicating whether a livestock facility was northwest or south of the house.

Herriges et al. found that livestock facilities do have a significant negative effect on property values. However, there was the lack of statistically significant effects of larger livestock facilities. The only statistically significant price elasticities with respect to the nearest livestock facility calculated were for moderate sized facilities. Herriges et al. argued that the lack of statistical significance was likely due to do to the different technology and manure management practices that were likely employed by larger facilities.

Kim and Goldsmith (2008) used a spatial lag dependence model to model the impact of swine production on rural-residential housing values. Assessed property values were modeled as a function of the dependent variable adjusted by a spatial autoregressive parameter and the k-nearest neighbors matrix, base area of the home, number of rooms in the home, number of bathrooms in the home, size of the lot that the home sat on, age of the home, median income by census block group, distance to the nearest central business district, distance to the nearest school, number of hogs at the nearest farm divided by the distance to the nearest farm, and a dummy variable to indicate if the size of the nearest farm was above 2,500 hogs.

Like Herriges et al., Kim and Goldsmith incorporated different distance bands and wind directions to capture the different levels of effects at different distances. The findings of Kim and Goldsmith were consistent with Herriges et al. They found a negative effect on housing values due to the presence of hog facilities. Additionally, they did not find a significant relationship between wind direction and housing values when a hog facility was present.

Contributions of This Study

There is an extensive set of previous studies that have examined the factors affecting agricultural land values. Furthermore, a few of these studies have examined the impact of confined animal feeding operations (CAFOs) on residential property values. This thesis research is like the previous hedonic agricultural land valuation in that specific attributes of agricultural land parcel sales are used to explain the variance in the sales price per acre of agricultural land. However, this research differs as the author is unaware of any published research that has examined the impact of CAFOs on agricultural land values. The findings from this study will provide insights to lenders, land owners, policy makers, researchers, and anyone else with a stake or interest in agricultural land.

Chapter 3 - Methodology

This chapter describes the economic framework used in this research. This chapter begins with a theoretical framework of hedonic modeling and follows with the empirical models used in this study. Following the empirical model discussion, the variables used in the model are described in detail.

Theoretical Framework

This study follows the theoretical framework for hedonic modeling put forth by Rosen (1974). In this current study, the price per acre of a parcel of agricultural land is theorized to be a function of the type of land in the parcel, size of the parcel, productivity of the land, general economy, and number of CAFOs within a set radius. The theoretical framework used was the following:

$$Price\ Per\ Acre = f(Land\ Type,\ Size,\ Productivity\ of\ Land, Economy,\ CAFOs) \quad (1)$$

Empirical Framework

Two empirical models are used by this study. Both empirical frameworks are used to estimate pooled models. These models are used to estimate the average effect of CAFOs on agricultural land prices for the years 2011 through 2017. The empirical framework for the first pooled model was the following:

$$\begin{aligned} lPPA = {} & B_0 + B_1 Size + \beta_2 Size^2 + \beta_3 \%Irr + B_4 \%Past + \beta_5 \%Home + \\ & \beta_6 CropIndex + \beta_7 Band_{25} + \beta_8 Band_{25-50} + \beta_9 Band_{50-100} + \\ & \beta_{10} rNFI + \beta_{11} rNFI^2 + \beta_{12} Mort + \beta_{13} S\&P + \beta_{14} Jan + \beta_{15} Feb + \\ & \beta_{16} Mar + \beta_{17} Apr + \beta_{18} May + \beta_{19} Jun + \beta_{20} Jul + \beta_{21} Aug + \\ & \beta_{22} Sep + \beta_{23} Oct + \beta_{24} Nov + \varepsilon \end{aligned} \quad (2)$$

The second empirical model uses the same variables as the above framework plus county dummy variables which will be discussed below. It is worth noting that adding a third pooled model where interactions between years and distance bands was considered, but this model is not included in the study because of collinearity concerns.

Variables

The explanatory variables used to explain the differences in the price per acre between parcels of land fell into the following categories: characteristics of the parcel, distance, macroeconomic factors, farm profitability, seasonal dummy variables, county dummy variables, and interactions terms.

Characteristics of the Parcel

Variables explaining the characteristics of a parcel included total acres in the parcel (*Size*), total acres in the parcel squared ($Size^2$), percentage of total acres that are irrigated (*%Irr*), percentage of total acres that are dryland (*%Dry*), percentage of total acres that are pasture (*%Past*), percentage of total acres that are homestead acres or contain a residence (*%Home*), and the crop index (*CropIndex*), and county dummy variables.

