The Dispersion of Farmland Values in the Tenth District

By Cortney Cowley

The value of U.S. farmland has varied widely within and across regions over the last 15 years. Although average farmland values have declined modestly over the past couple of years, farmland values in some areas have fallen sharply while farmland values in other areas have risen. In recent years, unusually high or low prices at farmland sales have become increasingly likely.

Understanding the dispersion of farmland values across regions is important for several reasons. Farmland is interconnected with all aspects of farm wealth and agricultural credit. For example, declining farmland values are typically correlated with farm financial stress, while increasing farmland values are associated with strength in the farm sector (Briggeman, Gunderson, and Gloy). Also, farm owners derive most of their wealth from farm real estate, which accounts for approximately 80 percent of the assets on farm balance sheets. As a result, farmland is an important aspect of the financial health of farms and vital collateral for agricultural lending.

In this article, I examine the effects of soil quality, natural amenities, climate, agricultural production, and other location-specific characteristics on farmland values in the Tenth Federal Reserve District. The Tenth District covers an area of more than half a million square

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miles over seven states and contains concentrated urban centers as well as vast rural counties with population densities less than one person per square mile. Average annual precipitation ranges from less than 10 inches in parts of the Mountain States (Colorado, New Mexico, and Wyoming) to over 50 inches in southeastern Oklahoma. Additionally, the type and quality of soil, the length of the growing season, and the availability of water differ by location and likely influence agricultural production and farmland values. I find that better soil quality, more precipitation, and larger corn and cattle sales are associated with higher farmland values, while greater distance from urban areas and higher temperatures are associated with lower farmland values.

Section I describes variations in farmland values throughout the Tenth District. Section II characterizes potentially important natural, agricultural, economic, and physical land attributes. Section III discusses the effects of these land attributes on the cross-sectional dispersion of farmland values among states in the Tenth District.

I. The Dispersion of Tenth District Farmland Values

Although farmland values vary across Tenth District states and counties, the distribution of these values has widened over time. To assess how land attributes affect the cross-sectional dispersion of farmland values, I use data from the Tenth District Survey of Agricultural Credit Conditions (henceforth referred to as the Ag Credit Survey). Of the 12 Federal Reserve Districts, the Tenth District is the most concentrated in agriculture by several measures, including average farm income as a share of personal income, farm-dependent counties, and agricultural banks.[1] Each quarter, the Ag Credit Survey asks bankers in the Tenth District to provide the current average market values of "good quality" or nonirrigated cropland, irrigated cropland, and ranchland/pastureland in their lending area. It also asks bankers to define the extent of their lending area. Therefore, farmland values from the Ag Credit Survey are bankers' assessments of the average market value of farmland in their lending area during the survey quarter. More than 200 agricultural lenders respond to the survey, representing almost 40 percent of all agricultural banks in the Tenth District.[2]

I use U.S. Department of Agriculture (USDA) data to cross-check the Ag Credit Survey data. The main difference between the two is that

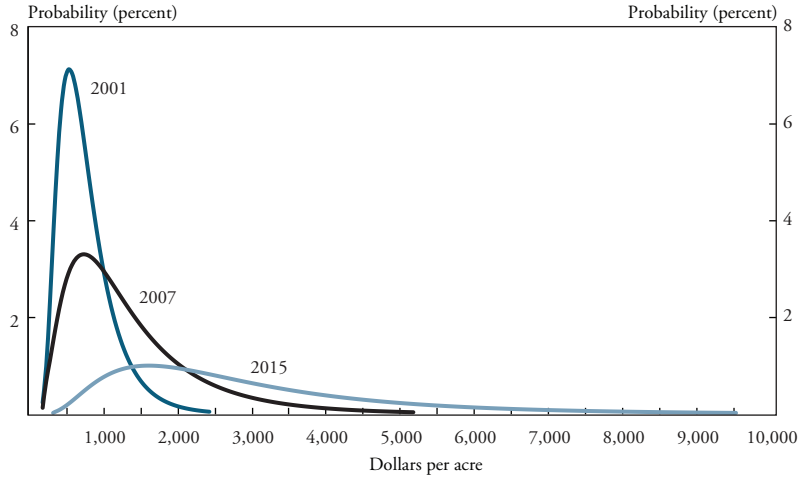
USDA land values are collected annually from agricultural producers. The USDA samples land segments throughout the United States and contacts all agricultural producers operating farmland within the sampled segments. Producers report farmland value information for land within the segments as well as an estimated value of all land and buildings for their entire farming operation. Unlike Ag Credit Survey data, county-level USDA data are aggregated for all farmland types. Although the Ag Credit Survey has the advantage of distinguishing between nonirrigated cropland, irrigated cropland, and ranchland, the current sample of respondents does not cover the entire District. Conversely, USDA data are available for every county in the District. Although the two surveys differ on some levels, previous research has shown that farmland value data from the Ag Credit Survey are highly correlated with farmland value data from the USDA (Zakrzewicz, Brorsen, and Briggeman).

From 2001 to 2015, average Tenth District farmland values increased, and the dispersion of these values became more diffuse. Chart 1 shows the probability distributions of nonirrigated cropland values in 2001, 2007, and 2015.[3] The vertical axis gives the percent probability of each farmland value observation in the three annual samples. As the distribution widened over time, the probability of observing a low or average farmland value declined, while the probability of observing a high farmland value increased. Chart 1 also shows that in 2007, farmland values varied from $200 an acre to more than $5,000 an acre, which was 115 percent higher than the maximum value of $2,400 in 2001. In 2015, farmland values were even more variable, ranging from $300 an acre to nearly $10,000 an acre, a 150 percent increase from the maximum value in 2007.[4] Throughout 2015, data from the Ag Credit Survey supported anecdotal reports of unexpectedly high and low prices in farmland auction results. Although minimum values for farmland have increased slightly since 2001, maximum values have increased dramatically, and the range of farmland values has expanded.[5]

The growing dispersion of farmland values in recent years occurred during a time of general decline in the farm economy. Prior to 2013, farmland values in the Tenth District appeared to be highly correlated with farm income. Chart 2 shows historically high farm income from 2011 to mid-2013, which was supported by a run-up in crop prices

Chart 1

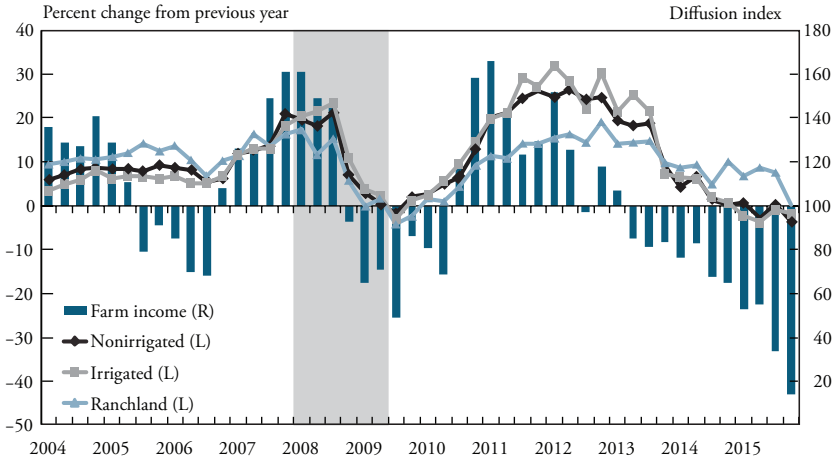
Distribution of Tenth District Nonirrigated Cropland Values



Source: Ag Credit Survey.

Chart 2

Farm Income and Farmland Values



Note: Gray bar denotes NBER-defined recession.
Source: Ag Credit Survey and NBER.

due to higher demand for commodity crops in China and the ethanol industry. Correspondingly, farmland values increased by as much as 30 percent year over year. When crop prices and farm income began falling in mid-2013, many experts anticipated a corresponding drop in farmland values. On average, however, farmland values continued to increase until the first quarter of 2016.

In addition to growing disparity in District-level data, farmland values have varied widely across states in the Tenth District. Differences are first apparent in the distribution of farmland values for each state (Chart 3, Panel A). In 2015, farmland values were the lowest and least variable in Oklahoma and the Mountain States and the highest and most variable in Nebraska. In addition, the distribution of farmland values was slightly more skewed in Kansas and western Missouri than in other states. For example, the distribution of farmland values in Kansas and Missouri was positively skewed in 2015. The slightly longer tail to the right of the mode—represented by the curve's peak—indicates lower farmland values were more common and higher farmland values were less common. In addition, the distributions for Kansas, western Missouri, and Nebraska appear to be almost the same width, though higher-valued farmland was more likely in Nebraska.

