Effects of Severance Tax on Economic Activity: Evidence from the Oil Industry

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Background

- Taxation of nonrenewable resources increasingly important for many US states, with tax revenue from nonrewable resources reaching $10 billion per year from 2005-2015 (Weber et al., 2016)
- State governments often reassess and debate changes in 'severance tax' rates
  - Proponents: increases in the tax rates are opportunities to increase government revenue/pay environmental costs
  - Opponents: increases in taxation will lead drilling companies to go elsewhere to drill for oil and gas
    - "Capital is movable and seeks the greatest returns on investment" – American Petroleum Institute of PA (June 1, 2015 testimony before the US Senate)
- Despite evidence from specific states (Rao 2015; Reimer et al, 2017), no concensus on how industry responds to severance taxes

Research Questions

- How does drilling respond to changes in severance tax compared to price?
- How do changes in severance tax rates affect severance tax revenue?

Previous Literature on Oil Taxation

- There are few estimates of how oil producers respond to taxes
  - Simulation approaches: Kunce et al. (2003); Metcalf (2017); Maniloff and Manning (2017)
  - Econometric approaches: Rao (2015); Reimer et al. (2017); Black et al. (2018)
- Several have estimated the supply elasticity of oil
  - General consensus – inelastic response (Dahl and Duggan, 1996; Kilian, 2009)
  - Anderson et al. (2017) and Newell and Prest (2017) show that drilling responds more to price than production
- Responses to taxes may differ from responses to prices (Li et al, 2014)

Contribution

- Develop a 2-location theoretical model that shows drilling reponse to price and severance tax changes are different due to "opportunity cost channel"
- We use drilling data from 91 reservoirs in 17 states over 30 years to estimate the investment response to changes in state tax rates
- Previous research only focused on one state or multiple policy changes in one state
- Our identification strategy yields a more generalizable result because we exploit variation in multiple severance tax changes:
  - over time using observed drilling decisions along state boarders

Preview of Results

- We find that a one dollar per barrel increase in price leads to a 1 percent increase in wells drilled, but a one dollar per barrel increase in severance tax leads to a 8 percent decrease in wells drilled
- Drilling is inelastic with respect to severance taxes, $e_{w,\tau} =$ -0.3
- Results are robust to interstate spillovers, other state regulations, model specification, and choice set
- Our policy simulation implies that using state severance tax decreases to incentivize investment may lead to losses of government revenue

Theoretical Model

- A representative firm in every time period allocates a fixed amount of drilling capital between locations $l = 1$ and $l = 2$
- Firm maximizes profit from drilling by choosing the number of wells to invest in each location subject to drilling capital constraint

$$\max_{w_1, w_2} \sum_{l=1,2} [pq_l - c_l(q_l) - \tau_l q_l] w_l - d_l(w_l) \quad s.t. \quad d_1(w_1) + d_2(w_2) \leq B(p, \tau_1, \tau_2). \tag{1}$$

- Drilling costs are $d_l(w_l)$ with $d_l' > 0$ and $d_l'' > 0$
- Assuming the budget constraint binds, we can express w_2 as a function of w_1: $w_2(w_1; p, \tau_1, \tau_2)$

Model Predictions

- Net marginal cost of drilling in l_1 is foregone net marginal benefit of drilling in l_2
- Using implicit function theorem we can recover: $w_1^*(p, \tau_1, \tau_2, \phi)$ and $w_2^*(p, \tau_1, \tau_2, \phi)$ that balances the net marginal benefit and cost
- Output price increase has three effects: higher revenue $(+)$, opportunity cost (–), budget effect $(+)$
- Tax decrease in location 1: revenue effect $(+)$, budget effect $(+)$, but no opportunity cost effect
- Impacts of price and tax changes are theoretically ambiguous
- We expect the magnitude of price response to be smaller than tax response because of the opportunity cost effect

Effect of Severance Tax on Government Revenue

- Severance taxes are often set as rates charged per dollar of revenue, $\tau_l = pt_l$, where t_l is tax charged per dollar of revenue

- Government revenue R earned in location l:

$$R_l = t_l \cdot p \cdot q_l \cdot w_l^*(p, pt_1, pt_2, \phi), \quad (2)$$

- where we assume a constant price and pt_l has been substituted for τ_l in the solution to the firm drilling problem

