Tax Policy and Energy Markets: Evaluating the Efficacy of Production Tax Relief on Sector Activity

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Between 1979 and 2000, state legislatures across the country enacted some of the largest incentive programs for oil and gas producers on record. To evaluate the impact of these severance tax breaks, we collect county-level panel data of varying production outcomes to construct difference-in-differences (DiD) models to estimate pre- and post-treatment results of each policy change in Louisiana, Mississippi, Kansas, and Utah. Contrary to the intent of severance tax relief, based on these case studies, our findings indicate that drilling incentives do not increase sector activity and in some cases decrease it.

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1 Introduction

How do energy operators of nonrenewable natural resources react to changes in tax policy? The long-standing expectation from conventional economic theory is clear: increasing severance taxes burdens drillers with higher production costs, decreasing the incentives to extract hydrocarbons. Conversely, reducing or eliminating severance taxes should lead to higher production and associated economic activity (Hotelling, 1931). Policymakers have often relied on altering tax structures to influence market activity in various fields, such as reducing adult smoking by increasing sales taxes (McLeod and DeCicca, 2007), imposing carbon taxes to curb CO_2 emissions (OECD, 2021), and providing education subsidies to grow school enrollment (Ay, 2004). This is especially prevalent in policies related to exhaustible resources economics.

Mid-to-late twentieth-century studies such as Slade (1984) supported Hotelling's assertion that taxes affect resource extraction and production. However, modern evidence from natural experiments has failed to detect negative effects on production outcomes from marginal increases of severance tax rates (Reimer, Guettabi, and Tanaka 2017). Moreover, large reductions in severance taxes have yielded mixed evidence (Kunce, 2023) and (Gade, Maguire, and Makamu 2016).

This paper measures the effect of severance tax breaks on county-level oil and gas production activity. We analyze production outcomes based on changing tax structures, i.e. severance tax breaks, on a subset of nine states whose legislatures passed similar, substantial severance tax reductions or exemptions to increase energy activity, relying on careful selection of control and treatment groups given detailed criteria of tax regimen. Comparisons of oil and gas production, as well as drilling levels, before and after the periodical introduction of severance tax breaks offer a consistent method for evaluating the effects of tax incentives on industry activity. Further analyses of within-treatment-state outcomes (based on a county's presence on described geological factors such as oil basin or shale plays) provide estimations on how a county's production capability might influence its reaction to changing tax policies, while specific comparisons of geologically similar counties across the country allow for robust examination of these new tax policies.

Overall, accurate causal estimation of a severance tax cut's impact on energy markets remains an important question for policymakers and consumers alike. For instance, oil and gas production fund more than 40% of

New Mexico's state budget, amplifying possible ramifications of a law's impact on the state budget.[1] In New Mexico, where early childhood education is a constitutional right, oil and gas taxes finance 25% of the state's early childhood education programs.[2] Other oil and gas states have a similarly-high reliance on severance taxes to fund state programs, making any marginal change to the tax rate, or to commodity prices, a sizable impact on government budgets.

In Louisiana, oil and gas extraction and refining sectors accounted for roughly 18% of Louisiana's Gross Domestic Product (GDP) in 2011 (Scott, 2014). In the late 50s to early 60s, over half of the state's revenue came from oil and gas, but provides less than five percent today (Upton and Richardson, 2020). If the argument in favor of these laws is that loss of tax revenue will be offset by increasing production, as some policymakers have claimed, then closer scrutiny must be placed on whether the laws worked as intended. From one tax relief program alone, Louisiana's Legislative Auditor estimated a loss of $1.1 billion in just four years, suggesting this might not be the case (Purpera, 2015).

Studying the impact of amendments that cut extraction taxes for energy operators also has important welfare implications. In New Mexico and Louisiana alike, as well as in other energy-dependent states, oil and gas make up a large share of GDP and private-sector employment, particularly so in counties—or parishes—near geological formations that enable sector activity. Oil and gas represent integral parts of these communities, as demonstrated by various shale boom studies that track ameliorating industry conditions to community economic well-being. For example, Brown (2014) finds that second-stage results show positive effects from higher natural gas extraction across germane economic outcomes, each "billion cubic feet of natural gas production" being associated with an additional 12.7 jobs in a producing county, implying an increase in employment of thirteen percent from the total increase in natural gas production during the shale boom from 2001 to 2011.

Furthermore, understanding the effects of these policies is crucial for creating laws that encourage sustainable energy development. If these policies show limited or no benefits, it suggests that new initiatives like the Inflation Reduction Act might also struggle to promote green energy. It is important to understand how

[1] Taken from: Redfern, Capital & Main, 2024.
[2] Taken from: `https://shorturl.at/hmnpy`

such tax policies may affect the energy industry's supply chain, from reservoir discovery to filling up gas at the pump, and implications to the state.

In addition, the extended longitudinal nature of our panel study, parsed accordingly to varying case studies, allows us to overcome challenges prompted by the volatility of important input factors. For example, at the beginning of our period of interest, the price of oil sat at $17.86 per barrel, whereas it had dipped to $8.57 by the end.[3] Yet, previous analyses of policy interventions have largely established inference without enough diligence towards time-varying covariates such as the price of oil or other commodity prices, consumer demand, or even technological improvements.[4] Therefore, analyzing unique control and treatment observations over time, controlling for time-varying fixed effects, enables us to isolate the effect of severance tax breaks.

To our knowledge, there has not been another study that applies empirical methodology to so many akin tax interventions of this nature. In total, we construct four case studies to examine the impact of severance tax breaks on oil and gas extraction and drilling levels, providing one of the most robust set of analyses in the field of exhaustible resources economics. Aiming to provide new insights in a broad study of these policies through our panel study approach, our results provide important implications on the consistent effects of these policies—conclusions which either affirm or challenge the foundational premise that lowering severance tax rates increase oil and gas activity.

2 Background

Resource economists expect the imposition of severance taxes, ceteris paribus, to result in a decline in production, traced back to Hotelling's seminal work, *The Economics of Exhaustible Resources* (1931). The first to incorporate a severance tax in a model, Hotelling examined its long-term effects on mine extraction by factoring in the tax's burden on production as a project's profitability-decreasing variable, outlining the

[3]Source: Energy Information Administration (EIA)'s U.S. Crude Oil Prices.

[4]For instance, Eck (1983) attributed the oil and gas industry's weakening conditions in the early 80s to the growing tax burden in the nation. However, this period coincided with a sharp recession and subsequent economic fluctuations, paired with a decay in such commodity prices.

intricate relationship between severance taxes and the economic viability of mining projects.

Subsequent studies aimed to elucidate the causal relationship between severance taxes and production, consistently affirming Hotelling's initial findings. But early assessments often relied on basic supply and demand models or simple correlative measures of taxation and production, as seen in Millsaps, Spann, and Erickson (1974). While descriptive case studies abound, statistical econometric analyses specific to the ceteris paribus introduction of taxes were notably absent. Eck (1983), for example, attributed the oil and gas industry's weakening conditions in the early 80s to the growing tax burden in the nation. However, this period coincided with a sharp recession and subsequent economic fluctuations, complicating the isolation of tax effects. Despite favorable economic conditions later in the decade, a full industry recovery was hindered by plummeting commodity prices, particularly a significant drop in oil prices from $30 per barrel in 1982.[5] Brannon (1975) even argued that tax incentives have such a high effect on energy activity that "there is a bias toward overdrilling inherent in a tax law which permits a full deduction."

However, many nonexperimental studies faltered in constructing ceteris paribus scenarios to econometrically attribute production decline to taxation. Slade (1984) was an early test of Hotelling's profitability framework within metal extraction, with evidence to affirm his conclusions that taxes diminish the profitability of extraction. Yet, she introduced two considerations often overlooked. First, she highlighted the oversight in focusing predominantly on extraction effects, neglecting potential exploration effects measured not in production but in investment in new fields or future production. Second, the impact of tax changes on mining extraction depends on various factors—tax size, type, placement, effects on input/output prices, and extraction technology. This nuanced perspective underscores the complexity of tax effects in exhaustible resource economics beyond Hotelling's factorial model.

The underexplored interplay and reinforcement of factors shaping the relationship between higher taxation and lower production form a crucial gap in past and current research. Luckily, 21st-century literature has delved into panel data methodologies, examining pre- and post-tax imposition on production, state tax revenue, and related outcomes. These contemporary approaches offer credibility advantages over previous

[5] From the EIA's U.S. Crude Oil Prices.

methods, particularly in industries heavily reliant on volatile commodity prices. New panel data estimations of production and revenue better capture treatment effects of tax imposition, overcoming estimation challenges posed by fluctuating market conditions. This is exemplified by the observation of gasoline prices during the COVID-19 pandemic, where despite variations across gas stations and states, the universal fall and rise in prices underscored the equalizing impact of market conditions.

