THREE ESSAYS IN ENERGY, ENVIRONMENTAL AND REGIONAL ECONOMICS

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THREE ESSAYS IN ENERGY, ENVIRONMENTAL AND REGIONAL ECONOMICS

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Abstract: This dissertation is comprised of three studies on the relationship between energy and environmental issues and the regional economy. The first study presents evidence that electricity influx to the U.S. Northeast increased after the introduction of the Regional Greenhouse Gas Initiative (RGGI), a carbon emissions abatement program. Electricity influx means that emissions reductions achieved in the region are offset by increased emissions in other electricity-producing regions, as local generation is replaced with electricity imports. The empirical analysis is conducted using the synthetic control method. Results indicate that electricity imports increased after RGGI's establishment in 2009—with the increase predominantly coming after the emission cap was reduced in 2014—which suggests that leakage is occurring.

I then switch to exploring recent new energy development activity. In the second essay, I study a potential negative externality associated with hydraulic fracturing. More specifically, I examine the impact of unconventional drilling on housing prices. A prospective home buyer may want to avoid a place near sites that have been drilled using unconventional drill technologies, since those activities may lead to a variety of negative impacts including noise and underground water contamination. Adopting a hedonic price model, I estimate the avoided cost in two counties, Canadian and Payne, in Oklahoma. However, an environmental pollutant source and housing price may be difficult to explain with linear model, and I apply a semiparametric approach to deal with the possible non-linear relationship. The empirical results are consistent with in terms of physical housing characteristics and locational aspects in all cases, and find only a minimal impact of drilling activity on housing prices in the benchmark models. Further, the semiparametric estimation supports the finding that there is a limited relationship between unconventional drilling and housing prices in these counties.

In the third essay, I study a possible positive impact associated with recent energy development. I examine the regional employment change associated with recent energy developments in Arkansas, Kansas, and Oklahoma. Those three states have experienced a drastic increase in unconventional drilling, further, Kansas and Oklahoma show a rapidly growing wind energy sector. Those two types of relatively new energy development activities could be a beneficial source for employment in rural areas. Considering heterogeneous boom periods in the energy development activities in the three states, I apply a panel fixed effects model. I additionally incorporate a spatial econometrics specification to deal with spatial autocorrelation concerns. The results indicates that energy development activity does increase regional employment, but only for a small subset of industries. Moreover, the agricultural sector is negatively affected by energy development in most cases. In addition, unconventional drilling activity provides a larger positive impact on local employment than does activity for local wind farms.

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CHAPTER I

EVIDENCE OF INCREASED ELECTRICITY INFLUX FOLLOWING THE REGIONAL GREENHOUSE GAS INITIATIVE

Abstract

The Regional Greenhouse Gas Initiative (RGGI), a carbon emissions abatement program, focuses on regulating electricity generators to achieve its abatement targets. However, the program is geographically limited (a states in the northeast U.S.) and electricity can be easily imported from neighboring regions. This study presents evidence that electricity influx to the U.S. Northeast increased after the introduction of the RGGI. Electricity influx means that emissions reductions achieved in the region are offset by increased emissions in other electricity-producing regions, as local generation is replaced with electricity imports. The empirical analysis is conducted using the synthetic control method. Results indicate that imports increased after RGGI's establishment in 2009—with the increase predominantly coming after the emission cap was reduced in 2014—which suggests that leakage is occurring.

Key words: RGGI, Carbon Emissions, Synthetic Control Method, Leakage, Pollution Haven hypothesis

Introduction

Carbon emission trading is widely viewed as an important policy tool to mitigate climate change, but current trading initiatives are fragmented. For example, the United States has several regional efforts, including the Western Climate Initiative and the Regional Greenhouse Gas Initiative (RGGI), while many U.S. states choose to not participate in any emissions reduction program. Unfortunately, with interstate and international markets in carbon-producing industries, reducing global emission levels through an assortment of regional initiatives may be difficult. This is because regional initiatives can suffer from leakage, which occurs when emission reductions in regulated regions are offset by emission increases elsewhere, as industries shift production into unregulated regions.

To date, only a few studies empirically examine the effectiveness of carbon emissions abatement programs in the United States. Economic research on these programs has primarily used theoretical models to predict leakage; for example, Chen (2009) found in electricity market simulations that CO_2 leakage was positively related to higher carbon prices from the RGGI program. Several studies have studied leakage in California's carbon cap-and-trade program: Bushnell et al. (2014) and Caron et al. (2015) both concluded that California's carbon abatement policy increased electricity imports and increased carbon emissions in states exporting electricity to California.

There is a rich empirical literature on leakage and pollution havens (Levinson and Taylor, 2008; Wagner and Timmins, 2009; Antimiani et al, 2012; Aichele and Felbermayr, 2015). On the effects of RGGI specifically, Murray and Maniloff (2015) examined coal and natural gas utilization rates in power generation and found evidence of leakage into Pennsylvania. However, Murray and Maniloff (2015) recommend further study on the leakage issue. Fell and Maniloff (2015) examined electricity generator-level data and found some but not all of the emissions reduction due to RGGI was offset by increases in non-RGGI emissions. Kim and Kim (2016) performed a case study on the relationship between the introduction of RGGI and fuel switching from coal to natural gas among participating states; natural gas contains less carbon than coal, thus such fuel switching is one way to reduce carbon emissions.

This paper adds to the growing weight of evidence of carbon emissions leakage by examining trends in electricity imports into the RGGI region. If a leakage problem is associated with RGGI, then we expect electricity imports into the region increased following the establishment of the program. Our investigation extends the existing literature by applying the synthetic control method (SCM) to develop a counterfactual to measure leakage from the abatement program. Relative to standard regression-based comparisons such as difference-in-differences, SCM relies less on subjective researcher judgements to develop the comparison group and is robust to potential confounders that vary period-by-period. Kim and Kim (2016) use SCM to show that RGGI accelerated coal to natural gas fuel switching in affected states. We use SCM to compare electricity imports into RGGI states using a weighted average of non-RGGI states. To assess the sensitivity of these comparisons, we develop several alternative counterfactuals from revised donor pools of non-RGGI states (i.e. the comparison group), in addition to placebo experiments. Results indicate that electricity imports into the RGGI region increased after the emissions cap was put in place.

Overview of the Study Region

RGGI is a cap and trade program for greenhouse gas emissions (GHG) in the northeastern United States. The RGGI emissions cap went into effect January 1, 2009, making it one of the first U.S. GHG abatement programs. As of 2015, there are nine states participating, including Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. New Jersey participated between 2009 and 2011 but withdrew from the program in 2012. Currently, fossil fuel power plants in participating states with electricity generating capacity of 25 megawatts (MW) or larger capacity are subject to the GHG regulations of RGGI. The share of carbon emissions from electricity generation in the RGGI region is about 25% of the region's total carbon emissions. Over the previous decade, carbon emissions from electricity generation in the RGGI region accounted for 6 to 7% of all U.S. emissions.

The scale of the cap has changed over time as the number of participating states declined and decisions were made to reduce the allowable amount of emissions. Initially, the cap was set at 188 million CO_2 short tons per year for the ten states participating between 2009 and 2011. Following the withdrawal of New Jersey, the cap was reduced to 165 million CO_2 short tons per year. In 2013, based on a comprehensive review of emissions compliance over the first two years' (2009-2010), RGGI announced it would lower the cap beginning in 2014. The newly reduced cap was 91 million short tons, with planned reductions of 2.5% each year between 2015 and 2020.[1]

As a whole, the RGGI region consumes more electricity than it generates, making it a net importer of electricity. Panel A in Figure I-1 illustrates the aggregate level of

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[1] More details can be found in RGGI (2013) and http://www.rggi.org/design/overview.

imports between 2005 and the third quarter of 2017. Prior to RGGI, the region imported between 0 and 2 terawatt-hours (TWh), or 0 to 7%[2] of its total electricity consumption. The figure shows that after the establishment of RGGI, net imports rose considerably and consistently exceeded 1.5 TWh.

Empirical Strategy

We apply the synthetic control method (SCM) to measure the effect of RGGI on state-level electricity imports. Synthetic controls are a relatively new methodology to measure treatment effects in case studies. SCM was developed by Abadie and Gardeazabal (2003), who used it to estimate the effect of armed conflict on economic development. Abadie et al. (2010) further formalized the method to measure the effects of anti-tobacco legislation on cigarette consumption. Subsequently, there have been several applications of the SCM to carry out comparative case studies (Billmeier and Nannicini, 2013; Cavallo et al., 2013; Ando, 2015; Bilgel and Galle, 2015; Rickman et al., 2017).

Several studies have applied SCM to evaluate the effects of regional environmental policies. Maguire and Munasib (2016b) examined the effect of renewable portfolio standards (RPS) policy among states, and found that Texas is the only state to have substantially increased its renewable energy capacity; Maguire and Munasib (2016a) showed that the RPS policy did not raise electricity prices in Texas. As mentioned earlier, Kim and Kim (2016) found that the establishment of RGGI encouraged fuel switching from coal to natural gas among electricity generators.

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[2] During 2005-2015, average electricity consumption is 25.57 Twh per quarter in the whole RGGI region.

For the purposes of this investigation, SCM holds several advantages over propensity score matching (PSM) and regression-based methods such as difference-in-difference (DID) that are often used to measure program and treatment effects. First, the small cross-section component of our data makes finding a suitable match between a RGGI state and one or more non-RGGI states (among the 37 available, not including Alaska, California,[3] and Hawaii) dubious. Second, our data vary at the quarter-state level starting in 2005, which yields 16 pre-RGGI time periods. PSM is not well suited take advantage of long time series and while DID can, it relies on parallel pre-intervention trends between the treated and comparison groups. In contrast, SCM sets up a treated unit with a counterfactual composed of a weighted combination of the non-treated units; because these weights are determined by similarities across treated and non-treated units in the pre-intervention period, the validity of SCM's counterfactual actually improves with a longer time series (Abadie et al. 2010).

In our application, SCM works by constructing a weighted average of non-RGGI states to mimic the characteristics of a RGGI state prior to the adoption of the initiative. If the trend in electricity imports of the synthetic control closely resembles the trend in the RGGI unit prior to program adoption, then the post-adoption trend in the synthetic state will provide an unbiased counterfactual.

Following Abadie et al. (2010), we formally define the effect of an intervention with the equation:

$$\alpha_{jt} = Y_{jt}^{I} - Y_{jt}^{N} \quad (1)$$

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[3] California introduced carbon cap and trade in 2013. Thus, we exclude California from the donor pool.

where α_{jt} is the effect of the intervention for state *j* at time *t*, Y_{jt}^{I} is the observed outcome and Y_{jt}^{N} is the outcome that would have occurred if the intervention did not take place. In this study, the outcome *Y* is measured as electricity imports.[4] We define electricity imports as electricity consumption less electricity generation in a state:

(2) $$Imports = Electricity\ Consumption - Electricity\ Generation$$

Let intervention occur in period T_0, *j* = 1 represent a RGGI state and *j* = 2, 3,…, *J* represent the "donor pool" of states that could be used to estimate the counterfactual. Y_{jt}^{N} can be modeled as

(3) $$Y_{jt}^{N} = Z_j\theta_t + \lambda_t\mu_j + \epsilon_{jt}$$

where Z_j includes relevant covariates not affected by the abatement program, θ_t are time-specific parameters, μ_j are state-specific unobservables and λ_t are unknown common effects. For the covariates, we include indexes of heating degree days (HDD) and cooling degree days (CDD).[5] Electricity imports will rise in the months that residents and businesses need to use heating and cooling units to control indoor temperatures. We also include covariates for population and state gross domestic product (GSP), as well as the average electricity import level prior to the RGGI intervention. Define $\mathbf{w}$ as a $J \times 1$ vector of weights such that $0 \leq w_j \leq 1$ and $\sum_{j=2}^{J} w_j = 1$. Suppose there is a w_j^* such that

(4) $$\sum_{j=2}^{J} w_j^* Y_{jt} = Y_{1t}^{I} \text{ for } t = 1, \ldots, T_0 \text{ and } \sum_{j=2}^{J} w_j^* Z_j = Z_1$$

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[4] Cheaper prices could have cause electricity consumption and therefore imports to increase, but in fact electricity consumption has been fairly constant (or slightly decreasing) while electricity generation has decreased in RGGI states.

[5] HDD and CDD are defined as follows:

HDD for a given day = *Max* [*65˚F (or18˚C) - Average temperature for the day, 0*];
CDD for a given day = *Max* [*Average temperature for the day - 65˚F (or18˚C), 0*]

which means that there is a collection of weights w_j^* that matches the treated state in every pre-treatment period to the synthetic state. Then Abadie and Gardeazabal (2003) and Abadie et al. (2010) show that the effect of interest, α_{1t} for $t > T_0$, can be estimated by

$$(5) \qquad \widehat{\alpha_{1t}} = Y_{1t}^I - \sum_{j=2}^{J} w_j^* Y_{jt}$$

In practice equation (4) will not hold exactly so the synthetic control is selected so that it holds approximately. The scale of discrepancy—in this case, how closely the characteristics of the treated state are to the characteristics of the synthetic state—should be assessed carefully, because SCM should not be used if the synthetic control unit does not approximate the treated unit prior to treatment. We assess the synthetic control match for our application in the results section below.

To estimate the vector of weights, $\mathbf{w}$, let Ω_1 be the vector of pre-intervention characteristics of the treated unit and Ω_0 be the matrix of pre-intervention characteristics of the non-treated units. To generate the synthetic control, the weights are chosen to minimize the discrepancy between the treated and the non-treated units, $\|\Omega_1 - \Omega_0\mathbf{w}\|$. Specifically, following Abadie et al. (2010), $\mathbf{w}$ is chosen to minimize $\sqrt{(\Omega_1 - \Omega_0\mathbf{w})'\mathbf{V}(\Omega_1 - \Omega_0\mathbf{w})}$, where $\mathbf{V}$ is a positive definite and diagonal matrix that minimizes the mean squared prediction error (MSPE)[6] in the pre-intervention period.

An important matter in our application is that the RGGI intervention affects a group of states rather than a single state. The synthetic control method was designed for comparative case studies, rather than a collection of treated units. To circumvent this

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[6] $MSPE = \frac{1}{T_0}\sum_{t=1}^{T_0}(Y_{1t} - \sum_{j=2}^{J} w_j^* Y_{jt})^2$

limitation, we conduct two sets of case studies: The first calculates Ω_1 as weighted average of the characteristics of the nine constituent RGGI states; we refer to this as the composite RGGI state. Of course, this composite treatment group would obscure heterogeneity across individual states. We therefore implement a second case study that applies SCM to each RGGI state.

The variables for the composite RGGI were calculated as population-weighted averages. The weights were the population of each member state divided by the population in the RGGI region. As shown in Panel B in Figure I-1, proportionate changes in electricity imports in the composite region closely mimic changes in the region as a whole. Although not reported here, we experimented with other definitions of the treated unit but found the final results to be similar.[7] In our application, the SCM procedure constructs the synthetic control as a weighted combination of the states in the donor pool, based on the pre-treatment values of the variables measuring population, GSP, CDD, HDD, electricity imports and electricity prices. The effect of RGGI is then measured by the difference in imports between the composite RGGI state and the synthetic control in the post-initiative period.

Data

Our investigation uses quarterly state-level data. The electricity generation and consumption data come from the U.S. Energy Information Administration (EIA). We

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[7] We also applied SCM to a modification of equation (2), by measuring imports as the share of electricity consumed in the region. Expressing the variable of interest as a share is desirable because it normalizes the units of comparison between the RGGI region and non-RGGI states. This is akin to the approach used by Kim and Kim (2016), who examined the effect of RGGI on the share of electricity in the region produced by coal versus natural gas. Pre-RGGI imports averaged 4.83%, but after RGGI the average share doubled to 11.54%, while the synthetic control share increased only slightly from 5.98% to 7.05%. The implied effect in shares is therefore qualitatively similar to the effect in levels reported in this paper.

measure electricity generation from all energy sources through ‘Electric Power Monthly,’[8] which is provided by the EIA. More specifically, electricity generation is measured as the sum generated from all generating fuel sources in the electric power industry of each state. Electricity consumption data and electricity prices are collected from EIA-861M (formerly EIA-826) detailed data at the EIA.[9] This detailed data series include the sum of electricity consumption and sale prices from all sectors, including residential, commercial, industrial, transportation, and other sales sectors, in each state.

The sources for the other variables are as follows. State-quarterly total population data are not available, so we use the state population counts from the civilian non-institutional population aged16 years and older as a proxy. This data come from the Bureau of Labor Statistics (BLS).[10] Weather data (HDD and CDD) come from the National Oceanic and Atmospheric Administration (NOAA).[11] The best available time period for the GSP series is quarterly. Thus, we adjust the other data series to this time frame. Quarterly state GSP data are published by the U.S. Bureau of Economic Analysis (BEA).[12] The time span of the data runs from the first quarter of 2005 to the third quarter of 2017 (making the total number of time periods 51). Summary statistics of these variables are presented in Table I-1.

Results and Discussion

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[8] Available at https://www.eia.gov/electricity/data/state/.

[9] Available at https://www.eia.gov/electricity/data/eia861m/index.html.

[10] Available at http://www.bls.gov/lau/rdscnp16.htm.

[11] Available at ftp://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/.

[12] Available at http://www.bea.gov/regional/.

Case study 1: Results for the composite RGGI state

We first compare the trends observed for the composite RGGI state with its synthetic control. SCM produces a synthetic control made up of four states: Florida (9.7%), Texas (23.5%), Virginia (48.6%), and Wisconsin (18.3%). Table I-2 shows the means of the predictive variables used to generate the synthetic control. Between the composite RGGI and its synthetic counterpart, which are shown in columns one and two, respectively, the match is good in terms of population, GSP and electricity imports. The match is weaker in terms of CDD, HDD and electricity price. However, we can see that the other 37 states yields a comparison group that is on average less populated, lower GSP and were net exporters of electricity. Furthermore, it would be difficult to improve the match on CDD, HDD and prices because the RGGI region is has colder winters and higher prices compared to the rest of the country.[13]

Figure I-2 compares electricity import trends in the composite RGGI state and the synthetic control. During the pre-treatment period, the two trends tend to rise and fall simultaneously and fluctuate around 0.4 Twh (RGGI, 0.37; Synthetic RGGI, 0.35). However, the synthetic control's pre-treatment imports are more variable. This variability suggests the synthetic control provides a low-power test of the effect of RGGI on electricity imports, if the initiative is in fact suffering from leakage. Our analysis may therefore fail to detect an effect if the effect is small.

Figure I-2 shows that electricity imports into the RGGI region increased following the establishment of the initiative. The import level of the counterfactual fluctuates around 0.5 Twh with no discernable upward trend. In contrast, imports to the

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[13] Excluding variables such as electricity price can improve the match on the other predictors, but do not significantly affect the results.

composite RGGI fluctuate initially around 0.7 Twh and later around 1.0 Twh. In other words, electricity imports in the composite RGGI state exceed what the synthetic control predicts would have happened without the program. This suggests that the abatements achieved in the RGGI region have been at least partially offset by higher electricity imports and thus more emissions in non-RGGI states.

We use placebo experiments to infer the robustness of the SCM predictions. We use the techniques described in Abadie et al. (2010) to conduct these placebo experiments. Specifically, we iteratively apply SCM to each of the 37 states in the donor pool as if they had participated in a RGGI-like program. We then calculate the difference between the placebo state and the synthetic control's electricity imports. As no placebo state was part of RGGI, on average there should be no difference between the state's imports and the synthetic control's imports in the post-treatment period. Following Abadie et al. (2010), we drop the placebo runs that in the pre-treatment period have a synthetic control with a prediction error more than twice as large than the error of the RGGI synthetic control; this eliminates states that received a relatively poor comparison group from SCM. The placebo test provides statistically significant evidence if the estimated RGGI effect is consistently larger than the placebo effects.

Figure I-3 graphs the RGGI and placebo effects. The solid black line measures the effect in the composite RGGI state while the dashed lines measure the placebo effects. The figure shows that the effect in the composite RGGI state at first fluctuates considerably in the post-intervention period. In the first few years, this effect is not abnormally large compared with the placebos. However, the effect in the composite RGGI quickly rises above the other placebo effects after the emissions cap was reduced in 2014. This pattern is consistent with electricity imports increasing only after the emission cap became binding.

These results indicate that RGGI caused electricity imports to increase, generating a leakage problem. This effect is statistically significant based on the results of the placebo test. We also constructed p-values from the test (Cavallo et al, 2013), which averaged 0.098 after 2014, which indicates an effect that is statistically significant at the ten percent level. These results are available upon request.

The remaining robustness checks use synthetic controls developed from more restrictive donor pools and groups of covariates. Abadie et al. (2015) recommend excluding units from the donor pool that are dissimilar from the treated unit. These restrictions can help avoid interpolation biases and overfitting. In fact, since the counterfactual is a convex combination of the units in the donor pool, dropping some units as potential matches will sometimes improve the pre-intervention match. We consider six different donor pool restrictions: eliminating states with 10 times more or 10 times less 1) electricity consumption, 2) electricity generation and 3) GSP, and eliminating units with 5 times more or 5 times less 4) electricity consumption, 5) electricity generation and 6) GSP. We also examine the effect of dropping the weather indices CDD and HDD and, separately, dropping the GSP and population variables in generating the counterfactual. This yields 21 robustness checks (6 donor pool restrictions + no-donor pool restriction, and 2 covariate restrictions + no-covariate restriction). For brevity, we do not show the states and the associated weights that compose the counterfactual for each of the 21 cases. Wisconsin is selected in most of the 21 cases, generally with a weight exceeding 40%. The other states selected include Florida, Michigan, Minnesota, Nevada, Texas, and Virginia.

Figure I-4 compares electricity imports in the composite RGGI state with the 21 alternative synthetic controls. The solid black line measures imports in the composite RGGI state while the dashed lines measure imports in the synthetic controls. As with the original counterfactual, displayed in Figure I-2, electricity imports steadily rise in the composite RGGI over and above all of the synthetic controls. After the emissions cap is reduced, there is no quarter in which imports in a synthetic control exceed imports in the composite RGGI. Overall, these checks demonstrate that the large differences displayed in Figure I-2 are not due to idiosyncrasies in the synthetic control.

Case study 2: Using individual RGGI states as the treated unit

We now apply SCM to each state in the RGGI region as if it were an independently treated unit, while continuing to omit all other RGGI states from the donor pool. Table I-3 presents descriptive statistics of the characteristics of the nine RGGI states and their synthetic controls. Except electricity prices, the other matches are good for all states except the two least-populated states in the region (Delaware and Vermont) and the largest state (New York). In general, it is hard to construct close counterfactuals for the smallest and largest states, as there are relatively few states that can match their characteristics.

The results, displayed in Figure I-5, show six states (Delaware, Maine, Maryland, Massachusetts, New Hampshire, and New York) clearly increased their electricity imports compared to the synthetic controls. Electricity imports to Rhode Island fluctuate around the level of its synthetic control just after the introduction of the program, although the import level generally exceeds the synthetic control after the 2012. Electricity imports to Vermont did not substantially change until late 2014, when electricity imports increased rapidly; this late increase could nevertheless be due to RGGI policies, as it coincides with the reduction in the emissions cap. In fact, Vermont heavily relied on nuclear power up until 2014, with between 70% and 80% of electricity generated by nuclear power. However, nuclear power generation ceased after 2014 when the state switched to renewable sources of power generation. Since 2015, more than 50% of Vermont's electricity has come from hydraulic power generation, with wind power generation and biomass making up the balance. The dramatic fuel switch made in the first quarter of 2015 explains the abrupt increase Vermont's electricity imports. Connecticut is the only state that decreased imports after RGGI.

We apply here the robustness checks that were also applied in the case of the composite RGGI state. Figure I-6 displays these results. The solid black lines measure imports in the RGGI states and the dashed lines measure imports in the alternative synthetic controls. The alternative synthetic controls for Maine, Maryland, Massachusetts, New Hampshire, and New York continue to provide strong evidence that electricity influx into these states increased after the adoption of RGGI. The trend in Connecticut—the only state SCM suggests reduced imports—is generally but not consistently below the alternative synthetic controls; thus, there is not strong evidence that electricity imports into Connecticut decreased because of RGGI.

Table I-4 presents differences in electricity import levels between the treated and synthetic control units. These differences are averaged across the 21 alternative synthetic control counterfactuals. The first row is the (quarterly) average of the discrepancy prior to the establishment of RGGI. The values in the first row are close to 0 because SCM minimizes the discrepancy between treated and control units in the pre-intervention period. Overall, compared to their counterfactuals, electricity imports have increased following the establishment of RGGI in the composite state and every individual state. In addition, the average difference between the treated states and their counterfactuals has generally increased over time. The upward trend is prominent after the emissions cap was reduced in 2014.

Conclusions

This paper presents research on electricity leakage from the Regional Greenhouse Gas Initiative (RGGI). RGGI aims to reduce carbon emissions within participating states by limiting the emissions of fossil fuel power plants. If electricity generation from these plants is being shifted outside the region as a result of the initiative, creating a leakage problem, then this would be associated with increased electricity imports into the region. To date, there have been few empirical studies of the leakage problem, which we examined using data on electricity imports. We employed the synthetic control method (SCM) to measure the effect of RGGI on electricity imports, which develops a counterfactual for the region. Comparisons between the actual and counterfactual outcomes provide evidence that electricity imports increased following the establishment of RGGI, currently by 1 Twh per quarter. To examine heterogeneity in the effect of RGGI across individual states, we performed an additional case study that applied SCM on a state-by-state basis. The predicted outcome generally held up compared to numerous donor pool and covariate modifications.

A regional carbon emissions initiative may fail to achieve its goals if it suffers from a serious leakage problem. This study found a leakage effect is associated with RGGI. RGGI is an important step in reducing carbon emissions, but avoiding leakage will likely require a nationwide policy.