Total acres in the parcel is included to account for the variance in the sales price per acre due to the total size of the parcel. A negative relationship is expected between the sales price per acre and total acres in the parcel because larger parcels tend to have a lower sales price per acre when compared to smaller parcels. Pendell (2013) found a negative relationship between the sales price per acre of agricultural parcels and the total acres in the parcel. Additionally, he included a squared term and found a positive coefficient. A positive relationship is expected between the sales price per acre and the total parcel acres squared because the negative effect of parcel size on the price per acre is expected to lessen as parcels are larger.

Differences in the type of acres in the parcel are accounted for by measuring the different types of acres as a percentage of the total acres in the parcel. Percentages are used to prevent collinearity issues due to the fact that total acres in the parcel (*Size*) is also used as an explanatory variable. The percentage of dryland acres, irrigated acres, pasture acres, and home site acres are calculated. The percentage of dryland acres is omitted from the regression model to prevent collinearity. The percentage of acres that are irrigated, percentage of acres that are dryland, percentage of total acres that are pasture, and percentage of total acres that are homestead acres sum to equal 100 percent for every observation, so if all of these variables are included in the model, multicollinearity would exist. In order to avoid multicollinearity, one of these variables (i.e., dryland) is excluded from the model. *%Irr* is the percentage of the total acres in the parcel that are irrigated, *%Past* is the percentage of total acres in the parcel that are pasture, and *%Home* is the percentage of total acres in the parcel that are homesite acres. Each of these variables' effect is measured in relation to dryland acres. A positive relationship between the percentage of irrigated acres and price per acre is expected as irrigated acres are considered more valuable than dryland acres. A negative relationship is expected between the price per acre and the percentage of acres that are pasture because pasture acreage is less valuable when compared to dryland acreage. Finally, a positive relationship is expected between price per acre and percentage of homestead acres as homestead acres are more valuable than dryland acres.

CropIndex is the United States Department of Agriculture Natural Resources and Conservation Service National Commodity Crop Productivity Index (NCCPI). This index measures the productivity of the agricultural land for growing dryland crops. Each parcel has a score ranging from 0 to 100 where 100 is the most productive soil and 0 is the least productive soil regardless of whether the parcel had irrigated, dryland, pasture acres, or a combination of all types of acres. A positive relationship is expected between the NCCPI and the price per acre because it is logical to expect that more productive ground would be more valuable than less productive ground when all else is held constant.

County dummy variables are used to account for changes in effects from county-to-county. A dummy variable is included for each county in Kansas except for Johnson and Wyandotte counties as these two counties are not reported. While using net farm incomes, which will be discussed below, controls for regional differences, there are differences at the county level that would not be accounted for if only net farm incomes or regional dummies are included in the model. For this reason, county dummy variables are included.

Distance Variables

There are two variables measuring the distance of a parcel from another point or set of points including proximity to CAFOs and distances to metropolitan areas. The distance, in miles, is measured from each parcel to each CAFO and then grouped by distance in a band ($Band_{25}$, $Band_{25\text{-}50}$, $Band_{50\text{-}100}$). $Band_{25}$ represents the number of CAFOs within 25 miles of the parcel sale in question, $Band_{25\text{-}50}$ represents the number of CAFOs between 25 and 50 miles of the parcel sale, and $Band_{50\text{-}100}$ represents the number of CAFOs between 50 and 100 miles from the parcel sale. This method is modeled after the distance band approach used by Herriges et al. A positive relationship is anticipated between the number of livestock facilities within 25 miles of the parcel sale and the price per acre of that sale because of the option for selling grain and purchasing fertilizer created by having CAFOs in close proximity to the parcel. The same relationships are also expected for the 25-to-50-mile and 50-to-100-mile distance band, but the magnitude of the coefficients is expected to decline at both the 50-mile and 100-mile distance bands.

Macroeconomic Variables

The average S&P 500 value (*S&P*) for the month of the parcel sale is included to control alternative investments to purchasing land. It is anticipated a positive relationship between the S&P 500 and the price per acre of agricultural parcel sales. Baker et al. (2014) showed a competitive relationship between farm land returns and the returns from the S&P 500, implying that farmland and the stock market are competing investments.

The average 30-year fixed-rate mortgage rate for the month of the parcel sale (*Mort*) is included to account for the impact of financing options on farmland values. A negative relationship is expected between the price per acre and the 30-year fixed-rate mortgage rate because an increase in the mortgage rate would make financing the purchase of the parcel more expensive, ceteris paribus.

