Determinants of Agricultural Land Value in the United States

2022 Spring ACE592SAE Class Project

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1. Objective

The objective of this paper is to measure the determinants of agricultural land value in the United States. We also aim at understanding how these determinants have changed and how those changes could influence agricultural land value.

2. Data

2.1. Climate-related determinants

Pollution data: data on pollution comes from the Environmental Protection Agency (EPA). We collect daily measures on sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) for the years 1997, 2002, 2007 and 2012. One constraint in the data is that it reports information of contaminants from monitor stations located in specific counties across the country. In order to create county-by-year average concentrations of contaminants, measured in parts per billion (ppb), we first compute the distance between each county centroid to each monitor station. Then we restrict the sample to counties that are within a 200-mile radius of any monitor station. We then collapse the data and compute the average of SO_2 and NO_2 by county-year cell using the inverse of the distance to the monitor stations as weights. By construction, this computation will give more importance to the measured average of counties that are closer to monitor stations than those counties further away. Note that, given that the radius is arbitrary, we do not observe all counties in the country but a significant sample: on average we observe 2986 and 3022 counties per year for NO_2 and SO_2 concentration measures, respectively.

Land value, crop revenue, and cropland: The land value, crop revenue, and cropland data used in the paper are from the decadal Census of Agriculture (COA). The COA conducts surveys in years ending with 2 and 7 for each county in the United States. Our sample includes four rounds of land value data (1997, 2002, 2007, and 2012). We converted the Land value (per acre) and crop revenue (per acre) in real term deflecting by the Consumer Price Index (CPI) to overcome the inflationary effect.

Income and Population density: We collected the county-level per capita income and population data for the relevant from the USDA Economic Research Service department. Then we convert the per capita income into real terms using the CPI. To calculate the county-wise population density, the land area for each county is collected from the United Census Bureau (UCB) for the most recent census.

Weather: We control local temperature and rainfall using data from the PRISM climate group. The calculate the average rainfall for each county for the selected period, we took the five-year forward-looking moving average for each sample year. For example, to calculate the average temperature for 2012, we average the annual temperature from 2008 to 2012.

Extreme weather data: data on extreme weathers comes from the Storm Events Database entered by NOAA's National Weather Service (NWS). The data contains over 50 types of extreme weather from January 1950 to January 2022. Table 1 shows the total extreme events in the Storm Events Database and the total frequencies from 1997-2012. The first two events are the most frequent and the variations are very small.

Table 1 Extreme events in the Storm Events Database

Extreme weather	**Thunderstorm Wind**	**Hail**	**Flash Flood**	**Winter Storm**	**High Wind**	**Heavy Snow**	**Drought**	**Flood**
Frequencies	216417	209891	52939	47751	44090	41887	37442	32593
Extreme weather	**Winter Weather**	**Tornado**	**Heat**	**Marine Thunderstorm Wind**	**Strong Wind**	**Heavy Rain**	**Lightning**	**Ice Storm**
Frequencies	32019	22750	15700	14064	14023	13299	12849	8380
Extreme weather	**Blizzard**	**Dense Fog**	**Frost/Freeze**	**Cold/Wind Chill**	**Extreme Cold/Wind Chill**	**Funnel Cloud**	**Excessive Heat**	**High Surf**
Frequencies	8253	7754	7678	7587	6237	6056	5597	5597
Extreme weather	**Wildfire**	**Tropical Storm**	**Waterspout**	**Hurricane (Typhoon)**	**Coastal Flood**	**Lake-Effect Snow**	**Storm Surge/Tide**	**Rip Current**
Frequencies	4995	3722	3477	1584	1392	1243	1133	806
Extreme weather	**Dust Storm**	**Marine Hail**	**Sleet**	**Avalanche**	**Debris Flow**	**Landslide**	**Tropical Depression**	**Astronomical Low Tide**
Frequencies	631	517	495	436	387	362	313	279
Extreme weather	**Freezing Fog**	**Marine High Wind**	**Dust Devil**	**Volcanic Ash**	**Marine Strong Wind**	**Seiche**	**Lakeshore Flood**	**Tsunami**
Frequencies	252	215	148	74	71	42	41	24
Extreme weather	**Hurricane**	**Dense Smoke**	**Northern Lights**	**Marine Tropical Storm**	**Heavy Wind**	**High Snow**	**Sneakerwave**	**other**
Frequencies	18	15	8	6	4	1	1	1

One constraint in the data is that it only reports the extreme events without information about the death tolls and damage to properties. So in this study, we only calculate the frequencies for at disaster-county-year level.

2.2. Demographic factors

Changes in characteristics of counties (Rural/Urban Decomposition): The given dependent variable of this study, land value, evaluates the value of farm and their productivity by using real estate and expected return of crop in farm area. Therefore, the percentage change of land value in every five years (1997, 2002, 2007, 2012) could intuitively have distinctive behavior by how the value and portion of agriculture sector as a main industry of county has been changed while the characteristics of county and the role of main industry in county has been reorganized for decades. However, the impact of these changes on land value are not detected under the regression of land value on pollution with county fixed effect and time fixed effect since we need to define the dummy variables to categorize the change of county characteristics to observe the distinct behavior between unchanged counties and reorganized counties.

County Population (1993,2003,2013)[1]: County population data is extracted from U.S. decennial census data which were originally built in 1993,2003 and 2013. To decompose rural/urban area and to investigate how the rural area has been growing, we need to observe the population growth pattern of each county at the first glance.

USDA-ERS researchers define rural area as a countryside county with fewer than 2,500 people. The population ranging from 2,500 – 49,999 are recognized as an urban area but not a metropolitan area.

Rural Urban Continuum code (1993,2003,2013)[2]: Rural-urban continuum code is a classification scheme for checking the degree of urbanization and adjacency to a metro area. Hence, the change of Rural-urban continuum code directly shows how the characteristics and role of county as a rural or urban area has changed every half decade. In 2013, out of 3143 counties, 1,167 are classified as metro counties and 1,976 are nonmetro counties. For the nonmetro counties, rural area (population under 2500) is classified as a code 8 (adjacent to a metro area) and code 9 (non-adjacent to a metro area). Urban area with more than 20,000 people are classified as code 4(adjacent) and 5(non-adjacent). Urban area with population between 2500 to 19999 are classified as code 6 (adjacent) and code 7(non-adjacent).

County level Statistics of U.S Business(SUSB) data (Portion of industry by size)[3]: SUSB data shows the number of firms and the number of establishments by enterprise employment Size

[1] Data Resource: ESDA-ERS
[2] Data Resource: ESDA-ERS
[3] Data Resource: U.S. Census, County Business Pattern

for Counties from 2000 annually. By looking into the change of ratio between large size enterprise and small size firms, we can observe how the business pattern of each county has been changed from 2000 to 2012 and this change could act as a key factor to determine if a certain rural county has been reorganized as an urbanized area.

3. Descriptive Analysis

3.1. Climate-related determinants

3.1.1. Pollution

In the United States there are several identified contaminants that have shown to affect the health of populations, as well as environmental and economic dynamics. SO_2 and NO_2 are air contaminants that result from emissions from fossil-powered vehicles (cars, trucks, buses); power plants, firm production and other off-road equipment. Understanding the relationship between these air pollutants on land value is not trivial, as there are reported mixed benefits and costs related to the emission of air contaminants. For example, Metaxoglou and Smith (2020) show that increased air pollution reduces crop yields because air contamination hampers photosynthesis. Reduction of nitrogen oxides is associated with increases in the yield of corn (2.46%) and soybean (1.62%) for the period 2003-2011. On the other hand, Sanders and Barreca (2022) show that, under the Acid Rain Program (ARP), which aimed at reducing ambient sulfate levels, there were costs in terms of land value and crop yield for corn and soybean, mainly because crops need sulfur and nitrogen in some level.