Kunce's (2003) state-level panel data analysis on oil and gas extraction and severance tax incentives revealed that tax incentives "yield moderate to little change in oil drilling and production activity," but "substantially reduce state tax revenue." Contrary to earlier literature, Kunce warns against using tax policy to properly incentivize the energy industry, emphasizing the need for states to exercise caution in evaluating "arguments asserting that large swings in oil field activity can be obtained from changes in severance tax rates."

Recent empirical studies have prompted a significant shift in economic theory, challenging the once unambiguous prediction that higher severance taxes lead to a decline in production activities. Gade, Maguire, and Makamu (2016) found that Oklahoma's 2002 horizontal drilling severance tax incentive (a reduction from seven percent to one percent) did not significantly influence horizontal drilling in the state. Reimer, Guettabi, and Tanaka (2017) examined the impact of a tax increase in Alaska's 2007 ACES program, which tripled the tax liability for oil producers. They found no discernible differences in outcome variables of interest between Alaska and its synthetic control. Lastly, Brown, Maniloff, and Manning (2020) showed energy firms' investment in U.S. oil projects exhibits inelastic responsiveness to changes in state tax rates. These studies underscore the need for a reevaluation of the assumed relationship between severance taxes and production activities.

3 Empirical strategy

Taking data from each state's agency respective energy administration through Enverus, a private energy data provider often used by large oil and gas enterprises and service firms, we construct a sample frame of county-level production covariates for the period from 1980 to 2000. We focus on this time frame for two reasons. First, most state agencies report energy data for this time frame.[6] This also allows us to provide a varied and robust set of regressions using a large subsample across the same time between states. Second, and perhaps more importantly, severance tax breaks across several states went into effect to incentivize oil and gas production during this period.

Then, we use the annual publication of "Investments in Energy Security," 2002 version, by the Interstate Oil and Gas Compact Commission (IOGCC) to detect homogeneous policy changes in severance tax law that either severely reduced severance tax rates or provided outright exemptions. The IOGCC is a multi-state government body which, among other responsibilities, provides encompassing historical information about member states' energy rules and regulations.[7] Our publication of interest contains all of the law changes that occurred in these states, detailed descriptions of the amendments or new laws, their intended purposes, and other relevant information. Using this document, we develop consistent criteria made up of two main characteristics: universality and substantiality of the tax break. First, we focus specifically on tax amendments that aim to increase state drilling. To "encourage [state] exploration," policymakers have sought to create policies that, expectedly, would increase the level of drilling in an area by way of creating new wells.[8] Often, these are noted in tax amendements simply as "new wells," but they can take the name of "new discovery well," as it is the case for Louisiana, "new pools," as it is the case for Mississippi, or other variants of such. These policies, in turn, provide tax reductions or exemptions from the hydrocarbons produced in such new wells, given a certain period of time or recuperation of initial drilling cost, often referred to as "well payout." Therefore, the most immediate effect we expect to see would be a higher count of new wells, followed by substantial production from these new sites. The second characteristic of these policies is how large they are. While there is no single standard in the literature as to the level of substantiality of a certain policy, for a researcher to expect to see an effect, we have noted that all of these policies have come with an undoubtedly high level of substantiality. For example, the 1994 Louisiana tax amendment gave a 100% tax exemption from severance taxes to new wells drilled in the state, at a time when the tax

[6] For example, while Alaska's Oil & Gas Conservation Commission began recording data in 1919, Pennsylvania's Bureau of Oil and Gas Management did not start recording data until 1980.

[7] Link: `https://oklahoma.gov/iogcc.html`

[8] See the IOGCC publication, page 17 for a reference to the Mississippi amendment.

rate for oil extraction was 12.5% of its market value.[9] To put into perspective, these tax rates brought to Louisiana roughly $700 million the year prior. The fact that these laws are substantial is to be expected. Severance tax law is complicated, varies greatly from state to state, and there are a lot of players in energy impacted differently, from upstream to downstream. Therefore, if a state would go to the length to pass any amendment, it is reasonable that it would not be of mere marginal nature.

In our sample of "case studies," we have defined nine states whose legislatures enacted policies based on the detailed criteria above. For the bulk of our study, in which we analyze simple pre and post-treatment comparisons of production covariates, we rely on a ten-year time interval for each policy.

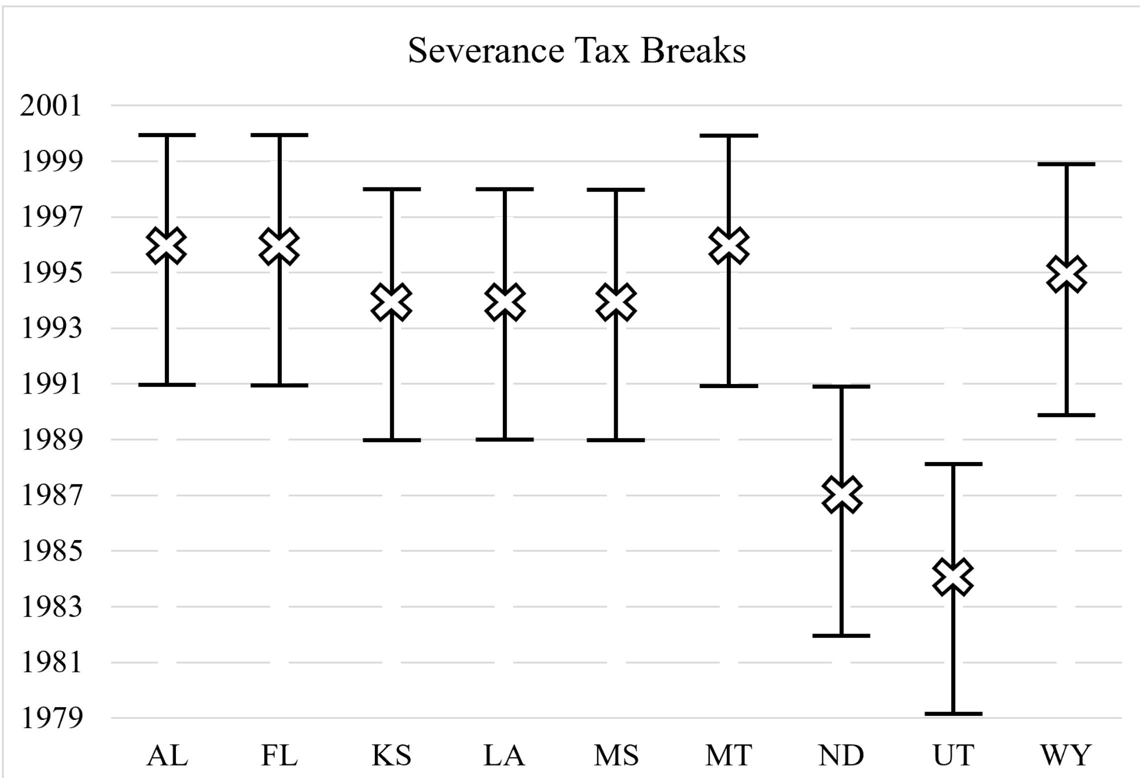

Figure 1: Time Intervals of Examined Policies

Production data is aggregated at the county level, from 1950 to 2011 for most states. We focus our analysis on 33 oil and gas producing states, which includes two regions in the Pacific Ocean and the Gulf of Mexico with drilling, which both are assigned respective county-like boundaries that are consistent over time. The

[9] Source:`https://shorturl.at/eopE3`

33 states examined are: AK, AL, AR, AZ, CA, CO, FL, FO GULF, FO PACIFIC, KS, KY, LA, MD, MI, MO, MS, MT, ND, NE, NM, NV, NY, OH, OK, OR, PA, SD, TN, TX, UT, VA, WV, WY. Similarly, we have 1,237 county aggregations, out of a total of 3,143 counties and equivalents in the U.S. The large drop in counties, from an analogous drop in states from the total number of them, is due to the fact that, like states, counties can also be completely non-producing of oil and gas, even in large oil and gas-producing states like Pennsylvania, where roughly 30 counties are not present in the data.