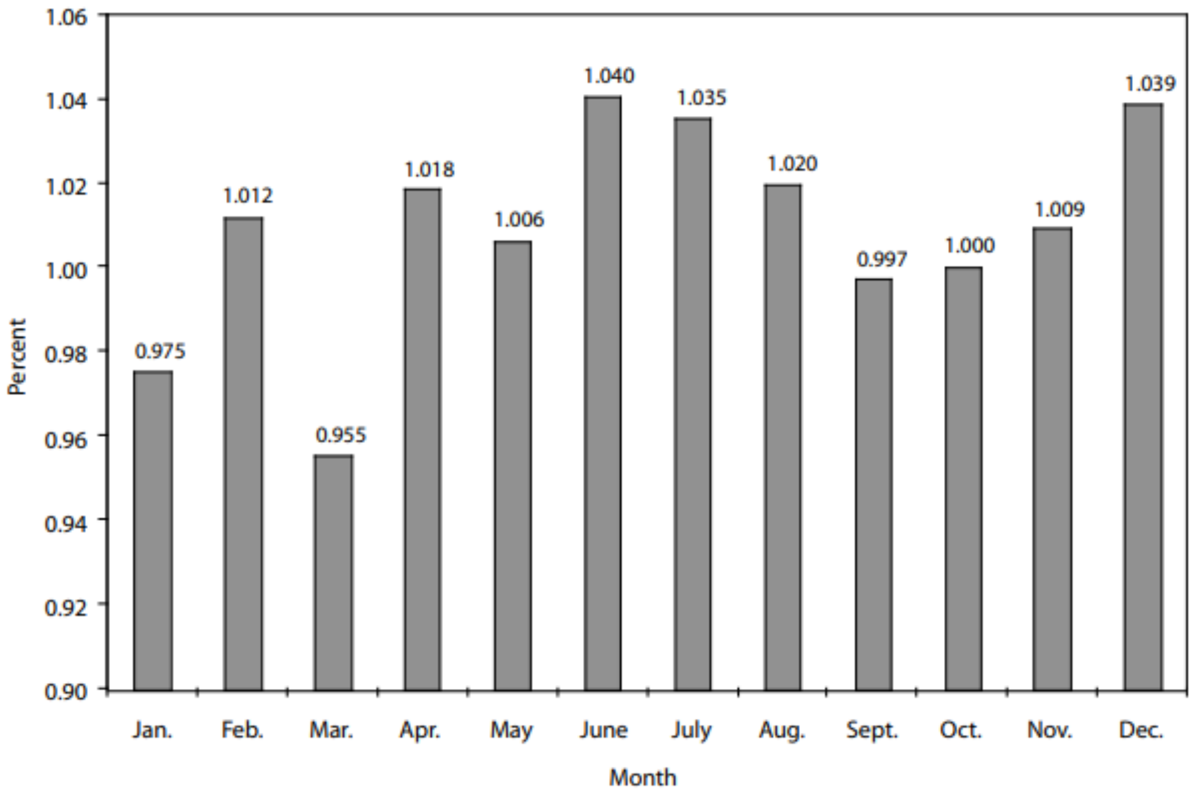
Farm Profitability

The Kansas Farm Management Association's average net farm income (*NFI*) from the previous year for the parcel's region and the average net farm income squared (NFI^2) are included to control for changes in the profitability of the parcel. The net farm income average from the previous year was used as opposed to the net farm income average from the current year because the purchaser of the land parcel would not know what the current year's net farm income would be. He or she would only know the previous year's net farm income. A positive relationship is expected between the lagged net farm income and the price per acre of the parcel. It is logical to expect that when agricultural land is more profitable, the price per acre of agricultural land sales would be higher. The sign on the coefficient of NFI^2 is expected to be negative as the effect of increases in farm income would likely be increasing at a decreasing rate.

Seasonal Dummy Variables

Seasonal dummy variables are included to account for the seasonality in the price per acre of parcel sales across the different months of the year. Pendell and Featherstone (2005) showed the seasonal effects on the price per acre of agricultural land using Kansas farmland data from the period of 1980 to 2003. Figure 2 illustrates the difference in agricultural land sales prices across the different months of the year using an index of Kansas farmland prices across the months of the year. The dummy variable for December is dropped for all regressions to prevent collinearity.

Figure 2. An Index of Kansas Farmland Values Across Months of the Year



Source: Pendell and Featherstone (2005)

Table 1. Explanatory Variables and Their Expectations

Variable	**Description**	**Expectation**
%Irr	percentage of the total parcel acres that are irrigated	Positive
%Past	percentage of the total parcel acres that are pasture	Negative
%Home	percentage of the total parcel acres that are homestead acres	Positive
Size	total acres in the parcel	Negative
$Size^2$	total acres in the parcel squared	Positive
CropIndex	NRCS National Commodity Crop Productivity Index (NCCPI)	Positive
$Band_{25}$	total number of CAFOs within 25 miles of the parcel sale	Positive
$Band_{25-50}$	total number of CAFOs between 25 miles and 50 miles of the parcel sale	Positive
$Band_{50-100}$	total number of CAFOs between 50 miles and 100 miles of the parcel sale	Positive
rNFI	net farm income for the parcel's KFMA reporting district	Positive
$rNFI^2$	net farm income for the parcel's KFMA reporting district squared	Negative
S&P	S&P 500 index	Positive
Mort	The 30-year fixed-rate mortgage rate	Negative