We start in Panel A of Figure 1 describing the evolution of NO_2 concentration in the United States for our period of analysis. There is a remarkable reduction along the years for both type of contaminants, noting that the concentration of NO_2 is higher than that of SO_2 for all years. Panel

B shows the evolution of land value per acre (in real terms). Land agricultural value, however, grew a 61% for the period 1997-2012.

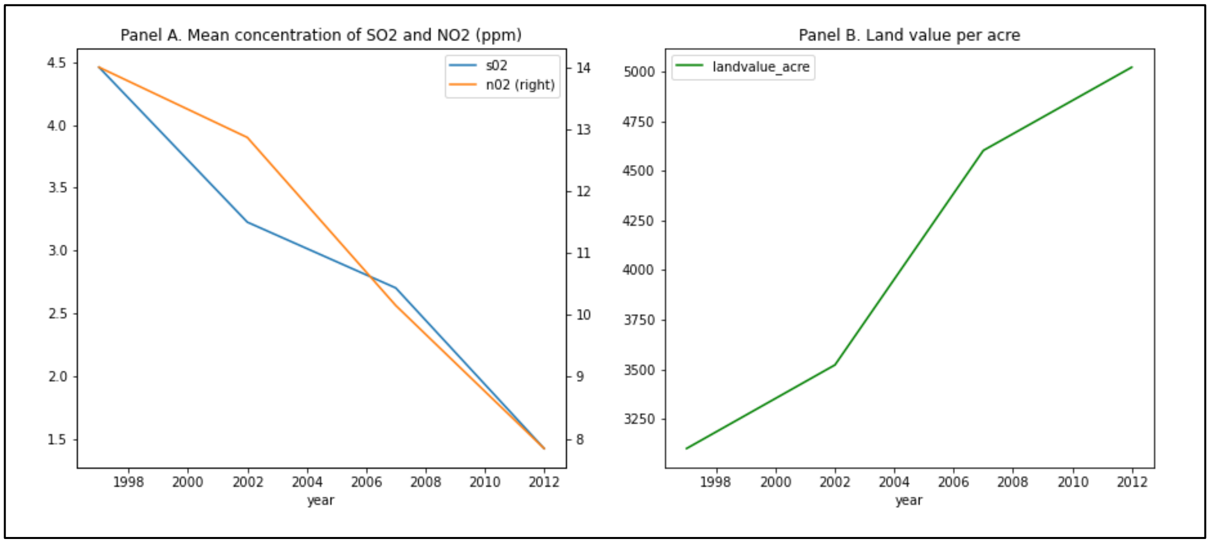


Figure 1. Time trend of contaminants and land value

Figure 2 shows the areas from which we can see high (low) variation from 1997 to 2012. Land value in the Midwest and in some areas of the south has increased at larger rates than for places in the northeast and southeast of the country. One explanation has to do with the vocation of crops (corn and soybean mostly) that relate to this type of land valuation given that not all geographic and soil features in the country are suitable for these crops.

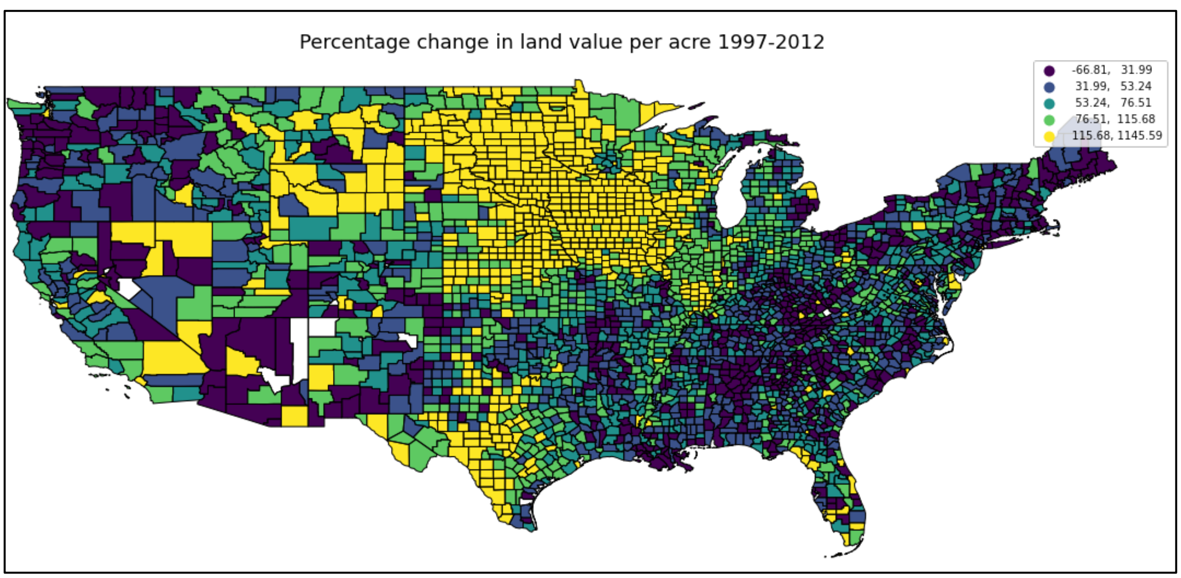
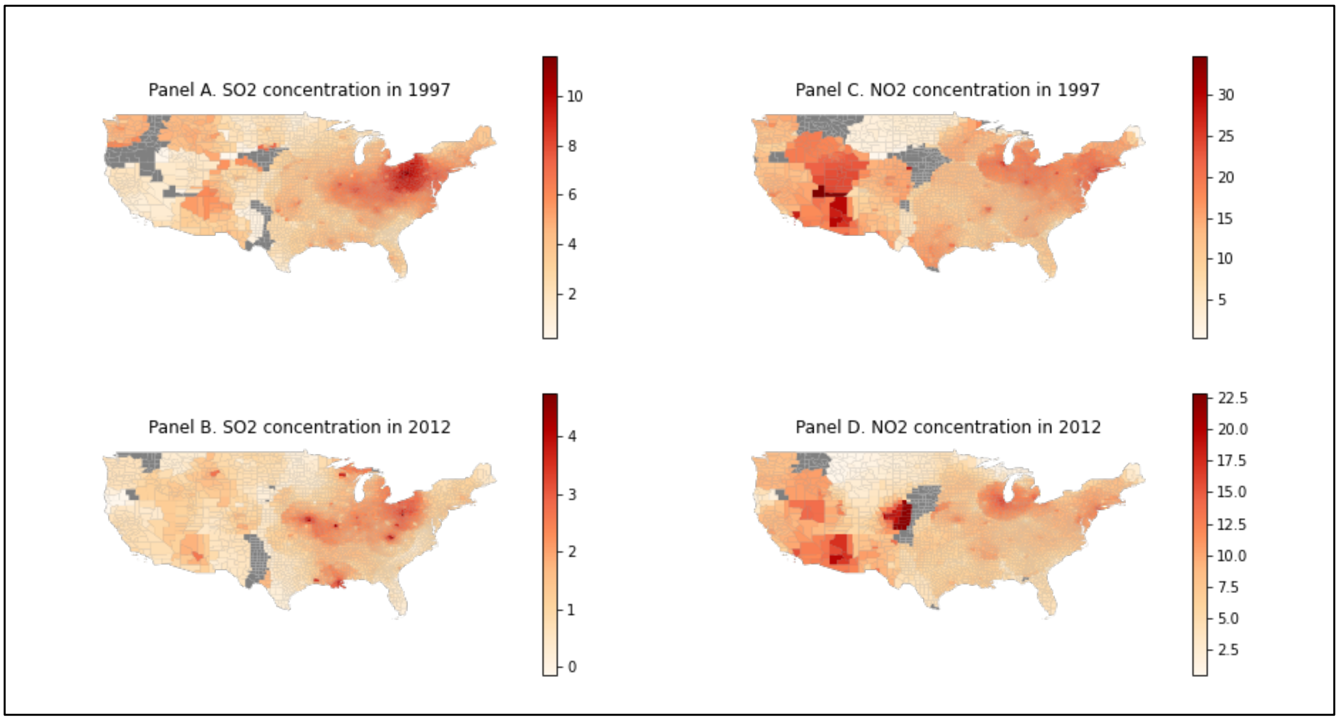


Figure 2. Percentage change in land value.