- Since $q_l \cdot w_l^*(p, pt_1, pt_2, \phi)$ is total production, total revenue is the product of the value of total production and the tax charged per dollar

- dR shows government revenue changes via 2 channels from changes in severance tax

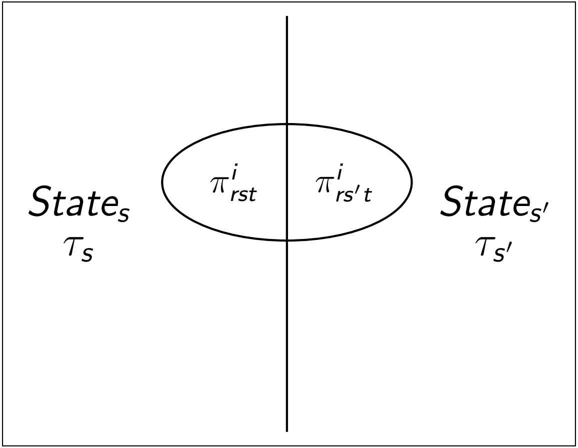
Econometric Model

We assume that the number of wells drilled in reservoir r, state s, and month t is distributed Poisson such that the expected number of wells drilled, w_{rst}:

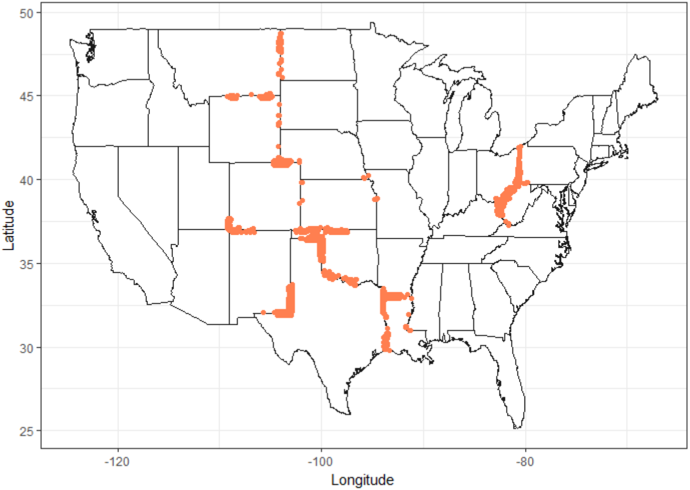
$$E(w_{rst}) = \lambda_{rst} = \exp(\beta_0 + \beta_1 p_t + \beta_2' \tau_{rst} + \beta_3 \gamma_{rt} W_{rt} + \mu_r + \delta_s + f(t)),$$

- p_t is the average monthly oil price (WTI)
- τ_{rst} is a vector describing the relevant tax policies for reservoir r in state s and month t
- Reservoir and state fixed effects, μ_r and δ_s
- γ_{rt} captures the cumulative resource extraction from reservoir r as of month t by the cumulative number of wells drilled as of month t
- $f(t)$ is a quadratic trend that allows for technological and other changes over time that are common to all reservoirs and states

Identification Strategy Using State Borders



Map of Wells Drilled Along State Borders



Source: Drillinginfo. Dots represent oil wells within 10 miles of state borders in the continental United States.

Descriptive Statistics on Drilling, 1981 to 2015

- Drilling data sourced from Drillinginfo
- Oil price data from CME Group
- Tax information collected from individual state agencies

	Mean	Standard Deviation
Wells Drilled - 5 miles[1]	0.155	1.639
Wells Drilled - 10 miles	0.298	2.372
Oil Price ($ per barrel)[2]	50.50	25.38
Tax Per Barrel ($ per barrel)[3]	3.266	2.345
N = 39,417		

Note: The unit of observation is reservoir-state-month.
Sources: [1]Drillinginfo, [2]WTI Spot Crude Oil Price from CME Group, [3]Books of States and state agencies, Authors' calculations.