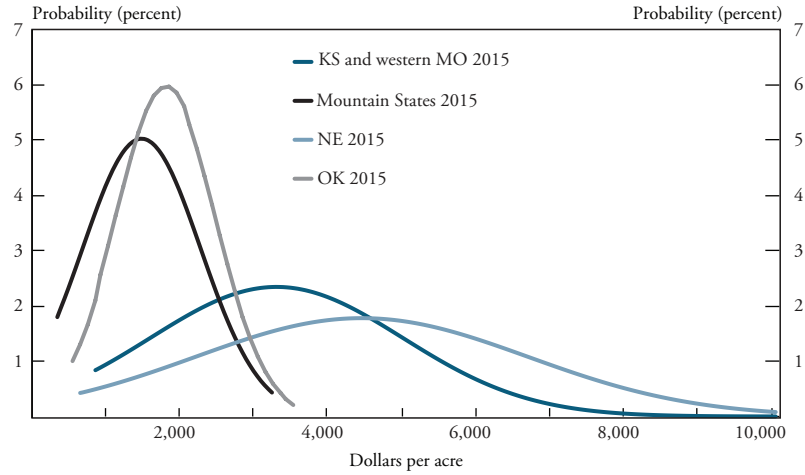
The distributions of farmland values have also changed within Tenth District states over time. Farmland values have increased in all states, but the magnitudes of the distributional shifts have differed. For example, Panel B of Chart 3 shows that farmland values became more diffuse in both Nebraska and Oklahoma over time, but the widening of the distribution was much more pronounced in Nebraska.

When annual gains of farmland values started slowing, the rate of change differed across states as well. Historically, farmland values have typically experienced larger annual gains in states with more corn and soybean production, such as Kansas, Missouri, and Nebraska. Indeed, Chart 4 shows that growth in nonirrigated cropland values in these states consistently outpaced farmland value gains in Oklahoma and the Mountain States, which are more commonly associated with cattle, wheat, and energy production. However, that pattern changed in 2014: nonirrigated cropland values declined in crop-producing states and continued to increase, albeit at a decreasing rate, in Oklahoma and the Mountain States. Most notably, in the fourth quarter of 2014,

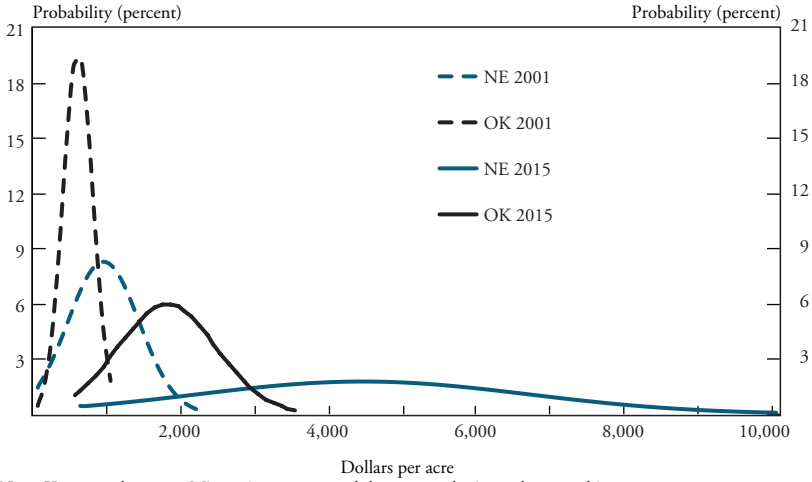
Chart 3

Distribution of Nonirrigated Cropland Values

Panel A: Tenth District Farmland Values, 2015

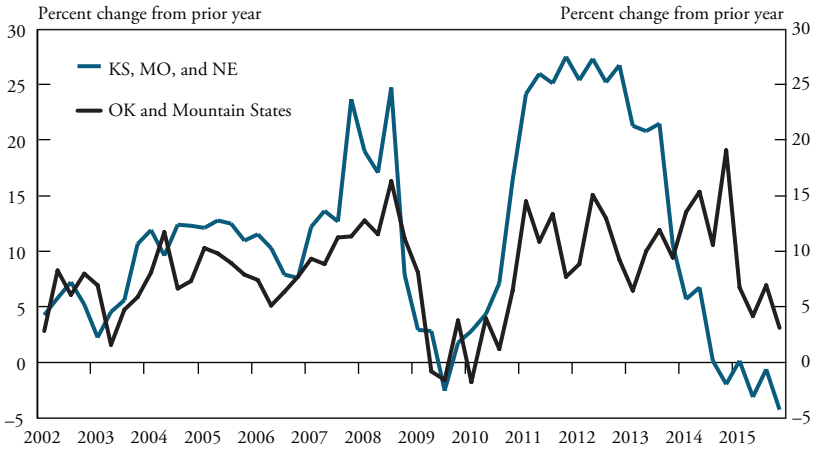


Panel B: Nebraska and Oklahoma Farmland Values, 2001 and 2015



Note: Kansas and western Missouri are aggregated due to sample size and geographic extent.
Source: Ag Credit Survey.

Chart 4
Tenth District Nonirrigated Cropland Values



Source: Ag Credit Survey.

nonirrigated cropland values declined by 2 percent from the previous year in Kansas, Missouri, and Nebraska but increased by 19 percent in in Oklahoma and the Mountain States. Bankers in the District reported similar differences for other types of farmland. Although ranchland values increased in all states in 2015, irrigated cropland values declined slightly in Kansas, Missouri, and Nebraska but continued to increase in Oklahoma and the Mountain States. In contrast, the general decline in commodity prices and farm income since mid-2013 has been even and widespread. However, movements in farmland values over the same period have varied by location. Therefore, examining the cross-sectional variability in farmland values in 2015 should provide a better understanding of the underlying fundamental drivers.

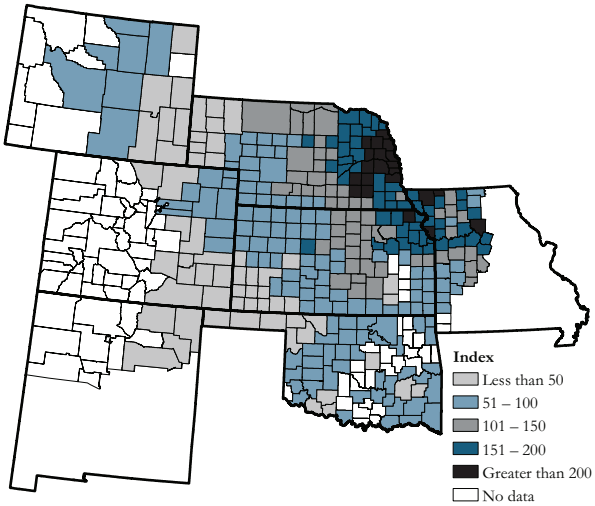
II. Factors Contributing to the Cross-Sectional Dispersion of Farmland Values

For most of the District, farmland values are similar within localized areas. Data from the Ag Credit Survey and USDA show that farmland values are highest in the far northeastern corner of the District and lower in the southwest (Map 1). Economists often describe this "clustering" of similar values or characteristics over space as spatial dependence (Anselin 2003a; Kim, Phipps and Anselin). In practice, this

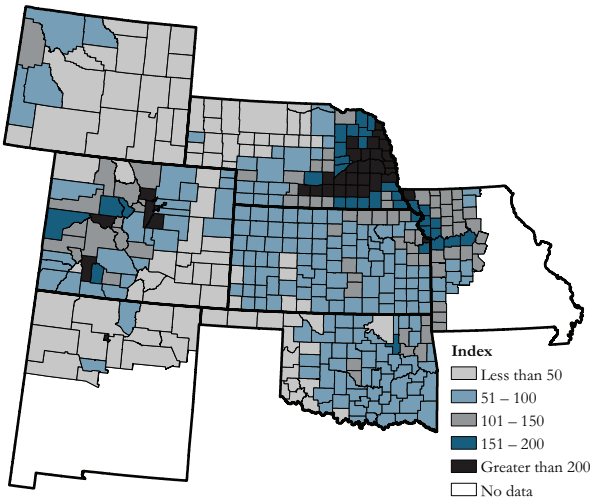
Map 1

Farmland Values in the Tenth District

Panel A: Ag Credit Survey Nonirrigated Farmland
2015 Index, District Average = 100



Panel B: USDA Farmland
2012 Index, District Average = 100*



*County-level farmland value data from USDA are only available every five years via the USDA Census of Agriculture.
Sources: Ag Credit Survey and USDA.

dependence means the price of one piece of farmland could influence the price of other farmland nearby. As a result, any analysis of the factors driving farmland values must account for both the direct effects of land attributes and the indirect, or spillover, effects of the values and characteristics (observed and unobserved) of neighboring farmland values.

Several factors contribute to farmland values, and the importance of these factors may vary by state or region. One such factor is the productivity potential of agricultural land, which varies widely across the Tenth District. Economic factors such as farm income, which Ag Credit Survey respondents have identified as important for farmland valuation, also vary across Tenth District states and could contribute to increasing farmland value variability. However, factors that influence farmland values in one state or region may be less important in another. For example, in 2015, 40 percent of bankers in the Mountain States ranked revenue from mineral rights or access to water as the most important factor contributing to the value of farmland in their areas compared with only 3 percent of bankers in Nebraska (a state with far fewer minerals). Although bankers in both states agreed on the importance of farm income and wealth to farmland values, natural resources were clearly more important contributors to farmland values in the Mountain States.

For this analysis, I sort all spatial factors that could contribute to farmland values at the county level into three broad categories: land quality and climate, commodity production and sales, and location characteristics.

Land quality and climate

Land quality is a primary factor in most farmland value models (Seifert and Sherrick). Nickerson and others, for example, find that farm real estate values are positively correlated with land productivity. Since soil quality is a good indicator of land productivity, farm land sale brochures and auction announcements (such as those from Farmers National or the Hertz Real Estate Service) typically report soil quality as an index or with a "corn suitability rating" depending on the area.

