Environmental Justice of Hydraulic Fracking: A Spatial Analysis in Texas

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Abstract

This project conducts a spatial analysis of gas and oil fracking sites in Texas census tracts. It examines the socio-demographic characteristics of local communities around fracking sites to understand the spatial distribution of fracking wells. Utilizing spatial analysis methods in ArgGIS, the study explores site distribution through hotspot analysis, proximity to residential areas, and correlations with demographic variables of ethnicity and race.

Introduction

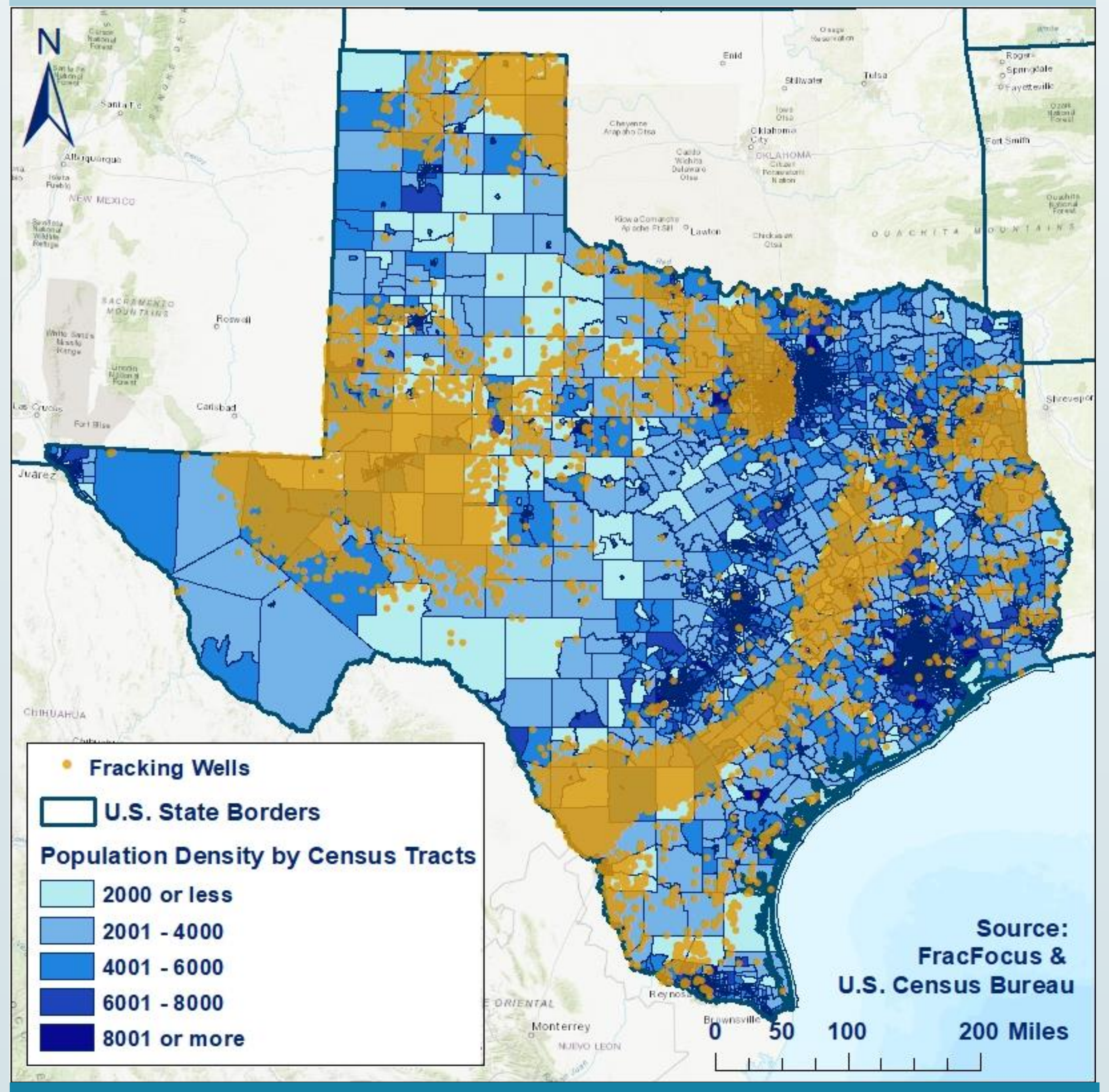
Hydraulic fracturing, commonly known as fracking, is a method used to extract natural gas and oil from underground rock formations such as shale. It involves injecting a high-pressure mixture of water, sand, and chemicals into the rock to fracture it and release the trapped gas or oil (U.S. EPA). Fracking has gained significant attention due to its environmental impacts, including water contamination, air pollution, and habitat disruption etc, as well as its socio-economic implications for local communities, especially in states, like Texas, with rich shale oil and gas resources. Texas is chosen for this research because it produces 42% of crude oil and 27% of natural gas in U.S.(Mazur, 2024).