Summary of Severance Tax Rates, 1981–2015

State	Percent of State-Reservoir-Month Observations	Revenue Tax (y/n)	Barrel Tax (y/n)	Number of Policy Changes	Average over Time (%)	Average over Time ($/bbl)
AR	9.4	y	y	3	5.1	2.76
CO	4.3	y	n	0	5.0	2.71
KS	0.3	y	y	8	6.5	3.29
KY	1.6	y	n	1	4.5	2.44
LA	11.7	y	y	1	12.5	6.78
MO	0.2	n	n	0	0.0	0.00
MT	5.0	y	n	7	8.8	5.23
ND	0.8	y	n	1	11.4	6.21
NE	0.7	y	n	4	4.0	2.18
NM	13.2	y	y	2	7.0	3.78
OH	3.1	n	y	1	0.1	0.03
OK	14.6	y	n	1	7.1	3.84
PA	1.5	n	n	0	0.0	0.00
TX	26.1	y	y	2	4.6	2.50
UT	2.3	y	n	7	5.5	2.73
WV	1.6	y	n	0	5.0	2.71
WY	3.6	y	n	9	6.0	3.27

Sources: Book of States, state agencies, authors' calculations

Main Results

	(1) 5mi	(2) 10mi
Coefficients		
Oil Price	0.0113**	0.0107***
	(0.00550)	(0.00401)
Tax	-0.133**	-0.0813**
	(0.0523)	(0.0381)
Elasticities		
Oil Price	0.571**	0.539***
	(0.278)	(0.202)
Tax	-0.436**	-0.266**
	(0.172)	(0.124)
Different Coefficients?	0.011	0.043
N	38577	39417

Notes: Standard errors clustered at the reservoir-state level. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. All specifications include a quadratic time trend; month, state, and reservoir fixed effects; and cumulative drilling. "Different Coefficients" describes the p-value for testing the null hypothesis that the coefficients for oil price and tax are equal in magnitude.

Tax Rates in Other Locations

	(1)	(2)	(3)	(4)
	Adjacent State		Single-State Firm	
	5 mi	10 mi	5 mi	10 mi
Coefficients				
Oil Price	0.0154	0.0189*	0.0128***	0.0126***
	(0.0116)	(0.0103)	(0.00426)	(0.00277)
Tax	-0.191***	-0.131**	-0.0839**	-0.0291
	(0.0712)	(0.0578)	(0.0368)	(0.0335)
Other Tax	0.0101	-0.0809		
	(0.108)	(0.109)		
Elasticities				
Oil Price	0.781	0.952*	0.649***	0.638***
	(0.588)	(0.518)	(0.216)	(0.140)
Tax	-0.627***	-0.428**	-0.275**	-0.0949
	(0.234)	(0.189)	(0.121)	(0.110)
Different Coefficients?	0.004	0.022	0.033	0.602
N	36943	37783	35068	37863

Notes: Standard errors clustered at the reservoir-state level. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. All specifications include a quadratic time trend; month, state, and reservoir fixed effects; and cumulative drilling. "Different Coefficients" describes the p-value for testing the null hypothesis that the coefficients for oil price and tax are equal in magnitude.

Robustness Checks

- Our results are robust across multiple specifications and controls
    - We consider a negative binomial specification to allow dispersion in the count
    - Oil price futures (e.g., 12 and 24 month) versus spot prices
    - Quarterly and annual time steps instead of monthly
- Other state energy regulations:
    - Share of Republicans in State House and Senate
    - League of Conservation Voter scores of US Senators (high score would indicate preference for non-tax regulations)
- Other taxes such as state corporate income tax
- Alternative choice sets

Policy Scenario

- We use our reduced form estimate of the severance tax elasticity to parameterize the government revenue equation in our theoretical model
- We consider a hypothetical scenario were TX increases it severance tax rate by 1 or 2 pp
  - We use TX average annual production per well, WTI price, and average number of wells drilled per month in 2015
  - Hold prices and state production the same for constructing initial severance tax revenue

Texas Severance Tax Rates (%)	Severance Tax Revenue ($)	Change in Severance Tax Revenue ($)	95% Confidence Interval	Percent Change (%)
4.6	151,741,174			
5.6	170,359,328	18,618,154	[7,514,711, 29,721,598]	12.27
6.6	188,977,482	37,236,308	[15,029,421, 59,443,196]	24.54

Conclusion

- We find a robust inelastic (medium-run) relationship between drilling and severance taxes
- Important caveats
  - we do not capture how oil and gas exploration may change as severance tax changes, which may have important long-term implications
  - our results are partial equilibrium in nature
- States may not be able to avoid a decrease in drilling if a neighboring state lowers severance tax rate,
- But it would likely lose much more revenue if it tries to compete by lowering its tax rate by a similar amount
- Our analysis provides policy-relevant information for states considering:
  - changes in a severance tax rate
  - engaging in tax competition to match neighboring states