Table I-1. Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	Observations
Electricity Generation (Twh)	7.045	6.225	0.130	45.464	2499
Electricity Consumption (Twh)	6.435	5.808	0.420	40.562	2499
Electricity Import (Twh)	-0.610	1.994	-7.674	6.314	2499
Electricity Price	9.668	2.842	4.613	18.973	2499
Population (Million people)	5.051	5.306	0.388	30.962	2499
GSP (Billions of current dollars)	330.913	390.575	0.000	2716.655	2451
CDD	100.984	133.922	0.000	625.667	2499
HDD	419.596	379.995	0.000	1618.333	2499

Table I-2. Comparing Predictor Means Between Baseline Case and Other Donor Pool Units

	Composite RGGI	Synthetic RGGI	The other 32 States[1]	The other 37 States[2]
Population	9,085,940.80	9,041,267.00	3,646,311.50	4,375,556.16
GSP (Millions of current dollars)	647,112.26	565,671.00	203,169.40	248,405.40
CDD	64.40	144.60	103.59	110.95
HDD	475.56	318.70	421.87	407.44
Electricity imports (Twh)	0.37	0.35	-1.20	-1.10
Electricity Prices	14.16	8.33	7.12	7.31

Table I-3. Predictor Means for SCM: Individual Member State Case

	CT	Synthetic CT	Synthetic CT (21 cases AVG)	DE	Synthetic DE	Synthetic DE (21 cases AVG)	MA	Synthetic MA	Synthetic MA (21 cases AVG)
Population	2,701,620.00	3,220,567.00	3,013,488.85	662,193.60	1,690,762.00	905,076.05	5,118,906.00	5,568,677.00	5,614,042.46
GSP (Millions current USD)	226,610.30	208,548.20	203,770.98	55,377.38	83,514.56	50,818.55	367,481.10	332,273.00	352,084.27
CDD	57.63	76.57	60.63	106.48	127.06	98.56	47.90	76.39	80.81
HDD	484.63	495.08	515.44	364.96	397.09	463.02	517.90	509.39	489.87
AVG Electricity Import (Twh)	-0.04	-0.04	-0.04	0.33	0.32	0.31	0.90	0.90	0.90
Electricity Prices	15.28	8.36	7.23	10.38	7.50	7.26	14.74	8.08	8.05
	MD	Synthetic MD	Synthetic MD (21 cases AVG)	ME	Synthetic ME	Synthetic ME (21 cases AVG)	NH	Synthetic NH	Synthetic NH (21 cases AVG)
Population	4,307,697.00	4,420,005.00	4,736,684.92	1,053,317.00	1,159,071.00	1,078,060.28	1,036,515.00	1,162,497.00	1,073,555.46
GSP (Millions current USD)	280,673.60	273,739.30	293,075.46	48,497.44	60,342.24	60,074.84	60,010.25	60,568.22	60,812.75
CDD	99.29	119.03	103.22	21.15	45.50	59.19	32.04	47.84	63.97
HDD	377.02	376.12	378.60	648.63	622.88	573.65	602.69	595.26	562.47
AVG Electricity Import (Twh)	1.27	1.27	1.27	-0.43	-0.44	-0.43	-1.00	-1.00	-1.00
Electricity Prices	10.61	8.30	8.10	12.70	7.17	7.55	13.75	7.47	7.65
	NY	Synthetic NY	Synthetic NY (21 cases AVG)	RI	Synthetic RI	Synthetic RI (21 cases AVG)	VT	Synthetic VT	Synthetic VT (21 cases AVG)
Population	15,143,189.00	14,133,658.00	13,024,415.69	837,655.20	974,534.80	858,311.50	500,477.60	634,982.40	630,096.02
GSP (Millions current USD)	1,082,367.00	756,677.60	730,935.44	47,265.63	59,978.64	48,922.56	24,543.19	34,083.83	34,034.09
CDD	66.40	283.07	111.09	55.52	92.43	65.06	26.40	57.49	53.54
HDD	465.81	66.94	455.62	479.56	517.00	565.52	648.98	613.97	615.53
AVG Electricity Import (Twh)	0.19	0.13	0.18	0.11	0.10	0.11	-0.05	-0.05	-0.05
Electricity Prices	15.16	9.96	9.39	13.77	7.62	7.01	11.67	6.90	6.91

Table I-4. Differences in Electricity Imports Between Treated and Synthetic Control Units (Unit: Twh)

	Composite RGGI	CT	DE	MA	MD	ME	NH	NY	RI	VT
Total Electricity import levels (Before RGGI)	0.001	0.001	0.019	0.003	0.003	0.001	-0.003	0.014	0.002	0.001
Average electricity import per quarter (2009-2017.3)	0.690	-0.253	0.247	0.843	0.820	0.324	0.308	0.970	0.120	0.205
Average electricity import per quarter (2009-2013)	0.446	-0.238	0.260	0.524	0.502	0.173	0.275	0.684	0.080	0.085
Average electricity import per quarter (2014-2017.3)	1.016	-0.274	0.229	1.268	1.243	0.526	0.352	1.352	0.173	0.365

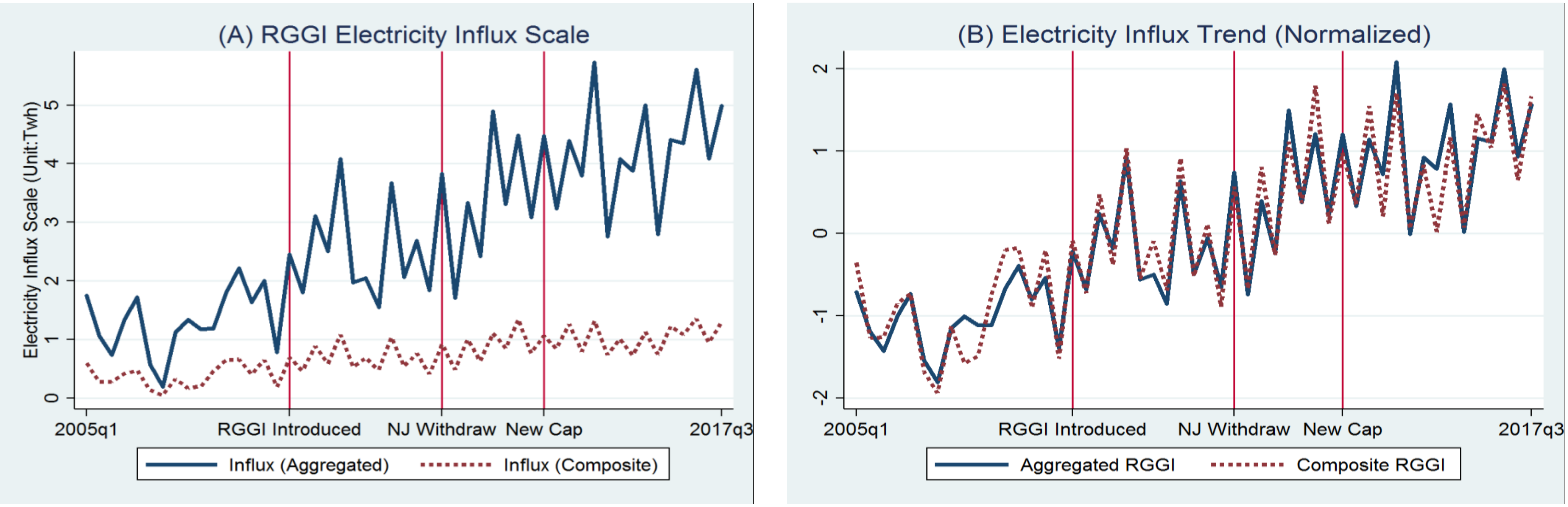

Figure I-1. Electricity Influx Scale and Trend in RGGI States.

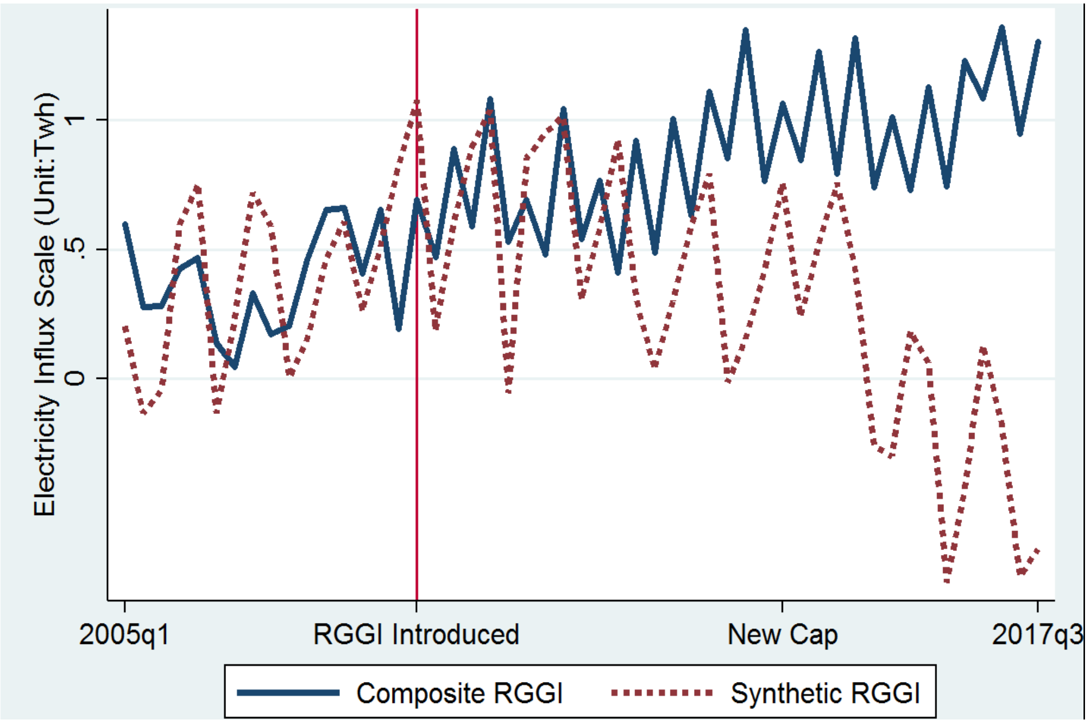

Figure I-2. RGGI and its Synthetic Electricity Imports

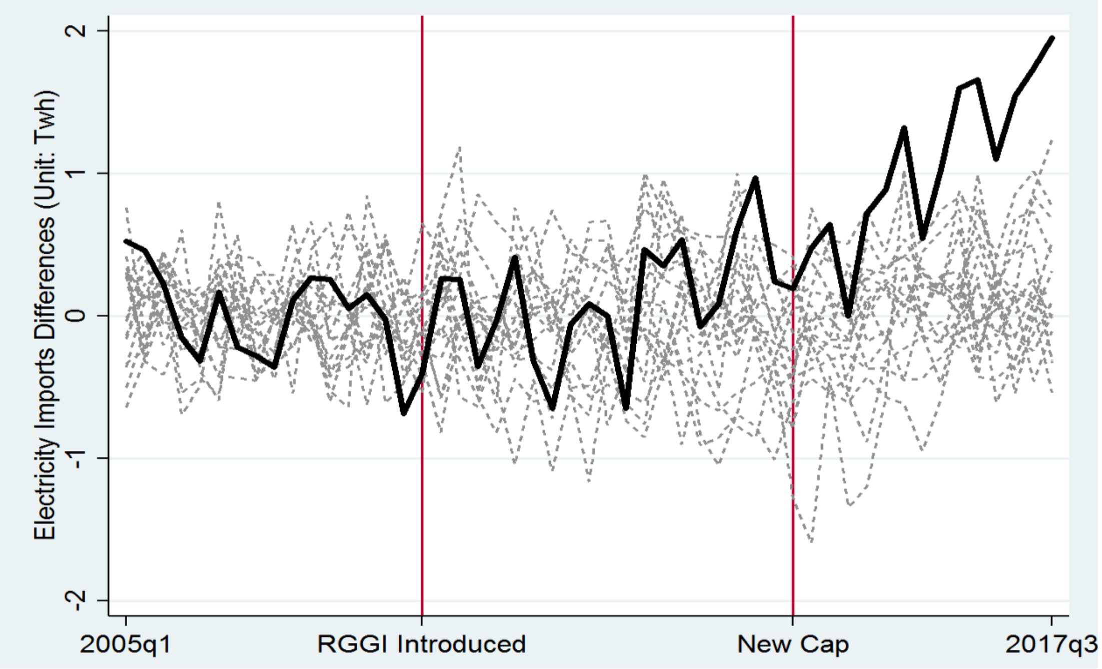

Figure I-3. Placebo Experiments for the Composite RGGI

Note: Solid lines represent for differences of electricity import level between RGGI and its synthetic control group, and dotted lines represent for differences of electricity import level between other donor pools and its synthetic control group.

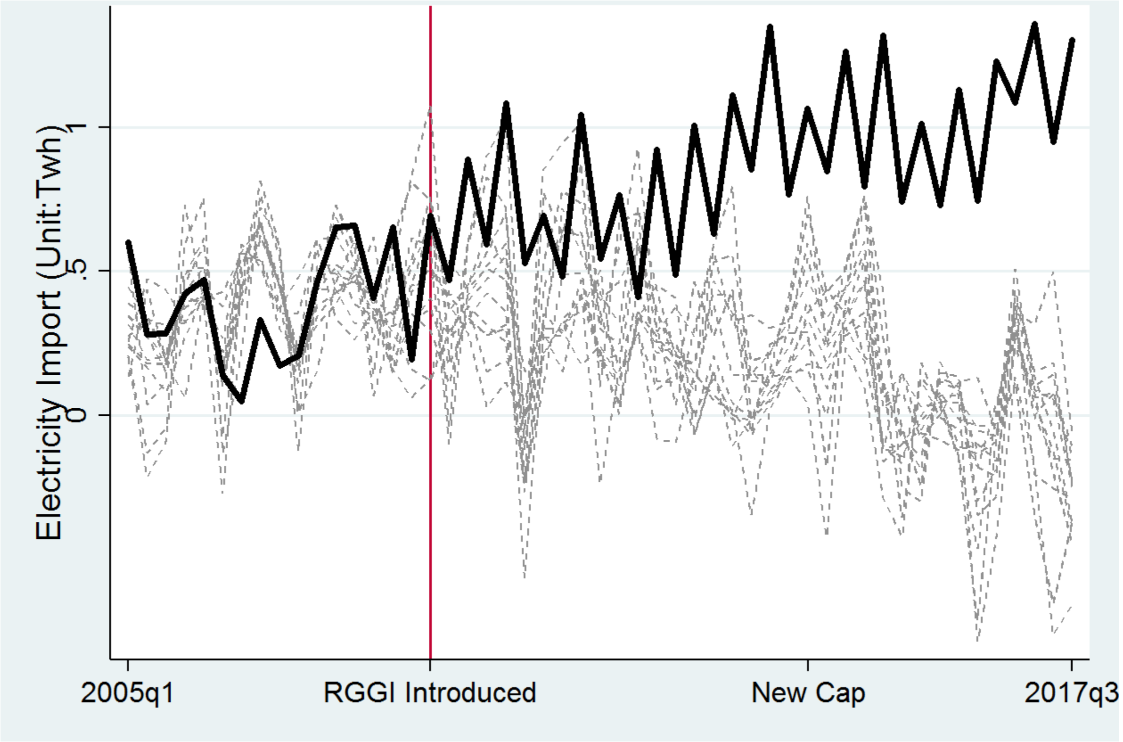

Figure I-4. Robustness Test for the Composite RGGI

Note: Solid lines represent for Composite RGGI, and dotted lines represent for synthetic RGGI from 21 robustness tests.

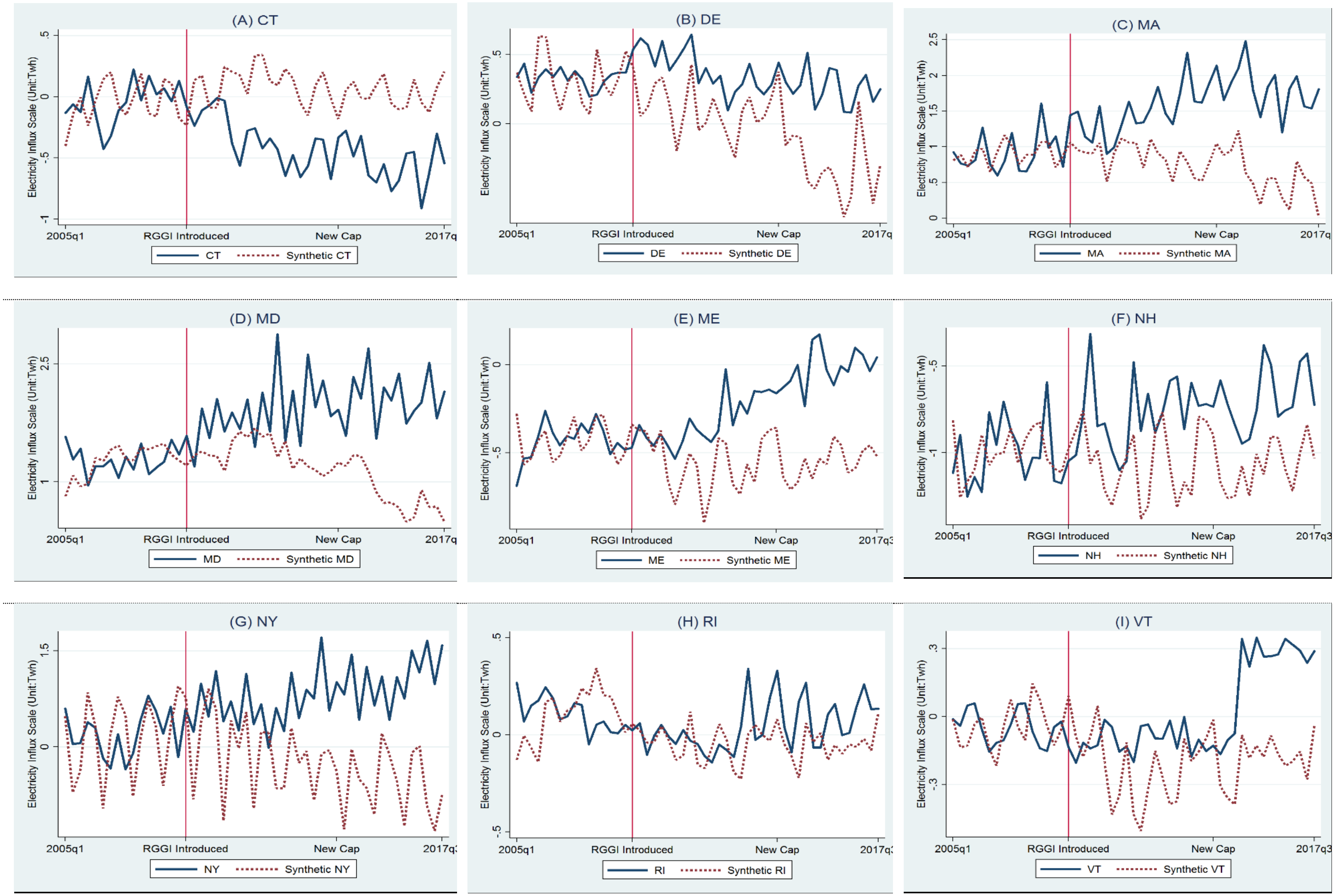

Figure I-5. RGGI Member States and Their Synthetic Electricity Imports

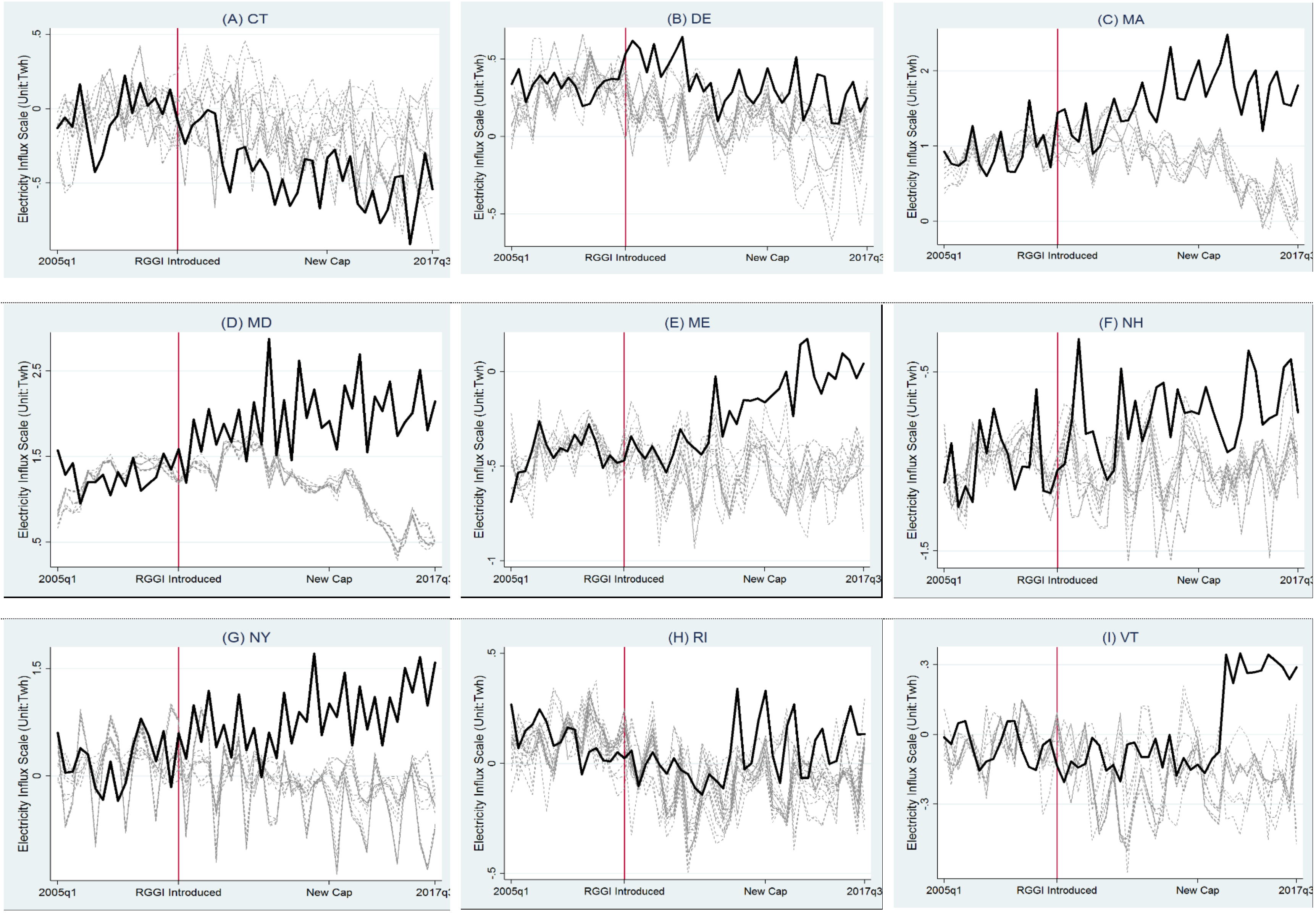

Figure I-6. Robustness Tests for Individual RGGI Member State

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CHAPTER II

THE IMPACT OF UNCONVENTIONAL DRILLING ON HOUSE PRICES IN CENTRAL OKLAHOMA

Abstract

Recent energy development may benefit some aspects of a regional economy (such as increased jobs), however there may also be negative impacts on the local environment such as noise and underground water contamination. I study one possible negative externality from recent energy development activity - namely, the impact of unconventional drilling on housing price. A prospective home buyer may want to avoid a place near sites that have been drilled using unconventional drill technologies. Adopting a hedonic price model, I estimate the avoided cost in two counties, Canadian and Payne, in Oklahoma. It may be possible that the relationship between an environmental pollutant source and housing price may be non-linear, and so I apply a semiparametric approach to deal with this possibility. The empirical results are consistent in terms of physical housing characteristics and locational aspects in all cases, with drilling activity having only a minimal effect in benchmark models. Further, the semiparametric estimation results support the findings that drilling activity has limited impacts on local housing prices.

Key words: Shale Gas, Hedonic Analysis, Housing Values, Environmental Costs, Semiparametric Estimation.

Introduction

Oklahoma has experienced a dramatic increase in unconventional shale gas drilling since the mid-2000s. From a regional economics perspective, this creates additional employment opportunities and likely generates positive externalities across many industries (for example, retail and construction). A significant amount of research has documented the associated regional economic impacts, including those for employment and income (Weber, 2012; Weber, 2014; Munasib and Rickman, 2015; Paredes *et al.*, 2015; Komarek, 2016; Maniloff and Mastromonaco, 2017). Additionally, several studies have examined negative externalities associated with the drilling increase, such as exacerbated educational attainment or declines in well-being in regions with high levels of drilling activity (Rickman *et al.*, 2017; Maguire and Winters, 2017).

There is a concern that a hydraulic fracturing contaminates underground water (Muehlenbachs *et al.*, 2015; Delgado *et al.*, 2016; Wrenn *et al.*, 2016). Thus, a prospective home buyer may want to avoid a place near sites that have been drilled using unconventional technologies. If this is the case, this preference would reveal itself in the house price. Several recent studies have found this to be the case. To date, at least, four papers (Muehlenbachs *et al.*, 2015); Gopalakrishnan and Klaiber, 2013; Delgado *et al.*, 2016; and Balthrop and Hawley, 2017) have examined this negative externality from energy development using a hedonic analysis.

Most of this previous literature focuses on the shale gas drilling impact on house prices in Pennsylvania, and one study examined same effect in Texas. Note that Oklahoma has lots of unconventional drilling activity (like Pennsylvania); alternatively, the state has a strong history of conventional oil production (like Texas). However, to our best knowledge, there are no similar studies for Oklahoma. Considering this, the aim of this study to fill in this research gap and estimate the impact of unconventional shale drilling on housing prices in Oklahoma.

Literature Review

How environmental quality influences housing price is a popular topic in hedonic analysis. In particular, newly introduced energy development activities – wind turbine installation and unconventional shale drilling – have recently attracted researchers' attention. On the whole, energy development activities generally have a negative impact on house prices. Our discussion start with two studies – Gibbons (2015) and Dröes and Koster (2016) – that examine the negative effect of wind farms on nearby house prices. Gibbons (2015) noted people's concerns with the negative visual impacts from nearby wind farm. This study used housing transaction data in England and Wales during 2001-2012, however, unlike traditional hedonic analysis, the inclusion of housing characteristics are optional, and instead the focus is on the visual impact from wind farms to house prices. Dröes and Koster (2016) explored same topic using house transaction data in Dutch for years 1985-2011. The result of this study support the one of Gibbons (2015). Those two studies both found that wind farms negatively influenced nearby housing prices.

Shale drilling activities incur concerns about noise and water contamination, and economic theory suggests that such environmental disutility would lower nearby housing prices. Several studies examined these negative externalities from shale gas development by applying hedonic analysis to the local housing market (Muehlenbachs *et al.*, 2015; Gopalakrishnan and Klaiber, 2013; Delgado *et al.*, 2016; and Balthrop and Hawley, 2017).

Among those, three papers (Muehlenbachs *et al.*, 2015; Gopalakrishnan and Klaiber, 2013; Delgado *et al.*, 2016) focus on a county (or counties) in Pennsylvania, but their results are varied. Gopalakrishnan and Klaiber (2013) is the first published research work examining shale drilling booms effect on house prices. Applying housing transaction data of Washington County in Pennsylvania, this study is performed using standard hedonic analysis. They consider housing characteristics (such as area, number of rooms, etc), and use geographical data for shale well and land use of its surrounding area. They found that property values are negatively impacted by nearby shale gas exploration activity. The time span of their housing transaction dataset covers 2008-2010. Regrettably, it is hard to argue that this analysis fully encompasses pre and post shale boom period, considering the fact that the shale boom started in the mid-2000s. Muehlenbachs *et al.* (2015) show that such an impact can be represented in two different ways. They consider a more comprehensive geographical area (36 counties in Pennsylvania) and time period (1995-2012). They found that the impact is large and negative for the nearby groundwater-dependent homes, while a small and positive impact is found for piped-water-dependent homes. This implies that people are concerned about water contamination caused by shale drilling, and this concern is captured in housing prices located near shale drilling sites. Delgado *et al.* (2016) studied same issue. In this study, two counties in Pennsylvania are considered in 2006-2012 and 2004-2013 for each county. They show that a robustly significant negative effect does not exist for unconventional gas wells on property values. Balthrop and Hawley (2017) empirically show that unconventional drilling has a negative influence on a housing prices for 2005–2011 in Tarrant County, Texas. Further, they estimate the conventional well impact as well, and do not find a statistically significant effect from a conventional well. This difference between conventional and unconventional impacts on the local housing market is an important part of their analysis.

In sum, relatively few papers provide empirical evidence that environmental concerns caused by unconventional shale drilling lower house prices. Three studies focus on Pennsylvania in the Marcellus shale play region, and one paper considered a single county in Texas. To date, there is no study on this issue for Oklahoma, even though the state of Oklahoma is one of the most heavily drilled regions for unconventional wells. This paper attempts to fill in this research gap. Referencing previous literatures and the economic theory of negative externality, we expect that house prices may be lowered where they are located near a well site or as a shale drilling has increased. However, we need to consider localized characteristics as well. Compared to Pennsylvania, Oklahoma has a long history for fossil fuel mining. This implies that people in Oklahoma may be less apprehensive to new energy development activity. Thus, the sign of the effect is theoretically ambiguous.

Study Region: Canadian County and Payne County in Oklahoma

Oklahoma is one of the leading states in the nation for unconventional drilling activity. During 2001-2016, a total of 4,644 shale wells were drilled across the state. Twelve counties including Canadian and Payne counties, had more than 100 shale well sites drilled during this time.[14] In this study we consider two counties – Canadian and Payne[15]. Canadian county is one of seven counties in the Oklahoma City metropolitan area. 673 shale wells were drilled during the period of analysis, giving the county the highest shale well density in Oklahoma (See Table II-1). Canadian county is composed of part of one major city (Oklahoma City) and 10 other communities including medium-sized cities such as Mustang, El Reno, and Yukon. Most of these are located in the eastern portion of the county. Our housing transaction data (from the county assessors' office) shows that purchases took place close to these 10 communities. Alternatively, most of the drilling activity took place in more remote western portion of the county (See Figure II-1).

Payne County had 173 shale wells from 2001-2016, making it the 9th highest shale well density in Oklahoma. Stillwater and Cushing are the biggest cities in the county and these two cities generate about 81% of all total housing transactions. Counter to the pattern seen in Canadian County, however, the well sites and residential area are more overlapping in nature[16] (See Figure II-2). Thus the two counties chosen offer different scenarios for the relationship between drilling site, and housing transaction in Oklahoma.

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[14] Twelve counties where have more than 100 wells are Canadian, Pittsburg, Hughes, Coal, Grady, Carter, Blaine, Wagoner, Payne, Stephens, Marshall, and Logan. Six counties (Atoka, Garvin, Johnston, Noble, Garfield, and Dewey) have more than 50 wells. 25 counties do not have any well.

[15] The population of Canadian county is 116,332 and the population of Payne County is 77,448 in 2010.

[16] It can be verified in our dataset. Mean value of the number of drillings within specific radius from a house for Payne County are bigger than the one of Canadian County. In addition, mean value of distance between a house and the nearest shale well in Payne County is smaller than its counterpart in Canadian County (See Table II-2).

Methodology

Hedonic price model

To examine how unconventional shale drilling impact on house price, we adopt a hedonic price analysis. Hedonic analysis is the most commonly used empirical methodology to study housing price evaluation. The spirit of hedonic analysis is that the value of an item can be estimated using its characteristics. Further, an implicit price of each attribute corresponds to the market equilibrium price for that attribute. This can be verified by a classical microeconomic foundation.