Research Questions

This research strives to answer the following two questions:

- Are there spatial patterns in the distribution of fracking sites concerning factors such race/ethnicity?
- Given the environmental justice implications, which census tracts should be priority for addressing those effects?

Map 1: Population density and distribution of fracking wells.



Data Collection

Relevant data was retrieved from the U.S. Census Bureau by identifying datasets containing demographic information such as race (white and black), ethnicity (Hispanic), median income, cash assistance, educational attainment, and population density. This dataset was collected from the 5-year data of American Community Survey from 2016 to 2020. Race and ethnicity indicators will function as independent variables, while other demographic variables are in control, with census tracts serving as the unit of analysis.

Additionally, publicly available datasets were accessed from the independent fracking well registry, FracFocus, launched in 2011, which has reported more than 106 thousand fracking wells on oil and gas extraction sites. This data will serve as dependent variable in this case.

Methodology

This process involves the following methods:

First, using the spatial distribution of fracking sites and population density data, this research creates Map 1 to identify patterns and potential visual correlations between these variables.

Second, hot spot analysis is employed to identify clusters of fracking wells based on two dependent variables that were generated from the FracFocus dataset:

a. **The number of wells in each census tract**. This process was conducted as follows: Geocoding was performed to determine the location of each well based on the longitude and latitude information provided in the FracFocus data. After locating them, a spatial join was performed, linking all wells to the Texas census tracts.. Since only 14% (985 out of 6896) of census tracts have at least one fracking well, this simple count is not good dependent variable in this case. The hotspot analysis on this variable is shown in Map 2a.

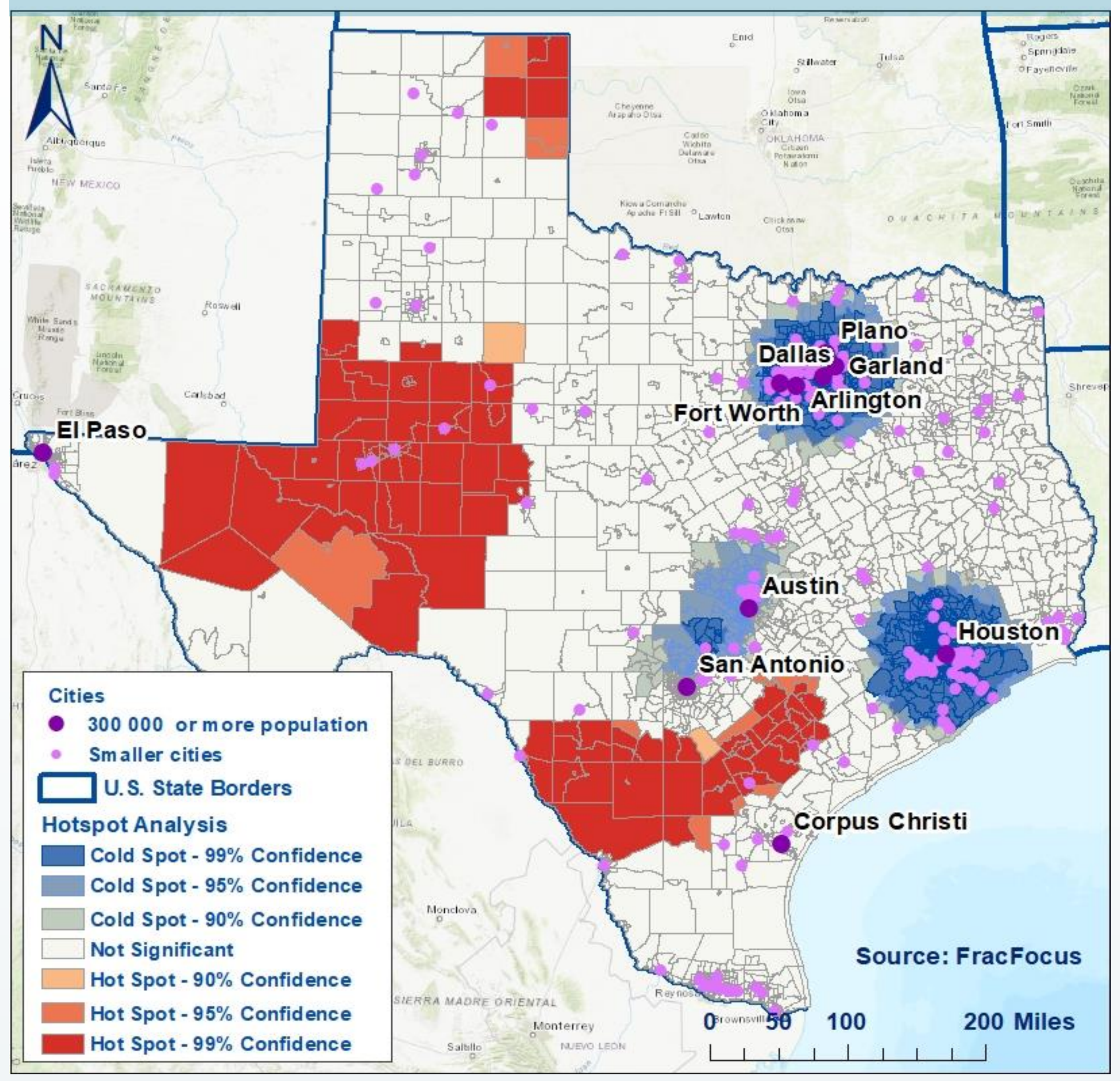
b. **The distance (in kilometers) from the census tract centroids to the nearest well.** This calculation involved two main steps: Firstly, determining the centroids of each census tract. Then, the distance to the nearest well was measured from these centroids. The hotspot analysis of this variable is shown Map 2b. This dependent variable is better than the first one. Unlike the limited number of census tracts with at least one fracking well, all 6,896 tracts have values for this indicator. Distances are calculated to the nearest well, located both within and outside the tract. However, one limitation of this variable is that census tract centroids are calculated based on tract geographic areas rather than population-weighted calculations.