The dataset contains a total of 76,694 observations of annual production of oil, gas, and water. While crude production, including condensate, is measured by barrels, natural gas production is measured by thousand cubic feet (MCF) at 15.025 psia and 60 degrees Fahrenheit. Water represents an undescribed measure of residue in well activity, as well as injection to extract further oil and gas. In addition, we collect the total number of actively producing wells (oil wells and gas wells measured together), as well as the number of new wells, a variable that represents the addition of wells to a county in a given year (while intuitively new wells can be thought of a measure of delta total wells, this is not the case; rather, this variable records newly drilled wells in a county. In other words, while new wells can increase over time, total wells can decrease over time). Additionally, FIPS codes allow us to visualize county data. Several regions do not have FIPS codes, so they remain unable to be mapped, namely FO PACIFIC and FO GULF and states with offshore drilling that are aggregated and assigned to an "offshore" county. These counties are assigned a FIPS code of 0; in total, 4,960 observations, or 6.48 percent of our dataset, lack a FIPS code. In addition, we geocode information from the U.S. Energy Information Administration (EIA), relying on a map that indicates all the sedimentary basins associated with the EIA plays, data the agency takes from a combination of the US Geological Survey, Enverus, and state agencies like the WY Geological Survey, among others.[10]

This dataset only displays contiguous United States, so we merge Alaska basin plays from a variety of official state sources. Similarly, FO PACIFIC and FO GULF are not part of the EIA maps, but, unlike Alaska, they cannot be reconciled with official state sources. Therefore, analyzing the data and possible geophysical similarities of each county-like aggregation for those areas, we conclude that an accurate representation of the "basin" of these areas is a hypothetical basin that encompasses all counties within these regions. To

[10] Map can be obtained at: `https://shorturl.at/hiDRZ`

establish appropriate controls, it is very important that all observations do not miss values on respective control variables. Therefore, for these two areas, we create a respective "Pacific Gulf Basin" and "Gulf of Mexico Basin." Similarly, we geocode another EIA map pertaining to county shale information.[11] Following analogous procedures when we introduced the basin variable to the dataset, we assign respective hypothetical shale plays to both FO PACIFIC and FO GULF. From this new merge, we also gain an area's primary lithology and primary age. Shrinking our dataset for our period of interest in which policies began to be enacted (1979-2000), we are left with 27,214 observations. Shrinking our dataset further to a ten-year period of study for each respective policy, we can analyze a total of over ten thousand observations for each regression.

Relying on a straightforward difference-in-differences (DiD) model, we compare production outcomes for those counties that had no exposure to treatment to those that were part of a state in which a severance tax break was granted. Given that we analyze several different policies, we run separate models for each tax break; therefore, we compare production outcomes of counties in a treatment state to those counties within our subset of control states.

Intuitively, DiD estimations rely on an outcome's post-treatment difference substracted from its pre-treatment difference, given treatment and control groups, respectively. Therefore, we say that:

$$\delta_{DiD} = (Y_{i_1,t} - Y_{i_0,t}) - (Y_{i_1,t-1} - Y_{i_0,t-1})$$

where Y represents a given production outcome, i indexes a given county with a binary in which 1 stands for treatment state and 0 for control state, and t represents the year of treatment.

Forming a classic DiD regression, we define the average treatment effects of a severance tax on a state's production as:

[11] Map can be obtained at: `https://shorturl.at/ivIY1`

$$Y_{ijt} = \alpha + \delta_j \times (Treat_{ij} \times Post_t) + \mu_i + \lambda_t + \epsilon_{ijt}$$

where the subscript $_{ijt}$ indicates the specific treatment state, so $Treat_{ij}$ is the treatment indicator for state j. μ_i represents individual (county-level) fixed effects, and λ_t represents time fixed effects, while ϵ_{ijt} is the error term.

However, we sophisticate our DiD approach by combining county-level fixed effects with controls for geophysical fixed effects that we gather from geocoded data. In our new model, we include interactions of time fixed effects with fixed effects of a county's presence on a given basin. We estimate the following regression model using Poisson pseudo-maximum likelihood (PPML) with high-dimensional fixed effects:

$$\begin{aligned} Y_{ijt} = \alpha + \delta_j \times (Treat_{ij} \times Post_t) + \mu_j + \lambda_t \\ + \sum_k \gamma_k \times (Basin_k \times Time_t) + \epsilon_{ijt} \end{aligned}$$

where:

- Y_{ijt} represents the outcome variable of interest, which is measured at the county level (i), within states (j), and over time periods (t).
- α is the intercept term capturing the baseline level of the outcome.
- δ_j represents state-specific treatment effects, interacted with a post-treatment indicator ($Post_t$), denoting the differential impact of the treatment across states.
- $Treat_{ij}$ is a binary treatment variable indicating whether a county (i) within a state (j) received the treatment.
- $\mu_i j$ represents county fixed effects, capturing unobserved county-level heterogeneity that is constant

over time.

- λ_t represents time fixed effects, accounting for time-specific shocks or trends affecting all units equally.
- $Basin_k$ represents basin fixed effects, capturing unobserved heterogeneity across different sedimentary basins.
- $Time_t$ denotes time periods under consideration.
- γ_k represents coefficients associated with the interaction of specific sedimentary basins ($Basin_k$) with time periods ($Time_t$), capturing the varying effects of sedimentary basins over time.
- ϵ_{ijt} is the error term, capturing unobserved factors and random noise affecting the outcome.

Likewise, we construct another DiD estimator, refining our regression model by including shale fixed effects across the country. Our new model is represented by:

$$\begin{aligned} Y_{ijt} = \alpha + \delta_j \times (Treat_{ij} \times Post_t) + \mu_j + \lambda_t \\ + \sum_k \gamma_k \times (Basin_k \times Time_t) \\ + \sum_l \theta_l \times (Shale_l \times Time_t) + \epsilon_{ijt} \end{aligned}$$

where:

- $Shale_l$ represents shale fixed effects.
- θ_l represents coefficients associated with the interaction of specific shale indicators ($Shale_l$) with time periods ($Time_t$), capturing the varying effects of shale over time.

We present the results of these three regressions for every variable in our results section.

4 Results

Beginning with our Louisiana sample, we first test the parallel trends assumption. In lieu of treatment, it is assumed that the trends in the outcome variable for the treatment and control groups are parallel to each other, moving together over time. Let Y_0 represent the outcome variable, and D be the belonging to the treatment or control group. Then:

$$E(Y_t|D = 1) - E(Y_{t-1}|D = 1) = E(Y_t|D = 0) - E(Y_{t-1}|D = 0)$$

where $D = \begin{cases} 1 & \text{if treatment group} \\ 0 & \text{if control group} \end{cases}$

In simpler terms, when neither the treatment nor the control group receives treatment, the change in the treatment group is anticipated to mirror the change in the control group. Assessments of Y_t and Y_{t-1} are used to explain the pre-treatment trends in a group's outcome variable. We employ event studies to test parallel trends. These studies plot a regression's coefficient and associated confidence intervals on the y-axis. If zero is contained within the interval, it implies statistical equivalence and support for parallel trends.

Graphs of the event study coefficients based on corresponding regressions for the 10-year time interval used for Louisiana's exemption policy (which began in 1994) appear in Figures 2, 3, and 4, corresponding to pre-intervention trends in oil, gas, and total wells, respectively. All states and observations are standardized so that the year prior to treatment receives a value of 1. For instance, Louisiana is centered on 1993. Consequently, when regressed, the coefficient for the year before treatment is dropped from the horizontal axis.

The event study for Louisiana shown in Figure 2 shows that the parallel assumption holds compared to our subset of control groups. Further, both the pre-treatment period and the post-treatment period include zero, signifying the absence of a treatment effect.