Different states typically use different classification systems for land quality. To consistently quantify land quality throughout the Tenth District, I use available water storage capacity in the root zone from the USDA Natural Resource Conservation Service (NRCS). Available water storage (AWS) is the total volume of water that is available to plants

when the soil is saturated. The NRCS estimates AWS as the amount of water held between field capacity (saturation) and the plant's wilting point (dry soil). The NRCS reports AWS as a single value (in centimeters) of water for the specified root depth in the soil. I use 150 centimeters (4.92 feet) as the root depth because some row crops, including corn, grow roots to depths at or exceeding 4 feet. Available water storage is an important soil property in designing and operating irrigation systems and predicting yield or land productivity. Soil properties that influence available water storage are similar to those that influence crop yield: particle size; organic matter; type of clay mineral; structure; and size, shape, and concentration of soil pores. Higher AWS in the root zone is positively correlated with higher land quality. Therefore, land with higher AWS could be more valuable.

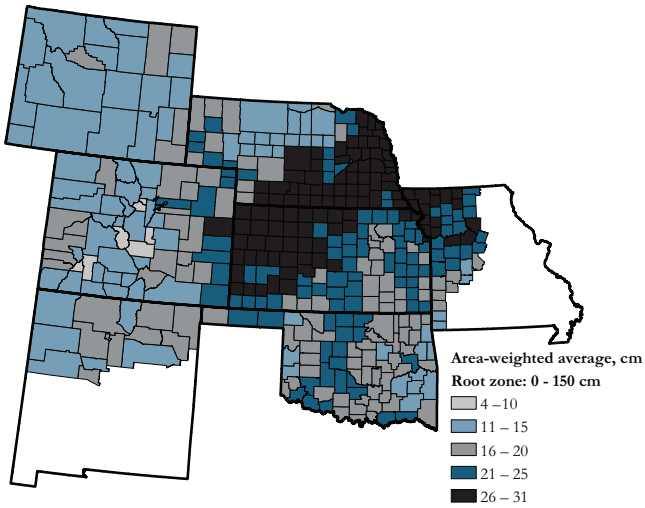
One explanation for the dispersion of farmland values in the Tenth District could be the prevalence of high-quality farmland across district states. The demand for high-quality farmland, for example, may have remained strong even as farm income decreased. Panel A of Map 2 shows the average AWS in the root zone for soils in each county, weighted by area. The USDA NRCS provides data on AWS for all soil-mapping units in the United States. Each county has multiple soil-mapping units, so I calculate an area-weighted average to determine a single value for each county. By AWS, higher-quality farmland is primarily located in eastern and southern Nebraska, west-central Kansas, and northwestern Missouri. The quality of land in Oklahoma appears slightly more variable, and lower-quality land is common throughout the Mountain States.

Another measure of land quality that could affect farmland values is the natural amenities scale, which measures the physical characteristics of a county that enhance the location as a place to live. Unlike AWS, which is typically used to measure soil's suitability for agricultural production, the natural amenities scale summarizes comfort, aesthetic appeal, suitability for recreation, and environmental and climate characteristics of the landscape that most people prefer. The USDA Economic Research Service (ERS) ranks counties on a natural amenities scale of 1 to 7 based on the presence of warm winters, winter sun, temperate summers, low summer humidity, variation in elevation and terrain, and water bodies such as lakes and rivers. The ERS gives counties with the lowest natural

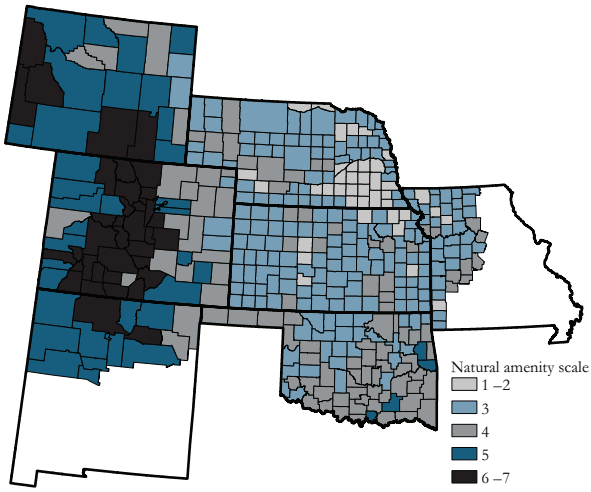
Map 2

Land Quality

Panel A: Available Water Storage



Panel B: Natural Amenities



Source: USDA.

amenities a rank of 1 and counties with the highest natural amenities a rank of 7.

In the Tenth District, counties with a high natural amenities rank often have low suitability for crop production (quantified by a low area-weighted average AWS). To illustrate, Panel B of Map 2 shows natural amenities classifications for each county in the Tenth District. Although counties in the Mountain States tend to rate lower in terms of soil quality, they rank much higher on the natural amenities scale. As a result, farmland in these counties could be in higher demand and thus have greater value despite poorer crop suitability.

Climate and availability of water resources are other natural qualities that affect farmland values. Several researchers have looked at the effects of climate, precipitation, and irrigation on the value of farmland. For example, Mukherjee and Schwabe conclude that water availability, reliability, and quality significantly influence farmland values. They also find that, for irrigated cropland in California, warmer weather in the growing season increases farmland values; precipitation, however, has little effect on farmland values, as crops are irrigated rather than rainfed. Most counties in the Tenth District receive from 11 to 30 inches of precipitation each year. Many of these counties are located within the boundary of the High Plains Aquifer and are thus more likely to have access to groundwater for irrigation. Access to groundwater, or a county's position within the High Plains Aquifer, could increase irrigated cropland values, but may not significantly affect nonirrigated farmland or ranchland.

Commodity production and sales

Soil quality and climate determine the commodities a region produces. Crops and livestock have different environmental requirements that influence their production, including proper temperature, moisture, and soil quality. Over time, farmers have developed management practices—such as terracing, irrigating, fertilizing, and rotational grazing—to overcome natural deficiencies. But some areas are still best suited for specific crops or livestock. As Henderson and others have pointed out, a farmer can derive the value of farmland from the expected flow of future income, which comes from the production and marketing of agricultural commodities.

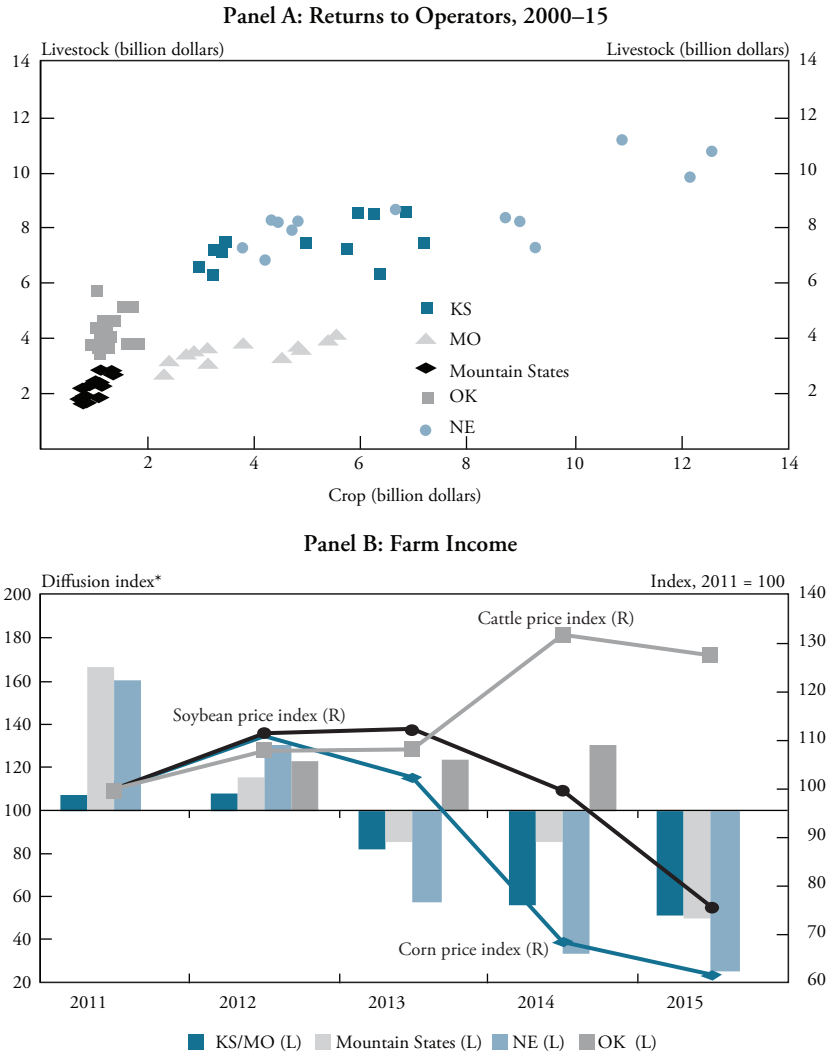
The production and sale of crops and livestock vary throughout the District and likely contribute to the wide dispersion of farmland values. Panel A of Chart 5 shows a positive, linear relationship between receipts from crop sales and receipts from livestock sales. The panel indicates that crop and livestock returns are greatest in Nebraska and lowest in the Mountain States. Moreover, the positive relationship between livestock returns and crop returns suggests that states with higher crop returns also have higher returns for livestock. States with higher livestock and crop returns, such as Kansas and Nebraska, likely have higher quality land and better climate conditions, which are important for both crop and livestock production. Consequently, the highest-value farmland in the District is located in Nebraska, and some of the lowest-value farmland is located in the Mountain States, on average.