Consider the following hedonic price function: $P_i = f(H_i, Q_i)$, where P_i refers to the price of the i th house, H_i refers to the characteristics of the i th house (such as number of rooms, number of bathrooms, age, and so on), and Q_i implies a quality of neighborhood environment for the i th house.[17] Then $\frac{\partial P_i}{\partial Q_i}$ can be regarded as the marginal implicit price of the house with respect to environmental quality. This can be verified by assessing the traditional utility maximization problem (UMP). A utility maximizing consumer has a utility function $u(e, H, Q)$, subject to $w = e + P(H, Q)$, where e refers to expenditure for the consumer, H and Q are same as above, and w is consumer's income. Then, we have following Lagrangian: $L = u(e, H, Q) + \lambda(w - e - P(H, Q))$. Taking derivatives with respect to Q and e to get an optimized solution, then $\frac{\partial L}{\partial Q} = \frac{\partial u}{\partial Q} - \lambda \frac{\partial P}{\partial Q} = 0$, and $\frac{\partial L}{\partial e} = \frac{\partial u}{\partial e} - \lambda = 0$. Combining those two equations gives us $\frac{\partial P}{\partial Q} = \frac{\partial u}{\partial Q} / \frac{\partial u}{\partial e}$. Let WTP

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[17] In this study, environmental quality represents relationship between a house and unconventional drilling site.

be a willingness to pay for an individual who has utility level u^0 for the house with characteristics H and Q. In this case, WTP satisfies $u(w - WTP, H, Q) \equiv u^0$. Taking a total derivative of this equation, we can find that $\frac{\partial WTP}{\partial Q} = \frac{\partial u}{\partial Q} / \frac{\partial u}{\partial e}$. This condition exactly matches the implicit market price derived above: $\frac{\partial P}{\partial Q} = \frac{\frac{\partial u}{\partial Q}}{\frac{\partial u}{\partial e}} = \frac{\partial WTP}{\partial Q}$. That is, the marginal willingness to pay for an environmental quality is exactly the same as the implicit market price.[18]

Empirical estimation strategy: Benchmark model

Regarding the estimation of the hedonic price function, there is no consensus on the specific functional form to use. Further, Harvorsen and Pollakowski (1981) found that the true hedonic functional form is generally unknown. In spite of limited guidance on this issue, several different transformation equations are commonly used, including the semi-log, double log, and Box-Cox. However, we include many dummy variables in our analysis, thus, the semi-logarithmic equation is preferred over double log form. Considering this, we start with semi-logarithmic equation as our benchmark model. Then, we estimate a hedonic price using the specification:

$$\ln(P_{it}) = \sum_j \alpha_j X_{itj} + \beta Drilling_{it} + \gamma PW_{it} + \delta Dist_{it} + \zeta_t + \eta_i + \varepsilon_{it} \tag{1}$$

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[18] This approach incorporates the market demand price using the consumer's utility maximizing problem. For the supply side, the market price can be derived with the producer's profit maximizing problem. We assume that housing supply is fixed in this study.

where the variable X_{it} includes control variables in terms of housing characteristics such as the number of bedrooms, number of bathrooms, area square feet, and age of building. $Drilling_{it}$ denotes control variables related to drilling information. The variable PW_{it} is a dummy that takes a value of one if the house has public water supply available to it. The variable $Dist_{it}$ includes controls for distance between a house and major road or highway. The ζ_t are time dummies—specifically, year fixed effects. The η_i are community fixed effects. A community is a city or town in the two counties. For Canadian County, there are seven community districts: El Reno; Mustang; Okarche, Oklahoma City; Piedmont; Union City; and Yukon. For Payne County, there are sixteen community districts: Coyle; Cushing (Rural); Cushing (Town); Drumright; Glencoe (Rural); Glencoe (Town); Morrison; Oak Grove; Perkins (Rural); Perkins (Town); Ripley (Rural); Ripley (Town); Stillwater (Rural); Stillwater (Town); Yale (Rural); and Yale (Town)[19].

To examine the impact of drilling on housing price, previous studies — Gopalakrishnan and Klaiber (2013); Muehlenbachs *et al.* (2015); Delgado *et al.* (2016); and Balthrop and Hawley (2017) — use a count variable, called a ring, to represent the number of wells within a specific distance (i.e. a density measure). Again, Muehlenbachs *et al.* (2015) and Delgado *et al.* (2016) considered how far a well is located from a house. In this study, we adopt both types, *distance* and *density*, of variables to measure drilling effects. Take those into account, we can re-state our benchmark models as follows:

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[19] These communities are defined by each county assessor.

$$\ln(P_{it}) = \sum_j \alpha_j X_{itj} + \rho D_{it} + \gamma PW_{it} + \delta Dist_{it} + \zeta_t + \eta_i + \varepsilon_{it} \tag{2}$$

$$\ln(P_{it}) = \sum_j \alpha_j X_{itj} + \sigma CNT_{it} + \delta PW_{it} + \delta Dist_{it} + \zeta_t + \eta_i + \varepsilon_{it} \tag{3}$$

where D_{it} refers to the *distance* between a house and its nearest shale drilling well location. CNT_{it} refers to the *number* of drillings within a specific radius from a house. We consider three radius criteria (0-3,500 ft; 3,501-5,000 ft; and 5,001-6,500 ft)[20].

Additional estimation: Semiparametric approach

To verify the robustness of the benchmark model results, we incorporate a semiparametric estimation approach. Although the physical housing characteristics are usually well explained by a linear relationship, some of attributes may not be identified by linear estimation. For example, Ekeland *et al.* (2004) argue that nonparametric estimations may better explain hedonic price model, due to an existence of nonlinearities between house prices and their associated attributes. On the other hand, nonparametric techniques have some disadvantages such as lesser precision and requiring a lot of observation (known as *curse of dimensionality*), although nonparametric modelling shows good robustness (Robinson, 1988). Anglin and Gencay (1996) applied semiparametric approach to estimate a hedonic price function. They argue that the semiparametric approach shows better empirical results than parametric model. Returning

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[20] Previous studies introduced similar, but slightly different, distance standards. Muehlenhachs *et al.* (2015) uses1km, 1.5km, and Gopahakrishnan and Klaiber (2014) considered 0.75 mile and 2miles. The range of Delgado *et al.* (2016) is 1mile-4miles. Balthrop *et al.* (2017) uses 0-3,500 ft, 3,501-5,000 ft, and 5,001-6,500 ft.

the effects of unconventional drilling on housing prices, Delgado *et al.* (2016) applied this semiparametric specification, and showed that a nonlinear relationship exist between housing price and unconventional drilling site. Applying this empirical strategy, physical housing characteristics such as number of bedrooms are specified in the linear part in the model, while the control for unconventional drilling well is modelled in the non-linear part.

To model a partially linear specification as our robustness test strategy, consider a following generalized partial linear equation,

$$y = X\Gamma + f(z) + \varepsilon \tag{4}$$

where y denotes house price, X is a control variable vector for physical housing attributes (e.g. number of rooms, age of building etc), and *z* is an impact from a drilling site. In this partially linear model, the unknown function $f(z)$ is determined by the data, and the rest of the controls are specified linearly. To estimate this, we adopt Robinson (1988)'s double residual model. To discuss how to derive a double residual estimator, we start with taking a conditional expectation (only for *Z*) in the equation (4). Then we get

$$E(y|Z) = E(\mathrm{X}|Z)\Gamma + f(z) + E(\varepsilon|Z). \tag{5}$$

Again, combining those equation (4) and equation (5) leads to

$$y - E(y|Z) = (X - E(X|Z))\Gamma + \varepsilon. \tag{6}$$

An advantage of this approach is that the unknown function $f(z)$ can be removed as equation (6) demonstrates. It can then restated as,

$$\tilde{y} = \tilde{x}\Gamma + \tilde{\varepsilon}, \text{where } \tilde{a} = [a - E(a|Z)]. \tag{7}$$

Equation (7) is exactly a linear equation form. That is, Γ is a consistent estimator, and we can estimate it by using a traditional OLS estimator, thus

$$\hat{\Gamma} = (\widetilde{\varepsilon_2}'\widetilde{\varepsilon_2})^{-1}\widetilde{\varepsilon_2}'\widetilde{\varepsilon_1}. \tag{8}$$

Then, by the nonparametric regression estimation for each of error term (ε_1 & ε_2), and replacing those estimates into equation (8), $\hat{\Gamma}$ can be estimated (note that ε_1 implies $(y - E(y|Z))$, and ε_2 implies $\left(X - E(X|Z)\right)$). Finally, we can obtain unknown function $f(z)$ by non-parametric regression (y- $X\hat{\Gamma}$) on Z.

Data

House transaction data

Our house transaction data were provided by the county assessor's office from both Payne and Canadian Counties. The dataset is composed of characteristics of house, sales price and date of sale, and precise geographic location (address or latitude/longitude coordinates). The housing characteristics include attributes such as the number of bedrooms and bathrooms, the year in which the house was built, living area in square feet, indicators for town of residence, indicators for basement, garage, fireplace, and central air. The time period of the dataset for both counties covers the years from 2001 to 2016. This time span encompass the pre and post shale gas drilling period (note that the peak drilling years were 2013 and from Table II-1). The raw data from the county assessor's office contained some observations with missing data or inappropriate location information. After removing these observations, our housing transaction sample for Canadian and Payne counties have 17,757 and 9,730 observations, respectively. Summary statistics are represented in Table II-2.

Drilling and the other geographical data

Historical unconventional drilling data was obtained from the Oklahoma Geological Survey[21]. This dataset includes precise geographical information (latitude and longitude coordinates) and date information for the completion of each shale drilling site. Using this information, a *distance* between a house and a well is calculated.[22] Under our modeling approach, this control can then explain how a house price can be influenced by the nearest distance to a drilling site. Based on the distance information, the number of drilling sites within a specific radius from a house are counted. Previous studies applied different, but relatively similar distance standards. Following Balthrop and Hawley (2017), we applied three different distances cases (0-3,500 ft; 3,501-5,000 ft; and 5,001-6,500 ft) in this study.[23] This control can explain how a house price can be influenced by the *density* of drilling near a house's location.

We also consider conventional wells in our analysis to assess if differences exist between the impacts for conventional and unconventional wells. Historical conventional drilling data was gathered from the Oklahoma Corporation Commission (OCC)[24]. The dataset from OCC contains all drilling logs from wells drilled since 1900. We eliminate

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[21] http://www.ou.edu/content/ogs/data/oil-gas.html

[22] All the distance information are valid only when the shale gas well was drilled prior the housing transaction date.

[23] Unlike the other three previous papers on Pennsylvania locations, Balthrop and Hawley (2017) studied Dallas Fort Worth area where has long oil mining history, similar to Oklahoma.

[24] http://www.occeweb.com/og/ogdatafiles2.htm

unconventional drilling (Directional Hole and Horizontal Hole) observations from the well completion master file to construct a conventional well dataset.

The other spatial data components are information on the distance between a house and a major highway and local road, and the accessibility of public water supply. Using a Shape file from the Oklahoma department of transportation[25] a distance is calculated in ArcGIS software. The public water accessibility was created using a shape file from the Oklahoma water resource board[26]. This variable takes on a value of one if the housing location overlaps with public water provision within the state. Roughly 93% of transacted houses in Canadian County are located inside the public water supply region. That is, about 93% Houses in Canadian County have public water accessibility. In Payne County, 81% of houses are connected to the public water supply. This variable is important because of environmental concerns about drilling sites and possible water contamination. If a property is located on a site not served by public water, there may be more concerns about the impact of nearby drilling (since the property likely maintains their own well)[27].

Results and Discussion

As described in the methodology section, our estimation model includes controls for shale well information, physical characteristics of the house, and information related to

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[25] http://www.okladot.state.ok.us/hqdiv/p-r-div/maps/shp-files

[26] http://www.owrb.ok.gov

[27] Based on the importance, previous studies (Muehlenhachs *et al.*, 2015; Gopahakrishnan and Klaiber, 2014; and Delgado *et al.*, 2016) are considered this measure in their studies.

location such as distance to highway and downtown. In general, estimates accord closely with theoretical expectations. For instance, the more bedrooms (or bathrooms), the higher the sale price. Further, both Canadian and Payne Counties show very similar estimation results to each other. Overall, the estimation results generally suggest that unconventional well impacts are not significant. We will document the case that considers community-level fixed effects for each of the two counties.

Baseline regression: Housing characteristics and locational components

Results of baseline regressions are estimated models in equation (2) and (3). The house transaction data include some suspicious entries, such as extremely low purchase prices (e.g. minimum value of housing price is $500 in Canadian County and $25 in Payne County). We suspect that some of house transaction cases could be not appropriately reported or transacted. Even though they are actual transacted price, it is hard to say that they are reflective of a real value of the houses. Considering this, we estimate our baseline regression models excluding observations with housing prices less than $5,000. However, regardless of whether these low housing price are excluded, the estimation results are not very different from the dataset of all observations. Thus, we will discuss the estimation results excluding the low housing prices. Baseline regression results are represented in Table II-3 (unconventional drilling well) and Table II-4 (conventional drilling well). And the estimation results with including all dataset are represented in Table II-Appendix-1 (unconventional drilling well) and Table II-Appendix-2 (conventional drilling well).

In general, the estimation results for the physical characteristics of a house are consistent with the results from most hedonic studies dealing with housing prices. Increasing the number of bedrooms and bathrooms raises the house price, other things being equal. More specifically, one extra bedroom lead to increase of housing price roughly 2.8-3.5% in Canadian County and 3.3-4.1% in Payne County. Similarly, one extra bathroom increases housing price 15.9-16.6% in Canadian County and 13.2-15.7%. On the other hand, the sale price is decreased around 0.6% in Canadian County and 0.4% in Payne County by each additional year of age, with older houses, leading to lower prices (*ceteris paribus*). Regarding the public water supply variable, if a house is located in public water piped area, the price of the house is roughly 3% higher than others in Canadian county. In Canadian county about 93% of house are linked in this public water supply region. In Payne County, the public water supply rate is 81%, and estimation results demonstrate that there is no impact of public water supply on the housing price in Payne County. One possibility since rural wells are relatively more common in Payne County, no premium exists for public water. Still, the difference between Payne and Canadian County in this regard are interesting, and require additional insight.

Estimation results for the control variables regarding geographical distances are also interesting. In general, the results on this category of independent variables are very similar to each other between the two counties, with one exception. This exception is the distance to center of the biggest city in the county; Stillwater or Oklahoma City. The Payne County results suggest that having a house located further away from Stillwater, results in a higher housing price. Alternatively, in Canadian County, housing prices do not reflect a significant effect in terms of the distance to Oklahoma City. One possibility is that Stillwater is a college town, with a heavy percentage of houses located in the city limits dedicated to student living. Houses located just outside of the town (in suburban Stillwater) would be larger, and more typically dedicated to family-oriented residences. This may lead to an increase in housing price as houses are located farther away from the center of the town. Positive signs for the non-square term (distance to highway or the nearest center[28]) implies that a house price is increased as the distance grows *ceteris paribus*. However, after a certain point this trend may change. For example, if we have a highway very close to our house, the noise and traffic congestion may reduce our welfare. Thus people do not prefer a very close interstate or highway. However, if highways are located too far from a house, travel to other towns and regions becomes too inconvenient. In addition, most major highways or interstates go through big cities rather than small towns. Considering those issue, the sign of the non-square term and the square term for highway are a reasonable result. But note that the value is very small (less than 0.1 % per mile).

Baseline regression: The impact of unconventional drilling well

Four variables – the nearest distance to shale well from a house and the number of unconventional drilling well within specific distances (0-3,500 ft; 3,501-5,000 ft; and 5,001-6,500 ft) – are used to model the impact of unconventional drilling on housing price. Unlike estimation results for physical and locational condition, discussed above,

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[28] Except Oklahoma City, the farther from the center may incur some inconvenience such as longer travel distance etc.

the estimation results for this category of variables are not significant in general. The nearest distance between a house and its nearest shale well are statistically insignificant in both Canadian and Payne counties. Only one estimate value (number of unconventional drilling wells between 5,001 and 6,500 ft) for Canadian county is significant, and its sign is negative. However, considering all the other estimation results regarding unconventional drilling impact, it is hard to argue that increasing the number of unconventional drilling wells between 5,001 and 6,500 ft would lower housing price. As we briefly noted, environmental quality is not necessarily linearly related with housing price (Ekeland *et al*., 2004 and Anglin and Gencay, 1996). Further, Delgado *et al.* (2016), examining the same issue in Pennsylvania, argued that a nonlinear relationship existed in one of the two counties in their study regions. We will discuss this issue further in the semiparametric estimation results section, following the discussion of conventional well impacts in the next section.

Baseline regression: Conventional drilling well impact and additional estimation

Unlike Pennsylvania, Oklahoma has a long energy mining history (See Figure II-3). Practically, Oklahoma residence may less pay attention to unconventional drilling wells, as many people may fail to recognize the difference between conventional drilling and unconventional drilling. Thus, examining the reaction to conventional drilling may be beneficial when discussing the possible impact of unconventional drilling. We estimate the impact using the same regression model as for the unconventional drilling well cases, and the results are represented in Table II-4. The estimation results show that all the physical housing characteristics and locational components are very similar to those for the unconventional drilling well estimation results in both counties. However, there is a conflicting result for the drilling impact explanatory variables. For Canadian County there is a negative significant effect from the nearest well distance variable. Although the other drilling control variables estimates do not show a significant effect, this is in direct contrast to the results from the unconventional drilling well (where no impacts were found) and compared to Payne County as well. Payne County shows the exact reverse effect compared to Canadian County. We will discuss this result further in the semiparametric estimation results section that follows.

On the other hand, some of the distance between a house and its' nearest unconventional drilling well is over 40 miles. Intuitively, being over 10 miles from a well should not have any impact on housing price. Taking this into account, we additionally estimates with change several conditions. To do this, we first allocate forcefully the distance variable as a missing if the distance larger than 25 miles. Then we apply same way with 10 miles standard. The estimation results are in Table II-Appendix 3 (Canadian County) and Table II-Appendix 4 (Payne County). All of the results for the physical housing characteristics are in accordance with the results from benchmark regression. In addition, the nearest distance to unconventional drilling well are not significant in any of the cases.

Semiparametric estimation results

Estimation results for the linearly modelled portion of the semiparametric approach are reported in Table II-5. All results for the housing characteristics are very close to those for the baseline regression models in Table II-3 and Table II-4. Now, we switch to a further discussion of the drilling impact. Previous studies argue for the possibility of a non-linear relationship between an environmental pollutant source and a housing price (Ekeland *et al*., 2004 and Anglin and Gencay, 1996). Most of all, Delgado *et al.* (2016) provide evidence of a nonlinear relationship between shale drilling activity and property value in their study region by applying semi-parametric estimation. Figure II-4 and Figure II-5 are the semiparametric results for the effect of distance to the nearest conventional (or unconventional) well on the log of housing price. For Canadian County, the distributions of both unconventional drilling and conventional drilling well make it difficult to distinguish whether a nonlinear relationship exists. For Payne County, the results show more vague relationship. Based on the semiparametric estimation, both counties do not show an evident relationship between housing price and distance to drilling site. We provide the Hardle-Mammen test results in Table II-5. The null hypothesis for this test is that the parametric and non-parametric fits are not different, and rejecting the null implies that the polynomial adjustment is suitable, (rather than a linear specification). Except for one case (conventional drilling well in Canadian County), we reject the null hypothesis at 90%, thus, we may argue for the non-linear relationship between a housing price and its' nearest drilling site. Moreover, the test statistics from both type of wells in Payne County are strongly rejected at the 99% level. Based on this we may argue that we do not find consistent and significant evidence to suggest that drilling activity significantly influences nearby housing price in both Canadian and Payne Counties.

Conclusions

In this study, we examined the existence of externalities from unconventional drilling on housing prices in two Oklahoma counties. In addition, considering the long tradition of resource mining in Oklahoma, we examined the impact from conventional drilling as well. The empirical results are consistent with prior hedonic models regarding the influence of physical housing characteristics and locational aspects in all cases. However, the results for all specifications in terms of drilling activity find minimal significant effects. To examine a possible non-linear relationship between housing price and drilling site, we provide a semiparametric estimation. The results from this empirical strategy support the absence of consistent evidence of any effect from drilling site on housing price. These results are in conflict with those from several earlier studies (Muehlenbachs *et al*., 2015; Gopalakrishnan and Klaiber, 2013; and Balthrop and Hawley, 2017). However, these results are in line with Delgado *et al.* (2016), which is the only study to use a non-linear empirical specification on this topic. One possibility for the lack of significance associated with any of the unconventional drilling variables is that countervailing impacts are at work: negative ones associated with environmental or scenic concerns and positive ones associated with possible gains from mineral rights. This study did not explicitly consider such mineral rights. It may be that potential gain from mineral rights may have a positive influence on housing price.

Several limitations exist for this study. Although we compare the results between unconventional drilling and conventional drilling, these are aspects associated with shale well activity that are not fully accounted for in our model. Gopalakrishnan and Klaiber (2013) argues that a prospective consumer may become aware of shale drilling through one of four paths—online open database, increased truck traffic, noise from drilling, or the visible aspect of drilling. Their study region is Pennsylvania, which has experienced a rapid increase in unconventional drilling since the mid-2000s, however, they do not have a comparatively long history of conventional crude oil mining. Because of this lack of history with conventional drilling, a prospective home buyer in Pennsylvania may be wary of environmental changes associated with shale gas drilling. Alternatively, Oklahoma has a long tradition of mining crude oil, and local residents may be accustomed to the sights of drilling activity or unable to distinguish between conventional and unconventional sites. This can be restated as people in Oklahoma having less sensitivity to unconventional drilling in comparison to Pennsylvania.[29] This implies that the extent of the impact may be comparatively small in Oklahoma than Pennsylvania, which may be one reason for the lack of results in this analysis.

The empirical results from this study suggest the effect of unconventional drilling does not have a clear impact on housing prices. However, the boom of unconventional drilling started less than 10 years ago (particularly in the counties considered here). The (lack of) results call for additional study over a longer time and more areas to observe potential exclusive effects from unconventional drilling. In terms of policy implications,

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[29] Wrenn *et al.* (2016) studied people's risk averting behavior on the unconventional shale drilling. Using consumer's water bottle purchasing data in Pennsylvania, they found that expenditures associated with risk-averting practices in Pennsylvania shale region was bigger than 19 million USD for the year 2010.

the minimal impact of drilling on housing prices in these two Oklahoma counties suggests that revamping property tax policy out of concern for oil and gas effects is likely not necessary. However, policy maker need to investigate further the possible negative health effects from environmental contamination associated with this activity.

Table II-1. Number of Unconventional Drilling and Transaction of House

Year	Canadian County		Payne County	
	Wells	House Transactions	Wells	House Transactions
2001	0	1	0	222
2002	0	3	0	285
2003	0	0	0	293
2004	0	4	0	424
2005	0	2	0	451
2006	0	5	0	480
2007	1	5	0	493
2008	20	1,747	0	509
2009	37	1,830	0	529
2010	59	1,579	2	508
2011	77	1,559	1	510
2012	132	1,813	14	728
2013	135	2,104	22	888
2014	85	2,324	77	1,012
2015	82	2,344	40	1,093
2016	45	2,437	17	1,305
Total	673	17,757	173	9,730

Note: 1. Numbers of house transactions are based on after data trimming of Assessor's Office raw data.

Sources: Drilled Well (the Oklahoma Geological Survey); House Transactions (the assessors' office in each county)

Table II-2. Summary Statistics

Variable	Canadian County					Payne County				
	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
Public Water	17757	0.93	0.26	0	1	9730	0.81	0.39	0	1
Distance to Nearest Road	17757	417.23	409.14	0.00	4152.35	9730	383.73	440.22	3.79	3157.57
Distance to Nearest Hway	17757	1155.47	1233.68	0.03	10652.10	9730	1136.68	1132.32	14.12	7172.08
Distance to Nearest Well (Un-conv. Drilling)	17748	12.63	6.24	0.26	47.87	7940	8.30	8.60	0.09	40.87
Count in Ring I (Un-conv. Drilling)	17757	0.00	0.02	0	1	9730	0.04	0.32	0	8
Count in Ring II (Un-conv. Drilling)	17757	0.00	0.02	0	1	9730	0.04	0.33	0	6
Count in Ring III (Un-conv. Drilling)	17757	0.00	0.02	0	1	9730	0.09	0.57	0	10
Distance to Nearest Well (Conv. Drilling)	17757	1.85	1.20	0.01	8.25	9730	2.21	1.12	0.03	6.98
Count in Ring I (Conv. Drilling)	17757	0.16	0.44	0	5	9730	0.07	0.41	0	10
Count in Ring II (Conv. Drilling)	17757	0.15	0.42	0	5	9730	0.10	0.37	0	6
Count in Ring III (Conv. Drilling)	17757	0.21	0.52	0	6	9730	0.14	0.44	0	6
Sale Price	17757	159960.7	169233.5	500	4,700,000	9730	125332.3	126248.7	25.00	6,100,000
Age of Bldg	17757	25.88	29.44	0	2010	8628	34.78	28.31	0	120
# of BATH	17603	1.95	0.55	0	6	9727	1.71	0.93	0	8
# of Beds	17562	3.10	0.75	0	38	8603	3.04	0.94	0	12
Area	17757	1754.66	664.64	72	8585	8618	2162.29	1036.99	0	11011.16

Sources: Drilled Well (the Oklahoma Geological Survey & the Oklahoma Corporation Commission); House Transactions (the assessors' office in each county); Road Information (the Oklahoma Department of Transportation); Public water accessibility (the Oklahoma water resource board)

Table II-3. Benchmark Model Results for Unconventional Drilling Well

Ln (Sale Price)	Canadian County				Payne County			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dist to the nearest	0.001	-	-	-	-0.003			-
drilling site	(0.002)	-	-	-	(0.003)			-
Ring Boundary I	-	-0.591	-	-	-	0.008		-
(0-3500 ft)	-	(0.551)	-	-	-	(0.032)		-
Ring Boundary II	-	-	0.203	-	-		0.021	-
(3501-5000 ft)	-	-	(0.163)	-	-		(0.034)	-
Ring Boundary III	-	-	-	**-0.269***	-			-0.009
(5001-6500 ft)	-	-	-	(0.150)	-			(0.017)
Bedrooms	**0.034*** **	**0.035*** **	**0.034*** **	**0.028** **	**0.041** **	**0.033** **	**0.033** **	**0.033** **
	(0.012)	(0.012)	(0.012)	(0.012)	(0.016)	(0.015)	(0.015)	(0.015)
Bathrooms	**0.166*** **	**0.166*** **	**0.166*** **	**0.159*** **	**0.157*** **	**0.132*** **	**0.132*** **	**0.132*** **
	(0.040)	(0.040)	(0.040)	(0.038)	(0.020)	(0.020)	(0.020)	(0.020)
Age of Building	**-0.006** **	**-0.006** **	**-0.006** **	**-0.006** **	**-0.004*** **	**-0.004*** **	**-0.003*** **	**-0.004*** **
	(0.003)	(0.003)	(0.003)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
Area	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Public Water Supply	**0.032** **	**0.032** **	**0.032** **	**0.024** **	0.026	0.057	0.058	0.053
	(0.014)	(0.013)	(0.013)	(0.012)	(0.053)	(0.048)	(0.047)	(0.047)
Dist to Biggest City	0.007	0.003	0.006	0.006	**0.044*** **	**0.051*** **	**0.051*** **	**0.051*** **
(OKC or Stillwater)	(0.014)	(0.014)	(0.014)	(0.013)	(0.011)	(0.010)	(0.010)	(0.010)
Dist to the	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
biggest city_sq	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
D_Nearest Highway	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_Highway_sq	**-0.000*** **	**-0.000*** **	**-0.000*** **	**-0.000*** **	**-0.000*** **	**-0.000*** **	**-0.000*** **	**-0.000*** **
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_nearest_road	**0.000***	**0.000***	**0.000***	0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_road_sq	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Community FE	Y	Y	Y	Y	Y	Y	Y	Y
R-sq	0.596	0.596	0.596	0.602	0.442	0.457	0.457	0.457
adj. R-sq	0.595	0.595	0.595	0.601	0.439	0.454	0.454	0.454
N	16848	16850	16850	16785	6730	8227	8227	8227

Robust Standard errors in parentheses

* p<0.1 ** p<0.05 *** p<0.01

Note: All the models in this baseline regression are estimated without housing price under $5,000