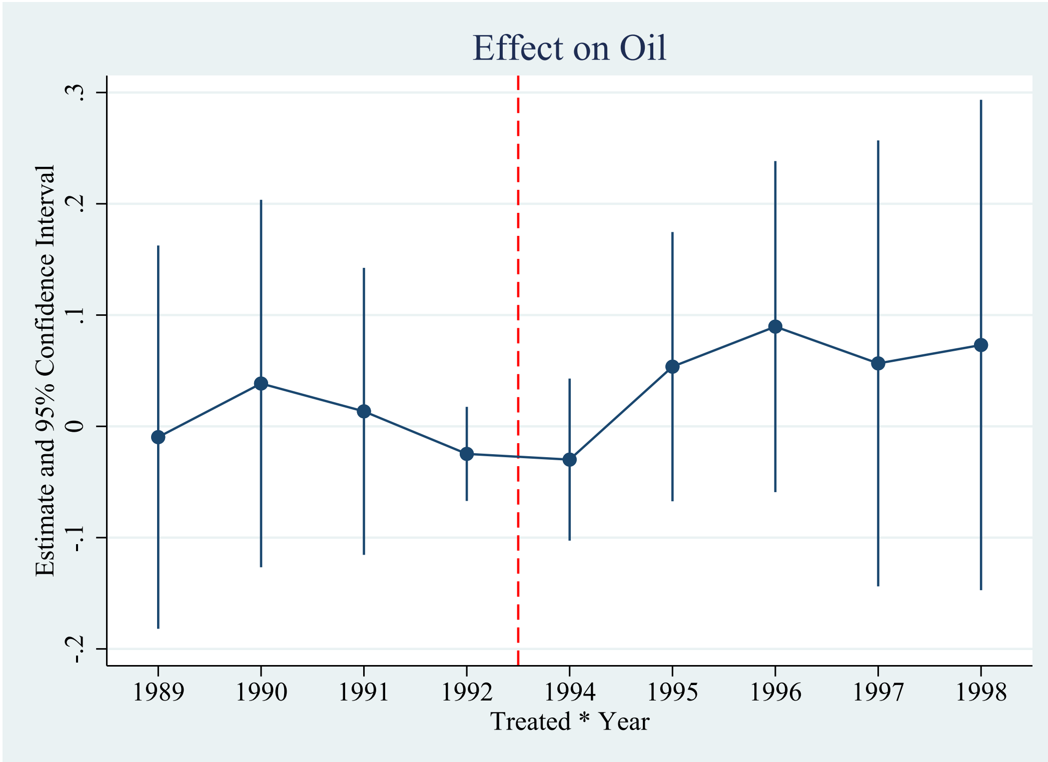

Figure 2: Louisiana Oil Production Event Study

The event study for gas production is in Figure 3. One pre-treatment period was close to but did not fall within zero. Likewise, the statistical significance in the first post-treatment period (1995) suggests the severance tax led to a decrease of natural gas production in Louisiana; however, we see that the effect is minimal, and that it levels off after that period, suggesting the effect was extremely small and was unlikely to be due to the severance tax break, as other factors, given the smallness of the effect, might have also been important in driving down gas production in Louisiana, such as randomness. Overall, what these findings suggest is that the effect of the severance tax break was non-positive, rather than negative.

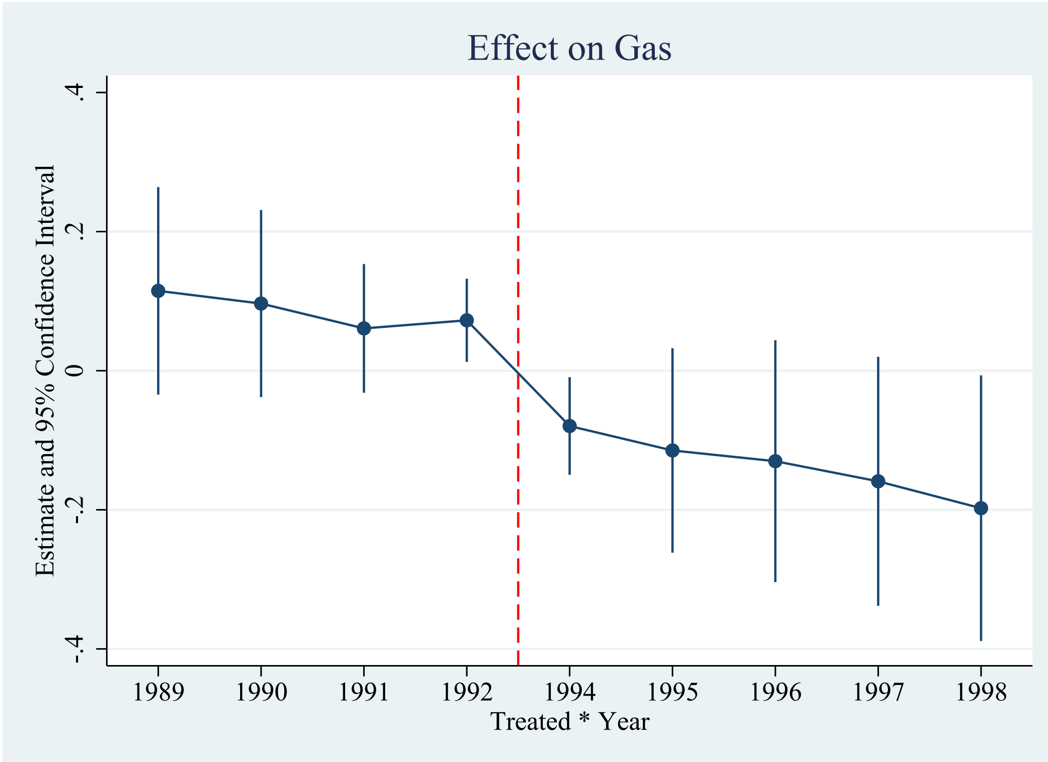

Figure 3: Louisiana Gas Production Event Study

Plotting coefficients for total wells, shown in Figure 4, reinforces previous results. Here, we see somewhat of a more pronounced effect over time, that does not level off to zero after the first post-treatment period. We, once again, conclude that we can reject the null that large severance tax breaks increase energy activity in a treatment state.

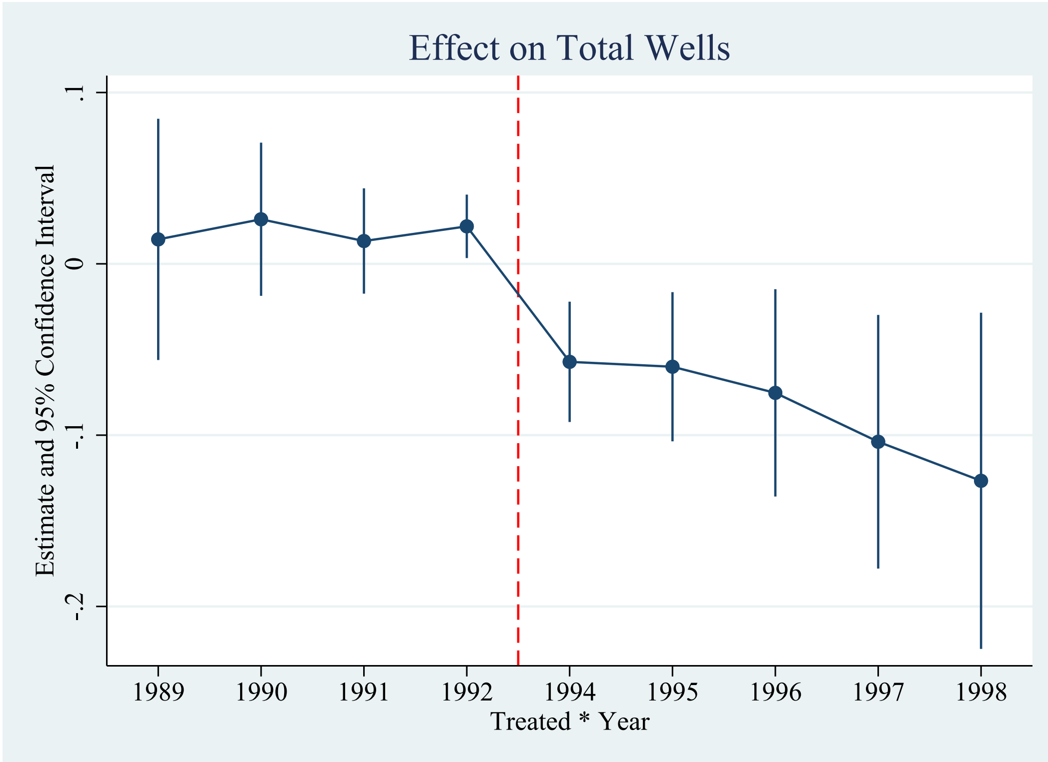

Figure 4: Louisiana Total Wells Event Study

Continuing with our Louisiana sample, results from all the regression models in which we regress treatment, which occurred in 1994, on Louisiana parish oil production, show statistically insignificant results. Table 1 presents these estimates, in order, along with standard errors and statistical significance. These initial results provide empirical evidence that the amendment to Louisiana's severance tax law, i.e., the tax break, did not lead to new production in the state.

Table 1: Effect of tax breaks on oil production in Louisiana

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1994	Tax Break	-0.047	0.104	0.044
		(0.063)	(0.071)	(0.060)
Constant	Constant	17.330***	16.354***	16.364***
		(0.002)	(0.003)	(0.002)
Observations		7,220	6,980	6,880
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Furthermore, to our surprise, when we repeat these models, we find negative, statistically significant effects of the severance tax break on natural gas production in the state. Moreover, as we refine our model, incorporating basin and shale fixed effects, we find that the negative effect enlarges, attributing a coefficient of -0.2 from the imposition of the severance tax break, holding other variables constant. A coefficient of -0.2 implies that, on average, the severance tax break is associated with a 20% decrease in the expected count of the dependent variable, in this case being natural gas production. Table 2 presents these estimates, in order, along with standard errors and statistical significance. In this case, the results actually provide empirical evidence that the severance tax break induced Louisiana to have lower natural gas production.