Chapter 4 - Data

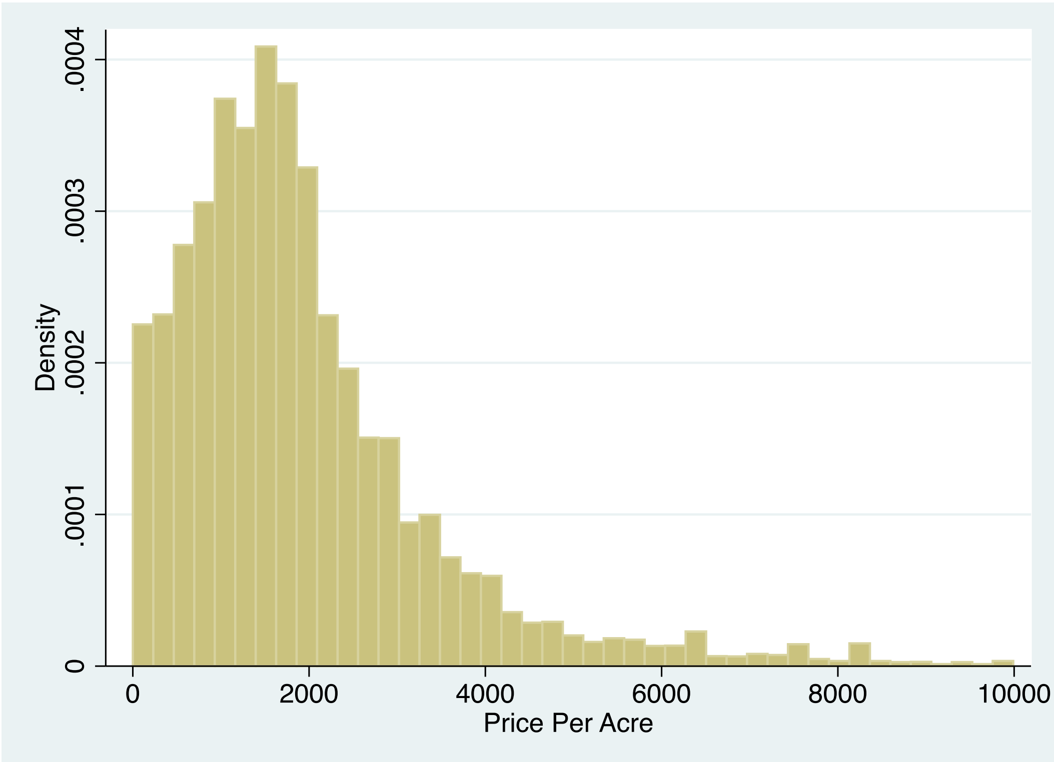
This chapter will describe the data used in this study, including sources and methods used to compile the data. The pooled cross-sectional data set used by this research encompasses the years 2011 through 2017.

Sources

The primary source of data for this study is the Kansas Department of Revenue Division of Property Valuation (PVD) database for agricultural land sales. Data for characteristics of the parcel such as the date of sale, composition of the parcel, size of the parcel (*Size)*, price per acre of the sale, and measures of productivity (CropIndex) were all taken from the PVD's agricultural land sales data set. Variables that are calculated using the PVD data are the percent of acres that are the natural log of the real price per acre (*lPPA*), percentage of acres that are irrigated (*%Irr*), pasture *(%Past*), homestead acres (*%Home*), and total parcel acres squared (*Size2*).

To adjust for inflation, the price per acre is deflated to 2017 dollars for each year using the Consumer Price Index (CPI) from the United States Bureau of Labor Statistics (BLS 2019). Figure 3 shows the distribution of the real sales price per acre of parcel sales included in this study. The natural log is then applied to the real price per acre to correct for skewness in the distribution of the data.

