Spatially Heterogeneous Regulation and the Search for Oil and Gas

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The U.S. has heterogeneous mineral ownership

Mineral rights are the right to extract subsurface minerals like oil and natural gas on a given plot of land

- Federal government owns 29% of onshore mineral rights
  - 20% of onshore US fossil fuel production
- State governments own ≈8% of onshore mineral rights
- Remainder in private ownership

U.S. is a patchwork of mineral ownership, with adjoining federal, state, and private ownership

Owners impose different policies on oil and gas firms

- Oil and gas firms contract with mineral rights owners
    - Owners impose different regulations and policies
- Federal land is (anecdotally) costlier to operate on
    - Environmental compliance (NEPA 1970/ESA 1973)
    - More permits required
    - Delays

Claims that costs on federal land are higher

"In recent years we have seen a boom in energy jobs and economic growth on state and private lands. I believe the only reason we haven't seen that same dynamic growth on federal lands is because of excess regulations." -Representative Doug Lamborn, Colorado

Claims that costs on federal land are higher

"Federal government NEPA delays are preventing 36,346 jobs and $9.2 billion in economic impact annually in Wyoming, and 40,641 jobs and $8.7 billion in economic impact in Utah." –Western Energy Alliance

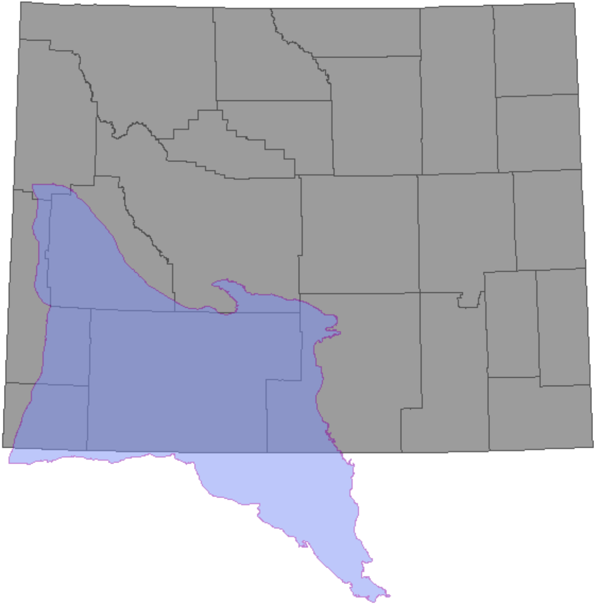
Research Questions

1. How does spatially heterogeneous regulation affect the search for and development of oil and gas resources?
    - Does regulation on one plot have spillovers onto nearby plots?
2. Are revealed drilling and production consistent with hypothesis of higher federal costs?

What this paper does

- A model of the search for oil and gas under spatially heterogeneous regulation
  - Predictions about spatial and temporal patterns of drilling and production
- Natural experiment with exogenous mineral rights ownership
  - Ownership by Federal Government and State of Wyoming
  - Land Ordinance of 1785
- Oil and gas industry data from Wyoming
  - Leasing and well drilling back to 1900
  - Well production back to 1978
  - Mineral ownership