Table II-4. Benchmark Model Results for Conventional Drilling Well

Ln (Sale Price)	Canadian County				Payne County			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dist to the nearest	-0.006**	-	-	-	0.039***	-	-	-
drilling site	(0.003)	-	-	-	(0.008)	-	-	-
Ring Boundary I	-	0.008	-	-	-	0.004	-	-
(0-3500 ft)	-	(0.007)	-	-	-	(0.036)	-	-
Ring Boundary II	-	-	0.009	-	-	-	-0.070***	-
(3501-5000 ft)	-	-	(0.007)	-	-	-	(0.027)	-
Ring Boundary III	-	-	-	-0.001	-	-	-	-0.001
(5001-6500 ft)	-	-	-	(0.005)	-	-	-	(0.020)
Bedrooms	0.037***	0.037***	0.029**	0.029**	0.031**	0.033**	0.032**	0.033**
	(0.012)	(0.012)	(0.012)	(0.012)	(0.015)	(0.015)	(0.015)	(0.015)
Bathrooms	0.168***	0.168***	0.160***	0.160***	0.136***	0.132***	0.133***	0.132***
	(0.042)	(0.042)	(0.040)	(0.040)	(0.020)	(0.020)	(0.020)	(0.020)
Age of Building	-0.007**	-0.007**	-0.006**	-0.006**	-0.003***	-0.004***	-0.003***	-0.004***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
Area	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Public Water Supply	0.036***	0.036***	0.029**	0.029**	0.062	0.055	0.062	0.055
	(0.014)	(0.014)	(0.012)	(0.012)	(0.048)	(0.048)	(0.048)	(0.048)
Dist to Biggest City	0.007	0.007	0.010	0.010	0.045***	0.051***	0.052***	0.051***
(OKC or Stillwater)	(0.014)	(0.014)	(0.013)	(0.013)	(0.011)	(0.010)	(0.010)	(0.010)
Dist to the	0.000	0.000	-0.000	-0.000	0.000	0.000	0.000	0.000
Biggest City_sq	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
D_Nearest Highway	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_Highway_sq	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_nearest_road	0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_road_sq	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Community FE	Y	Y	Y	Y	Y	Y	Y	Y
R-sq	0.590	0.590	0.598	0.597	0.458	0.457	0.457	0.457
adj. R-sq	0.590	0.589	0.597	0.597	0.455	0.454	0.454	0.454
N	17241	17241	17145	17145	8227	8227	8227	8227

Robust Standard errors in parentheses

* p<0.1 ** p<0.05 *** p<0.01

Note: All the models in this baseline regression are estimated without housing price under $5,000

Table II-5. Results of Linear Part in Semiparametric Estimation

	Canadian County		Payne County	
Ln (Sale Price)	Unconventional Drilling Well	Conventional Drilling Well	Unconventional Drilling Well	Conventional Drilling Well
Bedrooms	**0.034*** **	**0.035*** **	**0.034** **	**0.032** **
	(0.012)	(0.012)	(0.016)	(0.015)
Bathrooms	**0.160*** **	**0.166*** **	**0.161*** **	**0.136*** **
	(0.037)	(0.040)	(0.020)	(0.020)
Age of Building	**-0.006** **	**-0.006** **	**-0.003*** **	**-0.003*** **
	(0.003)	(0.003)	(0.000)	(0.000)
Area	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **
	(0.000)	(0.000)	(0.000)	(0.000)
Public Water Supply	**0.037*** **	**0.033** **	0.033	0.058
	(0.014)	(0.013)	(0.054)	(0.048)
Dist to Biggest City	0.018	0.006	**0.055*** **	**0.055*** **
(OKC or Stillwater)	(0.013)	(0.014)	(0.012)	(0.011)
Dist to Biggest City_sq	-0.000	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.001)	(0.001)
D_Nearest Highway	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **
	(0.000)	(0.000)	(0.000)	(0.000)
D_Highway_sq	**-0.000*** **	**-0.000*** **	**-0.000*** **	**-0.000*** **
	(0.000)	(0.000)	(0.000)	(0.000)
D_nearest_road	0.000	0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
D_road_sq	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Year FE	Y	Y	Y	Y
Community FE	Y	Y	Y	Y
R-sq	0.563	0.596	0.381	0.418
adj. R-sq	0.562	0.595	0.377	0.415
N	16846	16852	6728	8225
Critical value (95%): 1.96				
Critical value (90%): 1.645				
Hardle-Mammen Test Statistics	**1.824**	0.787	**3.792**	**8.900**

Robust Standard errors in parentheses
* p<0.1 ** p<0.05 *** p<0.01

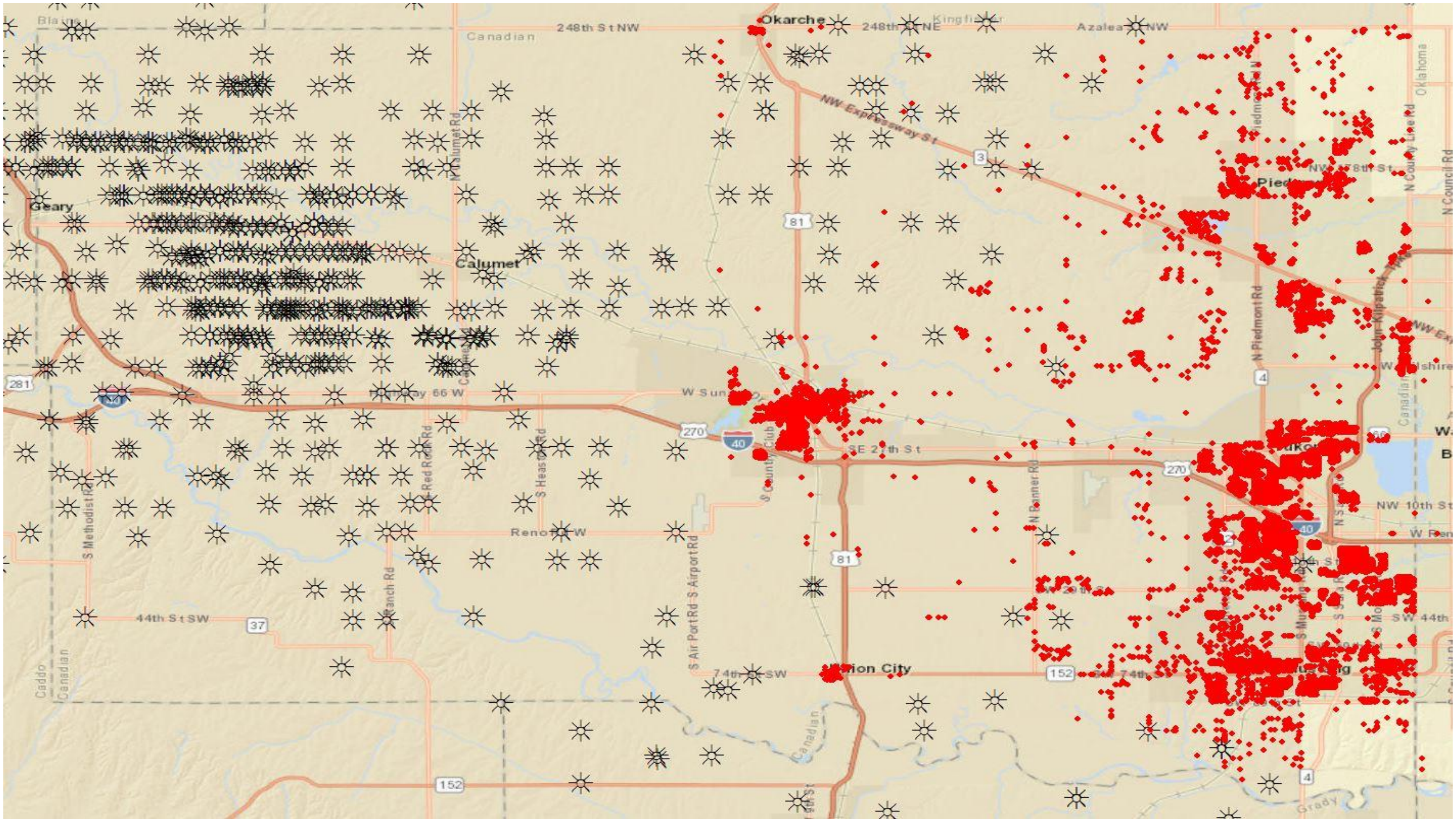


Figure II-1. Locations for House Transaction and Unconventional Drilling Well Sites in Canadian County

Note: ☼ indicates shale drilling site, and ● indicates the location of traded house

Source: Drilled Well (the Oklahoma Geological Survey, achieved on the July 21, 2017); House Transactions (the Canadian County assessors' office, achieved on the September 21, 2017)

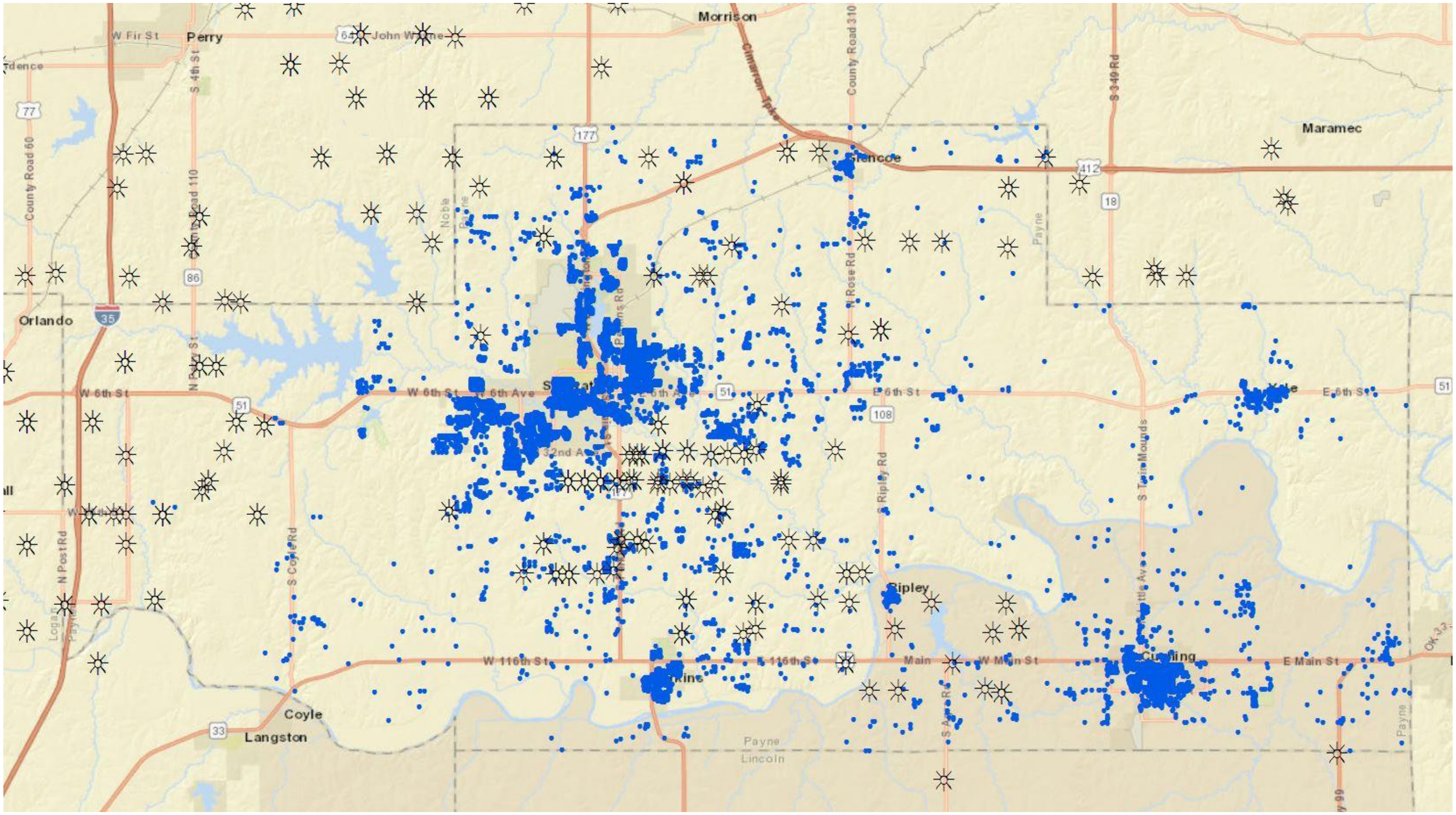


Figure II-2. Locations for House Transaction and Unconventional Drilling Well Sites in Payne County

Note: ☼ indicates shale drilling site, and ● indicates the location of traded house

Source: Drilled Well (the Oklahoma Geological Survey, achieved on the July 21, 2017); House Transactions (the Payne County assessors' office, achieved on the September 20, 2017)

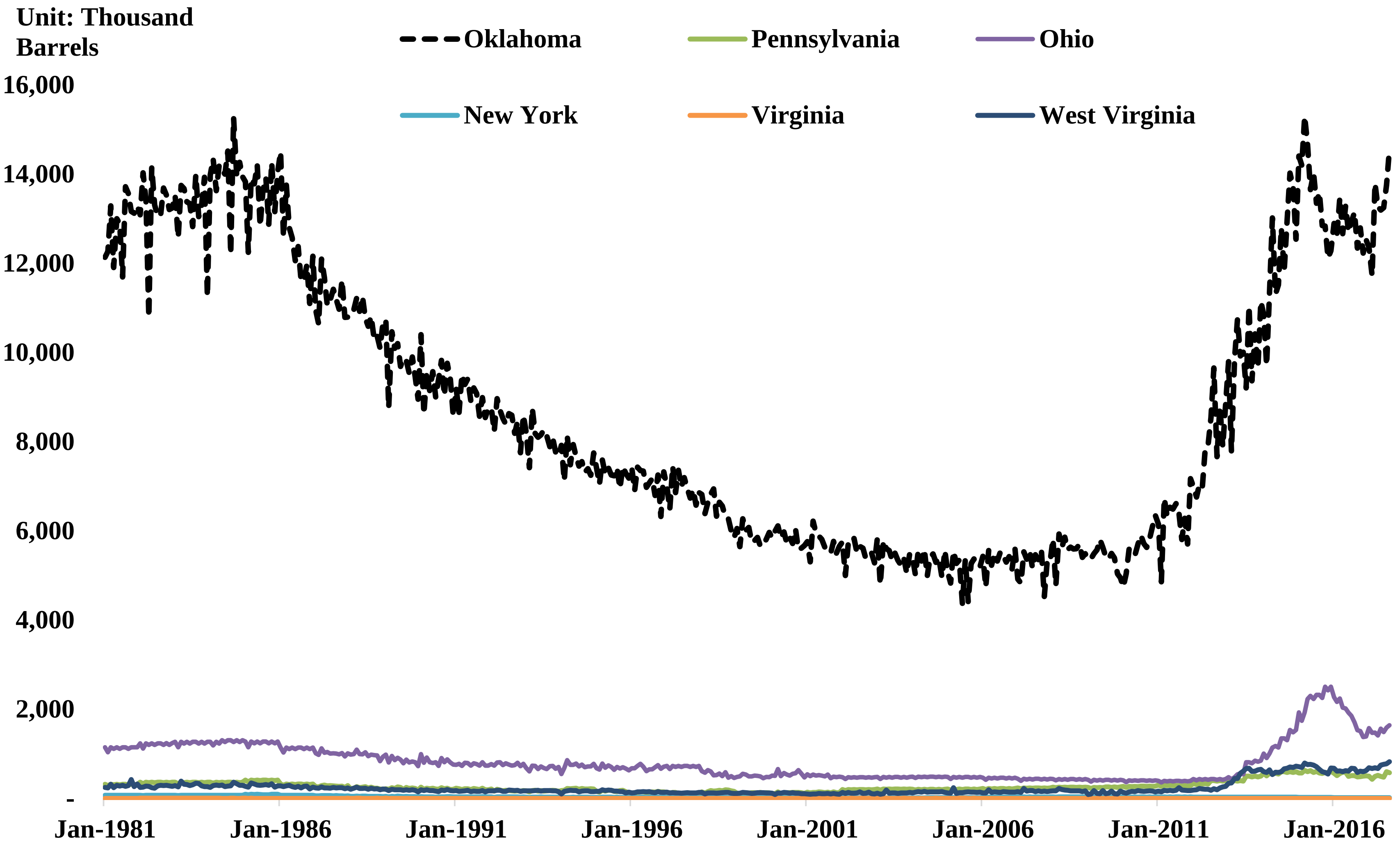
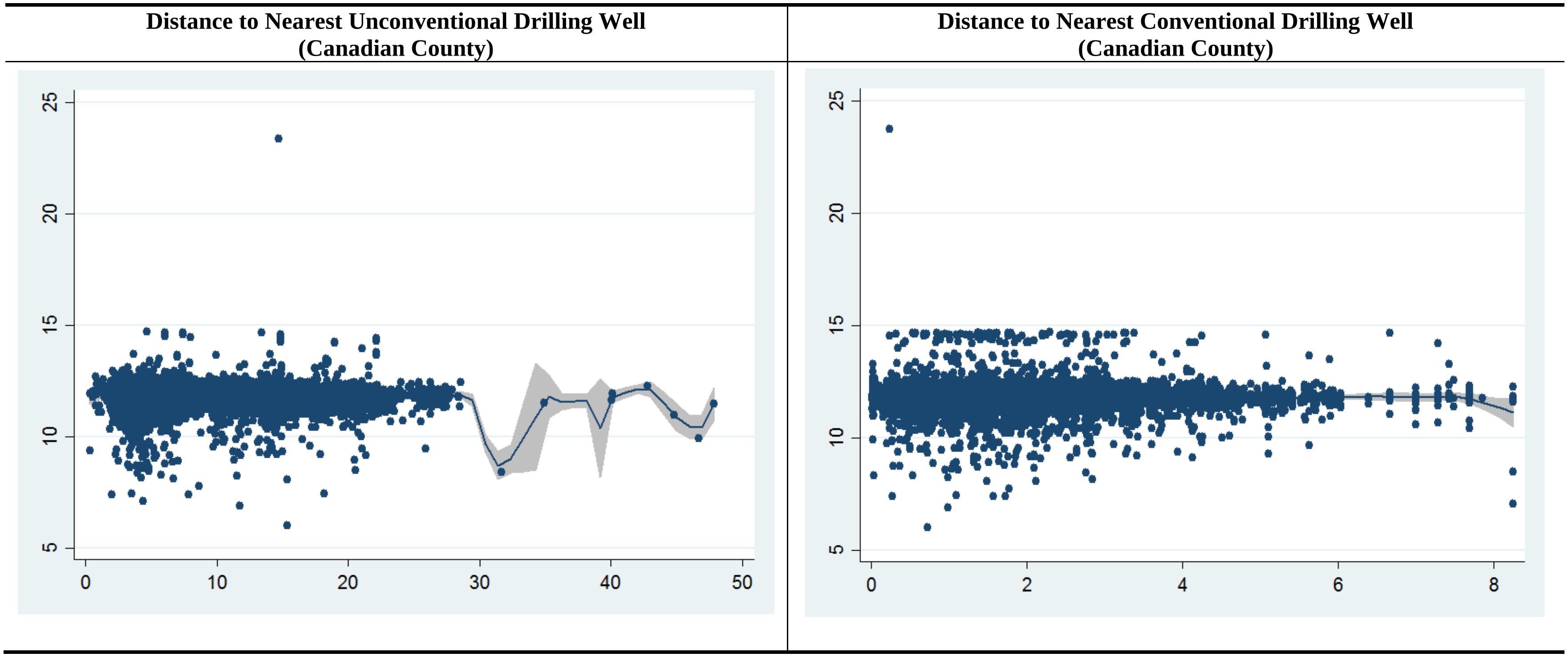


Figure II-3. Crude Oil Production Trend in OK, OH, PA, NY, VA, and WV

Source: U.S. Energy Information Administration (https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_m.htm)


Distance to Nearest Unconventional Drilling Well (Canadian County)

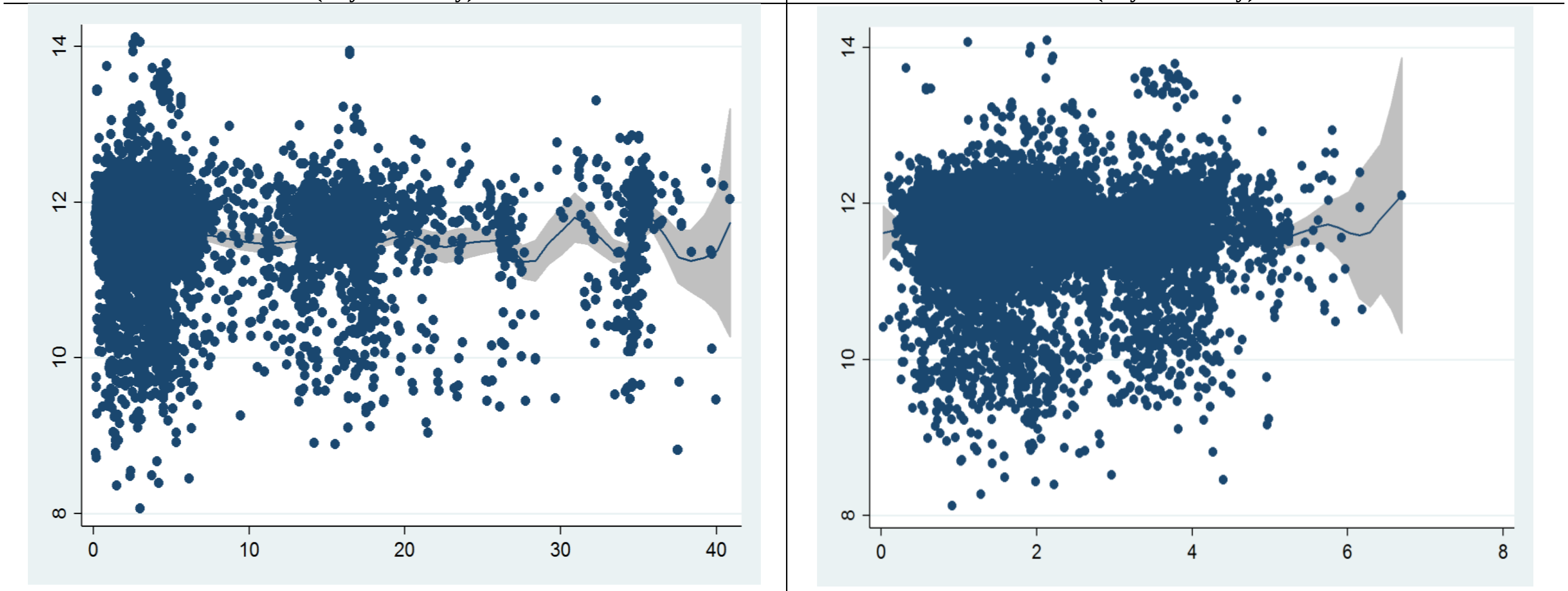
Distance to Nearest Conventional Drilling Well (Canadian County)

Figure II-4. Semiparametric Results for Canadian County

Note: 1. Both figures represent that the logarithm of housing price is against to a distance between a house and its nearest well (unconventional drilling well, left; conventional drilling well, right).

2. Horizontal axes are distance between a house and its nearest well. Vertical axes are logarithmic house sale prices.

3. The shaded areas indicating the computed 95% confidence interval.


Distance to Nearest Unconventional Drilling Well (Payne County)

Distance to Nearest Conventional Drilling Well (Payne County)

Figure II-5. Semiparametric Results for Payne County

Note: 1. Both figures represent that the logarithm of housing price is against to a distance between a house and its nearest well (unconventional drilling well, left; conventional drilling well, right).

2. Horizontal axes are distance between a house and its nearest well. Vertical axes are logarithmic house sale prices.

3. The shaded areas indicating the computed 95% confidence interval.

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CHAPTER III

REGIONAL EMPLOYMENT LEVEL CHANGES ASSOCIATED WITH RECENT ENERGY DEVELOPMENT ACTIVITIES IN ARKANSAS, KANSAS, AND OKLAHOMA

Abstract

A drastic increase in unconventional drilling and wind energy installation may be a beneficial source for employment in rural areas. This study examines the regional employment changes associated with those recent energy developments in Arkansas, Kansas, and Oklahoma. Considering heterogeneous boom periods in energy development activities (both oil and wind) in the three states, we apply a panel fixed effect model, and additionally try to correct for possible spatial autocorrelation by incorporating a spatial econometric approach. The results indicates that energy development activity does increase regional employment, but only for a small subset of industries. Moreover, the agricultural sector is negatively affected by energy development in most cases. I also find that the unconventional drilling activity provides larger positive impacts on local employment than does activity associated with wind farm installation.

Key words: Local Employment, Unconventional Drilling, Wind Farm, Resource Extraction

Introduction

Over the last decade, a new technology in energy development has emerged in the United States. This technique applies a combination of horizontal drilling and hydraulic fracturing and has changed the face of domestic energy production. This boom in unconventional drilling has made the share of crude oil production from hydraulic fracturing over 50% in 2015 (see Figure 1). Further, this drastic increase in unconventional drilling is an important source of employment in rural areas, although it is restricted to shale play regions. We study the broader economic impacts of these activities that may generate employment opportunities and income for residents of unconventional drilling boom counties. More specifically, we examine how recent energy development (shale gas drilling) influences employment levels across a variety of industries in Arkansas, Kansas, and Oklahoma. Arkansas and Oklahoma have seen sizable increases in unconventional drilling since the mid-2000s, while Kansas has seen smaller (but more recent) increases.

We also consider recent wind energy installations as another potentially influential variable for regional employment levels. As a policy option for reducing greenhouse gas emissions, wind energy is the most popular renewable energy source in the United States. Wind energy power plants require specific geographical conditions, and both Kansas and Oklahoma are sufficiently windy areas. The trend of wind farm installation overlaps with the shale drilling period, with some delay (See Table III-1). In particular, significant new wind installations took place in Oklahoma during 2009-2016, which is the same time frame for the increase in hydraulic fracturing shown in Figure 1. However, previous studies on the economic contributions of unconventional drilling generally do not consider the possible wind farm effect. Because wind power is increasing rapidly in recent decades, not controlling for its impact may overestimate the employment effects associated with unconventional drilling activity. Thus, the purpose of this study is to estimate the regional economic impact associated with recent energy development (both shale drilling and wind farm activity).

Literature Review

The recent literature regarding the regional economic impacts of shale drilling activities is quite extensive. In general, those studies can be categorized in two veins: one that finds positive associated economic effects (Weber, 2012; Weber, 2014; Munasib and Rickman, 2015; Paredes *et al*, 2015; Komarek, 2016; Maniloff and Mastromonaco, 2017) and another focused on the negative externalities from those energy developments (Rickman *et al*, 2017; Maguire and Winters, 2017; Wrenn *et al*, 2016).

On the whole, the results across the existing literature vary considerably. Most studies find that shale drilling has led to increased levels of employment. However, the results for the allocated income impacts are not consistent. Weber (2012) is the first published empirical research work for regional economic impact from shale drillings in the U.S. He used a triple difference in difference approach[30] to estimate the treatment effect in Colorado, Texas, and Wyoming. Weber (2012) found that each million dollar investment in shale gas production contributed 2.35 jobs in shale boom counties. Munasib and Rickman (2015) applied a synthetic control method to examine the shale

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[30] For the three time period (years in 1993, 1999, and 2007), he defined dependent variable as $y_i = (y_{i;\,2007} - y_{i;1999}) - (y_{i;\,1999} - y_{i;1993})$. Applying this, we may observe how economic conditions in boom counties increased through the boom period compared to pre boom period.

drilling impacts in Arkansas, North Dakota, and Pennsylvania. Their results demonstrate significant geographical heterogeneity. For North Dakota, they found that drilling activity had positive effects on the labor market and population growth, and lowered the poverty rate. Arkansas shows similar results, but only for the four most drilled counties. In fact, shale drilling in Arkansas is highly focused in those four counties. In our dataset, drilling activities in those four counties corresponds to 88.68% of all activity across whole state. Lastly, the results for Pennsylvania do not a show positive impact across any of the outcome measures.

Paredes *et al* (2015) and Komarek (2016) studied the treatment effect of unconventional drilling activity in the Marcellus shale play region. This region lies across Ohio, New York, Pennsylvania, and West Virginia. These two studies applied same empirical strategy (panel fixed effect model), although Paredes *et al* (2015) used propensity score matching as well. In general, their results show that shale drilling led to increasing levels of employment. However, the results for the income impacts are varied. The result for income from Paredes *et al* (2015) tells us that the income impacts were not consistent across the Marcellus region. Komarek (2016)'s results reveal that income levels generally increased by 11%, however, they declined four years after the drilling activity. Maniloff and Mastromonaco (2017) consider the entire U.S., and applied a difference-in-difference approach with two time periods (2005 and 2011). They found that the shale boom created 550,000 jobs over the entire nation.