Analyzing the spatial distribution of the air pollution, we find that there was a change in terms of the intensity across former hot spots in the country. Figure 3 depicts the spatial distribution of NO_2 and SO_2 in the United States for 1997 and 2012. The geographic concentration of both contaminants is notably reduced for the case of counties in the northeast, for example, due to reductions in coal burning and other factors that trigger air pollution concentration.

Figure 3. Spatial distribution of contaminants



Note that the evolution of the distribution of air pollutants has also been subject to change (Figure 3). For both pollutants, in 1997 the distribution exhibited more variation than in 2012 which shows a distribution that is more centered towards the mean, skewed to the left. This suggests that along the years the reduction in the level of air contamination in the United States has been more equalized across counties.

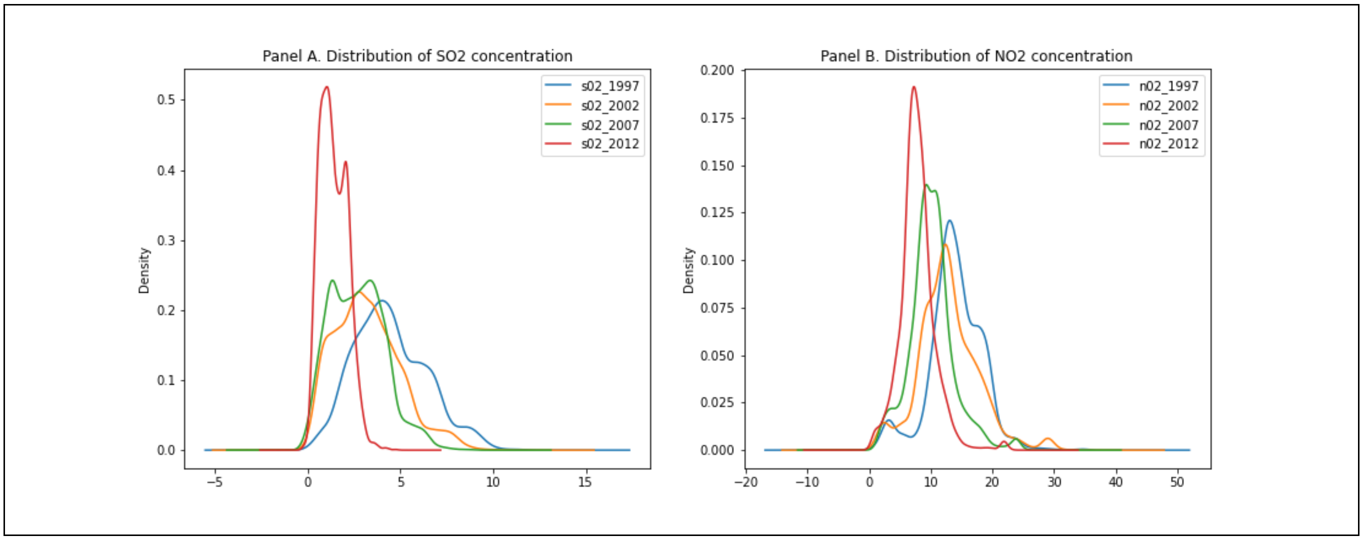


Figure 4. Distribution of contaminants across time

From figure 4 we investigate the non-parametric relationship[4] between the logarithm of each contaminant and the logarithm of land value. Note that higher rates of SO_2 do not show a clear pattern of higher (or lower) rates of land value per acre. Conversely, higher rates of NO_2 show a positive correlation with land value per acre, reaching plateau at some point in the distribution of NO_2. This result for NO_2 goes in line with what has been argued by Sanders and Barreca (2022): land productivity needs some levels on nitrogen dioxide and it somewhat corresponds with the price of land, though this relationship seems to be nonlinear.

[4] We use Locally Weighted Scatterplot Smoothing (LOWESS)

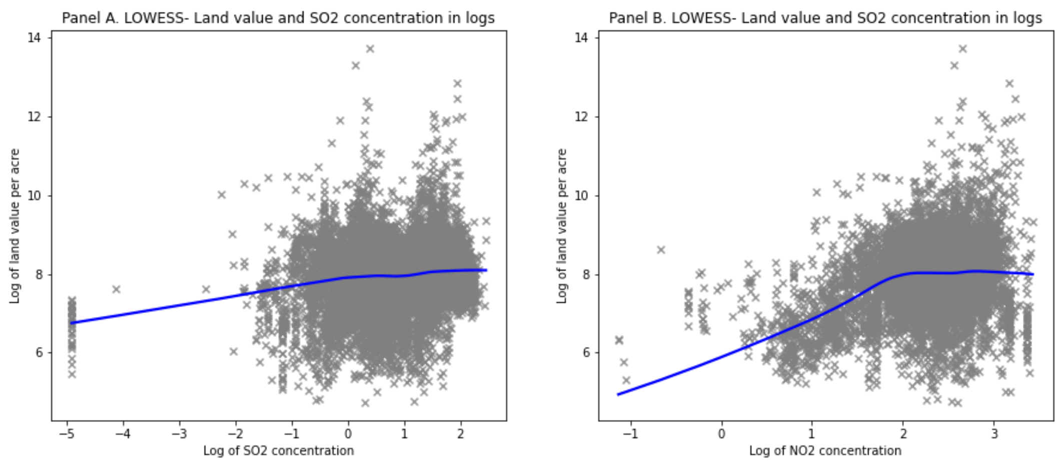


Figure 5. Relationship between contaminants and land value per capita

3.1.2. Ethanol production

The top panel of figure 6 shows the annual average real land value per acre for agricultural land in the United States. From the graph, we see that the Agri. Land value in the US is increasing until 2013, and it follows a downward trend after that. Thus, we choose a sample period of 1997, 2002, 2007, and 2012 shown by the blue color when the land value increases substantially.

The bottom panel of figure 6 shows the annual fuel ethanol production in the US. From 2000 to 2011, ethanol production has increased from 1.6 billion gallons to 14 billion gallons. Ethanol production in the US is mainly concentrated in the Midwest, contributing to around 93% of the national production. Since Corn and Soybean are the primary raw materials for production, the emergence of the ethanol factories in the Midwest has influenced the increasing demand for agricultural land. It could lead to an increase in land values in the region. Thus, we tried to describe the descriptive statistics using regions and corn-belt/non-corn-belt 1 groups in the following.