Table 2: Effect of tax breaks on gas production in Louisiana

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1994	Tax Break	-0.159**	-0.183***	-0.206***
		(0.067)	(0.069)	(0.075)
Constant	Constant	18.684***	18.254***	18.259***
		(0.003)	(0.003)	(0.003)
Observations		7,520	7,374	7,304
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Model results for the count of total wells in Louisiana appear in Table 3. We find similar results, a negative and statistically significant treatment effect with decreasing magnitude with additional controls. This suggests that the severance tax break in Louisiana corresponds to a decrease of roughly 10% on the total wells in the state.

Table 3: Effect of tax breaks on well drilling in Louisiana

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1994	Tax Break	-0.144***	-0.104**	-0.099**
		(0.021)	(0.042)	(0.043)
Constant	Constant	7.633***	7.642***	7.647***
		(0.001)	(0.001)	(0.001)
Observations		8,030	7,824	7,744
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Following the same procedure, we provide results for gas, oil, and total wells for Mississippi, Kansas, and Utah. Beginning with Mississippi, Figures 5, 6, and 7, plot oil, gas, and total wells, respectively, event studies. For all event studies of the three respective outcome variables, we see an initial drop followed by a gradual leveling off due to the tax break, indicating slight short-term reduction in activity. We show the event studies as follows:

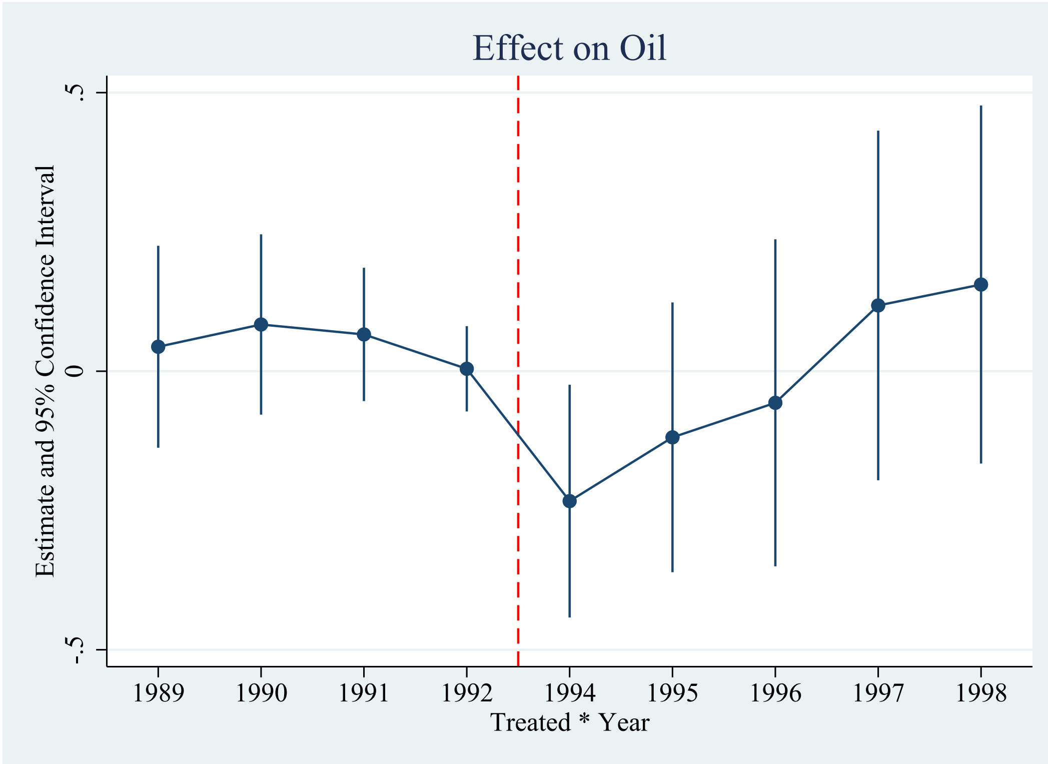

Figure 5: Mississippi Oil Production Event Study

For the gas event study, we note a small coefficient of 1990 whose confidence interval does not bound zero.

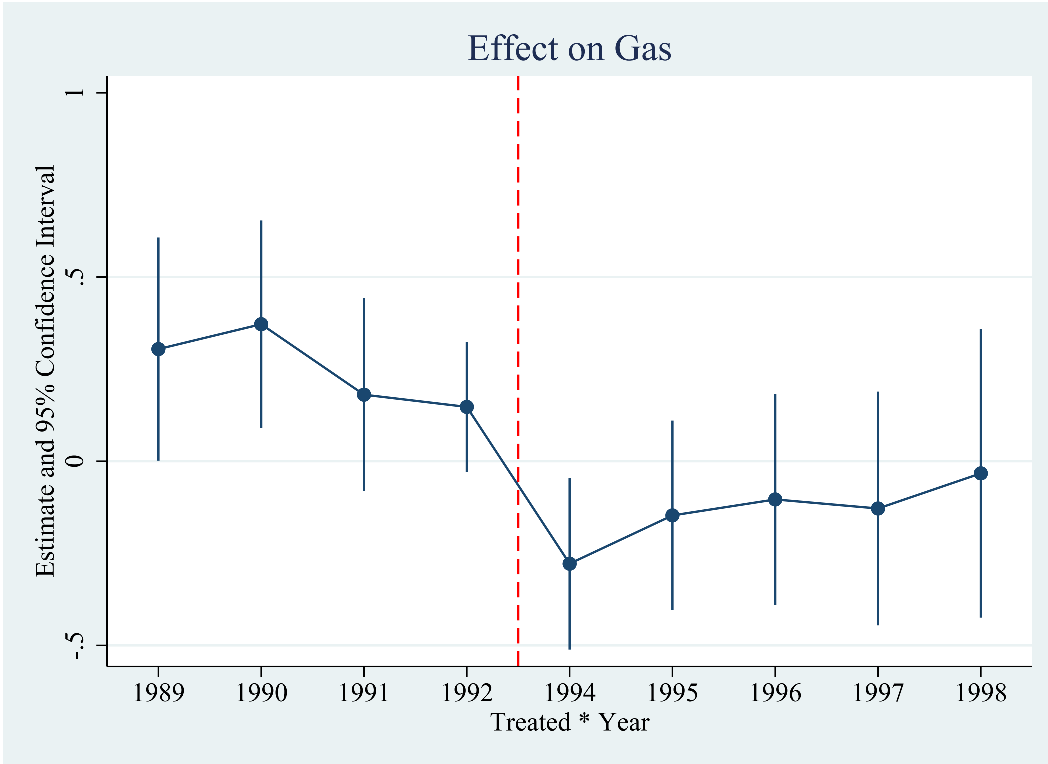

Figure 6: Mississippi Gas Production Event Study

Nevertheless, overall, these results indicate signs of parallel trends prior to treatment and slight negative results due to treatment.