Several studies consider negative externalities from shale development. Weber (2014) applied the same approach as Weber (2012), but expanded the time span up until 2010, and considered different states (Arkansas, Louisiana, Oklahoma, and Texas). The economic impact results for this updated analysis are in accordance with those for Weber (2012). However, this study took the analysis one step further. Using educational attainment as a dependent variable, the study showed that participating in a shale boom did not lead to a decline in overall educational attainment. Alternatively, Rickman *et al.* (2017) also examined educational attainment levels in shale boom regions across Montana, North Dakota, and West Virginia. They applied a synthetic control method, and found that educational attainment in both high school and college completion in the boom regions were lowered compared to their counterfactual. Sensitivity analysis using placebo tests support the results. This is in direct contrast to the result from Weber (2014). Wrenn *et al* (2016) studied people's risk averting behavior associated with unconventional shale drilling. Specifically, they tested whether perceptions about the link between unconventional drilling and unsafe drinking water could be quantified. Using consumer's water bottle purchasing data from Pennsylvania, they found that concerns about unsafe water in areas with unconventional drilling led to over $19 million in risk-averting water purchases in 2010 in the Pennsylvania shale region. Maguire and Winters (2017) applied a panel regression model using household well-being survey data. Their estimation results tell us that horizontal wells lower a resident's life satisfaction and raise the number of poor mental health days. Those results are statistically significant for the full sample in Texas and specifically for the Dallas Fort Worth metro area.

In sum, an array of literature has studied how unconventional shale development influences the drilling boom regions. The contribution of this paper is to consider a longer, continuous time period, which allows for a more persuasive result. From a geographical perspective, we focus on Arkansas, Kansas, and Oklahoma. Among those three states, Both Arkansas and Oklahoma were examined in previous studies: Weber (2014) and Maniloff and Mastromonaco (2017). However, these two studies use just two or three time periods, while we consider a continuous 16 year time span. In addition, Kansas was not considered in any other study. Moreover, we consider another newly introduced and rapidly increasing energy development project– wind farms. To our best knowledge, wind energy was not considered in any other study. Finally, we will apply newly available employment data from the *Upjohn Labor Institute*. Although most previous studies dealing with regional economic impacts of shale drilling use county level official government employment data from the Bureau of Labor Statistics (BLS), this dataset has serious problems with missing data in many rural counties. The Upjohn data overcomes this issue by applying a 2-stage technique to estimate missing observations. This updated dataset will allow for more precise impacts, particularly in rural counties where drilling can play a large role in the local economy.

Study Region: Shale Plays and Wind Farm

The geographical region for our study comprises three shale plays: the Excello Mulky, Fayetteville, and Woodford. The Excello Mulky is a shale play across Southern Kansas and Northern Oklahoma. The Fayetteville is a shale play region that exists mostly in Arkansas, and very a small part of Oklahoma. The Woodford play is limited to Oklahoma (See Figure 2). 6,447 shale wells were drilled in Arkansas during the 2001-2016 period, and 918 wells and 4,644 wells had drilled in same period in Kansas and Oklahoma, respectively (See Table III-2).

Shale wells are focused in a small number of counties. However, the density of drilling activity is somewhat different over the three states. Arkansas shows the most density, with nearly all drilling activity focused on a small number of counties. More specifically, four counties – Cleburne, Conway, Faulkner, Van Buren, and White[31] – account for about 97.15% of the total number of drilled wells in the state during the 2001-2016 time frame. In Kansas, the drilling is slightly more spread out. Six counties – Barber, Comanche, Harper, Reno, Sherman, and Sumner[32] – make up 71.79% of the Kansas state total. Twelve counties – Blaine, Canadian, Carter, Coal, Grady, Hughes, Logan, Marshall, Payne, Pittsburg, Stephens, and Wagoner[33] – in Oklahoma have more than 100 wells, and the total number of wells among those counties is 82.11% of the state total. The most distinguishing characteristics of wells in Oklahoma is that four counties (Canadian, Grady, Logan, and Wagoner) with significant drilling activity are classified as metropolitan.

There is another recent energy development activity of interest in our study region, which is wind energy. Kansas and Oklahoma have been adopting wind energy as part of their energy portfolio, and the share of electricity generation by wind energy have been increasing rapidly. Table III-1 shows wind farm installation status in both states in terms of capacity in megawatts during the 2001-2016 period. On the other hand, there are no wind farms in Arkansas.

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[31] Number of wells are as follows: Faulkner (546), Cleburne (1,205), Conway (1,333), Van Buren (1,453), and White (1,726)

[32] Sherman (47), Sumner (49), Reno (64), Barber (80), Comanche (115), Harper (304)

[33] Logan (122), Marshall (148), Stephens (163), Payne (173), Wagoner (185), Blaine (199), Carter (237), Grady (298), Coal (490), Hughes (555), Pittsburg (570), Canadian (673)

Empirical Strategy

We apply a panel data econometric approach to examine the causal relationship between the unconventional drilling boom and changes in regional employment levels. There are four widely-used approaches to examine a treatment effect: (1) difference in difference; (2) panel regression model; (3) synthetic control method, and (4) propensity score matching. Each method has its own challenge to show a true treatment effect. For example, the difference in difference technique can argue for a causal relationship if the common trend assumption is shown to hold. Synthetic control methods require good balancing between the control and counterfactual group. Panel regression models require the isolation of an interesting variable, and take advantage of both time and geography variation across the data.

We first use panel regression model to identify the effect of shale drillings on regional economic impacts in Arkansas, Kansas, and Oklahoma. The most critical reason is that the difference in difference and synthetic control method consider one specific intervention time. However, it is hard to pinpoint a single intervention starting point in our study region, although some previous studies consider the year 2006 as the start of shale boom. Shale drilling in both Arkansas and Oklahoma reached the three digit level after 2006, however, there were several dozen drillings in 2004 and 2005 as well (See Table III-2). Kansas shows some delay in its pace of drilling. Their boom seems to start after 2012, but more than 40 drillings were recorded in 2006 (See Table III-2). On the other hand, as discussed earlier, we also consider wind farm capacity in our empirical model. The introduction of wind farms overlaps with shale drilling activity, although most wind farms began slightly later. In addition, the time of installation of the wind turbines varies. All things considered, we start our empirical specification with a panel regression model.

We expect an increase in employment level, as the number of shale drillings increases and (or) wind farm capacity is increased, other things being equal. We test this hypothesis using the specification:

$$\text{(1)} \qquad \ln(E_{sit}) = \beta_1 Drillings_{it} + \beta_2 WindFarm_{it} + \beta_3 X_{it} + \gamma Group + \tau_t + \delta_i + \varepsilon_{it}$$

where E_{sit} is an employment level for industrial sector s of county *i* in year *t*. We consider six industrial fields, which are sectors for total, agricultural, mining, construction, retail trade, and oil and gas extraction. These are sectors that are likely to be influenced by energy activity (Komarek, 2016; Weber, 2014; Paredes et al., 2015). The variable $Drillings_{it}$ refers to the number of newly added unconventional drillings.[34] $WindFarm_{it}$ is measure of newly added installation of wind farm. X_{it} includes time varying control variables, including population. Additionally, we categorized three or four groups in each state in terms of metropolitan status and drilling activity.[35] This group effects are captured in $Group$. The τ_t are time (year) fixed effects. The δ_i are individual (county) fixed effects. As we discussed in study region section, there exist different characteristics in the distribution of both shale drilling and wind farm activity in the three

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[34] Note that the panel nature of the data allows changes across years to be assessed.

[35] For Arkansas and Kansas, counties are categorized in three groups (group one is shale drilling counties; group two is non-shale drilling metropolitan counties; group three is non-shale drilling & non metro counties). There are four groups in Oklahoma (group one is non-metro shale drilling counties; group two is metro shale drilling counties; group three is non-shale drilling metropolitan counties; group three is non-shale drilling & non metro counties).

states. Considering this the heterogeneity, we run the empirical model for each state separately.

Spatial econometrics estimation

In general, one county's economy is closely related to its neighbor's. If this is the case, there is a high chance to have a spatial autocorrelation problem in simple the OLS specification. To take care of this concern, we additionally consider a spatial econometrics approach along with benchmark regression model. To do this, the two most common specifications, the spatial lag model and spatial error model, are adopted in this study. The spatial lag model (denoted SAR in the results tables) takes the following form:

$$(2) \qquad y = \rho W y + X\beta + \varepsilon, \qquad \varepsilon \sim N(0, \sigma^2 I_n)$$

where y is a vector of observations on the dependent variable (log of sectoral employment level), and W denotes spatial weight matrix. The first term of the right hand side in equation (2) is a spatially lagged dependent variable. We construct the weight matrix following a queen contiguity method. This method regards a region as a neighbor when a common border is shared. Thus this technique considers a surrounding spatial lag effect. As equation (2) suggests, if ρ=0, then the spatial lagged dependent variable would be cancelled out, and there is no spatial dependence. The resulting model becomes basic OLS model.

The spatial error model (denoted SEM in the results tables) assumes that the errors of model are spatially correlated. Restating this, the value of the dependent variable can be influenced by the value of the independent variable of neighbor. The model form is as follow:

$$y = X\beta + \varepsilon, \qquad \varepsilon = \lambda W\varepsilon + u, \qquad u \sim N(0, \sigma^2 I_n) \tag{3}$$

where y is the dependent variable, W is the spatial weights matrix, X includes independent variables, and ε is a vector of spatially autocorrelated error terms. This spatial error model is appropriate when there is little theoretical reason to suspect y is directly affected by its neighbor, but spatial heterogeneity still exists in the data. Finally, note that both the spatial lag and error models are space recursive rather than time recursive. That is, we do not consider the impact of a neighbor from time t-1, only time t. Also, the weight matrix here does not change over time (since counties do not change neighbors).

Data

Employment levels

We use county-level employment data from Bureau of Labor Statistics (BLS)[36]. All of the counties in three states are used in the panel, which runs from year 2001 to year 2016. In general, both unconventional shale drilling and wind installation activity started in mid-2000s, thus the time period includes both prior and post for the event time. We consider the employment level on the six industrial sectors, which are total industry (NAICS Code: 10), agriculture (NAICS Code: 11), mining (NAICS Code: 21),

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[36] https://www.bls.gov/cew/datatoc.htm

construction (NAICS Code: 23), retail trade (NAICS Code: 44-45), and oil and gas extraction (NAICS Code: 211). This two and three digit NAICS data is generally available for our counties of interest.

When we consider a more detailed level (i.e. three digits NAICS code), we face a significant missing data issue. Further, this data problem becomes worse for rural counties. This data issue is mainly due to data suppression in the process of data collection. BLS indicates that roughly 60 % of the most detailed level data are suppressed for confidentiality reasons (to protect identity or identifiable information of employers). This data suppression problem can be very problematic for researchers. To circumvent this issue, Isserman and Westervelt (2006) apply a two stage approach to estimate employment numbers for counties with missing data. Following Isserman and Westervelt (2006), *Upjohn Labor Institute* estimates the missing data for all six-digit NAICS codes for all counties across to county. This *Upjohn* data serves as the basis for the remainder of our discussion, although results using the original BLS data reported in the appendix. One downside of using the *Upjohn* data is that it is only available through 2015.

Unconventional drilling data

Historical unconventional drilling data for Arkansas, Kansas, and Oklahoma were obtained from Geological Surveys in each state[37]. This dataset includes precise geographical information (latitude and longitude coordinates) and date information for

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[37] Arkansas (http://www.geology.ar.gov/fossilfuel_maps/fayetteville_play.htm); Kansas (http://chasm.kgs.ku.edu/ords/qualified.ogw4.HorizWells); and Oklahoma (http://www.ou.edu/content/ogs/data/oil-gas.html)

the completion of each unconventional drilling site. The unconventional drilling site records for Arkansas conflicts of all well drilling logs for the Fayetteville Shale play region. Hydraulic fracturing has also been applied to mine natural gas in the Fayetteville shale area. The Kansas shale drilling data contains all records for horizontal wells in Kansas, including both oil and natural gas. The Oklahoma data is for the completion of all oil and gas shale wells.

Wind farm and population data

Wind Farm installation data come from U.S. Department of Energy Information Administration (EIA). More specifically, we collect all installed electricity generator information from EIA-860. EIA-860 includes the status of all equipment associated with existing and operating electric generating plants in the United States. This report contains county-level geographical information and is updated annually. We have data from 2001-2016.

Population data was acquired from the U.S. Census. The Census provides population measures every five years as part of the American Community survey. However, our dataset requires estimates for each year. Thus, the county intercensal estimates dataset from the U.S. Census[38] was used. Summary statistics for the discussed data are presented in Table III-3-A (BLS Data) and Table III-3-B (Upjohn Data).

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[38] https://www.census.gov/data/datasets/time-series/demo/popest/intercensal-2000-2010-counties.html

Results

Each state shows different trends in population and employment growth of the mining sector (See Figure 3). In general, metro areas perform better when compared to the other regions in all three states. Population levels in unconventional drilling counties in Arkansas increased compared to non-metro and non-shale drilling regions. However, both Kansas and Oklahoma shows similar trends between unconventional drilling counties and non-unconventional drilling counties in terms of population growth. Regarding the mining sector employment, Arkansas shows a huge increase for hydraulic fracturing counties during 2006-2011, however, employment in the mining sector in Oklahoma increased substantially less when compared to the other regions.

We will focus our discussion on the estimation results using the *Upjohn Labor Institute* dataset. The BLS dataset results are similar, but have some noticeable differences. The BLS dataset results are reported in the Appendix (Tables III-Appendix-5 through III-Appendix-10). As noted, we modeled the unconventional drilling and wind farm impact on employment levels across five industrial sectors (Total, Retail Trade, Construction, Agriculture, and Mining). And we additionally examine one three digit NAICS code, 211, that corresponds to Oil & Gas Extraction (OGE). Like the population trends, the estimation results for sectoral employment change associated with unconventional drilling are different in each state. In addition, we perform a preliminary test for spatial dependence using the total aggregate employment variable in each year for all those three states. These results are shown in the Appendix (Table III-Appendix-2 through III-Appendix-4). They show that spatial modeling techniques may be appropriate in KS and OK, but not Arkansas.

The estimation results for Arkansas are represented in Table III-4 (baseline model) and Table III-5 (spatial model). In general, additional unconventional drilling lead to employment growth across all industry sectors, except in agriculture. The extent of the increased employment level associated with each additional unconventional drilling are 0.1-1.4% in these benchmark models, and 0.2-1.1% in the spatial models. Although the levels of change vary, the increasing rates for the mining and OGE fields are noticeable. Further, the employment decreases in the agricultural sector is statistically significant in both results. This is consistent with the idea that mining activity could detract from the local agricultural sector.

The results for the group dummies do not follow our expectation in the benchmark models. Group I (unconventional drilling counties) shows a negative statistically significant sign across all sectors, except mining. Although the statistical significance and sign are switched in the spatial econometrics estimation results, the reason for the sign for the mining and OGE fields are not clear. These negative estimates suggest that these groups have a negative impact compared to the benchmark group (Group III: Non-metro & Non-unconventional drilling counties). One possibility is that a high share of drilling activity are near county boundaries, and a neighboring county has increased their own employment statistics.

There are two limitations on the spatial econometrics estimation result in Arkansas. The first one is negative ρ values in both the total aggregate and retail trade sector. This may be possible in cases where one big shopping area strongly attract shoppers from its' neighbors. It is unclear that this is the case for Arkansas. The second limitation is the post specification test (global Moran's I) still strongly against the null that error has no spatial autocorrelation, except construction sector. This implies the spatial autocorrelation issue is not fully taken care of in our spatial econometrics specification, although the estimation are fairly consistent among two different spatial models (spatial lag model and spatial error model) and baseline regression models (those benchmark model include county fixed effect).

The results for Kansas are as follows (Table III-6 and Table III-7). Except for the construction sector, the baseline results show similar trends to Arkansas in terms of the drilling effect. More specifically, only the construction sector does not show a statistically significant impact across the six industrial fields. Parameter estimates on Group I show a positive sign that implies employment levels in unconventional drilling counties are increased across all the six industrial sectors. Group II dummy estimates show somewhat unexpectedly large values, although these values are lowered in the spatial econometrics estimation (Table III-7). Additional wind farm installations led to increases in the total aggregate employment level, although the value is not economically meaningful. However, spatial econometric estimation makes noteworthy changes to the results. Most of all, additional unconventional drillings are no longer significant in most sectors, except for mining. The signs of the group dummy parameters remain the same, but the values are lowered to double-digit percentage range. The impact of wind farm activity is also different. There is no statistically significant result for total employment anymore, however the mining sector switched to positive and significant. Like the Arkansas result, global Moran's I show that strongly against the null in most industry sectors, although no significance is shown for the retail trade sector. However, ρ values are all positive in the spatial econometrics results for Kansas. Also the residual Moran's I values has been reduced from their aggregate levels (Table III-Appendix-4), suggesting that the model does account for some spatial autocorrelations.

Overall, the results of drilling impact in the baseline models for Oklahoma are closely line with those results of Kansas (Table III-8 and Table III-9). Except for the retail trade and agricultural sectors, additional unconventional drilling leads to an increase in employment at the 0%-0.4% range. The case of wind farm does provide any effect on employment level. Results from spatial econometrics specification show that the drilling impact on employment level is generally no longer significant, however, it does increase employment in the mining and OGE sectors around 0.8%-1.2%. The same limitation for the spatial econometrics specification in Oklahoma is seen in the post-estimation test result. Only the construction sector specification provides evidence that the error terms are not spatially correlated.

Now we combine two states, Kansas and Oklahoma, considering the existence of both types of energy development activities in both locations. To perform this integration, three categories for the group control variable (Group I for unconventional drilling counties; Group II for metro counties; and Group III for all the other remained counties) are applied. The results are represented in Table III-10 (baseline regression) and Table III-11(spatial model). The results of benchmark models show all positive and significant effects, except for the agricultural sector (a negative and significant effect is found for the agricultural sector). In addition, additional wind energy has positive effects in the total aggregate, mining, and OGE sectors. However, the scale of those estimates is small compared to unconventional drilling activity. These results are fairly consistent with the other estimation results (Tables III-6 and III-8). One unexpected result for this case is that estimates of Group I are negative and highly significant for sectors in mining and OGE. This is inconsistent with our theory, and may indicate a specification problem. The results for the unconventional drilling from the spatial models show similar trends (Table III-11). They all have positive and significant impacts, except for the agricultural sector. The agricultural sector does not have any significant effect in this spatial specification. In addition, the scale of the estimates is larger than for the baseline results. There is one more notable change in the spatial model results. For all cases we consider (spatial lag or spatial error), the unexpected results for Group I estimates are switched to positive and significant. This suggests that it is important to control for spatial effects when seeking a model consistent with economic theory. Global Moran's I show that strongly against the null in all across the industry sectors, and this is the limitation of this spatial econometrics specification.

Conclusions

Two types of relatively new energy developments, unconventional drilling and wind energy, have been increasing rapidly in the United States. This surge in both types of energy development may be an important source of employment in rural areas. In some areas, wind farm installations overlap with the unconventional drilling period; other states have both types of activity but occur in mutually exclusive timeframes; still others have only one type (and not both). The majority of the previous literature on this topic has examined the economic contributes of unconventional drilling in various regions or states, and a small number of studies have looked at impacts associated with wind development. However, these studies typically focus on a single type of energy development, and generally do not consider the possible effects of alternative energy expansion.

The purpose of this study is to estimate the regional employment impacts associated with recent energy development (both shale drilling and wind farm activity) in Arkansas, Kansas, and Oklahoma. The time span of our dataset (2001-2015) encompasses both pre and post- energy development growth periods. We take advantage of the fact that each county has a different boom period for the alternative types of energy development (including many that never experienced any type of boom). We estimate the treatment effect of the two types of energy activity by applying a panel regression model, with county-level employment in a variety of industries as the dependent variable. Further, to take into account possible spatial dependence, we additionally applied a spatial econometrics strategy, including both the spatial lag model and spatial error model.

The results indicate that energy development activity does increase regional employment, but only for a small subset of industry sectors and regions. Although wind farm activity spurred employment growth in the mining sector in both Kansas and Oklahoma, they are relatively smaller than the unconventional drilling impact. That is, the employment impacts for unconventional drilling activity are larger than those for wind farms in these regions. A reasonable conjecture based on this limited and small employment impact is that both shale drilling and wind farm installation can lead to employment growth in some industries. However, the employed period may not be long, and it is possible that newly available job is a temporary one. Some job seekers may have found a temporary position in the energy development project, however, it is not counted since it was temporary. Even though the increased job is not a permanent position, it may lead to an increase in consumption in a market. This may lead to growth in the retail trade sector.

One notable contribution of this study is the use of newly available county-level employment data from the *Upjohn Labor Institute*. Most previous studies on this topic use official governmental county business patterns (CBP) employment numbers, which suffer from missing data in many rural counties. This updated data applies Isserman and Westervelt's (2006) technique to overcome this employment suppression. This, in turn, allows for the estimation of more precise impacts, particularly in rural counties where drilling or wind development can play a large role in the local economy. In addition, we applied spatial econometric approach to deal with potential spatial autocorrelation. As discussed, the spatial econometrics specification provide relatively consistent results with the non-spatial models. However, post estimation test statistics indicate that spatial autocorrelation is not fully treated, and this is a limitation of the study.

In future work, we may consider some additional dependent variables. For example, if we try the accommodation (NAICS code 72) sector, we may discuss on the effect of mobility of workers (influx from outside workers). In addition, we can try other industrial sectors (transportation; NAICS code 48) or some alternative measures, such as income levels (from BLS), poverty rates (from USDA), unemployment (from BLS), and educational attainment or crime rate. Finally, we will look into the life span of drilling-related employment in the future. Detailed information on the employment structure (e.g.

how many jobs are created for drilling and how many jobs are needed to O&M) would be a useful topic for further discussion.

As discussed, employment changes associated with the recent energy development vary across industrial sectors. This study allows for a better understanding of how industry employment responds to various energy development activities. In particular, advocates of wind energy development can point to increased employment in several industries (construction, agriculture, and mining); however, their impacts are always lower than those for newly drilled wells. Policy makers should recognize the differences in employment impacts across these natural resource typologies as they design energy policy for the future.

Table III-1. The Status of Wind Farm Installation

Year	Kansas (MW)	Oklahoma (MW)	Kansas (New)	Oklahoma (New)
2001	112	0	0	0
2002	112	0	0	0
2003	113.4	176.3	1.4	176.3
2004	113.4	176.3	0	0
2005	263.4	474.3	150	298
2006	363.4	594.3	100	120
2007	363.4	688.8	0	94.5
2008	812.3	707.7	448.9	18.9
2009	1011.3	1129.8	199	422.1
2010	1071.8	1480	60.5	350.2
2011	1271.8	1810.8	200	330.8
2012	2718.4	3132.9	1446.6	1322.1
2013	2968.2	3132.9	249.8	0
2014	2968.2	3779.5	0	646.6
2015	3573.2	5001.4	605	1221.9
2016	4469.1	6644.1	895.9	1642.7

Source: U.S. Department of Energy Information Administration (EIA-860)

Table III-2. Number of Shale Drillings and Shale Gas Production Share

Year	AR	Share (%)	KS	Share (%)	OK	Share (%)	All	Share (%)
2001	1	N.A.	6	N.A.	2	N.A.	9	N.A.
2002	0	N.A.	4	N.A.	2	N.A.	6	N.A.
2003	0	N.A.	0	N.A.	5	N.A.	5	N.A.
2004	14	N.A.	4	N.A.	37	N.A.	55	N.A.
2005	47	N.A.	3	N.A.	64	N.A.	114	N.A.
2006	150	N.A.	41	N.A.	135	N.A.	326	N.A.
2007	492	7.27%	17	0.00%	318	3.09%	827	10.36%
2008	770	13.19%	11	0.00%	554	7.94%	1,335	21.12%
2009	939	16.95%	7	0.00%	352	8.01%	1,298	24.95%
2010	865	14.88%	10	0.00%	343	7.55%	1,218	22.43%
2011	850	11.76%	28	0.00%	439	5.95%	1,317	17.71%
2012	769	9.90%	225	0.01%	442	6.14%	1,436	16.05%
2013	585	8.99%	224	0.03%	485	6.11%	1,294	15.13%
2014	506	7.72%	236	0.01%	646	6.46%	1,388	14.19%
2015	438	6.07%	80	0.01%	528	6.53%	1,046	12.60%
2016	21	N.A.	22	N.A.	292	N.A.	335	N.A.
2001-2016	6,447		918		4,644		12,009	

Note: 1. The first column of each state is the number of shale drillings in the year.

2. The second column is shale gas production share over national shale gas production. The share is calculated based on the data from EIA (https://www.eia.gov/dnav/ng/ng_prod_shalegas_s1_a.htm)

Table III-3-A. Summary of Statistics (BLS Data)

All (AR, KS, OK)	Obs	Mean	Std. Dev.	Min	Max
Shale Wells (Count)	4,112	5.71	43.73	0	289
Wind Farm (MW)	4,112	12.46	61.31	0	496.6
Population	4,112	36453.83	80534.48	1210	782970
Employment (Total)	4,112	15251.97	45057.64	458	450460
Employment (Ag)	4,089	87.08	199.32	0	3656
Employment (Mining)	3,583	231.55	925.21	0	16205
Employment (211)	2,239	106.40	635.36	0	9391
Employment (Construction)	4,096	688.14	2079.08	0	20672
Employment (Retail Trade)	4,112	1759.17	5039.88	0	47616

Arkansas	Obs	Mean	Std. Dev.	Min	Max
Shale Wells (Count)	1200	5.37	29.08	0	289
Wind Farm (MW)	1200	0	0	0	0
Population	1200	38165.63	55179.40	5144	393250
Employment (Total)	1200	15056.95	31772.13	963	250394
Employment (Ag)	1200	113.86	149.98	0	859
Employment (Mining)	852	94.72	237.55	0	1828
Employment (211)	241	16.89	43.16	0	281
Employment (Construction)	1200	653.32	1396.57	0	11223
Employment (Retail Trade)	1200	1772.40	3412.88	0	26303

Kansas	Obs	Mean	Std. Dev.	Min	Max
Shale Wells (Count)	1680	0.55	4.55	0	118
Wind Farm (MW)	1680	2.59	25.88	0	470.2
Population	1680	26801.00	72750.72	1210	584451
Employment (Total)	1680	12475.64	39591.53	458	337886
Employment (Ag)	1670	60.28	102.79	0	673
Employment (Mining)	1531	71.05	152.41	0	936
Employment (211)	985	25.10	65.94	0	547
Employment (Construction)	1664	566.33	1851.67	0	14928
Employment (Retail Trade)	1680	1392.87	4564.32	0	40635

Oklahoma	Obs	Mean	Std. Dev.	Min	Max
Shale Wells (Count)	1232	3.77	14.03	0	142
Wind Farm (MW)	1232	5.39	33.52	0	496.6
Population	1232	47949.44	105891.50	2162	782970
Employment (Total)	1232	19227.82	60269.35	637	450460
Employment (Ag)	1219	97.43	308.10	0	3656
Employment (Mining)	1200	533.48	1533.03	0	16205
Employment (211)	1013	206.74	932.55	0	9391
Employment (Construction)	1232	886.59	2790.52	0	20672
Employment (Retail Trade)	1232	2245.77	6681.79	0	47616

Note: This BLS dataset includes observations from 2001 to 2016

Table III-3-B. Summary of Statistics (Upjohn Data)

All (AR, KS, OK)	Obs	Mean	Std. Dev.	Min	Max
Shale Wells (Count)	3855	3.03	18.35	0	289
Wind Farm (MW)	3855	2.20	22.12	0	496.6
Population	3855	36336.98	80051.43	1210	775949
Employment (Total)	3855	13065.03	40684.07	242	374277
Employment (Ag)	3027	34.47	71.85	0	877
Employment (Mining)	3271	213.64	800.00	0	15226
Employment (211)	2072	114.89	535.28	0	7827
Employment (Construction)	3851	676.95	2073.23	0	19415
Employment (Retail Trade)	3855	1796.10	4954.84	28	46079

Arkansas	Obs	Mean	Std. Dev.	Min	Max
Shale Wells (Count)	1125	5.71	30.00	0	289
Wind Farm (MW)	1125	0	0	0	0
Population	1125	38053.78	54803.21	5175	392932
Employment (Total)	1125	13154.43	28633.71	406	231352
Employment (Ag)	1052	73.59	101.35	0	877
Employment (Mining)	797	101.61	243.43	1	2397
Employment (211)	273	60.90	107.67	0	571
Employment (Construction)	1125	612.48	1340.35	5	12738
Employment (Retail Trade)	1125	1856.78	3510.62	54	28167

Kansas	Obs	Mean	Std. Dev.	Min	Max
Shale Wells (Count)	1575	0.57	4.69	0	118
Wind Farm (MW)	1575	2.20	23.43	0	470.2
Population	1575	26741.83	72380.29	1210	578758
Employment (Total)	1575	10727.39	37445.14	242	328124
Employment (Ag)	1205	9.53	13.77	0	121
Employment (Mining)	1350	87.07	170.55	0	1494
Employment (211)	876	37.19	78.32	0	706
Employment (Construction)	1571	589.90	2018.03	0	16820
Employment (Retail Trade)	1575	1419.74	4560.34	28	37850

Oklahoma	Obs	Mean	Std. Dev.	Min	Max
Shale Wells (Count)	1155	3.77	14.23	0	142
Wind Farm (MW)	1155	4.33	29.60	0	496.6
Population	1155	47749.05	105222.10	2200	775949
Employment (Total)	1155	16165.63	52912.37	323	374277
Employment (Ag)	770	20.06	52.00	0	403
Employment (Mining)	1124	445.08	1305.70	1	15226
Employment (211)	923	204.61	787.20	0	7827
Employment (Construction)	1155	858.16	2646.23	2	19415
Employment (Retail Trade)	1155	2250.21	6420.11	63	46079

Note: This BLS dataset includes observations from 2001 to 2015

Table III-4. Baseline Regression Results for Arkansas (Upjohn Data)

Arkansas	ln (Total)	ln (Retail Trade)	ln (Construction)
Drilled Wells	**0.001*** **	**0.000*** **	**0.002*** **
(Newly Added)	(0.000)	(0.000)	(0.000)
Population	**0.000*** **	**0.000*** **	**0.000*** **
	(0.000)	(0.000)	(0.000)
Group I	**-1.739*** **	**-1.548*** **	**-2.062*** **
	(0.029)	(0.031)	(0.147)
Group II	**0.961*** **	**1.167*** **	**1.855*** **
	(0.104)	(0.090)	(0.189)
R-sq	0.995	0.994	0.955
N	1125	1125	1125

Arkansas	ln (Agricultural)	ln (Mining): NAICS_21	ln (Oil & Gas Extraction): NAICS_211
Drilled Wells	**-0.000* **	**0.014*** **	**0.008* **
(Newly Added)	(0.001)	(0.002)	(0.005)
Population	**0.000*** **	**0.000*** **	0.000
	(0.000)	(0.000)	(0.000)
Group I	**-1.692*** **	-0.364	**-1.443*** **
	(0.141)	(0.408)	(0.501)
Group II	**-4.058*** **	-0.157	-1.023
	(0.818)	(0.896)	(3.408)
R-sq	0.855	0.844	0.786
N	1051	797	266

Note: Year fixed effects and county fixed effects are included for all results.