Figure 3. Histogram of Sales Price Per Acre of Agricultural Parcels

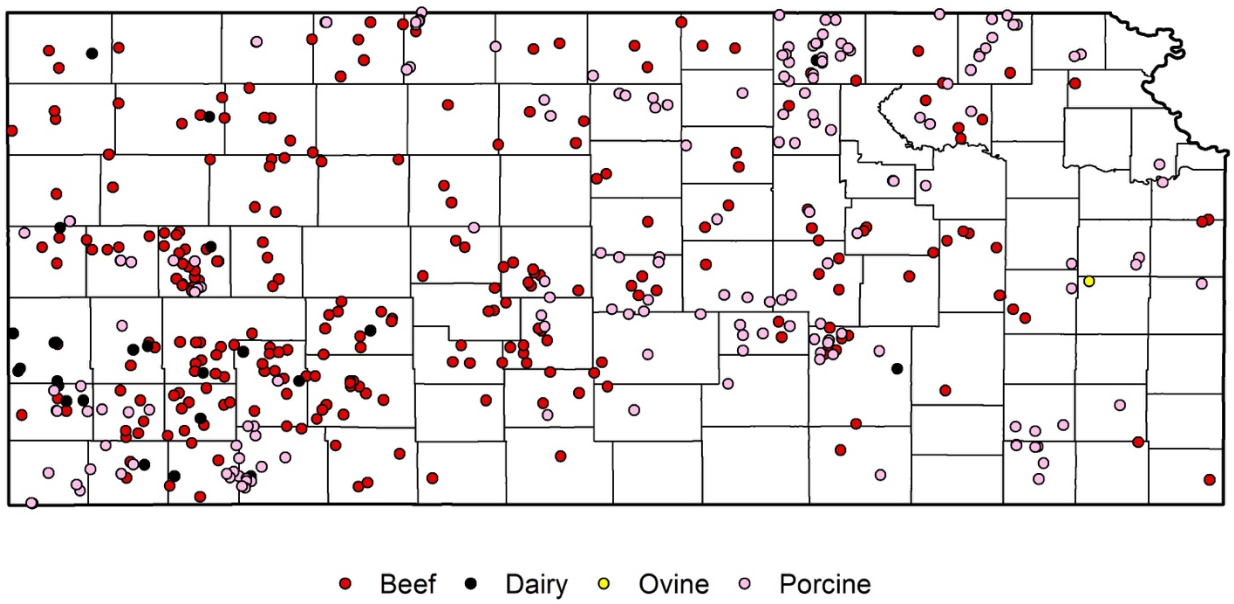


The percent of the total acres that are irrigated (*%Irr*), pasture (*%Past*), and homestead acres (*%Home*) are calculated from the PVD data. Each of these variables is calculated using the same method. Equation X is an example of how the percent of the total acres that are irrigated is calculated for each parcel.

$$\%Irr = \frac{Irrigated\ Acres}{Total\ Acres} \quad (3)$$

A list of CAFOs including their physical addresses is provided for each year for 2011 through 2017 by the Kansas Department of Agriculture (KDA). These facilities included beef cattle, dairies, ovine, and porcine. Figure 4 shows the distribution of CAFOs across the state of Kansas in 2016. The physical address is geocoded to produce a longitude and latitude for each facility. After each facility's address is geocoded, the distance from each parcel sale to each CAFO is measured using the law of cosines method to get an "as the crow flies" measure of distance. For each parcel, distances to the different CAFOs are grouped by distance bands. The distance bands used in this study are 25 miles and under, over 25 and under 50 miles, and 50 miles to 100 miles

Figure 4. Confined Animal Feeding Operations in Kansas in 2016



There are concerns of the reliability of the number of CAFOs reported by\ KDA for 2014, 2015, and 2017. Table 2 shows that each of these years had significantly fewer CAFOs reported than previous or subsequent years in this study. The difference in the number of facilities reported for the years in question appeared to be primarily porcine facilities. The difference in the number of facilities was unlikely to be due to facilities opening and closing, but rather an error in reporting. The lists of CAFOs for these years were neither excluded or edited in any way but left as is.

Table 2. Number of Confined Animal Feeding Operations by Year

Year	Number of CAFOs
2011	511
2012	514
2013	514
2014	432
2015	298
2016	544
2017	449

Data for the S&P 500 (*S&P*) is collected from Yahoo! Finance (Yahoo!, 2019). Monthly averages for the S&P 500 are used in the pooled regression model. Monthly averages are chosen because of the use of monthly dummy variables. Data for the monthly 30-year fixed-rate mortgage rates are collected from the St. Louis Federal Reserve (Fed, 2019).

Net farm income is provided by the Kanas Farm Management Association (KFMA, 2018). An average net farm income from its members in each of its six reporting districts in Kansas are reported annually by KFMA. The KFMA reporting districts are Northeast, Southeast, North Central, South Central, Northwest, and Southwest (Figure 5). KFMA net farm income numbers are adjusted to 2017 dollars using the CPI (*rNFI*). A real squared net farm income variable ($rNFI^2$) is added to correct for the nonlinearity of the net farm income data.