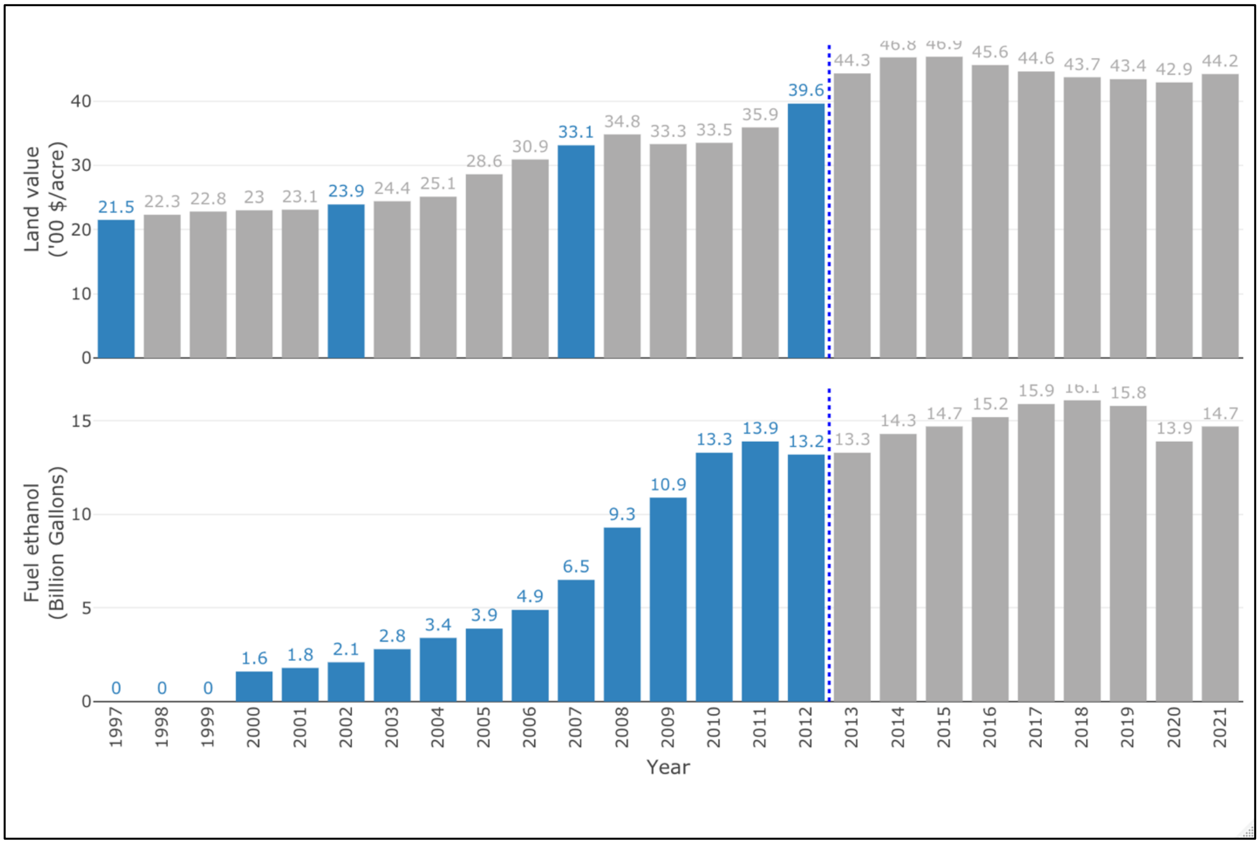


Figure 6. Annual Land value and fuel ethanol production

Figure 7 shows the county-wise average Agri land value per acre in the US. The most left group offers the overall county-wise average land value that increased from 31 hundred to 51.1 hundred USD between 1997 to 2012. However, the most substantial increase is in the Corn-belt region, from 23.5 hundred USD to 48.5 USD during the sample period. In the right segment of the graph, we see that the Northeast has the highest Agri land value among the regions. The region mainly produces expensive fruits and has less cropland. On the other hand, the increase in the Agri land value in the Midwest is consistent compared to the South and West. The composition of crop revenue and cropland is shown in Figure 8.

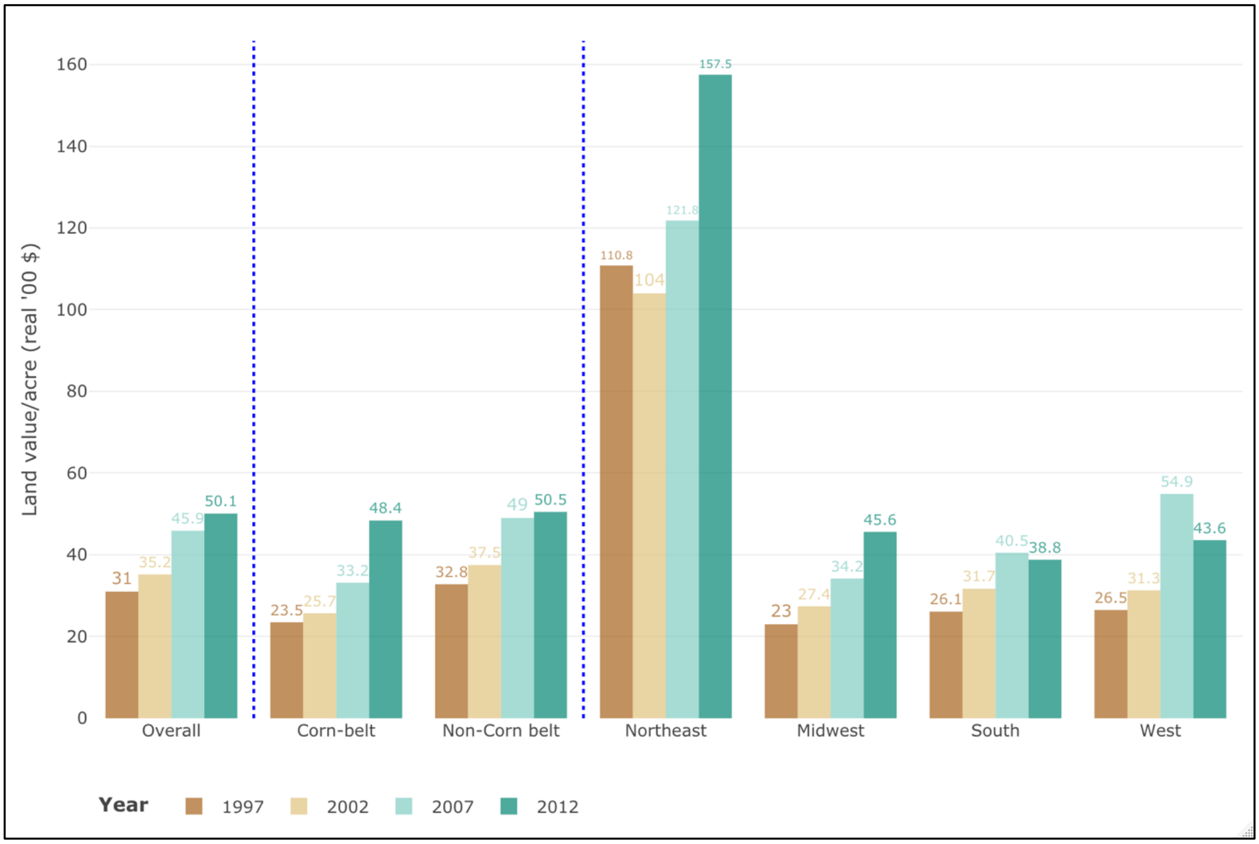


Figure 7. County-wise average Agri. land value (USD/acre) by region

Figure 8, the top panel in the following, shows the overall crop revenue per acre has increased from 540 USD to 740 USD during the sample period. The corn belt has a lower average revenue than the non-corn belt region. However, the rate of increase is higher in the area. The regional average shows the average crop revenue. Although high in the Northwest, the revenue has decreased substantially over the years. In addition, Midwest has the lowest crop revenue compared to the other region, as the area is known for producing lower-value crops.

The lower panel in figure 8 shows the average county-wise cropland availability in thousand acres. The northwest has the lowest cropland availability compared to other regions, and Midwest (Corn belt) has the height. However, the cropland is reducing over the years irrespective of the areas.