At the same time, crop revenues seem to have more annual variability than livestock revenues. States with higher revenues from crop production (specifically, Kansas, Missouri, and Nebraska, where more corn and soybeans are grown) could be more susceptible to changes in crop prices. For example, farm income in these states declined at a more rapid pace (Chart 5, Panel B). The diffusion index, which measures changes in farm income in each state, is generated from Ag Credit Survey responses. Diffusion indices are computed by subtracting the percentage of bankers who responded that farm income was "lower" than a year ago from the percentage who responded that farm income was "higher" than a year ago and adding 100. Therefore, a diffusion index below 100 would indicate that the majority of bankers in a state reported lower farm income. As corn and soybean prices declined, farm income declined at a quicker pace in Nebraska, Kansas, and western Missouri. In Oklahoma, however, farm income seemed to be supported by historically high cattle prices. Greater variability in crop returns, which are highly correlated with farm income in states such as Kansas and Nebraska, could help explain the wide dispersion of farmland values across Tenth District states.

Outside of agriculture, oil and gas are important commodities in the Tenth Federal Reserve District. Oil and gas production could have both positive and negative effects on farmland values (Weber, Brown, and Pender; Farm Credit Canada). Lease and royalty payments from oil and gas companies, for example, could boost farm household in-

Chart 5

Farm Returns, Commodity Prices, and Farm Income by State



* In the quarterly Ag Credit Survey, bankers respond to a question on farm income by indicating whether conditions during the current quarter were higher than, lower than, or the same as in the year-earlier period. Diffusion indices are computed by subtracting the percentage of bankers who responded "lower" from the percentage who responded "higher" and adding 100. I group Kansas and western Missouri together due to proximity and sample size.
Sources: Ag Credit Survey, USDA Farm Income and Wealth Statistics, and *farmdocdaily*.

come and generate spillover effects to farmland values. Energy production is most prevalent in Oklahoma and the Mountain States, but western Kansas also produces some oil and gas. Oil and gas activity in these states occurs in highly rural areas, where bankers and farmers often cite "limited options for investment" as a common factor that drives farmland purchases. When extra cash flows into farm businesses or households, many of these households invest in additional farmland. This increased demand could put upward pressure on farmland values. Conversely, an increase in energy production activity could put downward pressure on farmland values. Oil and gas production can significantly alter landscapes. If oil and gas production damages water quality, air quality, acoustics, scenic views, or infrastructure (such as county roads), farmland near the production site could decline in value.

Location characteristics

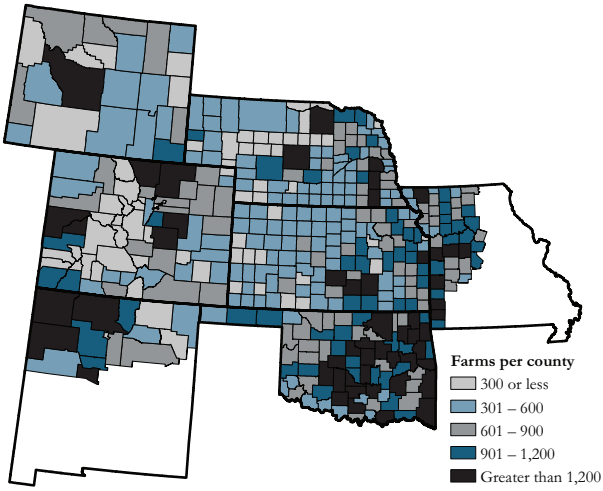
Location characteristics could lead to some variability in farmland values, especially for lower-quality land. In the Tenth District, limited supply of and strong demand for high-quality farmland have kept prices elevated (Kauffman and Clark). The value of lower-quality land, however, varies more dramatically by location. Local competition in purchasing or bidding for all types of farmland could drive prices higher. In addition, proximity to an urban area or grain elevator, for example, could significantly raise the value of low-quality land. Neighborhood or adjacency effects are also important in farmland valuation, since comparable sales nearby often influence appraisal values and auction results.

Supply and competition. Recent movements in farmland values could point to a decreasing availability of good-quality farmland and increasing interest in farmland investment following several years of record profits in the agricultural sector (Fairbairn). Supply and demand for farmland are difficult to quantify over a large area such as the Tenth District, but the number of farms in a given county can be counted. In most counties in the Tenth District, farms account for at least 70 percent of the total land area. The main exceptions are the Rocky Mountain region and the heavily wooded counties of southeastern Oklahoma. However, several counties that saw the largest annual gains in farmland values in 2015 were also counties with the lowest percentage of farmland and the greatest number of farms. As shown in Panel A of Map 3, counties in

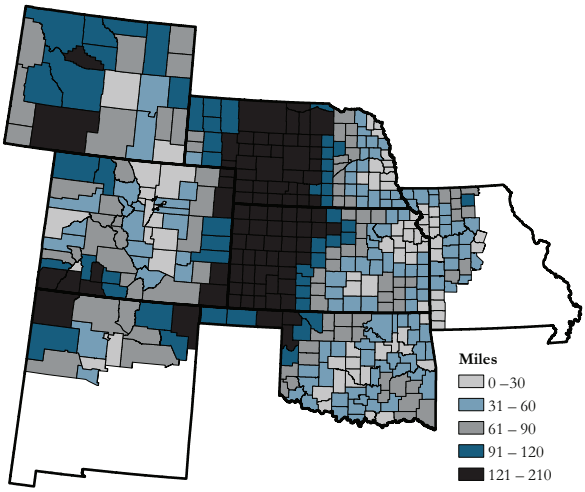
Map 3

Characterizing Supply and Demand for Farmland

Panel A: Number of Farms



Panel B: Distance to Nearest Urban Area



Source: USDA.

Oklahoma and along the eastern and western borders of the Tenth District have the greatest concentration of farms per county. Conversely, farms in western Nebraska and western Kansas have the lowest concentration of farms. These counties are also the most remote, in terms of distance from the nearest urban area, as shown in Panel B of Map 3.

Proximity to urban areas. Several researchers have documented the influence of nearby urban areas on farmland values (Nickerson and others; Shi, Phipps, and Colyer). Farmland values typically have an inverse relationship with the farm or county's distance to the nearest urban area (Kropp and Peckham). In addition to the value agricultural production provides, farmland near urban areas could gain value from nonfarm uses such as residential, commercial, or industrial development. Farmland closer to urban areas could also be closer to points of sale for crops or livestock and amenities such as restaurants, retail, and entertainment for farm families. To better understand this relationship for the Tenth District, I calculate distances from the center of each county to the center of the nearest urban area with a population of 70,000 or more (U.S. Census Bureau).[6] Most counties in western Nebraska and Kansas are more than 120 miles from the nearest large urban area. In fact, in Nebraska, the average distance to the nearest urban area is 100 miles; in Oklahoma, the average distance to the nearest urban area is only 37 miles.

III. Quantifying the Effects of Land Attributes on Farmland Values

Because counties that are closer together seem to have more similar farmland values than counties that are far apart, I construct an empirical model that accounts for spatial dependence. Spatial dependence often violates important statistical assumptions in traditional ordinary least squares (OLS) regression analysis (Lasage and Pace). If the model does not incorporate spatial dependence, it may generate biased and inconsistent results (Arbia). Details on the model and its construction are available in Appendix A.

How do land attributes affect farmland values in the Tenth District?

In 2015, farmland values increased in some parts of the district but declined in others even as market fundamentals suggested all farmland values should moderate. To identify the cross-sectional fac-

tors driving these unusual movements, I regress the values of four different types of farmland on variables measuring land quality and climate, commodity production and sales, location characteristics, and state-level fixed effects.[7] In estimating the model, I make three assumptions: first, that location matters in the relationships between farmland values and land attributes; second, that farmland values are a function of neighboring farmland values; and third, that the model will incorporate spatial interactions (Anselin 2003a; Lasage and Pace).

Following results of goodness-of-fit statistics, I choose a log-log functional form (using natural logs) for the continuous dependent variable (farmland values) and continuous independent variables. The log-log functional form has the benefit of fitting data properly even when the continuous variables have different measurement units (Mukherjee and Schwabe). In the log-log model, continuous variable coefficients are typically interpreted as elasticities—in other words, they show the percent change in farmland values caused by a one percent change in each explanatory variable. To account for the effect of the High Plains Aquifer on farmland values, I create an indicator variable by assigning a 1 to counties within the boundary of the aquifer and a 0 to all others. State fixed effects are created in a similar fashion and are approximately interpreted as percent effects on the dependent variable. The natural amenities classification is an ordinal, ranked variable that is not log-transformed and which represents the percent change in farmland values caused by a one-unit change in natural amenity rank.