Figure 5. Kansas Farm Management Association Reporting Districts

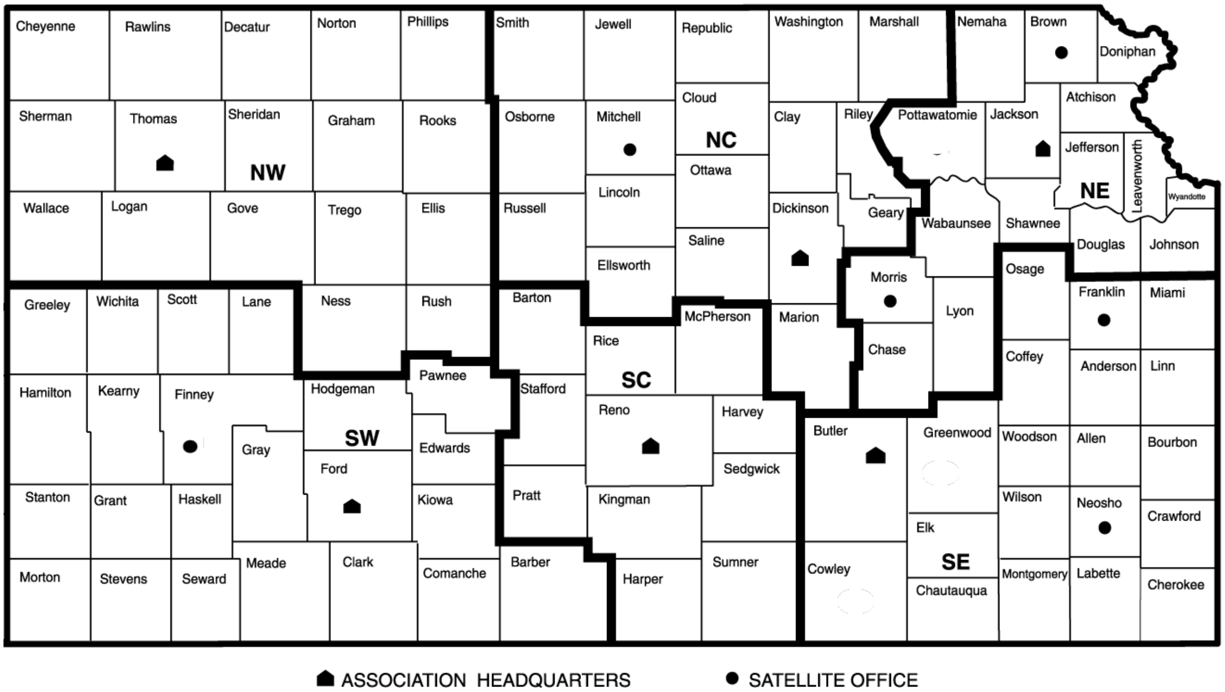


Table 3. Summary Statistics of Dependent and Independent Variables

Variable	Mean	Std. Dev.	Min	Max
PPA	2646.81	9962.90	1.00	542264.90
lPPA	7.28	1.07	0.00	13.20
%Irr	1.77	11.35	0.00	100.00
%Past	22.86	55.13	0.00	665.00
%Home	0.03	0.86	0.00	54.93
Size	133.50	116.45	0.10	1634.70
CropIndex	3.96	0.36	3.35	4.95
S&P	1889.64	403.58	1131.42	2673.61
Mort	42.84	12.69	0.00	89.47
$Band_{25}$	10.41	9.59	0.00	54.00
$Band_{25-50}$	24.80	18.95	0.00	111.00
$Band_{50-100}$	77.40	42.67	2.00	221.00
rNFI	114594.70	93228.79	-11659.21	472882.30

n = 23,504.00

Chapter 5 - Results

This chapter will serve as a review of the results of this study. This section will discuss the results from both pooled regressions and draw comparisons between the findings of the pooled regression without county dummy variables and the pooled regression with county dummy variables.

Pooled Regressions Without County Dummy Variables

Appendix A displays the results from the pooled regression without county dummy variables. A positive relationship was found for the percent of the total parcel acres that were irrigated and the price per acre when compared to the percent of the total parcel acres that were dryland acres. The coefficient estimated for *%Irr* showed that a 1 percent increase in the percentage of total acres that were irrigated lead to a 0.653 percent increase in the sales price per acre of an agricultural parcel, meaning this estimated coefficient is the premium received for irrigated acres relative to dryland acres. A negative relationship was found between the percent of the total parcel acres that were pasture acres and the price per acre when compared to dryland acres. A 1 percent increase in the percent of total parcel acres that were pasture relative to dryland acres would lead to a 0.109 percent decrease in the price per acre of a parcel sale, meaning this coefficient was the discount at which pasture acres sold relative to dryland acres.