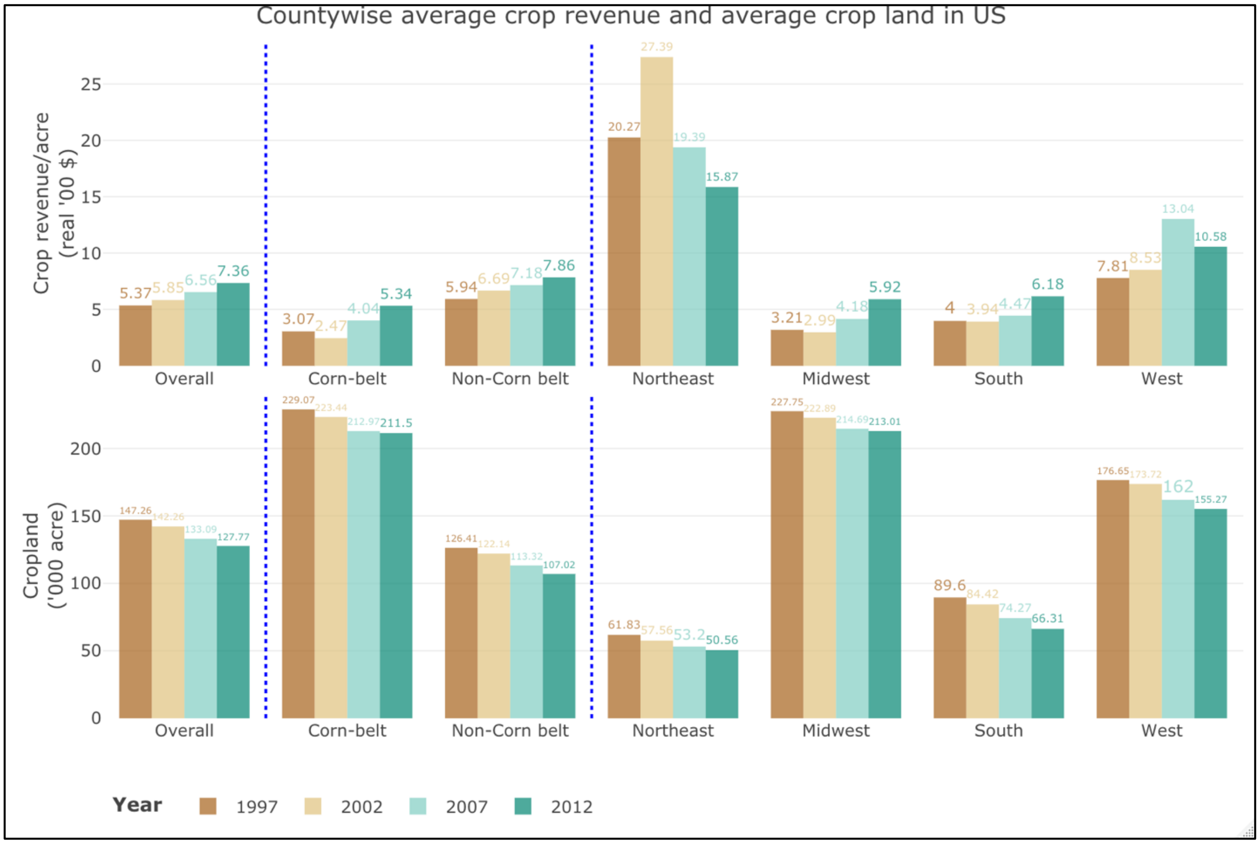


Figure 8. County-wise average crop revenue and cropland

The demographic characteristics also play a significant role in determining the land valuation across the different regions. Thus, we have incorporated the per capita real income and population density in our analysis. The following scatter plot (figure 9) shows the relation between county-wise per capita income and per-acre Agri land value in log form in the US.

From figure 9, we see that the Agri land value positively correlates with the per-capita annual income. However, the correlation has become weaker gradually over the years. In the graph, Midwest emerges as the highest per capita income group. Therefore, the variation in the positive correlations between land value and per-capita income implies that income has a crucial role in determining land value.

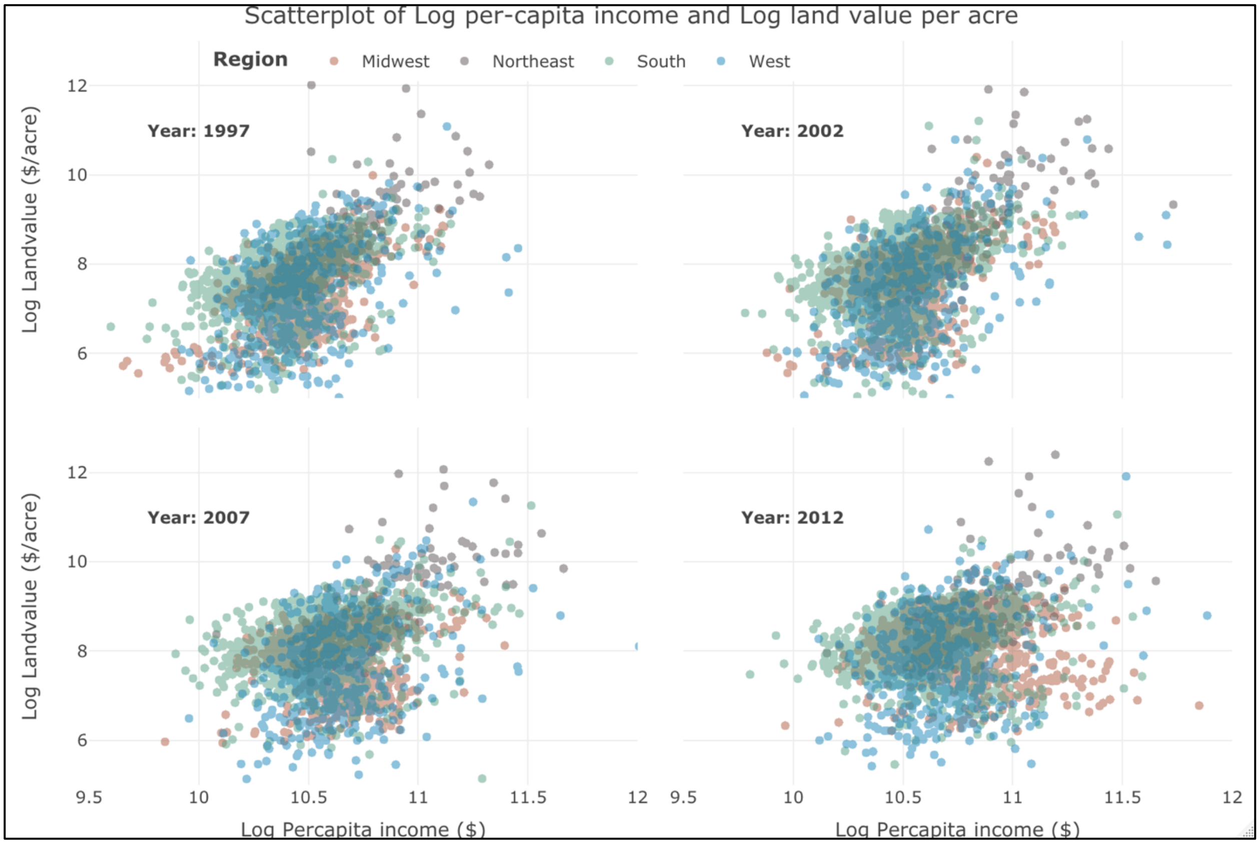


Figure 9. Scatterplot of county-wise per-capita income and Agricultural land value

As the population density increases, it creates additional pressure on cropland usage—the incremental demand for cropland influences the increase in the land value. The following figure shows the scatter plot between county-wise land value and population density (sqm).

In Figure 10, we see a strong correlation between population density and Agri land value. Although the positive correlation is almost similar across all the regions, the correlation becomes stronger in Midwest in the year 2012. Therefore, population density is a strong determinant of the variation in land valuation.

Figure 10. Scatterplot of county-wise population density and Agri. land value

3.1.3. Extreme events

The relationship between natural disasters and land value is a frequently studied issue. Disasters cast threat on households' safety for lives and assets in urban areas and significantly impact rural areas by their effects on agriculture. Both attributes of natural disasters and households are channels that affect land values. For example, sudden-onset and slow-onset may affect land value in different directions. The risk aversion level among households also causes heterogeneities. We begin by showing the trend of extreme events with top-ranked frequencies.