Table III-5. Spatial Model Estimation Results for Arkansas (Upjohn Data)

Arkansas	ln (Total), SAR	ln (Total), SEM	ln (R. T.), SAR	ln (R. T.), SEM	ln (Const.), SAR	ln (Const.), SEM
Drilled Wells	**0.003*****	**0.002*****	**0.002*****	**0.002*****	**0.007*****	**0.007*****
(Newly Added)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	0.025	-0.024	**0.198*****	**0.167*****	0.021	0.000
	(0.064)	(0.059)	(0.058)	(0.053)	(0.089)	(0.089)
Group II	0.040	-0.071	0.102	-0.008	**0.312*****	**0.303*****
	(0.078)	(0.074)	(0.082)	(0.075)	(0.080)	(0.079)
Rho	-0.202***	-	-0.182***	-	0.005	-
	(0.042)	-	(0.042)	-	(0.038)	-
Lambda	-	-0.238***	-	-0.260***	-	-0.082
	-	(0.049)	-	(0.047)	-	(0.056)
Global Moran' I	-0.074	-0.074	-0.086	-0.086	-0.026	-0.026
P-Value > Z (·)	0.000	0.000	0.000	0.000	**0.178**	**0.178**
R-sq	0.615	0.616	0.600	0.601	0.576	0.576
N	1125	1125	1125	1125	1125	1125

Arkansas	ln (Ag), SAR	ln (Ag), SEM	ln (Mining), SAR	ln (Mining), SEM	ln (211), SAR	ln (211), SEM
Drilled Wells	**-0.005*****	**-0.006*****	**0.011*****	**0.011*****	**0.009*****	**0.009*****
(Newly Added)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000***	**0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**-0.362*****	**-0.349*****	**-0.242***	0.194	-0.128	-0.093
	(0.105)	(0.124)	(0.143)	(0.164)	(0.228)	(0.243)
Group II	**-0.444*****	**-0.380*****	**-0.231***	-0.089	-0.079	-0.056
	(0.089)	(0.095)	(0.119)	(0.121)	(0.215)	(0.228)
Rho	0.489***	-	0.271***	-	0.091	-
	(0.029)	-	(0.037)	-	(0.057)	-
Lambda	-	0.503***	-	0.302***	-	0.074
	-	(0.029)	-	(0.041)	-	(0.061)
Global Moran' I	0.386	0.386	0.170	0.170	0.154	0.154
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.034	0.033	0.185	0.263	0.084	0.078
N	1125	1125	1125	1125	1125	1125

Table III-6. Baseline Regression Results for Kansas (Upjohn Data)

Kansas	ln (Total)			ln (Retail Trade)		
Drilled Wells	**0.001*****	-	**0.001*****	**0.003*****	-	**0.003*****
(Newly Added)	(0.000)	-	(0.000)	(0.001)	-	(0.001)
Wind Farm	-	**0.000*****	**0.000****	-	0.000	0.000
(Newly Added)	-	(0.000)	(0.000)	-	(0.000)	(0.000)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**2.208*****	**2.209*****	**2.208*****	**2.028*****	**2.029*****	**2.028*****
	(0.028)	(0.028)	(0.028)	(0.033)	(0.033)	(0.033)
Group II	**4.678*****	**4.682*****	**4.677*****	**4.156*****	**4.170*****	**4.156*****
	(0.043)	(0.043)	(0.043)	(0.078)	(0.078)	(0.078)
R-sq	0.997	0.997	0.997	0.992	0.992	0.992
N	1575	1575	1575	1575	1575	1575

Kansas	ln (Construction)			ln (Agricultural)		
Drilled Wells	0.002	-	0.002	**-0.010*****	-	**-0.009*****
(Newly Added)	(0.002)	-	(0.002)	(0.003)	-	(0.004)
Wind Farm	-	0.000	0.000	-	-0.000	-0.000
(Newly Added)	-	(0.000)	(0.000)	-	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**-0.000****	**-0.000****	**-0.000****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**2.585*****	**2.585*****	**2.584*****	**0.251****	**0.254****	**0.251****
	(0.114)	(0.114)	(0.114)	(0.115)	(0.115)	(0.115)
Group II	**6.537*****	**6.543*****	**6.534*****	**1.314*****	**1.282*****	**1.315*****
	(0.169)	(0.169)	(0.169)	(0.454)	(0.453)	(0.454)
R-sq	0.967	0.967	0.967	0.689	0.687	0.689
N	1570	1570	1570	1202	1202	1202

Kansas	ln (Mining): NAICS_21			ln (Oil & Gas Extraction): NAICS_211		
Drilled Wells	**0.005****	-	**0.005****	**0.004****	-	**0.003****
(Newly Added)	(0.002)	-	(0.002)	(0.002)	-	(0.001)
Wind Farm	-	0.001	0.001	-	0.001	0.001
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000****	**0.000****	**0.000****	**0.000****	**0.000****	**0.000****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.999*****	**1.001*****	**0.999*****	**0.443*****	**0.444*****	**0.443*****
	(0.065)	(0.065)	(0.065)	(0.096)	(0.096)	(0.097)
Group II	**-1.555*****	**-1.537*****	**-1.563*****	**-2.781*****	**-2.773*****	**-2.792*****
	(0.417)	(0.417)	(0.417)	(0.639)	(0.639)	(0.639)
R-sq	0.879	0.879	0.879	0.840	0.840	0.840
N	1348	1348	1348	871	871	871

Note: Year fixed effects and county fixed effects are included for all results.

Table III-7. Spatial Model Estimation Results for Kansas (Upjohn Data)

Kansas	ln (Total), SAR			ln (Total), SEM			ln (Retail Trade), SAR			ln (Retail Trade), SEM		
Drilled Wells	-0.003	-	-0.003	-0.002	-	-0.001	-0.001	-	-0.001	-0.001	-	-0.001
(Newly Added)	(0.003)	-	(0.003)	(0.004)	-	(0.004)	(0.003)	-	(0.003)	(0.004)	-	(0.004)
Wind Farm	-	0.000	0.000	-	-0.000	-0.000	-	-0.000	-0.000	-	-0.000	-0.000
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.394*****	**0.391*****	**0.394*****	**0.458*****	**0.384*****	**0.385*****	**0.361*****	**0.360*****	**0.361*****	**0.385*****	**0.384*****	**0.385*****
	(0.054)	(0.054)	(0.054)	(0.058)	(0.059)	(0.059)	(0.057)	(0.056)	(0.057)	(0.059)	(0.059)	(0.059)
Group II	**0.427*****	**0.426*****	**0.427*****	**0.746*****	**0.879*****	**0.880*****	**0.567*****	**0.566*****	**0.567*****	**0.879*****	**0.879*****	**0.880*****
	(0.085)	(0.085)	(0.085)	(0.101)	(0.093)	(0.093)	(0.092)	(0.092)	(0.092)	(0.093)	(0.093)	(0.093)
Rho	0.317***	0.318***	0.318***	-	-	-	0.228***	0.228***	0.228***	-	-	-
	(0.028)	(0.028)	(0.028)	-	-	-	(0.030)	(0.030)	(0.030)	-	-	-
Lambda	-	-	-	0.172***	0.025	0.025	-	-	-	0.025	0.025	0.025
	-	-	-	(0.054)	(0.052)	(0.052)	-	-	-	(0.052)	(0.052)	(0.052)
Global Moran' I	0.062	0.063	0.062	0.062	0.063	0.062	0.009	0.009	0.009	0.009	0.009	0.009
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	**0.558**	**0.558**	**0.566**	**0.558**	**0.558**	**0.566**
R-sq	0.494	0.493	0.494	0.500	0.500	0.500	0.473	0.473	0.473	0.477	0.477	0.477
N	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575

Kansas	ln (Construction), SAR			ln (Construction), SEM			ln (Agriculture), SAR			ln (Agriculture), SEM		
Drilled Wells	0.007	-	0.007	0.005	-	0.005	-0.008	-	-0.008	-0.008	-	-0.008
(Newly Added)	(0.008)	-	(0.008)	(0.004)	-	(0.004)	(0.006)	-	(0.006)	(0.006)	-	(0.006)
Wind Farm	-	0.001	0.001	-	0.001	0.001	-	-0.001	-0.000	-	-0.000	-0.000
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.478*****	**0.468*****	**0.477*****	**0.551*****	**0.545*****	**0.550*****	**0.287*****	**0.280*****	**0.287*****	**0.290*****	**0.284*****	**0.291*****
	(0.068)	(0.068)	(0.068)	(0.074)	(0.074)	(0.074)	(0.064)	(0.063)	(0.064)	(0.064)	(0.064)	(0.064)
Group II	**1.033*****	**1.032*****	**1.033*****	**1.381*****	**1.380*****	**1.381*****	0.126	0.126	0.126	0.139	0.140	0.139
	(0.094)	(0.094)	(0.094)	(0.108)	(0.108)	(0.108)	(0.101)	(0.101)	(0.101)	(0.105)	(0.105)	(0.105)
Rho	0.327***	0.328***	0.328***	-	-	-	0.029	0.029	0.029	-	-	-
	(0.028)	(0.028)	(0.028)	-	-	-	(0.037)	(0.037)	(0.037)	-	-	-
Lambda	-	-	-	0.224***	0.227***	0.225***	-	-	-	0.037	0.039	0.037
	-	-	-	(0.047)	(0.047)	(0.047)	-	-	-	(0.039)	(0.038)	(0.039)
Global Moran' I	0.082	0.083	0.082	0.082	0.083	0.082	0.075	0.075	0.075	0.075	0.075	0.075
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.443	0.443	0.443	0.444	0.444	0.444	0.060	0.057	0.060	0.060	0.057	0.059
N	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575

Table III-7. Spatial Model Estimation Results for Kansas (Upjohn Data) (Continued)

Kansas	ln (Mining), SAR			ln (Mining), SEM			ln (211), SAR			ln (211), SEM		
Drilled Wells	0.005	-	**0.007****	**0.006***	-	**0.007****	-0.001	-	-0.002	-0.002	-	-0.002
(Newly Added)	(0.004)	-	(0.003)	(0.003)	-	(0.003)	(0.003)	-	(0.003)	(0.003)	-	(0.003)
Wind Farm	-	**0.003*****	**0.003*****	-	**0.003*****	**0.003*****	-	0.001	0.001	-	0.001	0.001
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.666*****	**0.658*****	**0.664*****	**0.671*****	**0.668*****	**0.673*****	**0.723*****	**0.721*****	**0.723*****	**0.750*****	**0.748*****	**0.751*****
	(0.078)	(0.077)	(0.077)	(0.082)	(0.081)	(0.082)	(0.085)	(0.085)	(0.085)	(0.083)	(0.083)	(0.083)
Group II	-0.096	-0.093	-0.093	0.073	0.082	0.077	**-0.252****	**-0.251****	**-0.251****	**-0.192***	**-0.191***	**-0.191***
	(0.117)	(0.117)	(0.116)	(0.119)	(0.119)	(0.119)	(0.102)	(0.102)	(0.102)	(0.101)	(0.101)	(0.101)
Rho	0.377***	0.376***	0.378***	-	-	-	0.098***	0.097***	0.097***	-	-	-
	(0.025)	(0.025)	(0.025)	-	-	-	(0.030)	(0.030)	(0.030)	-	-	-
Lambda	-	-	-	0.423***	0.422***	0.424***	-	-	-	0.109***	0.108***	0.109***
	-	-	-	(0.027)	(0.027)	(0.027)	-	-	-	(0.033)	(0.033)	(0.033)
Global Moran' I	0.272	0.273	0.272	0.272	0.273	0.272	0.258	0.259	0.258	0.258	0.259	0.258
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.093	0.095	0.093	0.201	0.200	0.199	0.188	0.188	0.187	0.189	0.189	0.188
N	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575

Table III-8. Baseline Regression Results for Oklahoma (Upjohn Data)

Oklahoma	ln (Total)			ln (Retail Trade)		
Drilled Wells	**0.000****	-	**0.000****	0.000	-	0.000
(Newly Added)	(0.000)	-	(0.000)	(0.000)	-	(0.000)
Wind Farm	-	0.000	0.000	-	0.000	0.000
(Newly Added)	-	(0.000)	(0.000)	-	(0.000)	(0.000)
Population	**0.000****	**0.000*****	**0.000****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**-0.232*****	**-0.230*****	**-0.231*****	-0.024	-0.023	-0.024
	(0.040)	(0.040)	(0.040)	(0.021)	(0.021)	(0.021)
Group II	**0.832*****	**0.833*****	**0.831*****	**0.764*****	**0.765*****	**0.764*****
	(0.039)	(0.040)	(0.039)	(0.038)	(0.038)	(0.038)
Group III	**3.971*****	**3.914*****	**3.961*****	**3.200*****	**3.170*****	**3.194*****
	(0.265)	(0.276)	(0.265)	(0.232)	(0.238)	(0.233)
R-sq	0.993	0.993	0.993	0.994	0.994	0.994
N	1155	1155	1155	1155	1155	1155

Oklahoma	ln (Construction)			ln (Agricultural)		
Drilled Wells	**0.003*****	-	**0.003*****	**-0.005****	-	**-0.005****
(Newly Added)	(0.001)	-	(0.001)	(0.002)	-	(0.002)
Wind Farm	-	-0.000	-0.000	-	-0.001	-0.001
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	-0.000	-0.000	-0.000	**-0.000*****	**-0.000*****	**-0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.269*****	**0.275*****	**0.268*****	**1.089*****	**1.061*****	**1.090*****
	(0.093)	(0.094)	(0.093)	(0.319)	(0.315)	(0.317)
Group II	**3.007*****	**3.020*****	**3.008*****	**0.792****	**0.742****	**0.799****
	(0.099)	(0.101)	(0.100)	(0.312)	(0.297)	(0.310)
Group III	**6.385*****	**6.111*****	**6.406*****	**7.958*****	**8.485*****	**8.036*****
	(0.492)	(0.478)	(0.491)	(1.657)	(1.648)	(1.650)
R-sq	0.958	0.958	0.958	0.784	0.783	0.784
N	1155	1155	1155	767	767	767

Oklahoma	ln (Mining): NAICS_21			ln (Oil & Gas Extraction): NAICS_211		
Drilled Wells	**0.003****	-	**0.003****	**0.004****	-	**0.004****
(Newly Added)	(0.001)	-	(0.001)	(0.002)	-	(0.002)
Wind Farm	-	0.000	0.000	-	0.001	0.001
(Newly Added)	-	(0.000)	(0.000)	-	(0.001)	(0.001)
Population	0.000	**0.000****	0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**3.931*****	**3.941*****	**3.931*****	**-3.480*****	**-3.444*****	**-3.456*****
	(0.336)	(0.334)	(0.336)	(0.462)	(0.461)	(0.463)
Group II	**1.278*****	**1.291*****	**1.276*****	**-3.348*****	**-3.310*****	**-3.333*****
	(0.323)	(0.321)	(0.323)	(0.242)	(0.247)	(0.244)
Group III	**5.763*****	**5.437*****	**5.731*****	**3.298*****	**2.897*****	**3.226*****
	(0.864)	(0.848)	(0.867)	(1.042)	(1.054)	(1.039)
R-sq	0.927	0.927	0.927	0.903	0.902	0.903
N	1124	1124	1124	917	917	917

Note: Year fixed effects and county fixed effects are included for all results.

Table III-9. Spatial Model Estimation Results for Oklahoma (Upjohn Data)

Oklahoma	ln (Total), SAR			ln (Total), SEM			ln (Retail Trade), SAR			ln (Retail Trade), SEM		
Drilled Wells	0.001	-	0.001	0.000	-	0.001	0.002	-	0.002	0.001	-	0.001
(Newly Added)	(0.002)	-	(0.002)	(0.002)	-	(0.002)	(0.002)	-	(0.002)	(0.002)	-	(0.002)
Wind Farm	-	-0.000	-0.000	-	-0.001	-0.001	-	0.000	0.000	-	-0.001	-0.001
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.406*****	**0.413*****	**0.406*****	**0.418*****	**0.411*****	**0.406*****	**0.404*****	**0.416*****	**0.405*****	**0.408*****	**0.411*****	**0.406*****
	(0.071)	(0.071)	(0.071)	(0.065)	(0.063)	(0.063)	(0.070)	(0.069)	(0.070)	(0.063)	(0.063)	(0.063)
Group II	**0.881*****	**0.907*****	**0.881*****	**1.130*****	**1.112*****	**1.095*****	**0.893*****	**0.930*****	**0.892*****	**1.090*****	**1.112*****	**1.095*****
	(0.098)	(0.091)	(0.099)	(0.089)	(0.074)	(0.086)	(0.095)	(0.087)	(0.095)	(0.085)	(0.074)	(0.086)
Group III	**0.582*****	**0.583*****	**0.582*****	**0.719*****	**0.691*****	**0.690*****	**0.607*****	**0.608*****	**0.607*****	**0.692*****	**0.691*****	**0.690*****
	(0.093)	(0.093)	(0.093)	(0.084)	(0.086)	(0.087)	(0.097)	(0.096)	(0.096)	(0.087)	(0.086)	(0.087)
Rho	0.053	0.052	0.053	-	-	-	0.016	0.015	0.016	-	-	-
	(0.035)	(0.035)	(0.035)	-	-	-	(0.036)	(0.036)	(0.036)	-	-	-
Lambda	-	-	-	-0.232***	-0.251***	-0.248***	-	-	-	-0.243***	-0.251***	-0.248***
	-	-	-	(0.048)	(0.046)	(0.047)	-	-	-	(0.046)	(0.046)	(0.047)
Global Moran' I	-0.079	-0.080	-0.079	-0.079	-0.080	-0.079	-0.084	-0.085	-0.083	-0.084	-0.085	-0.083
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.419	0.422	0.419	0.535	0.534	0.534	0.504	0.503	0.503	0.509	0.508	0.508
N	1155	1155	1155	1155	1155	1155	1155	1155	1155	1155	1155	1155

Oklahoma	ln (Construction), SAR			ln (Construction), SEM			ln (Agriculture), SAR			ln (Agriculture), SEM		
Drilled Wells	0.002	-	0.002	0.001	-	0.001	-0.004	-	-0.004	-0.003	-	-0.003
(Newly Added)	(0.002)	-	(0.002)	(0.002)	-	(0.002)	(0.002)	-	(0.003)	(0.003)	-	(0.003)
Wind Farm	-	0.000	0.000	-	-0.000	-0.000	-	-0.001	-0.001	-	-0.001	-0.001
(Newly Added)	-	(0.002)	(0.002)	-	(0.002)	(0.002)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.339*****	**0.349*****	**0.340*****	**0.387*****	**0.393*****	**0.387*****	**0.394*****	**0.371*****	**0.388*****	**0.397*****	**0.379*****	**0.391*****
	(0.085)	(0.085)	(0.086)	(0.085)	(0.084)	(0.085)	(0.125)	(0.125)	(0.126)	(0.127)	(0.126)	(0.128)
Group II	**1.469*****	**1.498*****	**1.468*****	**1.828*****	**1.849*****	**1.828*****	0.211	0.123	0.208	0.222	0.148	0.220
	(0.109)	(0.101)	(0.109)	(0.118)	(0.108)	(0.119)	(0.191)	(0.173)	(0.191)	(0.189)	(0.170)	(0.189)
Group III	**0.688*****	**0.690*****	**0.689*****	**0.899*****	**0.900*****	**0.899*****	-0.152	-0.160	-0.159	-0.142	-0.149	-0.149
	(0.126)	(0.126)	(0.126)	(0.125)	(0.125)	(0.125)	(0.146)	(0.147)	(0.147)	(0.148)	(0.149)	(0.149)
Rho	0.171***	0.171***	0.171***	-	-	-	0.086*	0.087*	0.085*	-	-	-
	(0.038)	(0.038)	(0.038)	-	-	-	(0.051)	(0.051)	(0.051)	-	-	-
Lambda	-	-	-	-0.059	-0.061	-0.060	-	-	-	0.109**	0.112**	0.108**
	-	-	-	(0.060)	(0.060)	(0.061)	-	-	-	(0.054)	(0.053)	(0.054)
Global Moran' I	-0.019	-0.019	-0.019	-0.019	-0.019	-0.019	0.095	0.102	0.096	0.095	0.102	0.096
P-Value > Z (·)	**0.357**	**0.341**	**0.358**	**0.357**	**0.341**	**0.358**	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.120	0.120	0.117	0.477	0.476	0.477	0.051	0.047	0.051	0.051	0.048	0.051
N	1155	1155	1155	1155	1155	1155	1155	1155	1155	1155	1155	1155

Table III-9. Spatial Model Estimation Results for Oklahoma (Upjohn Data) (Continued)

Oklahoma	ln (Mining), SAR			ln (Mining), SEM			ln (211), SAR			ln (211), SEM		
Drilled Wells	**0.010*****	-	**0.009*****	**0.012*****	-	**0.012*****	**0.008*****	-	**0.008****	**0.009*****	-	**0.009*****
(Newly Added)	(0.003)	-	(0.003)	(0.004)	-	(0.004)	(0.003)	-	(0.003)	(0.003)	-	(0.003)
Wind Farm	-	**0.004*****	**0.003*****	-	**0.003****	**0.003****	-	0.001	0.001	-	0.001	0.001
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.002)	(0.002)	-	(0.002)	(0.002)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.565*****	**0.642*****	**0.586*****	**0.479*****	**0.554*****	**0.497*****	**0.647*****	**0.703*****	**0.655*****	**0.664*****	**0.718*****	**0.670*****
	(0.111)	(0.109)	(0.111)	(0.126)	(0.128)	(0.127)	(0.116)	(0.115)	(0.117)	(0.126)	(0.126)	(0.127)
Group II	0.084	0.272	0.092	0.087	0.325	0.096	-0.004	0.150	-0.000	0.136	**0.307***	0.139
	(0.219)	(0.215)	(0.218)	(0.238)	(0.240)	(0.238)	(0.185)	(0.177)	(0.184)	(0.190)	(0.183)	(0.189)
Group III	**0.423*****	**0.449*****	**0.446*****	**0.530*****	**0.545*****	**0.543*****	0.148	0.160	0.158	**0.285***	**0.292****	**0.291***
	(0.124)	(0.124)	(0.124)	(0.133)	(0.134)	(0.133)	(0.142)	(0.142)	(0.142)	(0.148)	(0.148)	(0.148)
Rho	0.369***	0.362***	0.364***	-	-	-	0.239***	0.235***	0.237***	-	-	-
	(0.033)	(0.033)	(0.033)	-	-	-	(0.036)	(0.036)	(0.036)	-	-	-
Lambda	-	-	-	0.389***	0.372***	0.384***	-	-	-	0.237***	0.227***	0.235***
	-	-	-	(0.040)	(0.041)	(0.040)	-	-	-	(0.041)	(0.042)	(0.042)
Global Moran' I	0.188	0.170	0.177	0.188	0.170	0.177	0.249	0.234	0.240	0.249	0.234	0.240
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.267	0.270	0.274	0.249	0.250	0.254	0.269	0.267	0.271	0.105	0.103	0.107
N	1155	1155	1155	1155	1155	1155	1155	1155	1155	1155	1155	1155

Table III-10. Baseline Regression Results for Kansas & Oklahoma (Upjohn Data)

Oklahoma	ln (Total)			ln (Retail Trade)		
Drilled Wells	**0.001*****	-	**0.001*****	**0.001*****	-	**0.001*****
(Newly Added)	(0.000)	-	(0.000)	(0.000)	-	(0.000)
Wind Farm	-	**0.000*****	**0.000****	-	0.000	0.000
(Newly Added)	-	(0.000)	(0.000)	-	(0.000)	(0.000)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**-0.503*****	**-0.498*****	**-0.499*****	**-0.754*****	**-0.751*****	**-0.752*****
	(0.025)	(0.025)	(0.025)	(0.015)	(0.015)	(0.015)
Group II	**2.814*****	**2.750*****	**2.808*****	**2.006*****	**1.936*****	**2.004*****
	(0.167)	(0.181)	(0.168)	(0.190)	(0.204)	(0.190)
R-sq	0.995	0.995	0.995	0.993	0.993	0.993
N	2730	2730	2730	2730	2730	2730

Oklahoma	ln (Construction)			ln (Agricultural)		
Drilled Wells	**0.003*****	-	**0.003*****	**-0.006*****	-	**-0.006*****
(Newly Added)	(0.001)	-	(0.001)	(0.002)	-	(0.002)
Wind Farm	-	0.000	-0.000	-	-0.001	-0.000
(Newly Added)	-	(0.000)	(0.000)	-	(0.001)	(0.001)
Population	**-0.000****	-0.000	**-0.000****	**-0.000*****	**-0.000*****	**-0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**-1.368*****	**-1.363*****	**-1.368*****	**-1.088*****	**-1.108*****	**-1.098*****
	(0.098)	(0.099)	(0.098)	(0.311)	(0.312)	(0.313)
Group II	**4.186*****	**3.969*****	**4.186*****	**6.115*****	**6.527*****	**6.131*****
	(0.325)	(0.319)	(0.325)	(1.192)	(1.197)	(1.191)
R-sq	0.964	0.964	0.964	0.735	0.733	0.735
N	2725	2725	2725	1969	1969	1969

Oklahoma	ln (Mining): NAICS_21			ln (Oil & Gas Extraction): NAICS_211		
Drilled Wells	**0.005*****	-	**0.004*****	**0.005*****	-	**0.004*****
(Newly Added)	(0.001)	-	(0.001)	(0.001)	-	(0.001)
Wind Farm	-	**0.001*****	**0.001****	-	**0.001****	**0.001***
(Newly Added)	-	(0.000)	(0.000)	-	(0.001)	(0.001)
Population	0.000	0.000	0.000	**0.000****	**0.000****	**0.000****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**-2.180*****	**-2.157*****	**-2.164*****	**-0.839*****	**-0.808*****	**-0.814*****
	(0.092)	(0.094)	(0.095)	(0.124)	(0.130)	(0.130)
Group II	0.449	0.151	0.428	1.132	0.857	1.086
	(0.872)	(0.883)	(0.873)	(1.004)	(0.994)	(1.001)
R-sq	0.914	0.914	0.914	0.885	0.884	0.885
N	2472	2472	2472	1788	1788	1788

Note: Year fixed effects and county fixed effects are included for all results.