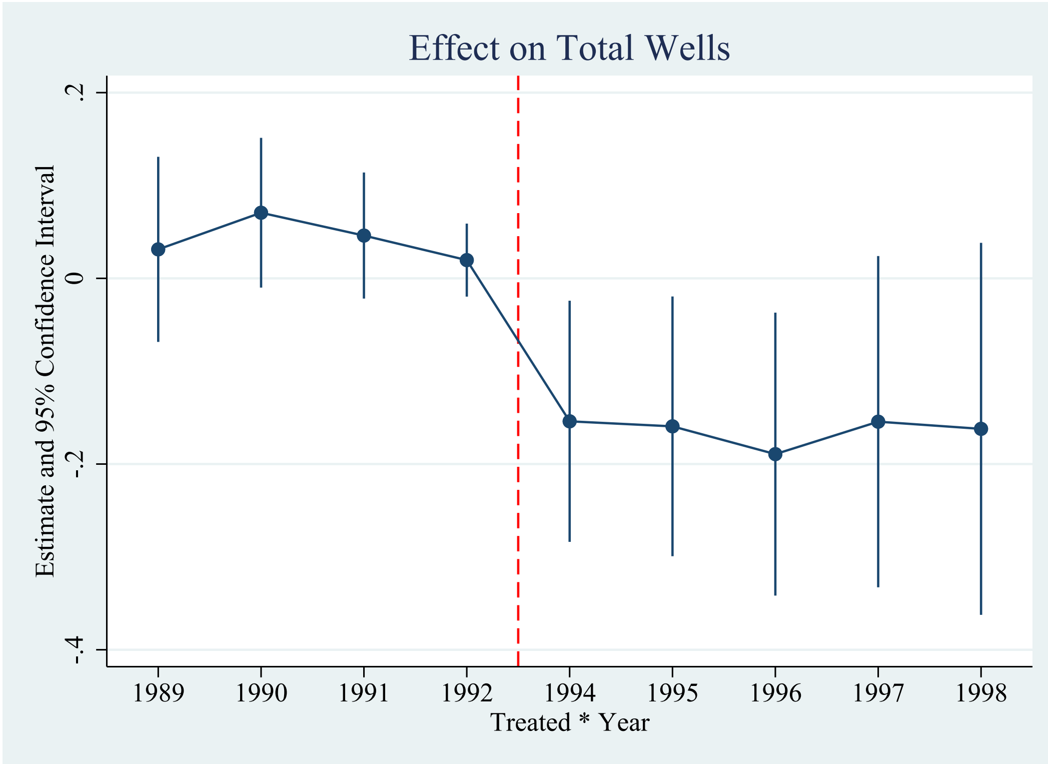

Figure 7: Mississippi Total Wells Event Study

Continuing with our Mississippi sample, regression results largely show that treatment coefficients that are negative and statistically significant. Moreover, as we refine our model by adding basin and shale fixed effects, we generally find that coefficients either shrink or lose power, reinforcing our claim that the result from these severance tax breaks is nonpositive. Table 6 is the best example of this, shown as follows:

Table 4: Effect of tax breaks on oil production in Mississippi

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1994	Tax Break	-0.144*	0.005	-0.071
		(0.087)	(0.108)	(0.151)
Constant	Constant	17.411***	16.395***	16.404***
		(0.000)	(0.001)	(0.001)
Observations		6,980	6,750	6,640
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Likewise, Table 7 shows the distinct models for Mississippi's gas production. Here, we find that tax relief led to a 34% drop in gas extraction at the 0.05 significance level.

Table 5: Effect of tax breaks on gas production in Mississippi

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1994	Tax Break	-0.480***	-0.453***	-0.343**
		(0.115)	(0.121)	(0.172)
Constant	Constant	18.714***	18.248***	18.252***
		(0.000)	(0.000)	(0.001)
Observations		7,310	7,174	7,104
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Model results for the count of total wells in Mississippi also reveal, though a smaller, drop in activity of roughly 20%.

Table 6: Effect of tax breaks on well drilling in Mississippi

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1994	Tax Break	-0.195***	-0.156**	-0.198**
		(0.040)	(0.067)	(0.096)
Constant	Constant	7.613***	7.623***	7.628***
		(0.000)	(0.000)	(0.000)
Observations		7,830	7,634	7,554
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Continuing to Kansas, Figures 8, 9, and 10, respectively, plot event studies for oil, gas, and total wells. We show the general plot for oil production in the state, in which we observe both clear parallel trends as well as no discernible difference between the pre-treatment interval and post-treatment interval.

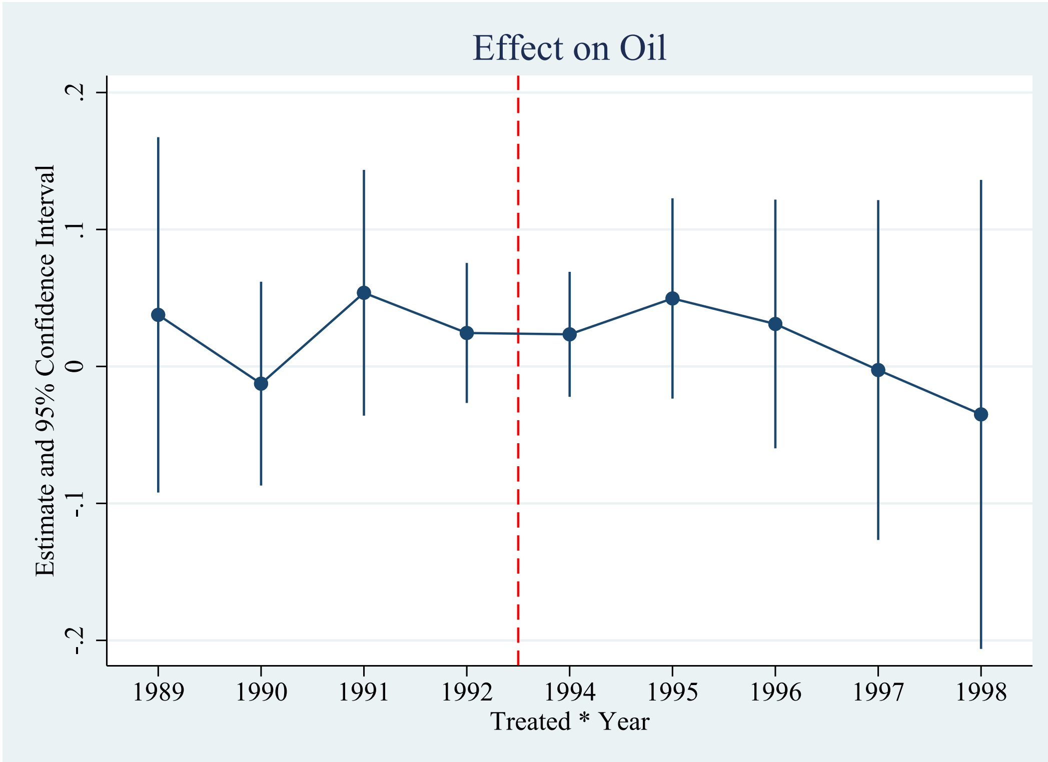

Figure 8: Kansas Oil Production Event Study

Kansas' gas production event study, however, shows a slight upward trend in the pre-treatment period, indicating that, compared to its control subset of states, oil production in Kansas was gradually increasing. Though it is not particularly strong, this plot reveals shows that immediately after the treatment the upward trend turns downward.

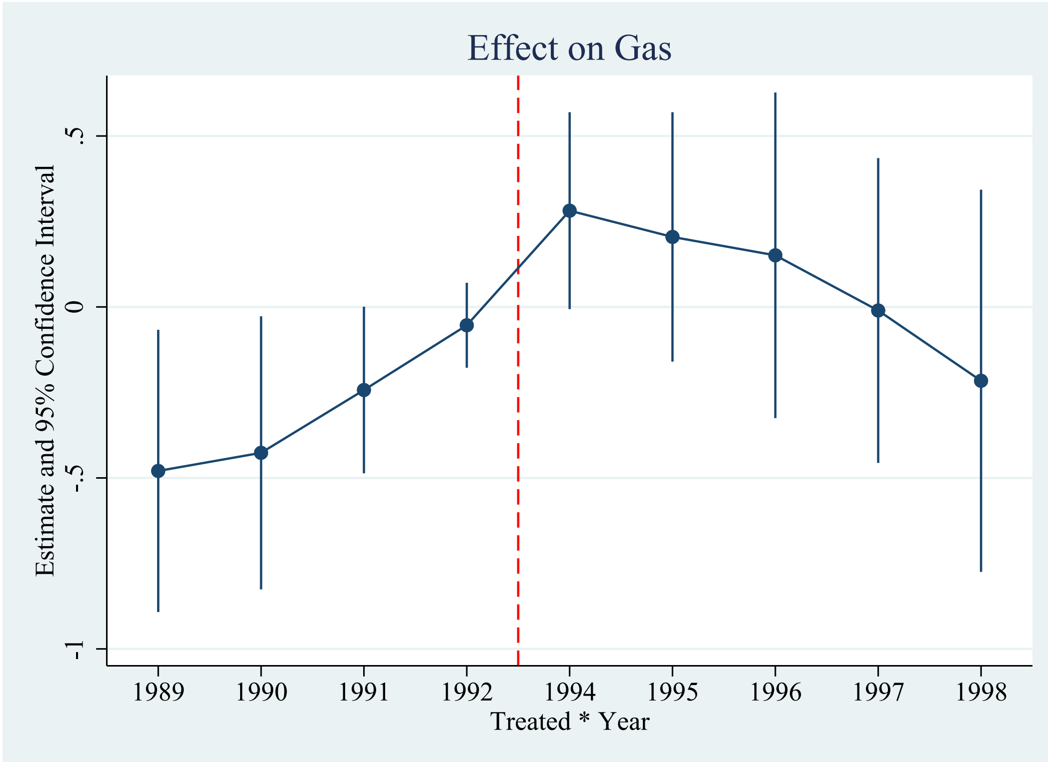

Figure 9: Kansas Gas Production Event Study

Kansas' total wells event study exhibits a stark difference frmo all previous event studies. While the coefficients in vast majority of pre-treatment periods are not significantly different from zero, we see a slight increase in the count of total wells, but only two years after the treatment took place. Thereafter, we see a substantial increase in the outcome.