Figure 11. Time trend of top five extreme events

Figure 11 shows different trends of the first two events and other three extreme weathers from top 5 most frequent disasters. Thunderstorm wind and hail show the trend of fluctuating upward. Flash Flood, Winter storm, and Heavy snow vary around median level and show no obvious upward or downward trend from 1997 to 2012.

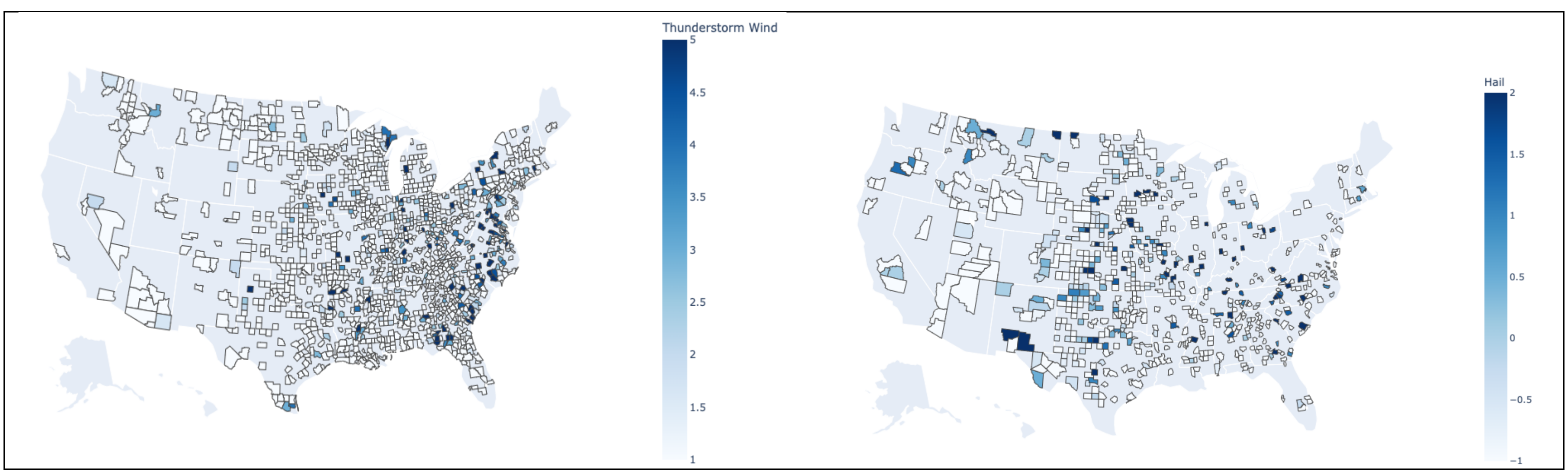


Figure 12. Percentage change distribution of top 2 extreme weathers

Figure 12 depicts the spatial distribution of percentage change of thunderstorm wind (left) and hail (right) in the United States from 1997 to 2012. Thunderstorm wind is more concentrated on the east US while hail is sparser in the middle of US. The mean of percentage change in thunderstorm wind is 24.5%, and -41.6% in hail.

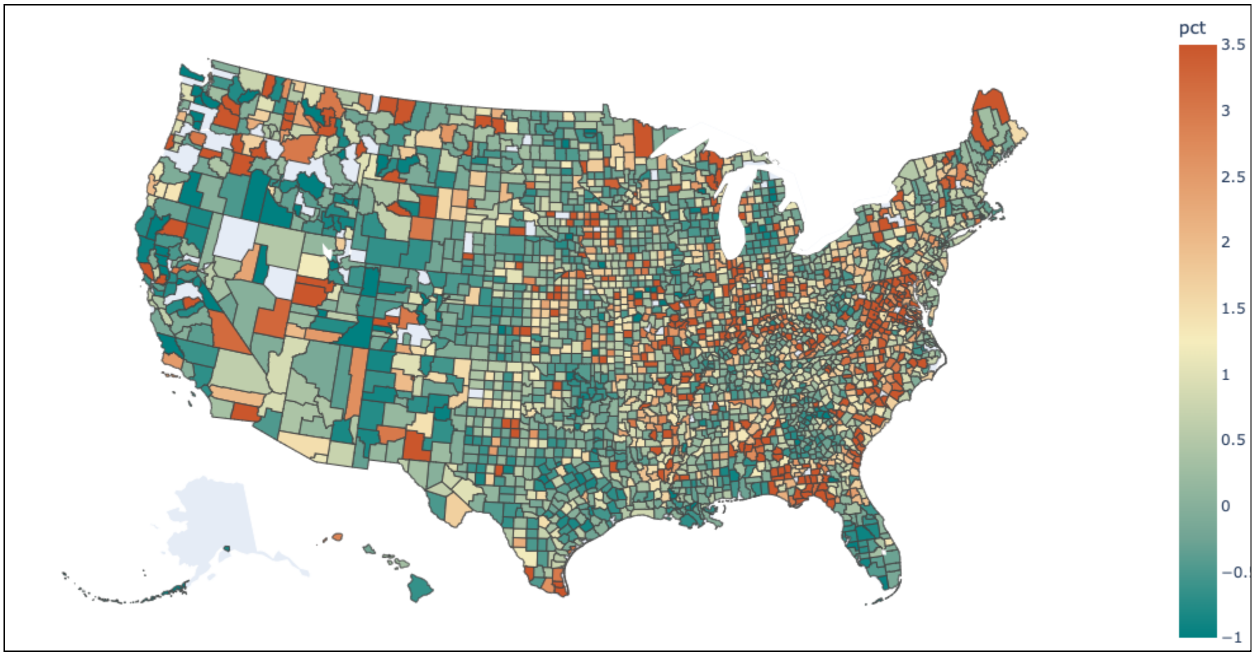


Figure 13. Percentage change distribution of total extreme weathers

In Figure 13, we pool all 56 extreme weathers together and calculate the frequencies and the percentage change rate for each county from 1997 to 2012. The range of total extreme weather change rate is from -100% to 3700%, but the mean is 104.8%. The change rate is 350% at the 90th percentile and around 70% changes rate is under 100%. Geographically, the total change rate is not noticeable in certain areas, which might be a sign of hidden heterogeneity.

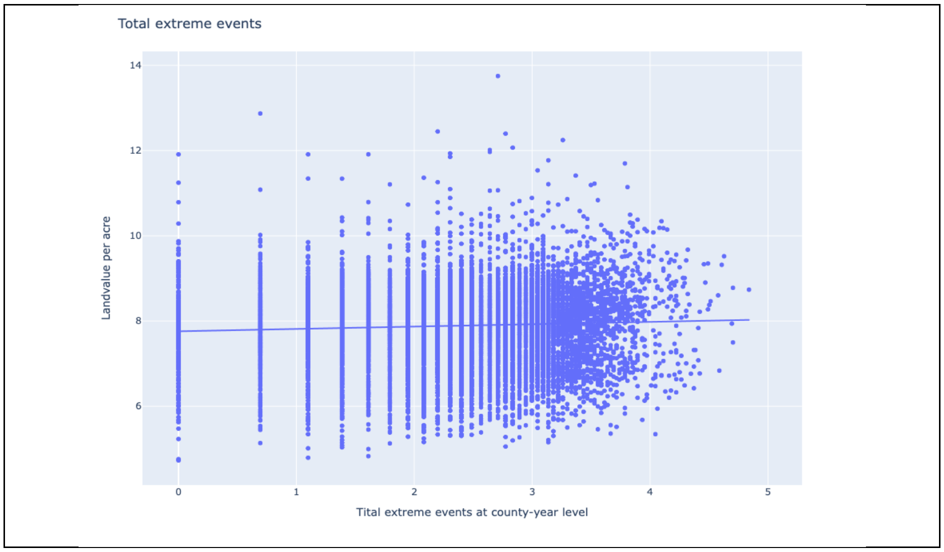


Figure 14. Correlation between extreme weathers and land value

Figure 14 is a scatter plot of total extreme weather and land value. The result is counterintuitive because extreme weather is considered a negative factor for land. However, the OLS estimation slope is slightly positive meaning a positive relationship between extreme events and land value, though might not be significant. As the aggregate data may hide heterogeneities, we further plot for the top 4 frequent extreme weathers in the following.