Table III-11. Spatial Model Estimation Results for Kansas & Oklahoma (Upjohn Data)

Oklahoma	ln (Total), SAR			ln (Total), SEM			ln (Retail Trade), SAR			ln (Retail Trade), SEM		
Drilled Wells	0.003*	-	0.003*	0.005***		0.007***	0.005***		0.005***	0.007***		0.007***
(Newly Added)	(0.002)	-	(0.002)	(0.002)		(0.002)	(0.002)		(0.002)	(0.002)		(0.002)
Wind Farm	-	0.001	0.001		0.001	0.001		0.001	0.001		0.001	0.001
(Newly Added)	-	(0.001)	(0.001)		(0.001)	(0.001)		(0.001)	(0.001)		(0.001)	(0.001)
Population	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	0.401***	0.412***	0.401***	0.460***	0.459***	0.438***	0.383***	0.401***	0.383***	0.437***	0.459***	0.438***
	(0.043)	(0.042)	(0.043)	(0.047)	(0.047)	(0.048)	(0.044)	(0.044)	(0.044)	(0.048)	(0.047)	(0.048)
Group II	0.397***	0.393***	0.398***	0.588***	0.629***	0.640***	0.448***	0.442***	0.449***	0.639***	0.629***	0.640***
	(0.062)	(0.062)	(0.062)	(0.071)	(0.074)	(0.073)	(0.067)	(0.067)	(0.067)	(0.073)	(0.074)	(0.073)
Rho	0.346***	0.349***	0.346***	-	-	-	0.310***	0.315***	0.310***	-	-	-
	(0.020)	(0.020)	(0.020)	-	-	-	(0.021)	(0.021)	(0.021)	-	-	-
Lambda	-	-	-	0.295***	0.247***	0.241***	-	-	-	0.240***	0.247***	0.241***
	-	-	-	(0.034)	(0.034)	(0.034)	-	-	-	(0.034)	(0.034)	(0.034)
Global Moran' I	0.098	0.099	0.098	0.098	0.099	0.098	0.082	0.085	0.082	0.082	0.085	0.082
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.496	0.494	0.496	0.497	0.495	0.497	0.469	0.466	0.469	0.470	0.467	0.470
N	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730

Oklahoma	ln (Construction), SAR			ln (Construction), SEM			ln (Agriculture), SAR			ln (Agriculture), SEM		
Drilled Wells	0.005**	-	0.004**	0.007***	-	0.007***	-0.003	-	-0.003	-0.003	-	-0.003
(Newly Added)	(0.002)	-	(0.002)	(0.002)	-	(0.002)	(0.002)	-	(0.002)	(0.002)	-	(0.002)
Wind Farm	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
(Newly Added)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Population	0.421***	0.437***	0.421***	0.462***	0.482***	0.464***	0.334***	0.324***	0.334***	0.341***	0.332***	0.340***
	(0.053)	(0.053)	(0.053)	(0.060)	(0.060)	(0.060)	(0.059)	(0.059)	(0.059)	(0.060)	(0.059)	(0.060)
Group I	0.766***	0.760***	0.767***	0.985***	0.973***	0.985***	0.025	0.024	0.023	0.039	0.039	0.037
	(0.076)	(0.075)	(0.075)	(0.091)	(0.091)	(0.091)	(0.081)	(0.081)	(0.081)	(0.083)	(0.083)	(0.083)
Group II	-	0.001	0.001	-	0.001	0.001	-	-0.001	-0.001	-	-0.001	-0.001
	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Rho	0.375***	0.379***	0.376***	-	-	-	0.060**	0.060**	0.060**	-	-	-
	(0.021)	(0.021)	(0.021)	-	-	-	(0.030)	(0.030)	(0.030)	-	-	-
Lambda	-	-	-	0.324***	0.330***	0.326***	-	-	-	0.075**	0.077**	0.075**
	-	-	-	(0.035)	(0.035)	(0.035)	-	-	-	(0.031)	(0.031)	(0.031)
Global Moran' I	0.111	0.113	0.111	0.111	0.113	0.111	0.108	0.112	0.108	0.108	0.112	0.108
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.430	0.428	0.430	0.427	0.424	0.427	0.070	0.066	0.069	0.069	0.066	0.069
N	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730

Table III-11. Spatial Model Estimation Results for Kansas & Oklahoma (Upjohn Data) (Continued)

Oklahoma	ln (Mining), SAR			ln (Mining), SEM			ln (211), SAR			ln (211), SEM		
Drilled Wells	__0.008***__	-	__0.007**__	__0.009***__	-	__0.009***__	__0.005**__	-	__0.005**__	__0.006**__	-	__0.006**__
(Newly Added)	(0.003)	-	(0.003)	(0.003)	-	(0.003)	(0.002)	-	(0.002)	(0.003)	-	(0.003)
Wind Farm	__0.000***__	__0.000***__	__0.000***__	__0.000***__	__0.000***__	__0.000***__	__0.000***__	__0.000***__	__0.000***__	__0.000***__	__0.000***__	__0.000***__
(Newly Added)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Population	__0.475***__	__0.507***__	__0.482***__	__0.398***__	__0.426***__	__0.409***__	__0.573***__	__0.598***__	__0.577***__	__0.599***__	__0.623***__	__0.603***__
	(0.066)	(0.065)	(0.066)	(0.070)	(0.069)	(0.069)	(0.071)	(0.070)	(0.071)	(0.073)	(0.072)	(0.073)
Group I	0.018	0.023	0.030	__0.257***__	__0.249***__	__0.265***__	-0.129	-0.130	-0.125	0.029	0.025	0.032
	(0.089)	(0.089)	(0.089)	(0.089)	(0.089)	(0.089)	(0.089)	(0.089)	(0.089)	(0.092)	(0.092)	(0.092)
Group II	-	__0.004***__	__0.003***__	-	__0.003***__	__0.003***__	-	0.001	0.001	-	0.001	0.001
	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Rho	0.485***	0.487***	0.483***	-	-	-	0.224***	0.226***	0.223***	-	-	-
	(0.017)	(0.017)	(0.017)	-	-	-	(0.022)	(0.022)	(0.022)	-	-	-
Lambda	-	-	-	0.537***	0.537***	0.535***	-	-	-	0.245***	0.246***	0.244***
	-	-	-	(0.019)	(0.019)	(0.019)	-	-	-	(0.024)	(0.024)	(0.024)
Global Moran' I	0.330	0.331	0.327	0.330	0.331	0.327	0.305	0.305	0.303	0.305	0.305	0.303
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.229	0.226	0.232	0.088	0.083	0.091	0.142	0.140	0.142	0.252	0.247	0.253
N	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730

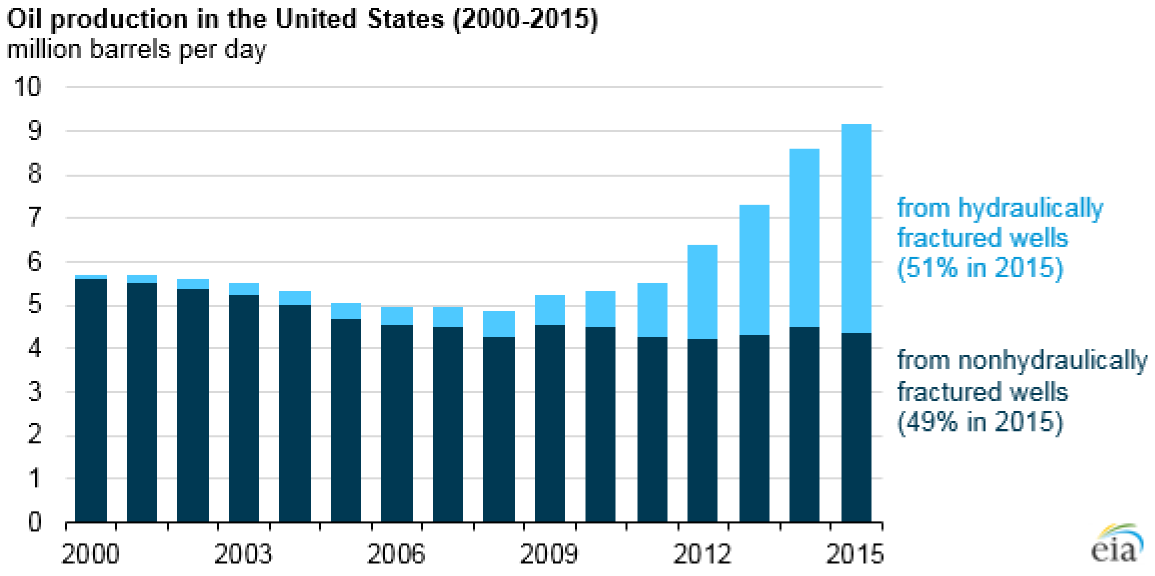
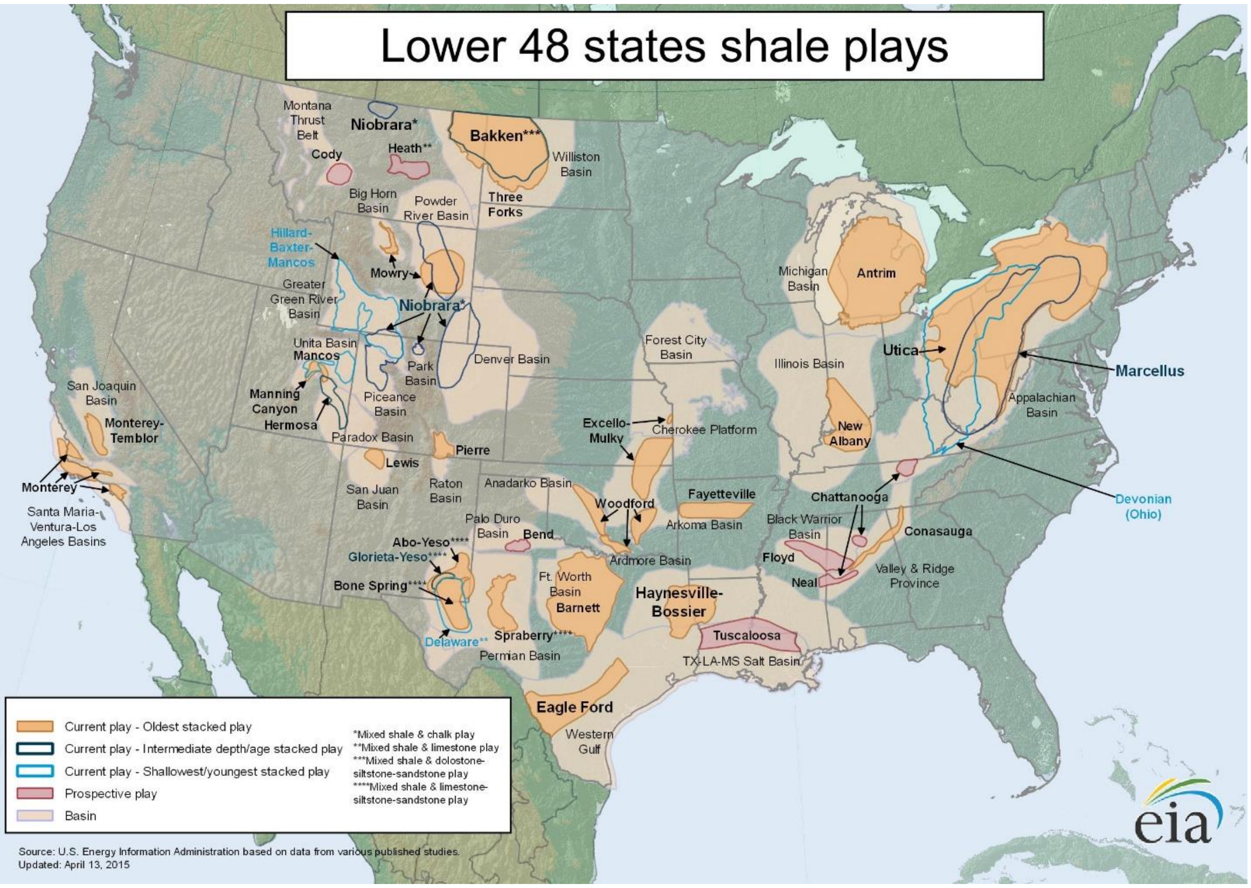


Figure III-1. Share of Oil Production in the U.S.
Source: U.S. Energy Information Administration


Lower 48 states shale plays

Source: U.S. Energy Information Administration based on data from various published studies.
Updated: April 13, 2015

Figure III-2. Locations of Shale Plays in the U.S.
Source: U.S. Energy Information Administration

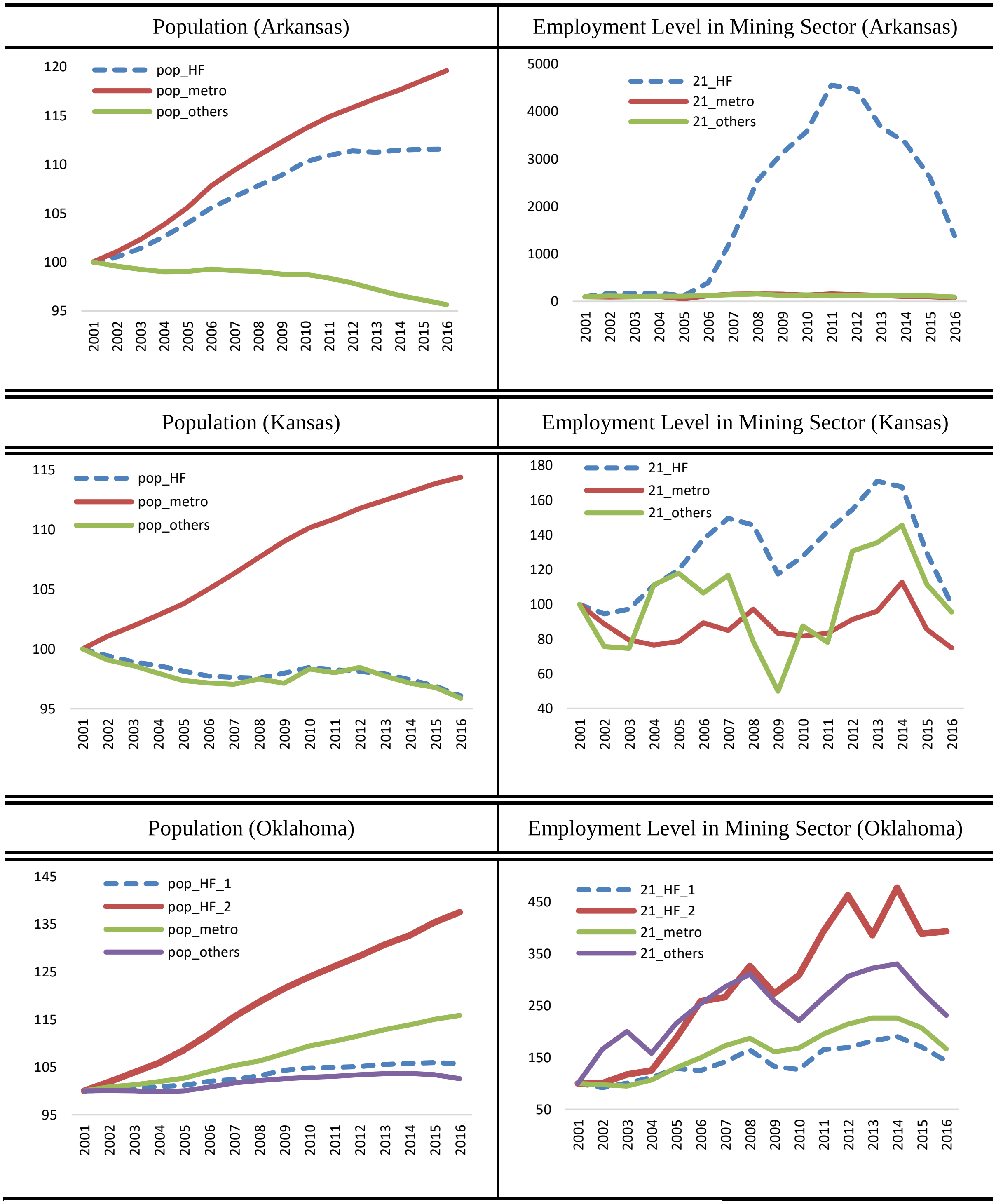


Figure III-3. Trends of Population and Employment Levels in Mining Sector
Source: Population (U.S. Census); Employment level (BLS)

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APPENDICES

Table II-Appendix-1. Unconventional Drilling Well Results (Estimation with All Data)

Ln (Sale Price)	Canadian County				Payne County			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dist to the nearest	0.002	-	-	-	-0.001	-	-	-
drilling site	(0.002)	-	-	-	(0.003)	-	-	-
Ring Boundary I	-	-0.623	-	-	-	0.016	-	-
(0-3500 ft)	-	(0.565)	-	-	-	(0.032)	-	-
Ring Boundary II	-	-	0.235	-	-	-	0.033	-
(3501-5000 ft)	-	-	(0.180)	-	-	-	(0.035)	-
Ring Boundary III	-	-	-	**-0.273***	-	-	-	-0.002
(5001-6500 ft)	-	-	-	(0.158)	-	-	-	(0.018)
Bedrooms	**0.046***	**0.046***	**0.046***	**0.046***	**0.049***	**0.043***	**0.043***	**0.043***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.018)	(0.017)	(0.017)	(0.017)
Bathrooms	**0.178***	**0.178***	**0.178***	**0.178***	**0.169***	**0.139***	**0.139***	**0.139***
	(0.042)	(0.042)	(0.042)	(0.042)	(0.022)	(0.022)	(0.022)	(0.022)
Age of Building	**-0.007**	**-0.007**	**-0.007**	**-0.007**	**-0.004***	**-0.004***	**-0.004***	**-0.004***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
Area	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Public Water Supply	**0.032**	**0.033**	**0.033**	**0.033**	0.010	0.020	0.023	0.017
	(0.015)	(0.015)	(0.015)	(0.015)	(0.059)	(0.053)	(0.053)	(0.053)
Dist to Biggest City	0.003	-0.004	0.000	-0.003	0.016	**0.024**	**0.024**	**0.024**
(OKC or Stillwater)	(0.016)	(0.015)	(0.015)	(0.015)	(0.013)	(0.012)	(0.012)	(0.012)
Dist to the	0.000	0.001	0.000	0.001	**0.003***	**0.002***	**0.002***	**0.002***
biggest city_sq	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
D_Nearest Highway	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_Highway_sq	**-0.000***	**-0.000***	**-0.000***	**-0.000***	**-0.000***	**-0.000***	**-0.000***	**-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_nearest_road	**0.000***	**0.000***	**0.000***	**0.000***	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_road_sq	-0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Community FE	Y	Y	Y	Y	Y	Y	Y	Y
R-sq	0.577	0.577	0.577	0.577	0.442	0.454	0.454	0.454
adj. R-sq	0.576	0.576	0.576	0.576	0.439	0.451	0.451	0.451
N	16900	16902	16902	16902	6813	8334	8334	8334

Robust Standard errors in parentheses
* p<0.1 ** p<0.05 *** p<0.01

Table II-Appendix-2. Conventional Drilling Well Results (Estimation with All Data)

Ln (Sale Price)	Canadian County				Payne County			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dist to the nearest	**-0.006***	-	-	-	**0.048*****	-	-	-
drilling site	(0.003)	-	-	-	(0.009)	-	-	-
Ring Boundary I	-	0.010	-	-	-	-0.027	-	-
(0-3500 ft)	-	(0.007)	-	-	-	(0.048)	-	-
Ring Boundary II	-	-	**0.013***	-	-	-	**-0.060****	-
(3501-5000 ft)	-	-	(0.007)	-	-	-	(0.029)	-
Ring Boundary III	-	-	-	0.003	-	-	-	-0.005
(5001-6500 ft)	-	-	-	(0.006)	-	-	-	(0.023)
Bedrooms	**0.056*****	**0.056*****	**0.056*****	**0.056*****	**0.040****	**0.042****	**0.042****	**0.043*****
	(0.014)	(0.014)	(0.014)	(0.014)	(0.017)	(0.016)	(0.017)	(0.017)
Bathrooms	**0.176*****	**0.176*****	**0.175*****	**0.176*****	**0.143*****	**0.139*****	**0.140*****	**0.139*****
	(0.045)	(0.045)	(0.045)	(0.045)	(0.022)	(0.022)	(0.022)	(0.022)
Age of Building	**-0.007****	**-0.007****	**-0.007****	**-0.007****	**-0.004*****	**-0.004*****	**-0.004*****	**-0.004*****
	(0.003)	(0.003)	(0.003)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
Area	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Public Water Supply	**0.033****	**0.033****	**0.033****	**0.033****	0.026	0.018	0.023	0.018
	(0.016)	(0.016)	(0.016)	(0.016)	(0.053)	(0.053)	(0.053)	(0.053)
Dist to Biggest City	0.002	0.002	0.002	0.002	0.017	**0.023****	**0.024****	**0.024****
(OKC or Stillwater)	(0.015)	(0.015)	(0.016)	(0.016)	(0.012)	(0.012)	(0.012)	(0.012)
Dist to the	0.000	0.000	0.000	0.000	**0.003*****	**0.002*****	**0.002*****	**0.002*****
biggest city_sq	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
D_Nearest Highway	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_Highway_sq	**-0.000*****	**-0.000*****	**-0.000*****	**-0.000*****	**-0.000*****	**-0.000*****	**-0.000*****	**-0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_nearest_road	0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_road_sq	-0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Community FE	Y	Y	Y	Y	Y	Y	Y	Y
R-sq	0.564	0.564	0.564	0.564	0.456	0.454	0.454	0.454
adj. R-sq	0.563	0.563	0.563	0.563	0.453	0.451	0.451	0.451
N	17312	17312	17312	17312	8334	8334	8334	8334

Robust Standard errors in parentheses
* p<0.1 ** p<0.05 *** p<0.01

Table II-Appendix-3. Additional Estimation for Canadian County

Ln (Sale Price)	Distance farther than	10 Mile		25 Mile	
	Data Treatment	Allocate to missing		Allocate to missing	
		(1)	(2)	(5)	(6)
Distance to the nearest Unconventional drilling Site		-0.000	-0.001	0.002	0.000
		(0.006)	(0.005)	(0.002)	(0.002)
Bedrooms		**0.037*****	**0.029****	**0.048*****	**0.035*****
		(0.012)	(0.012)	(0.013)	(0.012)
Bathrooms		**0.148*****	**0.142*****	**0.180*****	**0.168*****
		(0.018)	(0.016)	(0.043)	(0.040)
Age of Building		**-0.014*****	**-0.013*****	**-0.007****	**-0.006****
		(0.000)	(0.000)	(0.003)	(0.003)
Area		**0.000*****	**0.000*****	**0.000*****	**0.000*****
		(0.000)	(0.000)	(0.000)	(0.000)
Public Water Supply		0.035	**0.041***	**0.034****	**0.035*****
		(0.025)	(0.022)	(0.015)	(0.014)
D_OKC		**0.035****	**0.041*****	0.001	0.006
		(0.016)	(0.014)	(0.016)	(0.015)
D_OKC_sq		-0.001	**-0.001***	0.000	0.000
		(0.001)	(0.000)	(0.001)	(0.000)
D_Nearest Highway		**0.000*****	**0.000*****	**0.000*****	**0.000*****
		(0.000)	(0.000)	(0.000)	(0.000)
D_Highway_sq		**-0.000*****	**-0.000*****	**-0.000*****	**-0.000*****
		(0.000)	(0.000)	(0.000)	(0.000)
D_nearest_road		-0.000	-0.000	0.000*	0.000
		(0.000)	(0.000)	(0.000)	(0.000)
D_road_sq		-0.000	-0.000	-0.000	-0.000
		(0.000)	(0.000)	(0.000)	(0.000)
Excluding <$5,000		No	Yes	No	Yes
R-sq		0.628	0.652	0.575	0.594
adj. R-sq		0.626	0.650	0.574	0.593
N		6879	6840	16555	16502

Robust Standard errors in parentheses

* p<0.1 ** p<0.05 *** p<0.01

Note: Year fixed effects and community fixed effects are considered for all the results.

Table II-Appendix-4. Additional Estimation for Payne County

Ln (Sale Price)	Distance farther than	10 Mile		25 Mile	
	Data Treatment	Allocate to missing		Allocate to missing	
		(1)	(2)	(5)	(6)
Distance to the nearest Unconventional drilling Site		0.013	0.010	-0.003	0.001
		(0.011)	(0.010)	(0.005)	(0.004)
Bedrooms		**0.041****	**0.036****	**0.046*****	**0.042*****
		(0.019)	(0.018)	(0.018)	(0.016)
Bathrooms		**0.206*****	**0.189*****	**0.173*****	**0.162*****
		(0.024)	(0.022)	(0.022)	(0.021)
Age of Building		**-0.004*****	**-0.003*****	**-0.004*****	**-0.003*****
		(0.001)	(0.000)	(0.000)	(0.000)
Area		**0.000*****	**0.000*****	**0.000*****	**0.000*****
		(0.000)	(0.000)	(0.000)	(0.000)
Public Water Supply		-0.048	-0.008	0.017	0.024
		(0.071)	(0.064)	(0.063)	(0.057)
D_Stillwater		0.017	**0.053*****	0.018	**0.051*****
		(0.016)	(0.013)	(0.013)	(0.012)
D_Stillwater_sq		**0.003*****	0.000	**0.003*****	0.000
		(0.001)	(0.001)	(0.001)	(0.001)
D_Nearest Highway		**0.000*****	**0.000*****	**0.000*****	**0.000*****
		(0.000)	(0.000)	(0.000)	(0.000)
D_Highway_sq		**-0.000*****	**-0.000*****	**-0.000*****	**-0.000*****
		(0.000)	(0.000)	(0.000)	(0.000)
D_nearest_road		-0.000	**-0.000***	-0.000	-0.000
		(0.000)	(0.000)	(0.000)	(0.000)
D_road_sq		0.000	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)	(0.000)
Excluding <$5,000		No	Yes	No	Yes
R-sq		0.428	0.423	0.425	0.422
adj. R-sq		0.424	0.419	0.422	0.419
N		4772	4714	6394	6321

Robust Standard errors in parentheses
* p<0.1 ** p<0.05 *** p<0.01
Note: Year fixed effects and community fixed

Table III-Appendix-1. Wind Farm Counties

Kansas			Oklahoma		
County	Wind Farm (MW)	Shale Drilling (Count)	County	Wind Farm (MW)	Shale Drilling (Count)
Barber	**570.2**	**80**	Beaver	497.7	0
Butler	150	8	**Caddo**	**199**	**38**
Clark	200	8	**Canadian**	**298.5**	**673**
Cloud	201	0	Comanche	225.3	0
Coffey	199	6	Custer	147	18
Elk	200	0	**Dewey**	**853.6**	**57**
Ellis	205.7	1	Ellis	225	1
Ellsworth	201	0	**Garfield**	**398.8**	**60**
Ford	423.9	17	**Grady**	**408.8**	**298**
Gray	507.5	20	Grant	299	18
Haskell	249.8	13	Harper	233.4	0
Kiowa	116.5	6	Kay	558.8	0
Lincoln	249.3	0	Kingfisher	298	17
Marshall	73.8	0	Kiowa	148.8	0
Ness	198.6	16	Murray	250	1
Pottawatomie	0	0	Osage	150.4	5
Pratt	423.1	5	Roger Mills	453.1	0
Rush	50.7	2	**Stephens**	**249.9**	**163**
Sumner	**150**	**49**	Texas	320	0
Wichita	99	0	Washita	74	0
-	-	-	Woodward	355	0

Source: U.S. Department of Energy Information Administration (EIA-860)

Table III-Appendix-2. Moran’s I and Geary’s C Test Stat for Arkansas in each year

AR	Moran's I				Geary's C			
	Contiguity (Queen)		Distance Based W		Contiguity (Queen)		Distance Based W	
Year	I	p-value	I	p-value	c	p-value*	c	p-value
2001	0.042	0.431	0.066	0.241	0.940	0.411	0.891	0.124
2002	0.049	0.379	0.071	0.211	0.931	0.344	0.883	0.099
2003	0.055	0.332	0.075	0.190	0.924	0.297	0.877	0.084
2004	0.056	0.326	0.076	0.184	0.923	0.294	0.876	0.081
2005	0.057	0.316	0.076	0.184	0.920	0.274	0.874	0.076
2006	0.063	0.277	0.081	0.161	0.913	0.234	0.868	0.062
2007	0.070	0.236	0.087	0.139	0.906	0.197	0.862	0.051
2008	0.073	0.219	0.090	0.126	0.903	0.185	0.860	0.047
2009	0.074	0.216	0.091	0.122	0.903	0.185	0.858	0.045
2010	0.075	0.212	0.093	0.117	0.902	0.178	0.857	0.043
2011	0.079	0.191	0.099	0.098	0.898	0.160	0.851	0.036
2012	0.082	0.174	0.102	0.087	0.894	0.146	0.848	0.031
2013	0.084	0.165	0.105	0.081	0.892	0.137	0.845	0.028
2014	0.086	0.160	0.107	0.076	0.890	0.132	0.842	0.026
2015	0.088	0.151	0.108	0.072	0.889	0.126	0.840	0.024
2016	0.088	0.149	0.108	0.072	0.887	0.122	0.839	0.023