Results and discussion

Regression results provide information on how land attributes affect farmland values. The effects of some land attributes are consistent for all types of farmland, while others differ. As shown in Table 1, the effect of land quality, as measured by root-zone AWS, is positive for all types of farmland and statistically significant for nonirrigated farmland, ranchland, and USDA data on farmland values, which take the county average of all three types of farmland. I performed the regression analysis on the USDA dataset that contained all counties within the Tenth District and on a subsample that included only counties that are covered by the Ag Credit Survey. Counties with soils that have higher AWS also have higher farmland values. For example, farmland in a Kansas

Table 1

Regression Results: Total Effects

Dependent Variable: ln (farmland value, dollars per acre)

Variable	Nonirrigated	Irrigated	Ranchland	USDA (All Tenth District counties)	USDA (ACS sample)
Land quality and climate					
Root-zone available water storage	1.1***	0.11	0.85**	0.21**	1.3***
Natural amenity classification	-0.07	-0.12**	0.17*	0.06***	-0.05
Temperature, 30-year average	-0.39	-0.67**	-0.14	-0.07	-0.49**
Precipitation, 30-year average	0.01	0.72***	0.48*	0.05*	0.22**
County within High Plains Aquifer boundary	-0.69***	-0.07	-0.31	0.06	-0.001
Commodity production and sales					
Livestock sales	0.03**	0.004	0.04***	0.001	0.002
Corn sales	0.01	0.02***	0.01	0.01*	0.03*
Wheat sales	-0.05***	0.004	-0.001	-0.002	-0.02***
Oil and gas production	0.01	-0.01	-0.05*	-0.02***	-0.03**
Location characteristics					
Number of farms	-0.08	-0.12*	0.16	-0.05**	0.26***
Distance from urban area	-0.09	-0.02	0.01	-0.23***	-0.24***
Colorado	6.8***	8.6***	0.8	7.7***	3.4***
Kansas	7.3***	8.2***	1.8	7.9***	3.7***
Missouri	7.3***	8.1***	1.9	8.0***	3.6***
Nebraska	7.6**	8.3***	1.8	8.0***	3.9***
New Mexico	5.6**	8.4***	1.2	7.1***	2.9***
Oklahoma	6.7**	7.8***	1.7	7.8***	3.7***
Wyoming	6.7***	7.7***	1.3	7.2***	3.1***
Rho	0.86***	0.74***	0.92***	-0.49***	0.56***
Lambda	-0.35***	0.14	-0.63***	0.84***	0.28***

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

Notes: Agricultural commodity sales are available at the county level every five years from the USDA census of agriculture. Therefore, livestock sales, corn sales, and wheat sales are based on 2012 estimates from the USDA. The USDA also provides county level oil and gas production estimates, and the most-recent data are from 2011. Rho is the spatial autoregressive, or spatial lag, correlation coefficient. Rho reflects the spatial dependence that is inherent in the sample data, measuring the average correlation between farmland values in Tenth District counties with farmland values in the four nearest neighboring counties. Lambda is the coefficient on the spatially correlated errors. See Appendix A for more information.

county with soils that store 20 centimeters of water per 150 centimeters of soil depth would be worth 10 percent more than counties in Colorado with soils that store only 10 centimeters of water in the root zone, all else equal.

The effect of natural amenities classification on farmland values differs slightly among farmland types and is significant for irrigated cropland, ranchland, and the full sample of USDA values. Higher natural amenities classifications are correlated with lower values for irrigated cropland but higher values for ranchland. The disparity between ranchland and irrigated cropland is not surprising: ranchland is more versatile and typically located in areas with diverse topography, while irrigated cropland is commonly located in flat areas that are suitable for growing crops but less desirable for recreational activities. Irrigated cropland may be more valuable in areas where irrigation is more of a necessity, such as areas with hotter summers; hotter summers typically lower an area's natural amenity score. In this case, it is unlikely that natural amenities pull irrigated cropland values down; rather, higher-valued irrigated cropland is likely located in areas with fewer natural amenities. In other words, natural amenities probably have a negatively correlated, not causal, relationship with irrigated cropland values.

The effects of temperature, position in the High Plains Aquifer, and precipitation on farmland values are directionally consistent but different in magnitude for each farmland type. The negative signs on the temperature coefficients in Table 1 suggest farmland in areas with lower average temperatures, or a more moderate climate, is more valuable. The results also suggest that counties within the High Plains Aquifer boundary have lower average farmland values regardless of farmland type. Non-irrigated cropland values inside the High Plains Aquifer boundary are 0.69 percent lower than nonirrigated cropland outside the High Plains Aquifer boundary. Conversely, precipitation has a positive effect on values of all farmland types. Most notably, a county that receives 1 percent more precipitation than another county in the Tenth District would tend to have 0.72 percent higher irrigated cropland values.

The effect of precipitation on irrigated cropland values is positive and significant, in contrast to other studies of farmland values in more arid regions (specifically, California). These studies suggest that irrigation reduces the sensitivity of agriculture to climate-related factors and that

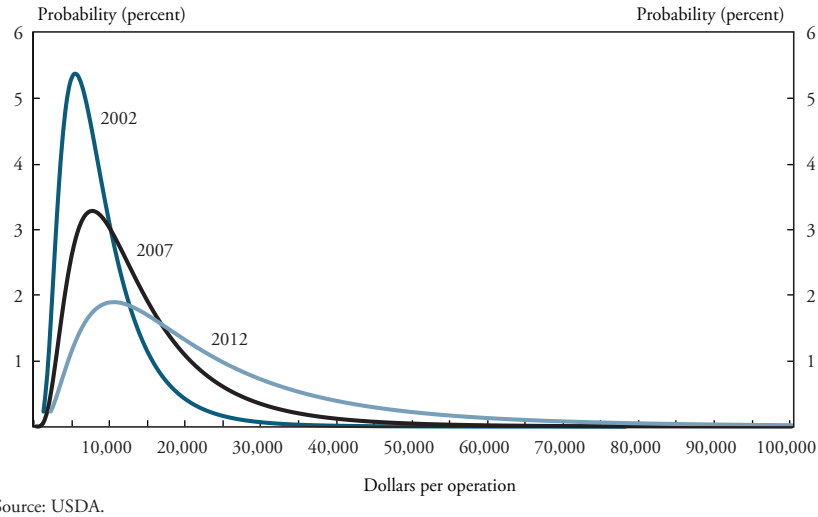
precipitation "does not have any appreciable impact on crop production, nor land values" (Mukherjee and Schwabe). Although some regions of the Tenth District receive limited rainfall, the minimum for the District is still greater than in other areas where irrigation is more essential for production.[8] In the Tenth District, irrigation is typically supplementary to local precipitation, and therefore, precipitation, even in combination with irrigation, is an important factor for farmland values.

Agricultural commodity sales also signifigantly affect farmland values, but results differ by type of farmland. Overall, farmland values are higher in counties with larger revenues from cattle and corn sales. Livestock sales—which includes hogs, dairy, and poultry as well as cattle—are significant for nonirrigated cropland and ranchland values. The importance of livestock sales for nonirrigated cropland likely reflects the importance of cropland for feed and fodder production—especially in enterprises that are vertically integrated—and the prevalence of dual-purpose dryland wheat production in some parts of the Tenth District. As expected, livestock sales have the greatest positive effect on ranchland values. Similarly, corn sales have the largest positive effect on irrigated cropland values. Conversely, nonirrigated cropland values are lower in counties that have higher wheat sales. Wheat revenues are typically smaller than corn and soybean revenues. In addition, wheat can grow on lower-quality land and in harsher climates than soybeans and corn. Therefore, higher wheat sales may be correlated with lower-quality, lower-valued farmland.

Agricultural commodity sales have a significant effect on the values of nonirrigated cropland, irrigated cropland, and ranchland. This finding helps explain changes in farmland value dispersion because commodity sales—unlike the other, temporally static factors—have become more variable over time. Chart 6 shows a similar pattern for farm commodity receipts as was shown for farmland values in Chart 1. Specifically, Chart 6 shows the probability distributions for farm receipts from agricultural commodity sales in 2002, 2007, and 2012.[9] The vertical axis gives the percent probability of each farm observation in the three annual samples. Similar to farmland values, the probability of observing a farm with relatively low receipts from commodity sales declined, while the probability of observing a farm with high receipts increased. Although the minimum amount of farm receipts stayed around $1,500, the maximum rose from approximately $40,000

Chart 6

Distribution of Farm Commodity Receipts in the Tenth District



Source: USDA.

in 2002 to approximately $100,000 in 2012. The growing variability of commodity sales, coupled with their significant relationship with farmland values, may help explain the widening distribution of farmland values across the District. When prices of a particular agricultural commodity decline, farmland values may decline more in a county with relatively higher sales of that commodity, unless factors such as natural amenities or local competition help support them.

Oil and natural gas production has a small and negative effect on values for all farmland types except nonirrigated cropland. This negative effect is perhaps surprising, since oil and natural gas production could provide an additional source of income. However, the infrastructure required for natural gas production could damage the production potential of irrigated cropland, which has a higher production and revenue potential than nonirrigated cropland. Additionally, cattle producers may opt out of leasing portions of ranchland for oil or natural gas production to keep more land for cattle grazing, Non-irrigated cropland is generally less productive and does not require the capital investment associated with irrigation. Therefore, it seems likely that energy production, which is correlated with lease and royalty payments, could positively affect nonirrigated cropland values, but the coefficient is small and insignificant.