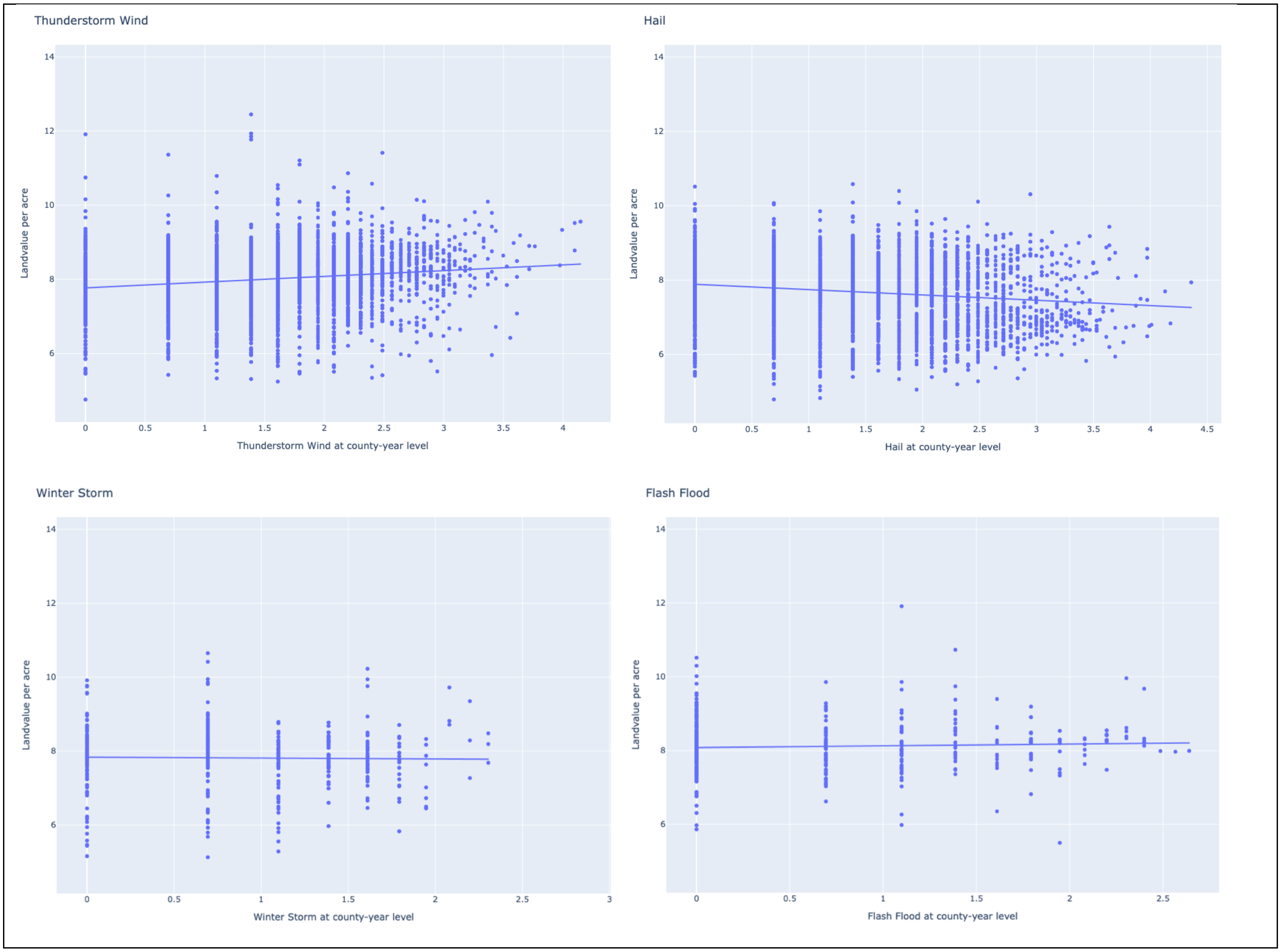


Figure 15. Scatter plot for top 4 extreme weathers

As Figure 15 shows, the heterogeneity among types of extreme events are significant- thunderstorm wind and flash floods are positively related with land value while hail and winter storm are negatively related to land value. The positive slope may be due to the same rising trend with land value rather than a correlation. For the third and fourth events, the slope may not significantly different from zero. The heterogeneity analysis shows that the positive slope shows in the aggregate extreme weather figure may be due to hidden heterogeneity or there is no significant correlation between land value and extreme weather.

3.2. Demographic factors

Table 2 Descriptive statistics of U.S. counties

Descriptive statistics of U.S. counties"

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
pop90	3,130	81,078.340	270,064.800	107.000	10,391.750	55,511.500	8,863,052.000
pop00	3,127	91,695.740	299,148.400	67.000	11,306.000	62,370.500	9,519,315.000
pop10	3,127	100,351.600	319,262.300	82.000	11,201.500	67,413.000	9,818,605.000
r_u_cont93	3,131	5.603	2.730	0	3	8	9
r_u_cont03	3,131	5.133	2.685	1	3	7	9
r_u_cont13	3,127	5.008	2.708	1.000	2.000	7.000	9.000
big_ent00	3,130	318.799	1,081.158	1.000	19.000	171.000	24,678.000
big_ent02	3,130	332.746	1,116.156	1.000	19.000	178.750	25,704.000
big_ent07	3,130	372.503	1,223.004	1.000	21.000	208.750	28,611.000
big_ent12	3,127	383.281	1,244.944	1.000	22.000	220.000	29,092.000
small_ent00	3,130	1,969.460	6,689.068	1.000	214.000	1,251.500	201,604.000
small_ent02	3,130	2,017.987	6,836.882	1.000	214.000	1,288.000	206,244.000
small_ent07	3,130	2,137.970	7,302.242	1.000	215.000	1,352.500	224,393.000
small_ent12	3,127	2,043.488	7,175.015	0.000	200.000	1,264.500	220,533.000

Table 2 shows the descriptive statistics of population, rural_urban continuum and big & small enterprise ratio changes by county. In county population terms (pop90, pop00, pop10), the population at low 25% population has grown up but the population at top 75% grows faster, and it shows the evidence that the population flows could move to urban and metropolitan area or the birth rate in a rural area could be decreased, so we need to check the more details of population changed by ages. Rural and urban continuum shows that the mean values gradually decreased every decade, but standard deviation is similar so that we can intuitively guess that the rural and urban decomposition or connection would not much change between, so we need to look at more details with within changes. Big and small enterprise ratio changes at low 25% county and top 75% county shows that the growth of big enterprises is concentrated in big cities, so we can roughly say that there were not much reorganization trends of rural area in county level for two decades.