Table III-Appendix-3. Moran’s I and Geary’s C Test Stat for Kansas in each year

KS	Moran's I				Geary's C			
	Contiguity (Queen)		Distance Based W		Contiguity (Queen)		Distance Based W	
Year	I	p-value	I	p-value	c	p-value*	c	p-value
2001	0.345	0.000	0.330	0.000	0.649	0.000	0.653	0.000
2002	0.344	0.000	0.329	0.000	0.651	0.000	0.655	0.000
2003	0.341	0.000	0.327	0.000	0.653	0.000	0.657	0.000
2004	0.342	0.000	0.328	0.000	0.652	0.000	0.655	0.000
2005	0.349	0.000	0.333	0.000	0.645	0.000	0.650	0.000
2006	0.351	0.000	0.335	0.000	0.642	0.000	0.648	0.000
2007	0.350	0.000	0.333	0.000	0.644	0.000	0.649	0.000
2008	0.356	0.000	0.339	0.000	0.638	0.000	0.643	0.000
2009	0.349	0.000	0.333	0.000	0.644	0.000	0.649	0.000
2010	0.346	0.000	0.330	0.000	0.647	0.000	0.652	0.000
2011	0.339	0.000	0.322	0.000	0.653	0.000	0.659	0.000
2012	0.336	0.000	0.319	0.000	0.656	0.000	0.661	0.000
2013	0.335	0.000	0.319	0.000	0.657	0.000	0.661	0.000
2014	0.338	0.000	0.321	0.000	0.653	0.000	0.658	0.000
2015	0.340	0.000	0.324	0.000	0.651	0.000	0.655	0.000
2016	0.346	0.000	0.331	0.000	0.646	0.000	0.648	0.000

Table III-Appendix-4. Moran’s I and Geary’s C Test Stat for Kansas in each year

OK	Moran's I				Geary's C			
	Contiguity (Queen)		Distance Based W		Contiguity (Queen)		Distance Based W	
Year	I	p-value	I	p-value	c	p-value*	c	p-value
2001	0.161	0.015	0.220	0.000	0.823	0.020	0.805	0.007
2002	0.160	0.015	0.218	0.000	0.823	0.020	0.807	0.007
2003	0.155	0.019	0.212	0.001	0.829	0.025	0.812	0.009
2004	0.156	0.018	0.215	0.001	0.828	0.023	0.810	0.008
2005	0.160	0.015	0.217	0.001	0.824	0.020	0.808	0.008
2006	0.159	0.016	0.214	0.001	0.825	0.021	0.811	0.008
2007	0.162	0.014	0.219	0.000	0.821	0.018	0.804	0.006
2008	0.160	0.016	0.218	0.000	0.823	0.020	0.803	0.006
2009	0.161	0.015	0.219	0.000	0.823	0.019	0.803	0.006
2010	0.155	0.019	0.212	0.001	0.830	0.025	0.811	0.008
2011	0.149	0.023	0.207	0.001	0.835	0.029	0.815	0.010
2012	0.142	0.029	0.202	0.001	0.843	0.039	0.821	0.013
2013	0.145	0.027	0.205	0.001	0.839	0.033	0.818	0.011
2014	0.148	0.024	0.208	0.001	0.836	0.030	0.817	0.011
2015	0.158	0.017	0.217	0.000	0.827	0.022	0.809	0.008
2016	0.164	0.013	0.222	0.000	0.821	0.018	0.803	0.006

Table III-Appendix-5. Baseline Regression Results for Arkansas (BLS Data)

Arkansas	ln (Total)	ln (Retail Trade)	ln (Construction)
Drilled Wells (Newly Added)	**0.000*** **	0.000	**0.001*** **
	(0.000)	(0.000)	(0.000)
Population	**0.000*** **	**0.000*** **	**0.000*** **
	(0.000)	(0.000)	(0.000)
Group I	**-1.522*** **	**-1.619*** **	**-1.668*** **
	(0.022)	(0.015)	(0.045)
Group II	**1.116*** **	**0.994*** **	**2.042*** **
	(0.064)	(0.086)	(0.158)
R-sq	0.998	0.996	0.962
N	1200	1183	1101

Arkansas	ln (Agricultural)	ln (Mining): NAICS_21	ln (Oil & Gas Extraction): NAICS_211
Drilled Wells (Newly Added)	**-0.002** **	**0.006*** **	0.000
	(0.001)	(0.002)	(0.009)
Population	**0.000* **	-0.000	0.000
	(0.000)	(0.000)	(0.000)
Group I	**-0.666*** **	**1.562*** **	0.016
	(0.101)	(0.382)	(4.166)
Group II	0.129	0.852	-1.966
	(0.273)	(0.658)	(6.849)
R-sq	0.938	0.839	0.971
N	675	355	52

Note: Year fixed effects and county fixed effects are included for all results.

Table III-Appendix-6. Spatial Model Estimation Results for Arkansas (BLS Data)

Arkansas	ln (Total), SAR	ln (Total), SEM	ln (R. T.), SAR	ln (R. T.), SEM	ln (Const.), SAR	ln (Const.), SEM
Drilled Wells	**0.002*****	**0.001*****	**0.002*****	**0.002*****	**0.004*****	**0.004*****
(Newly Added)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	0.052	0.005	**0.157*****	**0.133*****	**0.226*****	**0.245*****
	(0.052)	(0.047)	(0.056)	(0.051)	(0.074)	(0.076)
Group II	0.097	-0.009	0.068	-0.013	**0.159***	**0.209*****
	(0.065)	(0.061)	(0.080)	(0.072)	(0.083)	(0.078)
Rho	-0.221***	-	-0.145***	-	0.065**	-
	(0.041)	-	(0.038)	-	(0.030)	-
Lambda	-	-0.264***	-	-0.183***	-	0.038
	-	(0.052)	-	(0.041)	-	(0.038)
Global Moran' I	-0.081	-0.081	-0.026	-0.026	-0.019	-0.019
P-Value > Z (·)	0.000	0.000	**0.169**	**0.169**	**0.321**	**0.321**
R-sq	0.662	0.663	0.471	0.467	0.356	0.315
N	1200	1200	1200	1200	1200	1200

Arkansas	ln (Ag), SAR	ln (Ag), SEM	ln (Mining), SAR	ln (Mining), SEM	ln (211), SAR	ln (211), SEM
Drilled Wells	**-0.005*****	**-0.005*****	**0.003***	**0.003***	0.002	0.002
(Newly Added)	(0.001)	(0.001)	(0.002)	(0.002)	(0.010)	(0.010)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**-0.195****	**-0.194***	0.172	0.100	0.475	0.470
	(0.098)	(0.100)	(0.119)	(0.127)	(1.713)	(1.675)
Group II	0.061	0.053	**-0.458*****	**-0.425*****	**-2.044*****	**-2.071*****
	(0.088)	(0.088)	(0.131)	(0.137)	(0.178)	(0.180)
Rho	0.057**	-	0.326***	-	-0.001	-
	(0.024)	-	(0.039)	-	(0.061)	-
Lambda	-	0.049**	-	0.348***	-	-0.018
	-	(0.024)	-	(0.041)	-	(0.056)
Global Moran' I	0.087	0.087	0.242	0.242	0.219	0.219
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.002	0.002	0.150	0.129	0.007	0.007
N	1200	1200	1200	1200	1200	1200

Table III-Appendix-7. Baseline Regression Results for Kansas (BLS Data)

Kansas	ln (Total)			ln (Retail Trade)		
Drilled Wells	**0.001*****	-	**0.001*****	**0.002*****	-	**0.002*****
(Newly Added)	(0.000)	-	(0.000)	(0.001)	-	(0.000)
Wind Farm	-	**0.000****	**0.000****	-	**0.000*****	**0.000*****
(Newly Added)	-	(0.000)	(0.000)	-	(0.000)	(0.000)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**2.089*****	**2.089*****	**2.089*****	**1.938*****	**1.939*****	**1.938*****
	(0.012)	(0.012)	(0.012)	(0.027)	(0.027)	(0.027)
Group II	**4.449*****	**4.451*****	**4.448*****	**4.255*****	**4.258*****	**4.252*****
	(0.034)	(0.034)	(0.034)	(0.075)	(0.076)	(0.076)
R-sq	0.998	0.998	0.998	0.993	0.993	0.993
N	1680	1680	1680	1657	1657	1657

Kansas	ln (Construction)			ln (Agricultural)		
Drilled Wells	0.004	-	0.004	-0.000	-	-0.000
(Newly Added)	(0.003)	-	(0.003)	(0.003)	-	(0.003)
Wind Farm	-	0.001	0.000	-	-0.000	-0.000
(Newly Added)	-	(0.000)	(0.000)	-	(0.000)	(0.000)
Population	**0.000*****	**0.000*****	**0.000*****	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**2.562*****	**2.562*****	**2.561*****	**0.662*****	**0.661*****	**0.662*****
	(0.125)	(0.125)	(0.124)	(0.097)	(0.097)	(0.097)
Group II	**6.229*****	**6.240*****	**6.224*****	-0.592	-0.593	-0.591
	(0.148)	(0.149)	(0.148)	(0.383)	(0.383)	(0.383)
R-sq	0.964	0.964	0.964	0.923	0.923	0.923
N	1400	1400	1400	926	926	926

Kansas	ln (Mining): NAICS_21			ln (Oil & Gas Extraction): NAICS_211		
Drilled Wells	**0.008****	-	**0.008****	**0.007****	-	**0.008****
(Newly Added)	(0.003)	-	(0.003)	(0.003)	-	(0.003)
Wind Farm	-	0.000	-0.000	-	-0.000	-0.000
(Newly Added)	-	(0.000)	(0.000)	-	(0.000)	(0.000)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000****	**0.000****	**0.000****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.714*****	**0.742*****	**0.714*****	**0.151****	**0.153****	**0.151****
	(0.089)	(0.089)	(0.089)	(0.066)	(0.066)	(0.066)
Group II	**0.507***	**0.559***	**0.507***	**4.519*****	**4.602*****	**4.529*****
	(0.284)	(0.291)	(0.284)	(1.105)	(1.124)	(1.101)
R-sq	0.934	0.932	0.934	0.939	0.937	0.939
N	767	767	767	319	319	319

Note: Year fixed effects and county fixed effects are included for all results.

Table III-Appendix-8. Spatial Model Estimation Results for Kansas (BLS Data)

Kansas	ln (Total), SAR			ln (Total), SEM			ln (Retail Trade), SAR			ln (Retail Trade), SEM		
Drilled Wells	-0.003	-	-0.003	-0.002	-	-0.001	-0.000	-	-0.000	-0.001	-	-0.001
(Newly Added)	(0.003)	-	(0.003)	(0.003)	-	(0.003)	(0.003)	-	(0.003)	(0.003)	-	(0.003)
Wind Farm	-	0.000	0.000	-	0.000	0.000	-	0.000	0.000	-	0.000	0.000
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.339*****	**0.335*****	**0.338*****	**0.392*****	**0.402*****	**0.402*****	**0.393*****	**0.392*****	**0.392*****	**0.403*****	**0.402*****	**0.402*****
	(0.047)	(0.046)	(0.047)	(0.050)	(0.058)	(0.058)	(0.055)	(0.055)	(0.055)	(0.058)	(0.058)	(0.058)
Group II	**0.419*****	**0.419*****	**0.419*****	**0.746*****	**0.815*****	**0.815*****	**0.555*****	**0.555*****	**0.555*****	**0.815*****	**0.815*****	**0.815*****
	(0.076)	(0.076)	(0.076)	(0.087)	(0.090)	(0.090)	(0.089)	(0.089)	(0.089)	(0.090)	(0.090)	(0.090)
Rho	0.307***	0.307***	0.307***	-	-	-	0.201***	0.202***	0.202***	-	-	-
	(0.027)	(0.027)	(0.027)	-	-	-	(0.028)	(0.028)	(0.028)	-	-	-
Lambda	-	-	-	0.125**	0.038	0.037	-	-	-	0.037	0.038	0.037
	-	-	-	(0.053)	(0.043)	(0.043)	-	-	-	(0.043)	(0.043)	(0.043)
Global Moran' I	0.043	0.044	0.044	0.043	0.044	0.044	0.017	0.019	0.017	0.017	0.019	0.017
P-Value > Z (·)	0.004	0.003	0.004	0.004	0.003	0.004	**0.251**	**0.200**	**0.244**	**0.251**	**0.200**	**0.244**
R-sq	0.516	0.516	0.516	0.523	0.523	0.523	0.380	0.380	0.380	0.382	0.382	0.382
N	1680	1680	1680	1680	1680	1680	1680	1680	1680	1680	1680	1680

Kansas	ln (Construction), SAR			ln (Construction), SEM			ln (Agriculture), SAR			ln (Agriculture), SEM		
Drilled Wells	-0.007	-	-0.008	-0.007	-	-0.007	**-0.024*****	-	**-0.023*****	**-0.024*****	-	**-0.024*****
(Newly Added)	(0.009)	-	(0.010)	(0.004)	-	(0.004)	(0.006)	-	(0.006)	(0.006)	-	(0.006)
Wind Farm	-	0.001	0.001	-	0.001	0.001	-	-0.001	-0.000	-	-0.001	-0.000
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.459*****	**0.446*****	**0.456*****	**0.494*****	**0.484*****	**0.492*****	**0.166****	**0.139***	**0.167****	**0.187****	**0.160****	**0.187****
	(0.067)	(0.067)	(0.067)	(0.071)	(0.070)	(0.071)	(0.080)	(0.080)	(0.080)	(0.081)	(0.081)	(0.081)
Group II	**1.029*****	**1.027*****	**1.029*****	**1.251*****	**1.251*****	**1.252*****	**-0.464*****	**-0.462*****	**-0.464*****	**-0.423*****	**-0.416*****	**-0.424*****
	(0.091)	(0.091)	(0.091)	(0.100)	(0.100)	(0.100)	(0.097)	(0.097)	(0.097)	(0.096)	(0.095)	(0.096)
Rho	0.205***	0.205***	0.205***	-	-	-	0.146***	0.140***	0.146***	-	-	-
	(0.022)	(0.022)	(0.022)	-	-	-	(0.023)	(0.024)	(0.023)	-	-	-
Lambda	-	-	-	0.144***	0.145***	0.144***	-	-	-	0.148***	0.142***	0.148***
	-	-	-	(0.033)	(0.033)	(0.033)	-	-	-	(0.023)	(0.023)	(0.023)
Global Moran' I	0.068	0.067	0.068	0.068	0.067	0.068	0.077	0.077	0.077	0.077	0.077	0.077
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.268	0.268	0.267	0.147	0.147	0.147	0.059	0.069	0.059	0.064	0.075	0.064
N	1680	1680	1680	1680	1680	1680	1680	1680	1680	1680	1680	1680

Table III-Appendix-8. Spatial Model Estimation Results for Kansas (BLS Data) (Continued)

Kansas	ln (Mining), SAR			ln (Mining), SEM			ln (211), SAR			ln (211), SEM		
Drilled Wells	-0.002	-	-0.003	-0.003	-	-0.003	0.002	-	0.002	0.002	-	0.002
(Newly Added)	(0.004)	-	(0.004)	(0.004)	-	(0.004)	(0.002)	-	(0.003)	(0.002)	-	(0.003)
Wind Farm	-	0.001	0.001	-	0.001	0.001	-	-0.001	-0.001	-	-0.001	-0.001
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **	**0.000*** **
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.736*** **	**0.729*** **	**0.732*** **	**0.765*** **	**0.757*** **	**0.761*** **	0.196	0.205	0.201	0.192	0.202	0.198
	(0.097)	(0.097)	(0.097)	(0.095)	(0.094)	(0.095)	(0.154)	(0.153)	(0.154)	(0.155)	(0.154)	(0.155)
Group II	-0.010	-0.008	-0.011	0.077	0.077	0.075	**-0.492*** **	**-0.493*** **	**-0.493*** **	**-0.524*** **	**-0.524*** **	**-0.525*** **
	(0.116)	(0.117)	(0.117)	(0.108)	(0.108)	(0.108)	(0.180)	(0.179)	(0.179)	(0.182)	(0.180)	(0.181)
Rho	0.103***	0.100***	0.102***	-	-	-	-0.043	-0.043	-0.044	-	-	-
	(0.029)	(0.029)	(0.029)	-	-	-	(0.045)	(0.045)	(0.045)	-	-	-
Lambda	-	-	-	0.121***	0.119***	0.121***	-	-	-	-0.042	-0.041	-0.042
	-	-	-	(0.031)	(0.030)	(0.031)	-	-	-	(0.046)	(0.045)	(0.045)
Global Moran' I	0.160	0.164	0.160	0.160	0.164	0.160	0.088	0.090	0.088	0.088	0.090	0.088
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.215	0.215	0.214	0.214	0.215	0.213	0.134	0.132	0.134	0.133	0.131	0.133
N	1680	1680	1680	1680	1680	1680	1680	1680	1680	1680	1680	1680

Table III-Appendix-9. Baseline Regression Results for Oklahoma (BLS Data)

Oklahoma	ln (Total)			ln (Retail Trade)		
Drilled Wells	0.000	-	0.000	0.000*	-	0.000*
(Newly Added)	(0.000)	-	(0.000)	(0.000)	-	(0.000)
Wind Farm	-	0.000	0.000	-	0.000	0.000
(Newly Added)	-	(0.000)	(0.000)	-	(0.000)	(0.000)
Population	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	-0.354***	-0.353***	-0.353***	-0.030	-0.029	-0.030
	(0.030)	(0.030)	(0.030)	(0.019)	(0.019)	(0.019)
Group II	0.332***	0.333***	0.332***	0.578***	0.580***	0.578***
	(0.034)	(0.034)	(0.034)	(0.065)	(0.065)	(0.065)
Group III	3.447***	3.419***	3.436***	2.754***	2.724***	2.752***
	(0.199)	(0.204)	(0.200)	(0.343)	(0.347)	(0.344)
R-sq	0.996	0.996	0.996	0.994	0.994	0.994
N	1232	1232	1232	1228	1228	1228

Oklahoma	ln (Construction)			ln (Agricultural)		
Drilled Wells	0.002**	-	0.001*	-0.006***	-	-0.006***
(Newly Added)	(0.001)	-	(0.001)	(0.001)	-	(0.001)
Wind Farm	-	0.001**	0.001**	-	0.001***	0.001***
(Newly Added)	-	(0.000)	(0.000)	-	(0.000)	(0.000)
Population	-0.000	-0.000	-0.000	-0.000**	-0.000***	-0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	0.442***	0.449***	0.444***	-1.484***	-1.477***	-1.458***
	(0.147)	(0.148)	(0.148)	(0.211)	(0.204)	(0.209)
Group II	2.440***	2.443***	2.433***	-0.215	-0.235*	-0.203
	(0.141)	(0.141)	(0.142)	(0.138)	(0.129)	(0.136)
Group III	6.114***	5.901***	6.013***	2.829***	3.137***	2.694***
	(0.381)	(0.382)	(0.383)	(0.729)	(0.727)	(0.731)
R-sq	0.967	0.967	0.967	0.889	0.887	0.890
N	1072	1072	1072	904	904	904

Oklahoma	ln (Mining): NAICS_21			ln (Oil & Gas Extraction): NAICS_211		
Drilled Wells	0.001	-	0.001	0.004***	-	0.004**
(Newly Added)	(0.001)	-	(0.001)	(0.002)	-	(0.002)
Wind Farm	-	-0.000	-0.000	-	0.001	0.000
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	-3.401***	-3.410***	-3.406***	-6.010***	-5.996***	-6.009***
	(0.535)	(0.537)	(0.536)	(0.376)	(0.375)	(0.375)
Group II	-4.536***	-4.545***	-4.538***	-6.575***	-6.545***	-6.575***
	(0.133)	(0.136)	(0.134)	(0.216)	(0.223)	(0.218)
Group III	-2.325**	-2.199**	-2.299**	-3.667***	-3.671***	-3.713***
	(0.948)	(0.926)	(0.945)	(0.760)	(0.767)	(0.771)
R-sq	0.938	0.938	0.938	0.980	0.979	0.980
N	898	898	898	324	324	324

Note: Year fixed effects and county fixed effects are included for all results.

Table III-Appendix-10. Spatial Model Estimation Results for Oklahoma (BLS Data)

Oklahoma	ln (Total), SAR			ln (Total), SEM			ln (Retail Trade), SAR			ln (Retail Trade), SEM		
Drilled Wells	0.001	-	0.001	0.000	-	0.001	0.002	-	0.002	0.001	-	0.001
(Newly Added)	(0.002)	-	(0.002)	(0.002)	-	(0.002)	(0.002)	-	(0.002)	(0.002)	-	(0.002)
Wind Farm	-	-0.000	-0.000	-	-0.001	-0.001	-	-0.000	-0.000	-	-0.001	-0.001
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**0.362*****	**0.369*****	**0.361*****	**0.373*****	**0.436*****	**0.428*****	**0.421*****	**0.432*****	**0.420*****	**0.431*****	**0.436*****	**0.428*****
	(0.063)	(0.063)	(0.063)	(0.058)	(0.064)	(0.064)	(0.070)	(0.069)	(0.070)	(0.065)	(0.064)	(0.064)
Group II	**0.672*****	**0.701*****	**0.672*****	**0.887*****	**1.090*****	**1.066*****	**0.840*****	**0.882*****	**0.841*****	**1.057*****	**1.090*****	**1.066*****
	(0.096)	(0.088)	(0.096)	(0.087)	(0.081)	(0.091)	(0.099)	(0.092)	(0.100)	(0.090)	(0.081)	(0.091)
Group III	**0.515*****	**0.515*****	**0.515*****	**0.633*****	**0.694*****	**0.693*****	**0.587*****	**0.587*****	**0.587*****	**0.695*****	**0.694*****	**0.693*****
	(0.085)	(0.085)	(0.085)	(0.076)	(0.090)	(0.090)	(0.100)	(0.100)	(0.100)	(0.090)	(0.090)	(0.090)
Rho	0.036	0.035	0.036	-	-	-	0.037	0.035	0.036	-	-	-
	(0.034)	(0.034)	(0.034)	-	-	-	(0.035)	(0.035)	(0.035)	-	-	-
Lambda	-	-	-	-0.225***	-0.213***	-0.210***	-	-	-	-0.202***	-0.213***	-0.210***
	-	-	-	(0.045)	(0.046)	(0.046)	-	-	-	(0.045)	(0.046)	(0.046)
Global Moran' I	-0.078	-0.080	-0.079	-0.078	-0.080	-0.079	-0.076	-0.078	-0.077	-0.076	-0.078	-0.077
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-sq	0.479	0.483	0.480	0.543	0.543	0.543	0.445	0.447	0.447	0.471	0.471	0.471
N	1232	1232	1232	1232	1232	1232	1232	1232	1232	1232	1232	1232

Oklahoma	ln (Construction), SAR			ln (Construction), SEM			ln (Agriculture), SAR			ln (Agriculture), SEM		
Drilled Wells	0.001	-	0.000	0.001	-	0.000	**-0.007*****	-	**-0.007*****	**-0.007*****	-	**-0.008*****
(Newly Added)	(0.002)	-	(0.002)	(0.002)	-	(0.002)	(0.002)	-	(0.002)	(0.002)	-	(0.002)
Wind Farm	-	**0.002***	**0.002***	-	**0.002***	**0.002***	-	0.001	0.001	-	0.001	0.001
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.001)	(0.001)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	**-0.189****	**-0.181****	**-0.184****	**-0.190****	**-0.182****	**-0.184****	**-0.593*****	**-0.639*****	**-0.589*****	**-0.599*****	**-0.646*****	**-0.594*****
	(0.089)	(0.089)	(0.089)	(0.092)	(0.091)	(0.092)	(0.104)	(0.104)	(0.104)	(0.105)	(0.105)	(0.105)
Group II	**0.725*****	**0.726*****	**0.718*****	**0.813*****	**0.819*****	**0.809*****	**0.594*****	**0.442*****	**0.597*****	**0.633*****	**0.478*****	**0.637*****
	(0.107)	(0.097)	(0.106)	(0.120)	(0.110)	(0.119)	(0.128)	(0.118)	(0.127)	(0.124)	(0.114)	(0.123)
Group III	**0.214***	**0.222***	**0.222***	**0.284****	**0.293****	**0.292****	**-0.582*****	**-0.577*****	**-0.576*****	**-0.602*****	**-0.594*****	**-0.596*****
	(0.118)	(0.118)	(0.118)	(0.121)	(0.121)	(0.121)	(0.124)	(0.124)	(0.124)	(0.130)	(0.130)	(0.130)
Rho	0.117***	0.119***	0.119***	-	-	-	-0.003	0.002	-0.005	-	-	-
	(0.025)	(0.025)	(0.025)	-	-	-	(0.029)	(0.029)	(0.029)	-	-	-
Lambda	-	-	-	0.078**	0.079**	0.079**	-	-	-	-0.040	-0.036	-0.043
	-	-	-	(0.033)	(0.033)	(0.033)	-	-	-	(0.033)	(0.034)	(0.034)
Global Moran' I	0.035	0.034	0.036	0.035	0.034	0.036	0.043	0.039	0.037	0.043	0.039	0.037
P-Value > Z (·)	**0.053**	**0.058**	**0.047**	**0.053**	**0.058**	**0.047**	**0.018**	**0.034**	**0.040**	**0.018**	**0.034**	**0.040**
R-sq	0.249	0.249	0.250	0.163	0.163	0.163	0.101	0.104	0.104	0.102	0.105	0.105
N	1232	1232	1232	1232	1232	1232	1232	1232	1232	1232	1232	1232

Table III-Appendix-10. Spatial Model Estimation Results for Oklahoma (BLS Data) (Continued)

Oklahoma	ln (Mining), SAR			ln (Mining), SEM			ln (211), SAR			ln (211), SEM		
Drilled Wells	**0.007***	-	**0.007***	**0.008****	-	**0.008****	-0.003	-	-0.002	-0.003	-	-0.002
(Newly Added)	(0.004)	-	(0.004)	(0.004)	-	(0.004)	(0.004)	-	(0.005)	(0.004)	-	(0.005)
Wind Farm	-	0.002	0.001	-	0.001	0.001	-	-0.002	-0.002	-	-0.002	-0.002
(Newly Added)	-	(0.001)	(0.001)	-	(0.001)	(0.001)	-	(0.002)	(0.002)	-	(0.002)	(0.002)
Population	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Group I	-0.043	0.019	-0.031	-0.082	-0.022	-0.072	-0.114	-0.175	-0.162	-0.117	-0.176	-0.164
	(0.127)	(0.127)	(0.128)	(0.140)	(0.141)	(0.142)	(0.287)	(0.294)	(0.295)	(0.294)	(0.301)	(0.302)
Group II	**-0.614*****	**-0.459****	**-0.605*****	**-0.596*****	**-0.425***	**-0.587*****	-0.278	-0.371	-0.311	-0.247	-0.337	-0.280
	(0.217)	(0.214)	(0.217)	(0.227)	(0.225)	(0.227)	(0.385)	(0.348)	(0.391)	(0.382)	(0.344)	(0.389)
Group III	**-0.272***	**-0.252***	**-0.257***	-0.227	-0.212	-0.216	**-0.601***	**-0.655***	**-0.649***	**-0.553***	**-0.606***	**-0.599***
	(0.146)	(0.148)	(0.148)	(0.156)	(0.157)	(0.157)	(0.336)	(0.344)	(0.344)	(0.328)	(0.336)	(0.336)
Rho	0.219***	0.212***	0.216***	-	-	-	0.048	0.050	0.050	-	-	-
	(0.032)	(0.032)	(0.032)	-	-	-	(0.053)	(0.053)	(0.053)	-	-	-
Lambda	-	-	-	0.226***	0.216***	0.223***	-	-	-	0.019	0.022	0.021
	-	-	-	(0.034)	(0.034)	(0.034)	-	-	-	(0.053)	(0.053)	(0.053)
Global Moran' I	0.141	0.128	0.132	0.141	0.128	0.132	0.037	0.033	0.033	0.037	0.033	0.033
P-Value > Z (·)	0.000	0.000	0.000	0.000	0.000	0.000	**0.040**	**0.072**	**0.073**	**0.040**	**0.072**	**0.073**
R-sq	0.090	0.087	0.091	0.128	0.131	0.132	0.208	0.194	0.195	0.210	0.197	0.197
N	1232	1232	1232	1232	1232	1232	1232	1232	1232	1232	1232	1232

VITA

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