Third, simple OLS regression is employed to figure out general relationship between race/ethnicity and distance to the nearest well, while controlling for other demographic variables. Then to figure out nuanced coefficients on the proximity to fracking sites in each census tract, geographically weighted regression analysis is utilized, using the same variables. The Map 3 for example shows relationship between Hispanic population share and proximity to fracking wells.

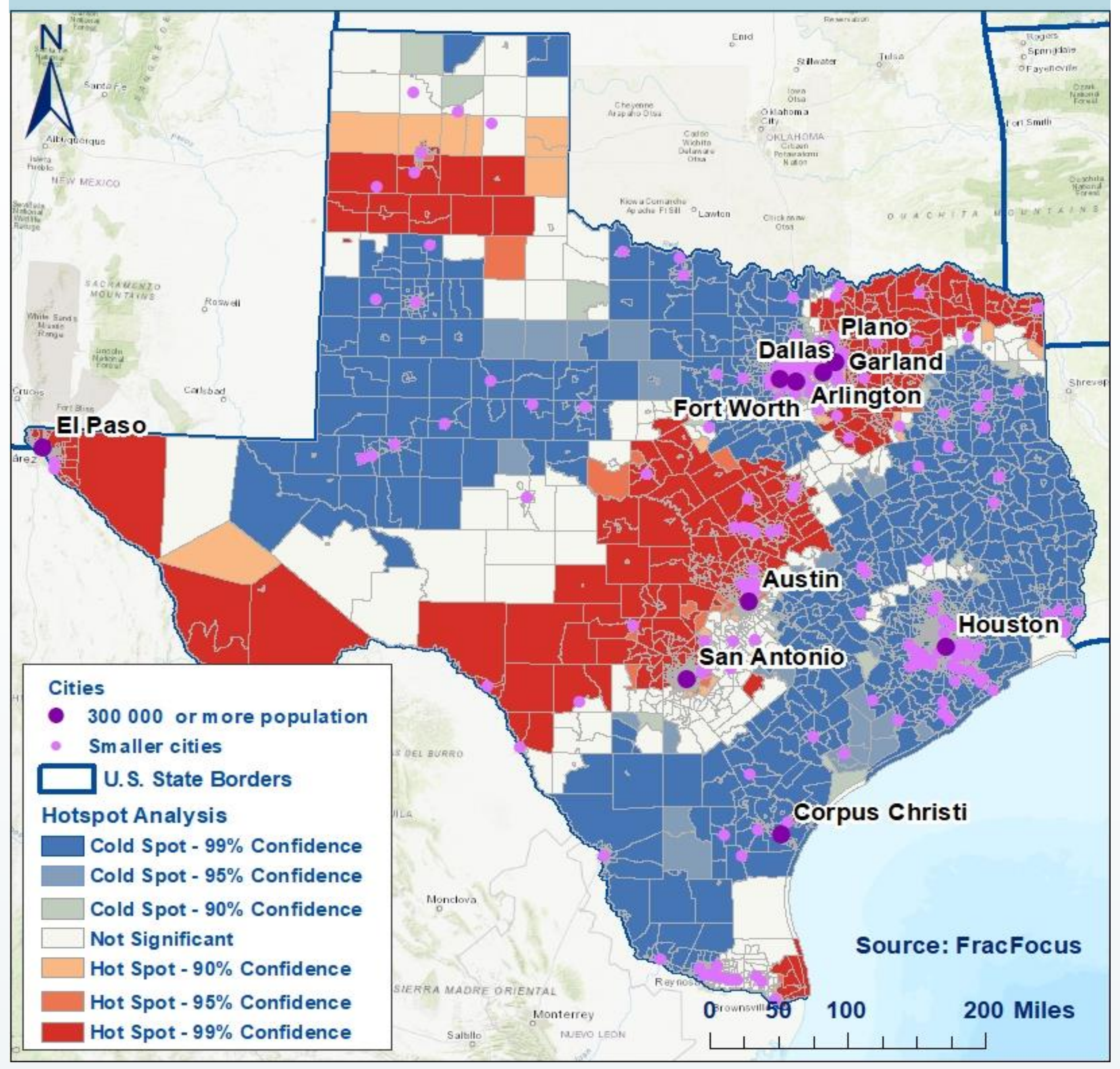
Results

- The spatial distribution depicted in Map 1 reveals that fracking wells tend to be located in census tracts with low population density.
- Hot spot analysis in Map 2a identifies clusters of fracking wells based on their numbers, with hotspots notably concentrated in areas associated with the Permian Basin, while cold spots are observed in urban areas. This aligns with expectations, as unconventional oil and gas development sites are typically situated away from residential areas.
- Interestingly, the hot spot analysis in Map 2b, focusing on the distance to the nearest well, presents a different perspective. It indicates that distances to the nearest wells in Central Texas are shorter compared to those near the Permian Basin or coastal areas. In essence, this perspective reveals that certain cities, such as Arlington and Dallas, along with neighboring towns, have relatively shorter distances to hydraulic fracking sites. This observation confirms findings from other research and underscores Arlington's reputation as the oil capital of Texas.

Map 2a: Number of wells in each census tract



Map 2b: Distance from tract centroids to the nearest well.



- Thirdly, the simple Ordinary Least Squares (OLS) regression in Table 1 indicates a statistically significant relationship between distance and the Hispanic population, suggesting that a higher proportion of Hispanic residents correlates with greater distances to fracking wells. However, this trend is generalized, and we need to understand the nuanced distances for each census tract using Geographically Weighted Regression (GWR).
- The GWR analysis depicted in Map 3 indicates the relationship between the proximity of the nearest fracking well and the proportion of the Hispanic population, while controlling for the aforementioned demographic variables. Particularly noteworthy is the strong correlation observed in eastern Texas, particularly the east side of Arlington, Garland, and other cities, as well as in certain census tracts of the Permian Basin. This suggests potential patterns in well-siting decisions.