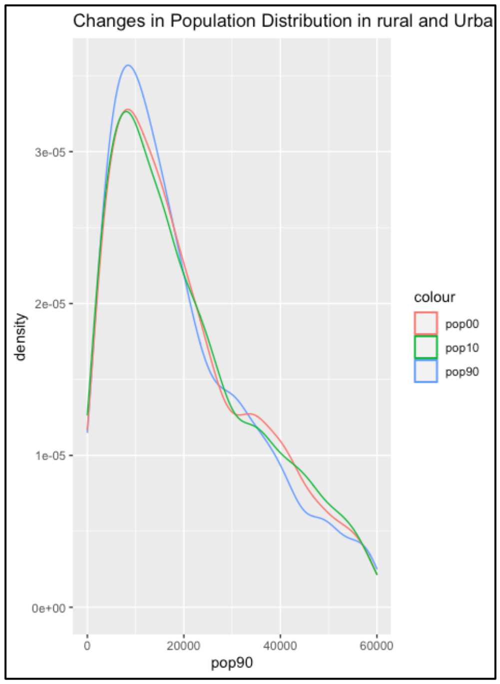


Figure 16. Changes in population distribution in rural and urban areas

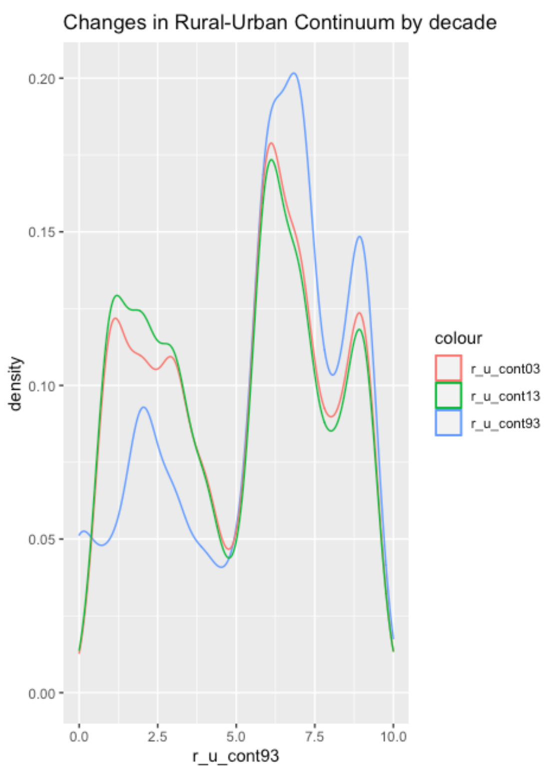


Figure 17 Changes in rural-urban continuum by decades

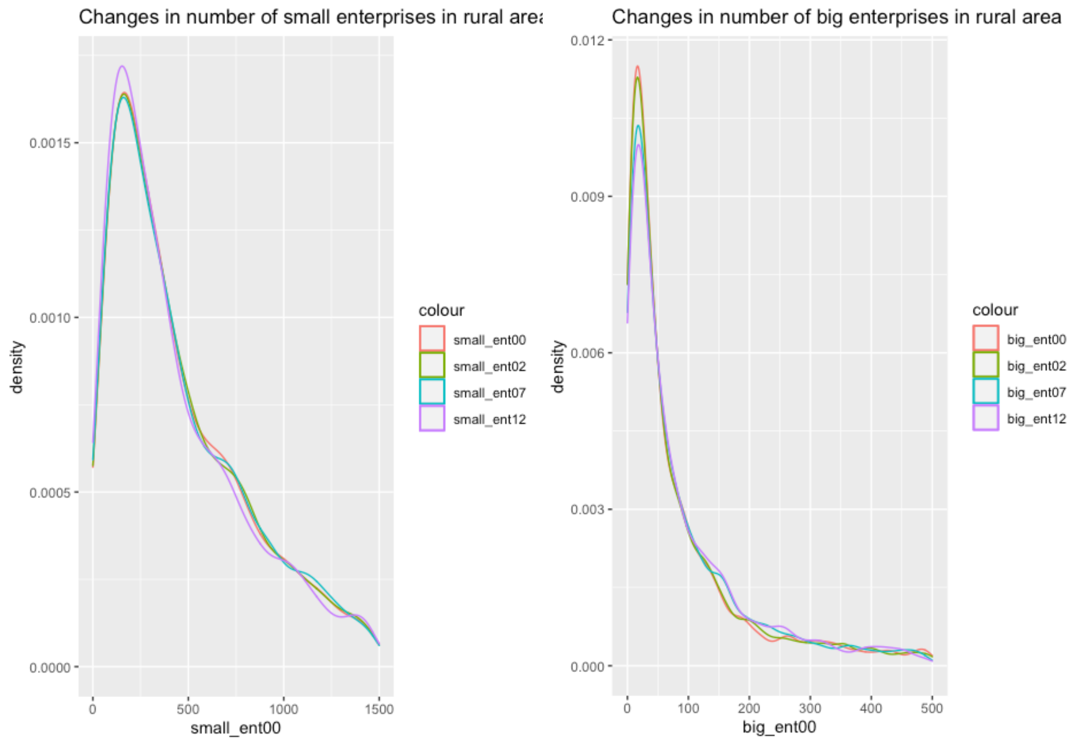


Figure 18 Changes in number of small and big enterprises in rural areas

Figure 16 to Figure 18 shows the time trends of population, rural_urban continuum and big&small enterprises ratio for about two decades.

4. Regression results

4.1 Pooled OLS

	Dependent variable:	
	Log of agri land value (usd/acre)	
	OLS	OLS
	(1)	(2)
Log coprevenue (usd/acre)	0.159***	0.091***
	(0.005)	(0.005)
Log cropland (acres)	-0.055***	-0.05***
	(0.005)	(0.005)
Log per capita income (usd)	0.441***	0.497***
	(0.025)	(0.023)
Log Population density (sqm)	0.237***	0.2***
	(0.005)	(0.004)
Temperature (F)	-0.009***	-0.009***
	(0.001)	(0.002)
Precipitation ('00 mm)	0.091***	0.081***
	(0.005)	(0.005)
N02	0.02***	0.009***
	(0.002)	(0.002)
S02	0.006 *	0.029***
	(0.003)	(0.004)
Freq of top 10 disasters	-0.008***	-0.005***
	0.000	0.000
2002	0.217***	0.212***
	(0.011)	(0.011)

2007	0.445***	0.439***
	(0.012)	(0.012)
2012	0.477***	0.501***
	(0.016)	(0.018)
Non-Corn belt	-0.069***	
	(0.010)	
Constant	1.797***	1.59***
	(0.272)	(0.281)
State (dummy)	No	Yes
Observations	10919.000	10919.000
Adj.R square	0.732	0.810
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$	

Table3 Pooled OLS results

Table 3 shows the results table of the pooled OLS results and the brief description of the table is

- Per-capita income (.44 to .5), Population density (.23 to .2), and crop revenue have the highest elasticity (.16 to .09) (positive).
- Disasters and Temperature increases affect negatively.
- Pollution and Rainfall have a slightly positive coefficient.
- Land value increases more in the Corn-belt region.
- Significant increase in land value in every round

	Dependent variable:	
	Fixed effect Model	Random effect Model
	(1)	(2)
log(cropland_acre)	−0.043***	−0.101***
	(0.012)	(0.006)
log(percap_income_r)	1.212***	1.153***
	(0.023)	(0.021)
log(pdensity_sqm)	0.185***	0.299***
	(0.032)	(0.006)
n02	−0.018***	−0.011***
	(0.001)	(0.001)
s02	0.002	−0.026***
	(0.003)	(0.003)
temp	0.054***	−0.001
	(0.004)	(0.001)
prec	0.014***	0.038***
	(0.005)	(0.004)
disas	−0.00005	−0.001***
	(0.0003)	(0.0003)
corn_beltNon-Corn belt		−0.170***
		(0.021)
s_ent_r	−0.001***	−0.00000
	(0.0004)	(0.0004)
Constant		−4.056***
		(0.261)
Observations	10,986	10,986
R^2	0.552	0.627
Adjusted R^2	0.391	0.627
F Statistic	1,107.276*** (df = 9; 8075)	13,820.140***
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 4. Panel OLS (fixed effect vs random effect)

Table 4 is the result of panel OLS with fixed effect and random effect model and brief description of the table is

- The sign of coefficient of 'n02' is in a opposite way comparing to pooled OLS.
- Random effect panel regression has same R-square and adjusted R-square.

- County specific fixed effects and time specific random effects are significantly existing**.**

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