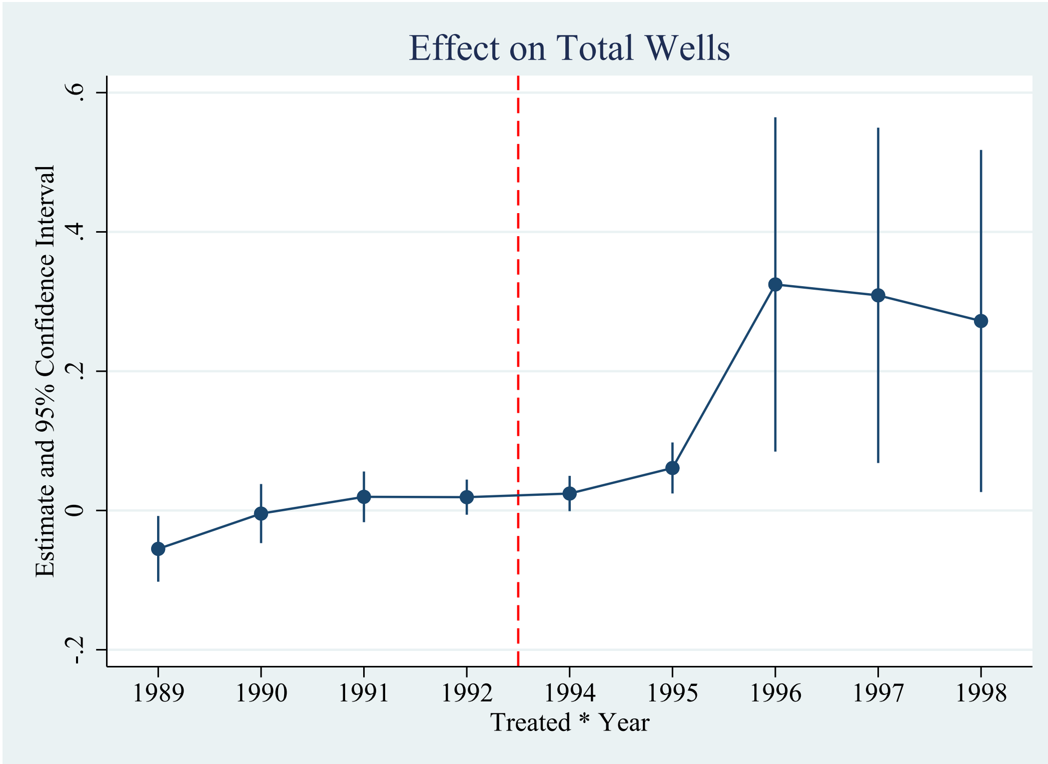

Figure 10: Kansas Total Wells Event Study

Regressing the Kansas treatment of these various outcomes, we find that, as expected, the severance tax break was not associated with production growth, as shown from the results of our most refined model. Table 7 in particular, where we regress treatment on oil production, shows our initial model detecting statistically significant negative effects, but then insignificant effects once we control for basin and shale fixed effects.

Table 7: Effect of tax breaks on oil production in Kansas

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1994	Tax Break	-0.157***	-0.043	-0.006
		(0.059)	(0.055)	(0.051)
Constant	Constant	17.364***	16.345***	16.355***
		(0.001)	(0.001)	(0.001)
Observations		7,550	7,320	7,210
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Likewise, Table 8 shows akin results for gas production in Kansas, detecting null effects due to the tax relief.

Table 8: Effect of tax breaks on gas production in Kansas

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1994	Tax Break	-0.014	0.352**	0.335
		(0.052)	(0.171)	(0.219)
Constant	Constant	18.702***	18.241***	18.246***
		(0.001)	(0.004)	(0.005)
Observations		7,560	7,434	7,354
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Consistent with event study results for the total wells outcome, our third model for Kansas attributes a jump in the count of total wells to the treatment at the 0.05 significance level.

Table 9: Effect of tax breaks on well drilling in Kansas

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1994	Tax Break	-0.015	0.196**	0.208**
		(0.043)	(0.090)	(0.082)
Constant	Constant	7.554***	7.554***	7.559***
		(0.002)	(0.004)	(0.004)
Observations		8,350	8,154	8,064
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Overall, while the result from regressing treatment on total wells yields positive, statistically significant results, oil and gas production outcomes remained unchanged.

Lastly, we analyze Utah's tax break, which occurred in 1984. Interestingly, Utah exhibits the opposite pattern as Kansas. While oil and gas production event studies show an uptick the year after treatment, the total wells study remains completely stagnant. Figure 11 plots Utah's oil production event study. What remains stark from this plot is the lack of parallel trends prior to treatment, indicating that Utah and its control group did not, in fact, have comparable trends that can lead to causal inference.

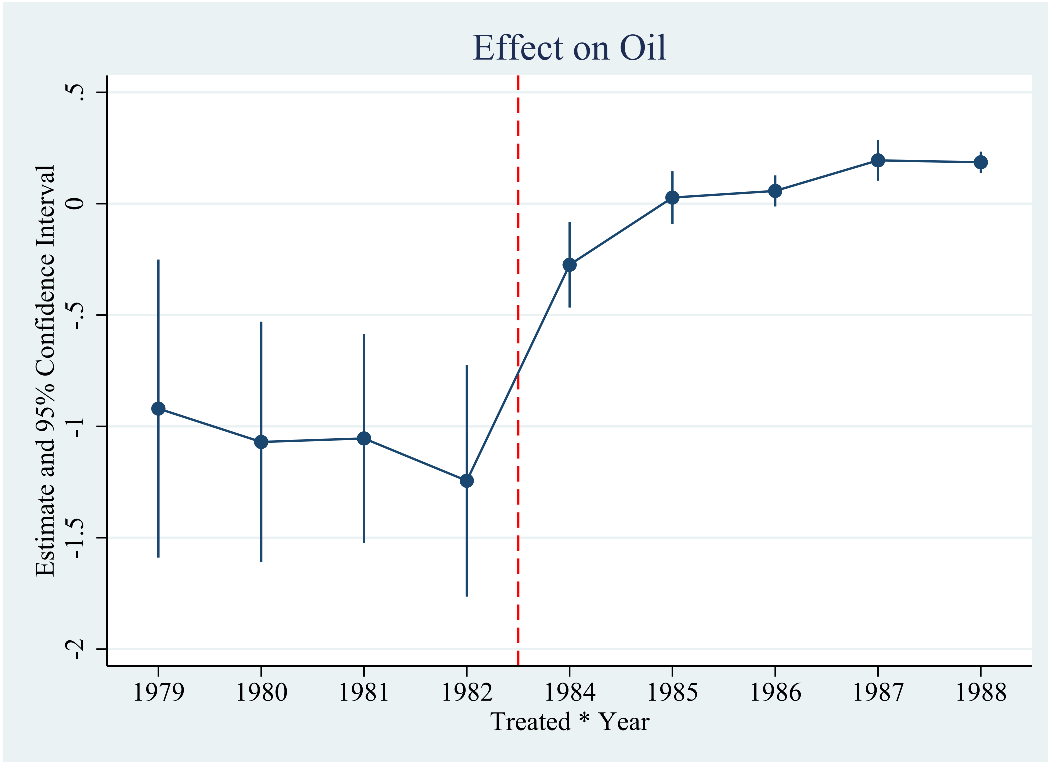

Figure 11: Utah Oil Production Event Study

Utah's gas production event study reinforces this paradigm. While the initial post-treatment coefficient exhibited a large jump, the lack of parallel trends makes causal inference complicated.