Map 3: Geographically-weighted regression analysis

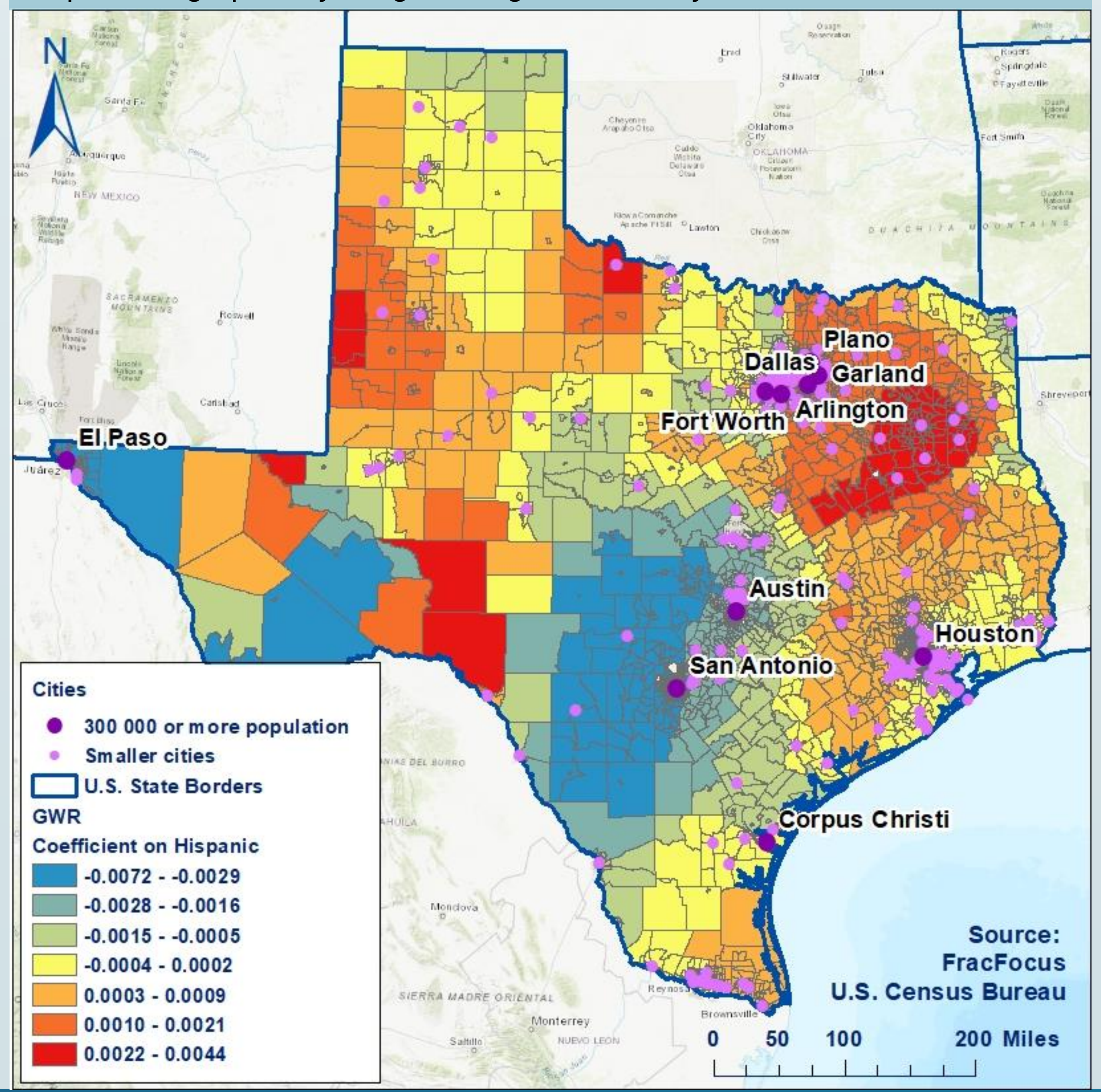


Table 1: OLS regression analysis

	(1) near_dist	(2) near_dist	(3) near_dist	(4) near_dist	(5) near_dist	(6) near_dist
black_aa	-0.000196	0.0000151	0.0000871	0.0000881	0.000111	0.000110
	(-1.89)	(0.14)	(0.82)	(0.77)	(0.95)	(0.93)
hisp		0.000598***	0.000913***	0.000943***	0.000954***	0.000954***
		(10.25)	(10.60)	(10.42)	(10.45)	(10.42)
no_hsd			-0.00132***	-0.00136***	-0.00135***	-0.00135***
			(-4.96)	(-4.94)	(-4.90)	(-4.90)
hh_medinco				-2.95e-08	-2.63e-08	-2.53e-08
				(-0.52)	(-0.47)	(-0.45)
pop_dens					-0.00000100	-0.000000998
					(-0.91)	(-0.91)
cash_ass						0.000113
						(0.15)
_cons	0.151***	0.125***	0.123***	0.124***	0.125***	0.124***
	(73.12)	(38.78)	(37.94)	(18.84)	(18.86)	(18.44)
N	6896	6896	6896	6786	6786	6786

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Recommendations

- Considering the environmental justice implications, prioritizing development initiatives aimed at addressing the social and environmental concerns of communities residing near fracking sites, as highlighted in Map 3 with red coloring, is crucial.
- In these census tracts, engaging local communities and stakeholders in decision-making processes related to fracking operations and regulatory frameworks is imperative.
- Further rigorous research is necessary to assess the causal effect of these independent variables on fracking citing. Continuous monitoring is also needed for assessing the long-term impacts.

Bibliography

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