Location characteristics also significantly affect farmland values. The first location variable, "number of farms" in a county, could affect farmland values in one of two ways. Anecdotal evidence suggests local competition for good-quality farmland is a major driver in maintaining elevated farmland values, even as farm income has declined. Therefore, a higher number of farms in a county could be a proxy for higher competition and be positively correlated with higher farmland values. The coefficient for "number of farms" in the USDA subsample that matches the Ag Credit Survey samples suggests farmland values increase with a higher concentration of farms in a county. Only 1 percent of farmland in the United States is transacted in a given year (Bigelow, Ifft, and Kluethe). At the county level, this would mean that counties with a higher number of farms would have more land owners vying for limited farmland when it comes up for sale. Accordingly, the statistically significant and positive result in the USDA subsample supports anecdotal evidence that more competition supports higher farmland values, especially when demand for farmland remains high.

Conversely, the coefficient for "number of farms" was negative and significant for irrigated cropland and for the full USDA sample (all counties in the Tenth District). For irrigated farmland, a smaller number of farms in a county could be correlated with larger farm sizes, so some counties could have fewer farms due to larger average sizes by land area. In this case, a negative relationship between number of farms and farmland values could be due to a wealth effect. For example, Weber and Key find "strong evidence that wealth gains from land appreciation permit, or motivate, farmers to purchase additional land." Therefore, larger farms with more irrigated cropland may be more motivated and able to purchase additional land at higher prices. Moreover, the full USDA sample includes counties in urban areas and counties in the Mountain States that have few (large) farms and high farmland values. Urban counties and scenic counties in mountainous areas likely have fewer farms, but proximity to urban areas and recreational values could support higher values for farmland available in those areas.

The results for the second location variable, "distance from urban area," show that farmland values decline as distances from urban areas increase. Although the effect of distance is small and insignificant for the Ag Credit Survey samples, the negative relationship between

farmland values and distance to urban areas is significant in the USDA samples. Additionally, most previous studies have reported that farmland values tend to decline the further the land is situated from urban areas (Nickerson and others, for example). Results from the USDA samples agree with previous research. Proximity to urban areas affects farmland values through both farm-related and nonfarm-related factors. From a farmer's perspective, farmland closer to urban areas may have increased access to markets and customers, thereby increasing expected agricultural returns. From a nonfarmer's perspective, farmland in close proximity to urban areas could be influenced even more by demand for residential, commercial, industrial, and municipal development.

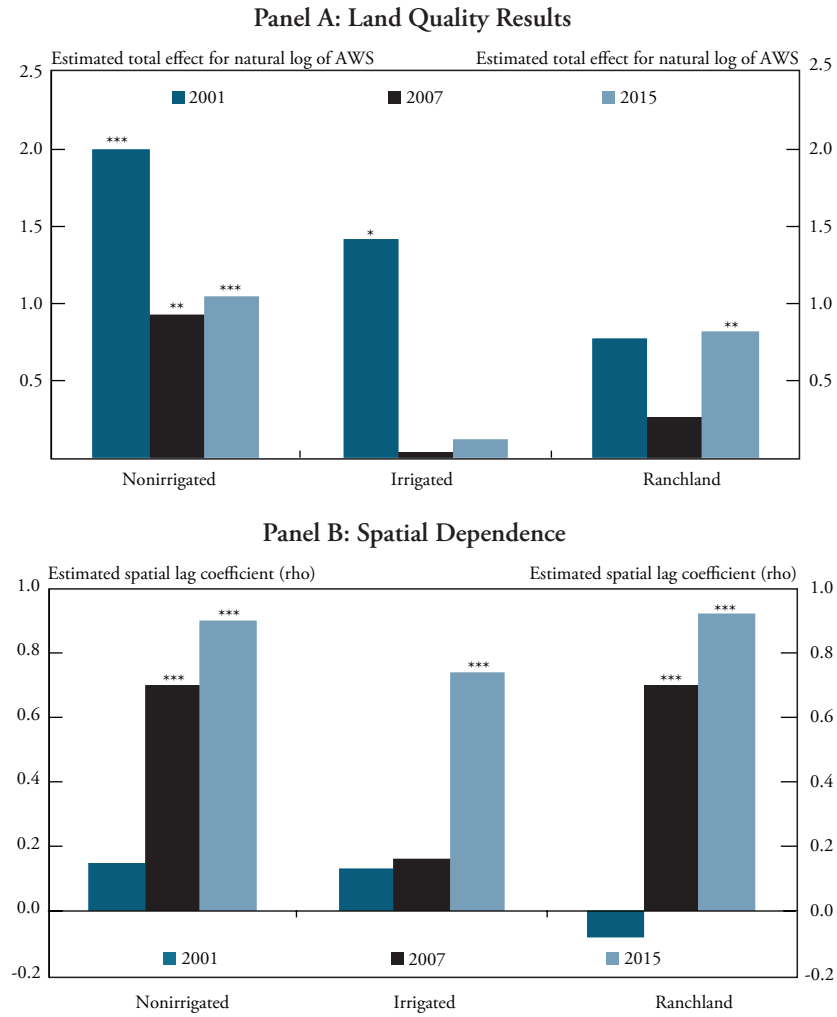
The remaining location variables in Table 1 show that cropland values vary significantly by state. For example, all else equal, nonirrigated and irrigated cropland values are highest in Kansas, Missouri, and Nebraska. Different states have different policies and regulations for real estate taxes, water management, and agricultural production, and the effects of these policies and other unspecified location characteristics are likely captured in the state fixed effects. Ranchland values, however, do not vary significantly by state.

Changes in significance of land attribute effects and spatial dependence over time

In 2015, several land attributes helped explain the cross-sectional variability of farmland values in the Tenth District, but the magnitude and significance of these factors have changed over time. To gain a better understanding of the growing dispersion of farmland values in the Tenth District and how land attributes may have affected farmland values differently over time, I perform additional regression analyses on data from 2001 and 2007. The magnitudes of the total effects for land quality (as measured by AWS) are much larger for nonirrigated and irrigated cropland in 2001 than in 2015 (Panel A of Chart 7). For irrigated cropland, the variable for land quality was significant in 2001 but not significant in 2015. For all types of farmland, the total effect for land quality dipped in 2007 and rebounded slightly in 2015. The variable for land quality was only significant for ranchland in 2015. However, the total effect of natural amenities was three orders of magnitude larger for ranchland values in 2001 than in 2015. Additionally, in 2001, natural

Chart 7

Changes in Magnitude and Significance of Factors over Time



*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level
Sources: Ag Credit Survey and author's calculations.

amenities, location within the High Plains Aquifer, and closer proximity to urban areas had a significantly larger effect on irrigated cropland values than in 2015. Although not significant in 2015, distance to urban areas was more negative and significant for nonirrigated cropland values in 2001.

At the same time, models for 2001 and 2007 farmland values show less spatial dependence than models for 2015 farmland values. In Panel B of Chart 7, the spatial lag correlation coefficient, rho, reflects the spatial dependence inherent in the sample data, measuring the average correlation between farmland values in Tenth District counties with farmland values in the four nearest neighboring counties. The spatial lag coefficient is insignificant for all farmland value types in 2001, indicating that farmland values in one county were not significantly affected by farmland values in neighboring counties. The opposite is true more recently. In 2015, farmland values in one county had a significant and positive relationship with farmland values in neighboring counties. In previous years, farmland values were more dependent on the direct effects of land attributes within a county, whereas farmland values today seem relatively more influenced by farmland values in neighboring counties.

IV. Conclusions

The value of farmland in the Tenth District varies widely by region. I analyze the effects of several factors on farmland values and find that the value of almost all types of farmland in the Tenth District increases as land quality and precipitation increase. I also find that the value of farmland declines as temperature increases, and the magnitudes of natural amenity effects are largest for ranchland. However, the sensitivity of farmland values to land quality and climate factors appears to have faded somewhat. In recent years, the distribution of farmland values has grown wider, largely due to spatial factors such as neighboring farmland values.

Although future projections are outside the scope of this analysis, the effect of climate on farmland values may change over time. The larger coefficients for the temperature and precipitation variables in the irrigated cropland and ranchland models may suggest lingering effects from the 2012 drought that devastated crops and the cattle herd in the Tenth District. First, lingering effects of the drought could place

a higher premium on irrigated cropland. Second, ranchers may have migrated cattle herds to areas with more rainfall, increasing demand for land in those areas. Third, ranchers may also be more cautious about maintaining herds in areas more prone to drought and thus look for land in more reliable areas. As a result, ranchland in areas with lower temperatures and more reliable precipitation may fetch a higher premium since the 2012 drought.

In addition to climate variables, location characteristics also appear to be primary drivers of cropland and USDA farmland values. Although location characteristics for a particular location are relatively static, I detect significant spatial variability across the District for farm concentration and proximity to urban areas. USDA farmland values in the Ag Credit Survey sample are positively affected by the number of farms per county, which could be a proxy for competition. State fixed effects and spatial dependence are responsible for most of the location effect on farmland values.