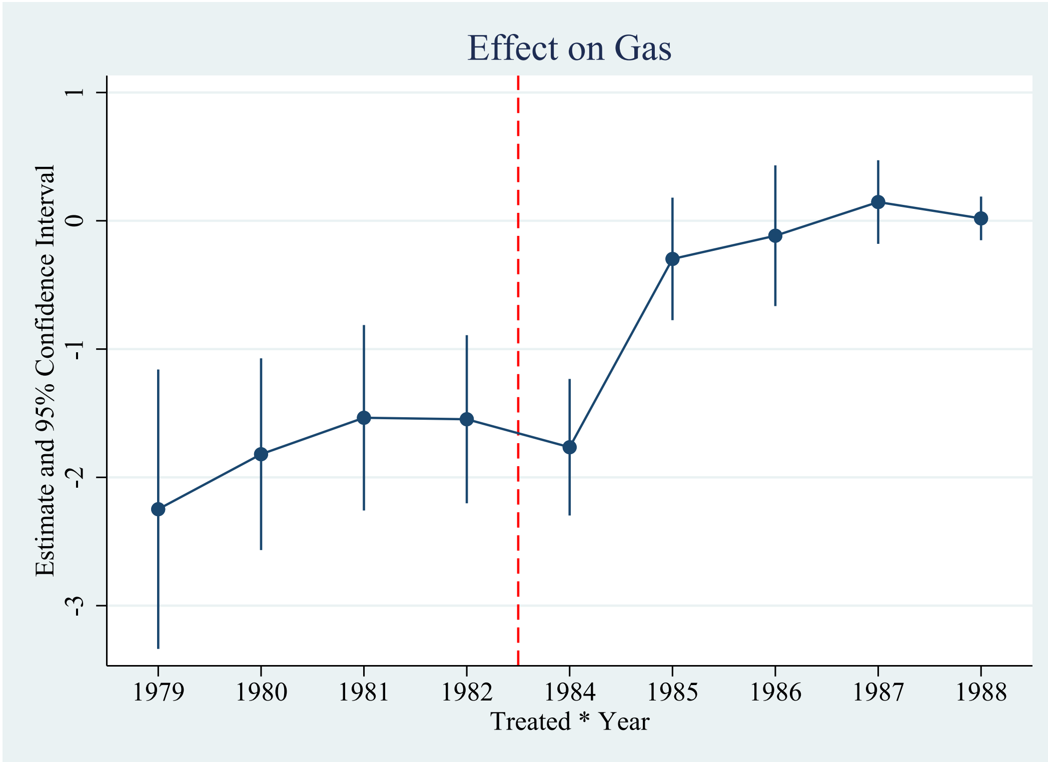

Figure 12: Utah Gas Production Event Study

Unlike Utah's two previous parallel trends plots, Utah's total wells plot fits quite nicely, with none of the pre-treatment years being significantly different than zero, as shown by the confidence intervals encompassing zero. However, it is necessary to take into account that the estimated errors for Utah seem to be much larger than for any other state. Therefore, while the plot for total wells in Utah seems to suggest nonpositive results, its inference should, too, be taken with caution as that of the oil and gas production plots.

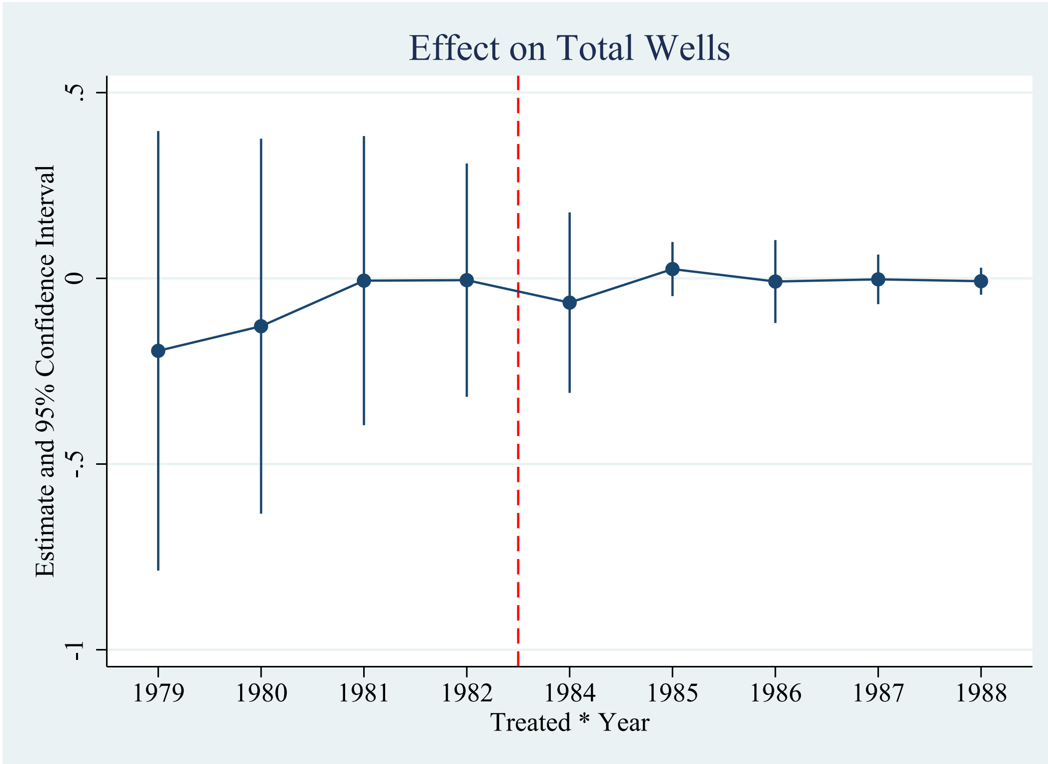

Figure 13: Utah Total Wells Event Study

Overall, it remains difficult to make inferences from the Utah case study. Now, we fit our regression models into the data and get estimates of the effect of the tax break for Utah.

Table 10: Effect of tax breaks on oil production in Utah

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1984	Tax Break	0.337	0.525**	0.936***
		(0.253)	(0.248)	(0.207)
Constant	Constant	17.240***	16.449***	16.449***
		(0.002)	(0.002)	(0.002)
Observations		7,420	7,242	7,166
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Table 10 summaries regression results for oil production in Utah. Overall, while estimates vary greatly, our basin and shale fixed effects model attributes treatment with an increase of roughly 90% on oil production.

Table 11: Effect of tax breaks on gas production in Utah

		(1)	(2)	(3)
VARIABLES	LABELS	Regression 1	Regression 2	Regression 3
change1984	Tax Break	0.964*	0.623	1.705***
		(0.529)	(0.633)	(0.327)
Constant	Constant	18.342***	18.235***	18.236***
		(0.003)	(0.004)	(0.002)
Observations		7,360	6,798	6,694
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Likewise, Table 11 shows a large increase in gas production due to treatment. In this case, that increase is magnified even further.

Table 12: Effect of tax breaks on well drilling in Utah

VARIABLES	LABELS	(1) Regression 1	(2) Regression 2	(3) Regression 3
change1984	Tax Break	0.200***	0.328***	0.076
		(0.069)	(0.068)	(0.205)
Constant	Constant	7.588***	7.603***	7.606***
		(0.000)	(0.000)	(0.001)
Observations		8,020	7,846	7,742
Basin X Year		No	Yes	Yes
Shale X Year				Yes

Observations at the county and year level. Standard errors clustered at the county level, *** p<0.01, ** p<0.05, * p<0.1.

Unlike in our last two regressions, our model does not find statistically significant results from the severance tax break when we rely on our most refined version of the model. Overall, while statistically significant large coefficients for both oil and gas production would suggest that the severance tax had substantial effects in spurring energy activity in Utah, it remains inconclusive whether the policy was the cause of this increase given the lack of parallel trends.

5 Conclusion

States often rely on revenues generated from severance taxes of natural resource extraction. Such taxes may also change the incentives of oil and gas producers in terms of their level of production, thus affecting total revenues. Collectively, our evidence suggests that reducing severance taxes in Louisiana, Mississippi, Kansas, and Utah did not affect oil production, gas production, or the total number of wells.

The current analysis focuses on production outcomes in Louisiana, Mississippi, Kansas, and Utah. Other states have also implemented severance tax exemptions that will be explored in the next steps of this study. In our next version of the paper, we will extend our analysis to these policies. Moreover, we will also incorporate a novel control from our data that details the specific type of shale, hoping to absorb these varying fixed effects in a more sophisticated model. We also add to our paper by analyzing segmented parts of states based on geophysical similarity. For example, we construct a DiD model for the Haynesville, which is a tight-gas area located in northeast Texas and northwest Louisiana. We zoom into counties in the Haynesville and perform analogous analysis. Similarly, we include other case studies that follow this methodology for other parts of the country.

While production outcomes may not be responsive to severance tax levels, this does not rule there is no economic effect. Local economy in the form of sales taxes or employment may still respond to such changes. While we do not include that type of analysis in this paper, it is important to consider the possibility that these variables might be more sensitive to severance tax relief policies.

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