The sales price per acre and the total acres in the parcel (*Size*) and the total acres in the parcel squared ($Size^2$) had a negative and positive relationship, respectively. However, the magnitude of the coefficient (-0.004) for the total acres in the parcel was very small. The coefficient on the squared term of the total price per acre was positive, but close to zero (0.000). The marginal effect of size on the price per acre was determined by taking the partial derivative of the estimated model with respect to the size of the parcel. Because the coefficient of the squared term was essentially zero, the coefficient for the size of the parcel was interpreted to mean that a one acre increase in the size of the parcel would lead to a 0.441 percent decrease in the sales price per acre. These findings were consistent with previous studies.

The coefficient for the crop index (*CropIndex*) was positive as expected. The estimated coefficient indicates that a one unit increase in the crop index score for a parcel would increase the sales price per acre by 0.704 percent.

The coefficient for the monthly average of the S&P 500 (*S&P*) was positive, but the magnitude of the coefficient was small. The coefficient for the estimated model showed that for a one unit increase in the monthly average of the S&P 500 would increase the price per acre by 0.018 percent. This finding is consistent with Sudbeck (2018).

The coefficient for the monthly average of the 30-year fixed-rate mortgage rate (*Mort*) was negative. The coefficient for the average mortgage rate was significantly greater than those reported by Sudbeck (2018) and Pendell (2013). The estimated coefficient showed that a one percent increase in the mortgage rate would decrease the price per acre by 12.845 percent

A positive relationship was found between the number of CAFOs within 25 miles of the parcel sale ($Band_{25}$) and the sales price per acre. The partial derivative of the estimated model with respect to the number of CAFOs within 25 miles multiplied by 100 revealed the marginal effect of one additional CAFO being located within 25 miles of a parcel sale which showed that each additional CAFO located within 25 miles of a parcel sale would increase the sales price per acre of an agricultural parcel by 0.927 percent.

Contrary to the expectations previously stated, negative relationships were found between the number of CAFOs between 25 and 50 miles ($Band_{25\text{-}50}$) and between 50 and 100 miles ($Band_{50\text{-}100}$) of the parcel sale and sales price per acre. The results suggest that an additional CAFO located between 25 and 50 miles of the parcel sale would decrease the sales price per acre of an agricultural parcel by 0.512 percent, and an additional CAFO located between 50 and 100 miles of a parcel sale would decrease the sales price per acre of an agricultural parcel by 0.218 percent. While the coefficients estimated for these two variables differed from the previous expectations, they did not seem illogical. It is possible that at distances greater than 25 miles, the positive effects CAFOs could provide as an alternative market to sell grain or buy fertilizer might be non-existent, and the increased traffic due to CAFOs located in the area might be a detriment.

The estimated coefficient for real net farm income (*rNFI*) was positive, but close to zero (0.000). The estimated coefficient for $rNFI^2$ was negative, but also very close to zero (0.000). This implies the marginal effect of lagged real net farm income on the sales price per acre was essentially zero. This finding was consistent with Sudbeck (2018).

Several of the monthly dummy variables' estimated coefficients were statistically significant. While their coefficients could not be interpreted, it was worth noting that presence of statistically significant coefficients was consistent with the findings of Pendell and Featherstone (2005) that the month in which a parcel is sold impacts the sales price of the parcel.

Pooled Regressions Without County Dummy Variables

All relationships estimated in the pooled model with county dummy variables were consistent with those estimated in the pooled model without county dummy variables. However, the magnitude of the coefficients estimated for the 30-year fixed-rate mortgage rate average for the month of the parcel sale (*Mort*) and the number of CAFOs between 50 miles and 100 miles of the parcel sale ($Band_{50\text{-}100}$) differed in magnitude from those estimated in the model without county dummy variables. The coefficient estimated for *Mort* increased from 0.128 to 0.201. When the county dummy variables were added, the coefficient estimated for $\mathrm{Band}_{50\text{-}100}$ was not statistically significant, meaning no relationship was found between the sales price per acre of an agricultural parcel and the number of CAFOs between 50 and 100 miles from the parcel sale.

Many of the coefficients estimated for the county dummy variables were statistically significant. While these coefficients cannot be interpreted, they do show that the county in which a parcel is located does have an impact on the value of the parcel.

Chapter 6 - Conclusion

This study sought to be the first to determine if there is a relationship, and to what extent, between the location of confined animal feeding operations (CAFOs) and agricultural land values in the state of Kansas. The information put forward by this study can benefit anyone with a stake in agricultural land in Kansas. Because agricultural land comprises such a large majority of the assets in the farm sector, understanding the factors driving the differences in land prices between parcels is pivotal.