When comparing across farmland types and data sources, commodity sales have a larger effect on farmland values in counties included in the Ag Credit Survey sample, which could highlight one of the benefits of the Ag Credit Survey. In addition, the Ag Credit Survey captures the effects of different types of commodities on the values of the three different types of farmland. For example, increases in livestock sales support higher ranchland values, and corn sales have a positive and significant effect on irrigated cropland values.

The effects of commodity sales on farmland values have been relatively constant over time. In contrast, the effects of land quality on farmland values have declined in both magnitude and significance since 2001. Therefore, the increasing distribution of farmland values over time could be due to two factors. First, although the effects of counties' commodity sales have remained relatively constant over time, the distribution of farm receipts has expanded. Since farmland values are significantly associated with commodity sales, if the distribution of farm receipts continues to widen (due to factors such as consolidation, for example), then the distribution of farmland values may also widen. Second, in previous years, farmland values were driven more by local, static land attributes such as land quality, distance to urban area, and proximity to ground water source (such as the High Plains Aquifer).

More recently, however, farmland values seem to be driven less by these physical attributes and more by spatial factors such as demand, local competition for farmland, and spatial dependence, which are more difficult to quantify.

Appendix A
Testing for Spatial Dependence

Traditional OLS models assume variables are statistically independent. In my analysis, for example, a traditional OLS model would assume farmland values in one county were independent of farmland values in other counties nearby. However, this assumption seems unlikely. In addition to the explanatory variables of county characteristics and land attributes (direct effects), the model assumes that farmland prices in each county are also affected by the spatially weighted average of farmland prices in neighboring counties (indirect effects) (Huang and others). Because the model controls for spatial dependence, I calculate and report the total effects for each explanatory variable, which account for both direct and indirect, or spillover, effects (Bivand; Pebesma; and Gómez-Rubio, LeSage and Pace). Therefore, I create a connectivity or "weights" matrix to test for spatial dependence. The simplest definition of a connectivity matrix (W) is

(1) $$_nW_n = \begin{Bmatrix} w_{11} & \dots & w_{n1} \\ \dots & w_{ij} & \\ w_{1n} & & w_{nn} \end{Bmatrix},$$

where each element is defined as

(2) $$W_{ij} = \begin{cases} 1 \text{ if } j \in N(i) \\ 0 \text{ otherwise} \end{cases},$$

and $N(i)$ is the set of the four nearest neighbors of county j. The connectivity matrix provides information on neighboring counties using a nearest-neighbor criterion to ensure all counties have at least one neighbor and to prevent "islands" in the estimation.

After constructing the connectivity matrix, I calculate the Moran's I statistic to test for global spatial dependence. Moran's I is a correlation between the OLS residuals for each farmland type (nonirrigated, irrigated, ranchland, and USDA farmland) and the spatially lagged weighted average of neighboring counties' farmland values (Moran).

Table A-1
Global Tests for Spatial Dependence

	Nonirrigated	Irrigated	Ranchland	USDA
Moran's I	0.48***	0.50***	0.46***	0.24***

***All significant at the 1 percent level

The coefficients in Table A-1 show that in the Tenth District, the relationship between farmland values in county *j* and the average values of neighboring counties is positive and significant at the 99 percent confidence level.

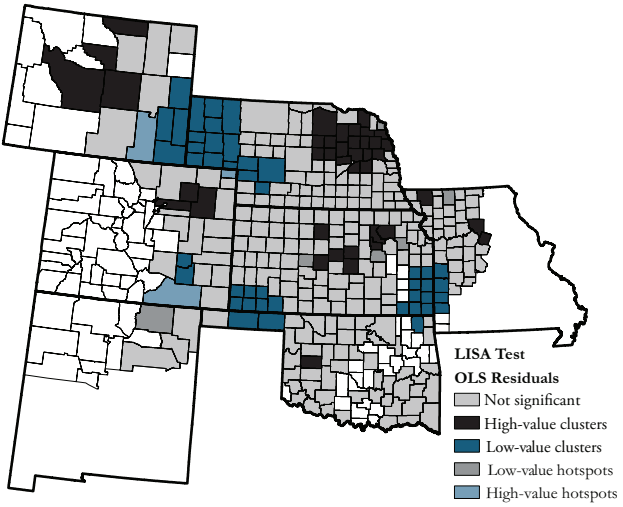
Global tests measure the extent of spatial dependence for the entire dataset, but I can also break down global measures to create localized tests intended to identify specific "clusters"—counties with neighbors that have very similar farmland values—and "hotspots"—counties with neighbors that have very different farmland values. To assess spatial dependence more locally, Map A-1 shows results from "local indicator of spatial association" (LISA) tests. LISA maps show counties clustered together by type of association: clusters or hotspots (Anselin 2003b).

For nonirrigated cropland, several counties in the district show significant spatial dependence for farmland values. Map A-1 shows significant clusters of high-value farmland in the northeast corner of the District. Likewise, Map A-1 shows clusters of low-value farmland in southwestern Kansas, Oklahoma, and the eastern edge of the Mountain States. LISA tests also detected a few hotspots in the District. The counties in dark gray are low-value hotspots. In these counties, farmland values are low even though they neighbor counties with high farmland values. Conversely, the three counties in light blue are high-value hotspots. These counties are characterized by high farmland values even though neighboring county farmland values are low. Interestingly, all three high-value hotspots are in the Mountain States, so higher values in these counties may be due to added recreational value or state-level fixed effects.

To identify how spatial factors affect farmland values, I construct an econometric model for four different types of farmland (k) that accounts for the effects of land quality and climate, agricultural and economic factors, location characteristics (X), state-level fixed effects (S), and adjacency effects, represented by the connectivity matrix (W_k), on 2015 farmland values (V_k) as shown by:

Map A-1

Nonirrigated Cropland Value Local Spatial Dependence, 2015



Sources: Ag Credit Survey and author's calculations.

$$V_k = \alpha_k + \rho_k W_k V_k + \beta_k X + \gamma_k S + \varepsilon_k , \quad (3)$$

where $\varepsilon_k = \lambda_k W_k \varepsilon_k + \mu_k$.

The spatial lag and spatial error estimates are significant in the models for all farmland types, indicating large adjacency effects across Tenth District counties. The spatial lag estimate, $\rho = 0.86$, for the model for nonirrigated cropland values is consistent with other farmland value studies that employ the spatial lag model (see, for example, Huang and others). Rho (ρ) indicates that a 1 percent increase in average farmland prices in neighboring counties increase farmland prices in the observed county by 0.86 percent. Rho is much larger for the models that include Ag Credit Survey farmland values, which could indicate the other independent variables have weaker explanatory power due to gaps in coverage (see Map A-1 for reference).

Appendix B
Additional Figures

Table B-1

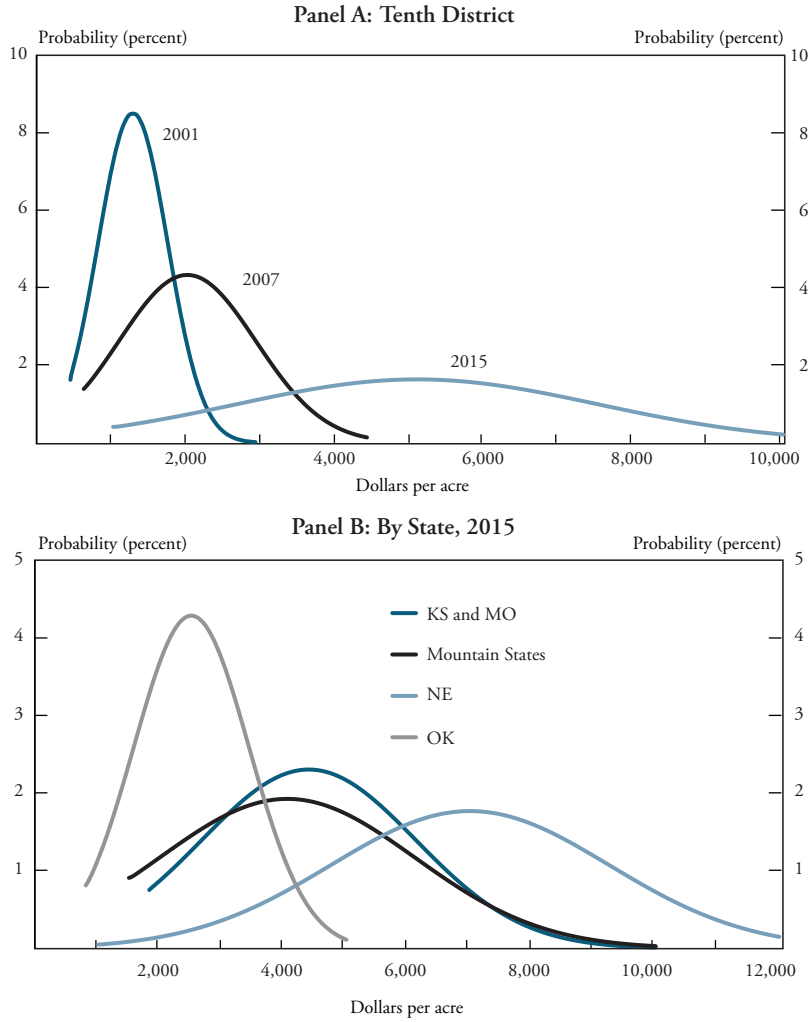
Descriptive Statistics of Land Characteristics by Region

Variable	Units	Kansas	Western Missouri	Mountain States	Nebraska	Oklahoma
Root-zone AWS	Cm water/ cm root zone	24 (4)	22 (5)	15 (3)	23 (6)	18 (3)
Natural amenity classification	Average rank	3.0 (0.4)	3.2 (0.5)	5.0 (0.9)	2.8 (0.6)	3.7 (0.6)
Farm income	$1,000 per farm	64 (56)	25 (30)	19 (31)	111 (66)	15 (25)
Number of farms	Farms per county	588 (299)	926 (308)	667 (543)	537 (324)	1,042 (384)
Average farm size	Acres	925 (500)	303 (94)	2,137 (1,675)	1,287 (1,310)	500 (352)
Land in farms	Percent*	88	77	53	90	79
Distance from nearest urban area	Miles	96 (59)	45 (23)	74 (74)	100 (58)	37 (30)
Farming-dependent counties	Percent**	67	43	28	87	34
Oil production	Percent***	19	1	44	1	35
Gas production	Percent***	5	0	73	0	22
Mean annual precipitation	Inches	30 (8)	35 (15)	17 (5)	25 (5)	37 (8)
Mean annual temperature	° Fahrenheit	55 (34)	53 (37)	46 (36)	50 (33)	60 (33)

*** Percent of total in Tenth District
** Percent of counties in state
* State average
Note: Standard deviations in parentheses.