Review of Study

This thesis employs a hedonic model in an attempt to explain the variability in the sales price per acre of agricultural parcel sales in Kansas for the years of 2011 and 2017. The price per acre of land sales was theorized to be a function of a vector of the parcel's physical characteristics, number of livestock facilities within a set radius, average S&P 500 value for the month of the parcel sale, average 30-year fixed-rate mortgage rate for the month of the sale, and average KFMA net farm income from the previous year in the parcel's region.

Relationships were found between the sales price per acre of agricultural parcels and the percent of the total parcel acres that were irrigated, percent of the total parcel acres that were pasture, total acres in the parcel, S&P 500, the 30-year fixed-rate mortgage rates, crop index score (a measure for quality), number of CAFOs within the set radius, and KFMA average net farm income from the previous year.

Future Work

This was the first study to show a relationship between the number of confined animal feeding operations within a set radius and the sales price per acre of agricultural land parcels. Future work can help to build upon the findings of this study. An opportunity for future work would be in model specification. The OLS model used by this study was a first attempt at model specification, but the OLS regressions did not control for spatial factors. Given the nature of this study, spatial autocorrelation might have existed. A future study could compare results from a spatial model to the results from the OLS model used in this study.

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Appendix A - Regression Outputs

TABLE A1. Regression Results

Variable	Pooled		Pooled w/County Dummies	
%Irr	0.007	***	0.008	***
%Past	-0.001	***	-0.001	***
%Home	0.018		0.016	
Size	-0.004	***	-0.003	***
$Size^2$	0.000	***	0.000	***
CropIndex	0.007	***	0.004	***
S&P	0.000	***	0.000	***
Mort	-0.128	***	-0.201	***
$Band_{25}$	0.009	***	0.009	***
$Band_{25-50}$	-0.005	***	-0.003	***
$Band_{50-100}$	-0.002	***	-0.001	
rNFI	0.000	***	0.000	*
$rNFI^2$	0.000	***	0.000	
Jan	-0.132	***	-0.077	**
Feb	-0.024		-0.001	
Mar	0.010		0.047	
Apr	-0.074	**	-0.010	
May	-0.044		-0.021	
Jun	0.018		0.051	
Jul	-0.041		-0.017	
Aug	-0.166	***	-0.133	***
Sep	-0.067	*	-0.070	*
Oct	-0.061		-0.017	
Nov	-0.017		-0.009	
AL			0.154	*
AN			0.739	***
AT			-0.284	**
BA			0.165	*
BT			0.162	**
BB			0.792	***
BR			0.605	***
BU			0.258	**
CS			-0.160	*
CH			0.288	***

CK	-0.196	
CN	-0.166	
CA	0.413	***
CY	0.424	***
CD	0.148	*
CF	-0.563	***
CM	0.056	
CL	0.036	
CR	0.047	
DC	0.397	***
DK	0.699	***
DP	1.059	***
DG	0.532	***
ED	0.172	*
EK	0.498	***
EL	-0.531	***
EW	-0.090	
FI	0.168	
FO	0.721	***
FR	0.242	*
GE	-0.096	
GO	-0.065	
GH	-0.130	
GT	-0.048	
GY	0.258	**
GL	0.053	
GY	-0.346	***
GW	0.292	***
HM	1.169	***
HP	0.154	
HV	-0.452	***
HS	0.603	***
HG	0.499	***
JA	0.258	**
JF	-0.481	***
JW	-0.004	
KE	0.054	
KM	-0.005	
LB	-0.030	
LE	1.026	***

LV	0.169	*
LC	0.332	***
LN	-0.007	
LG	0.291	***
LY	0.353	***
MP	0.855	***
MN	0.567	***
MS	-0.205	*
ME	0.929	***
MI	0.373	***
MC	-0.014	
MG	-0.190	
MR	-0.773	***
MT	0.551	***
NM	-0.194	*
NO	-0.073	
NS	0.085	
NT	0.205	***
OS	-0.257	**
OB	0.394	***
OT	0.200	**
PN	-0.136	
PL	0.451	***
PT	0.234	**
PR	0.020	
RA	0.825	***
RP	0.505	***
RC	0.317	***
RL	0.740	***
RO	-0.278	***
RH	-0.295	**
RS	0.193	*
SA	0.695	***
SC	0.223	*
SG	1.539	***
SW	0.620	***
SN	0.971	***
SD	0.655	***
SH	0.436	***
SM	0.314	***

SF			0.308	***
ST			-0.591	***
SV			-0.513	***
SU			0.208	**
TH			0.707	***
TR			-0.134	
WB			0.211	**
WA			0.070	
WS			0.271	***
WH			0.140	
WL			0.048	
WO			0.084	
cons	7.974	***	7.467	***
N	23,504		23,504	
r^2	0.142		0.257	

* p<.05, **p<.01, *** p<.001