Chart B-1

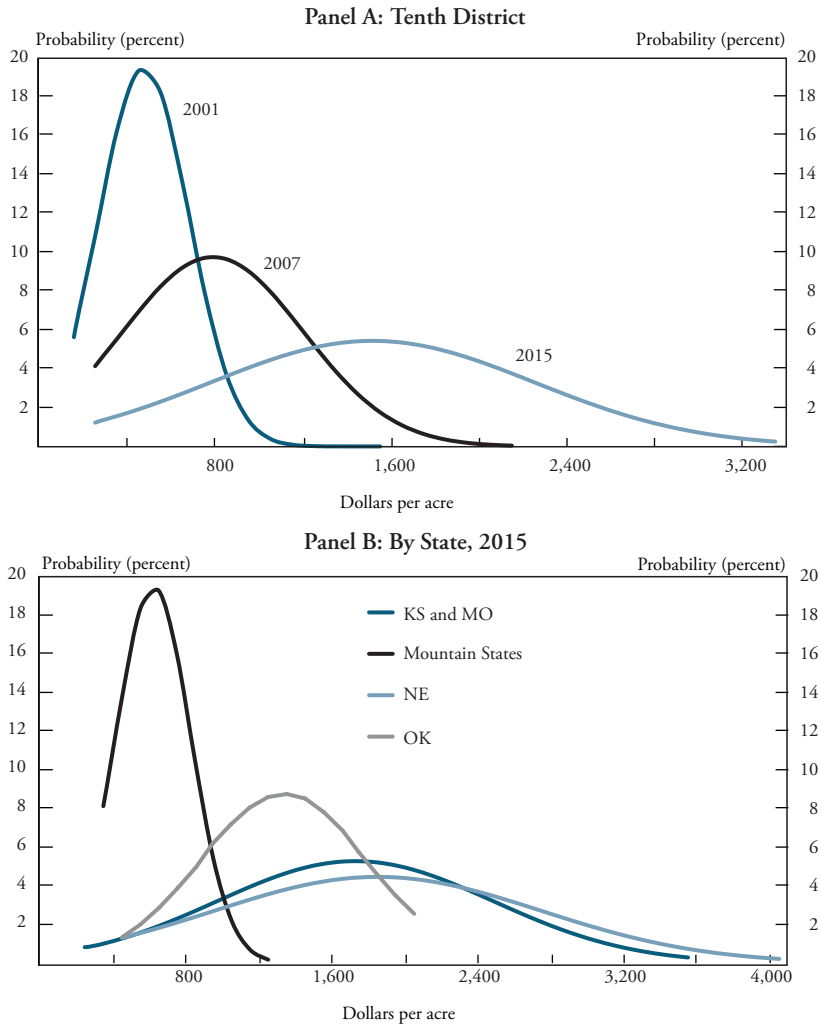
Distribution of Irrigated Cropland Values



Source: Ag Credit Survey.

Chart B-2

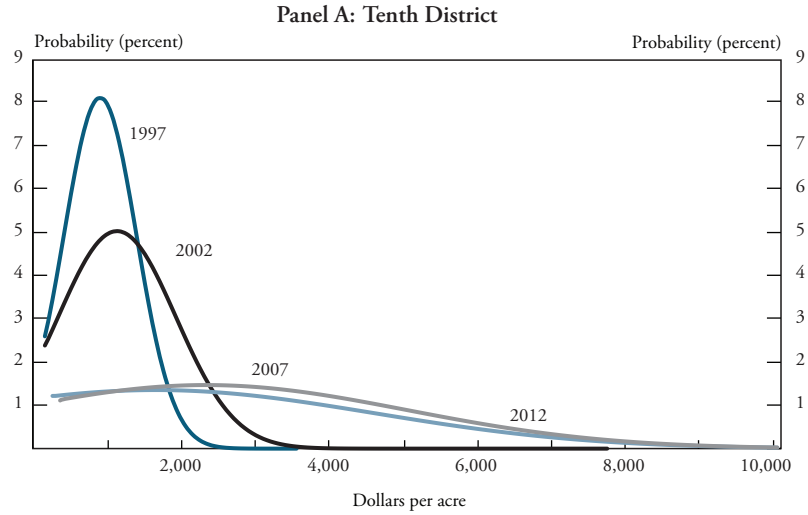
Distribution of Ranchland Values

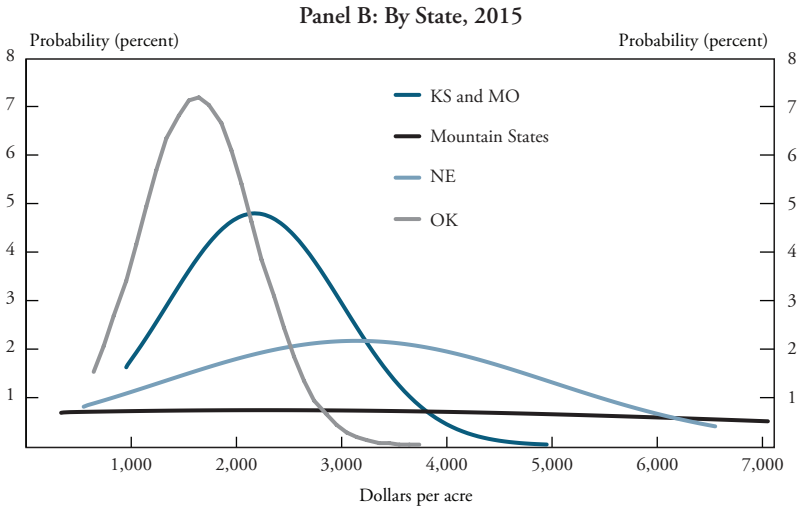


Source: Federal Reserve Bank of Kansas City Survey of Agricultural Credit Conditions.

Chart B-3

Distribution of USDA Farmland Asset Values





Source: Ag Credit Survey.

Endnotes

[1]According to the USDA, a farming-dependent county meets two thresholds: farm earnings account for an annual average of 25 percent or more of total county earnings or farm employment accounts for 16 percent or more of total employment during 2010–12. The Tenth District has the largest proportion of farming-dependent counties of the 12 Federal Reserve Districts.

An agricultural bank is defined as having 15 percent of total loans in farm loans. By this definition, the Tenth District also has the largest share of agricultural banks in the United States.

[2]According to the Federal Reserve Bank of Kansas City's Agricultural Finance Databook, 525 agricultural banks are located in the Tenth District. These banks have a minimum farm loan ratio of 17 percent. However, to be included as a respondent in the Agricultural Credit Survey, a bank only needs to have 15 percent of its loan portfolio in agricultural loans.

[3]Goodness-of-fit tests indicate that farmland value data are not normally distributed and have five to 10 outliers in the upper end of the distributions for each annual sample. The distributions in Chart 1 are computed based on a lognormal distribution.

[4]The distributions in Chart 1 look similar for irrigated cropland, ranchland, and the USDA sample of farmland values. See Charts B-1, B-2, and B-3 in Appendix B.

[5]Average nonirrigated cropland values increased by 100 percent from 2001 to 2007 and by 112 percent from 2007 to 2015. The 10th percentile increased by 43 percent from 2001 to 2007 and by 87 percent from 2007 to 2015. The 90th percentile increased by 120 percent from 2001 to 2007 and by 114 percent from 2007 to 2015.

[6]I allow the nearest urbanized area to be outside of the Tenth District.

[7]The regression also includes spatial effects in the form of a connectivity matrix, W_k. See Appendix A for details.

[8]According to Mukherjee and Schwabe, rainfall is limited to 1 to 2 inches in some parts of California.

[9]Data for county-level receipts of farm commodities are available every five years from the USDA Census of Agriculture. Goodness-of-fit tests indicate that data for farm commodity receipts are not normally distributed and have several outliers in the upper end of the distributions for each annual sample. The distributions in Chart 5 are computed based on a lognormal distribution.

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