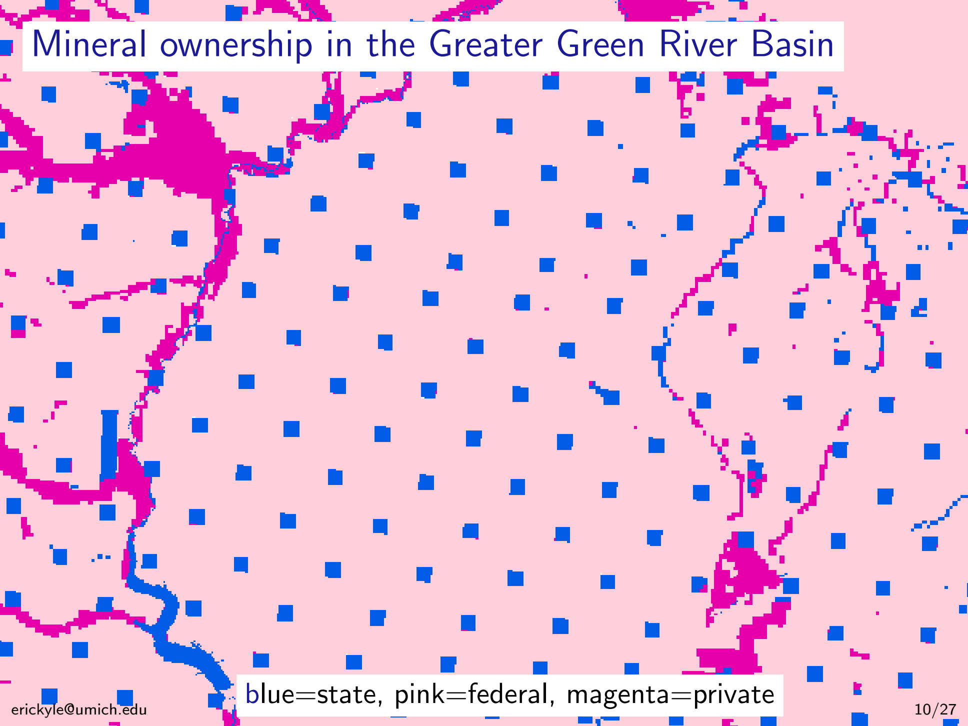
Greater Green River Basin in Wyoming



Why I focus on the Greater Green River Basin

- Very productive oil and gas region
- Cold and windy, with a low population:
  - Unlikely to have other economic activity that is correlated with mineral ownership
- Geological and regulatory reasons why common pools are unlikely

Mineral ownership in the Greater Green River Basin



blue=state, pink=federal, magenta=private

Modeling heterogeneous policies and search

Mapping a natural experiment to a model

Natural experiment → 3 types of plots

- Federal land **far** from state land
- Federal land **close** to state land
- State land

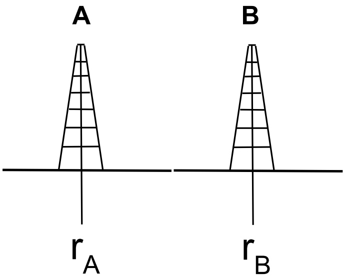
Simple 2 plot model of search with two cases

- federal far from state
  ⇒ **federal-federal**
- federal close to state and state
  ⇒ **federal-state**

Modeling federal and state policies

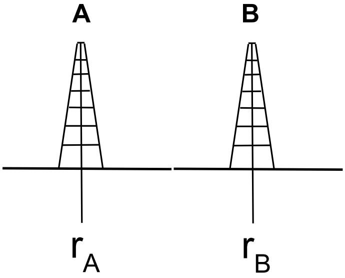
- Federal lands are (anecdotally) costlier to operate on
- Assume that federal land imposes a higher fixed cost prior to drilling
  - Federal land has more requirements prior to drilling
    - Environmental requirements prior to permit to drill
    - More permits and paperwork
  - Fitzgerald and Stocking (2014) also assume a higher fixed federal cost
- Compare the $(C_A, C_B) = (C_F, C_F)$ case with the (C_S, C_F) case, $C_S < C_F$
- (Similar results for other heterogeneous policies, e.g., heterogeneous delays, heterogeneous rental rates)

Model setup



- Firm can drill up to one well each for plots A and B
- Firm has a signal μ of plot expected productivity: $E(R_A) = E(R_B) = \mu$, where $\mu \sim G$
- Firm believes reserves R_A and R_B are distributed $F(R_A, R_B|\mu)$

Firm's choice



- Drill A first and maybe B next:

$$E(R_A - C_A + \max\{E(R_B|R_A) - C_B, 0\})$$

- Drill B first and maybe A next:

$$E(R_B - C_B + \max\{E(R_A|R_B) - C_A, 0\})$$

- Don't drill at all

What happens when we lower costs on A from C_F (federal) to C_S (state)?

Lowering costs on one plot affects revealed drilling and production through 3 mechanisms:

1. Increased willingness to operate on state
   - State plots with low μ are drilled that wouldn't be drilled under federal-federal
2. Substitution away from federal (and toward state)
   - Less activity on federal if federal is close to state
3. Spillovers: Because state land has more drilling, nearby federal land benefits conditional on good outcomes on state land
   - If reserves on B are profitable to extract ($r_B > C_F$), the firm is more likely to learn about it if A is state land

Empirical predictions about drilling and production

Comparing state land (S), federal land close to state (FC), and federal land far from state (FF)

1. Whether drilling ever happens:

$$S > FF > FC$$

2. Whether site of initial exploratory well:

$$S > FF > FC$$

3. Expected production:

$$S > FF > FC$$

4. Expected production conditional on production:

$$S < F, \; FF \overset{?}{\lesseqgtr} FC$$

Empirical strategy and results

How state land was allocated

- Land divided into 6x6 mile "townships", each with 36 square mile "sections"

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

How state land was allocated

- Land divided into 6x6 mile “townships”, each with 36 square mile “sections”
- Wyoming received sections 16 and 36 of each township

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Reduced form identification

6	5	4	3	2	1	6	5	4	3	2	1	6	5	4	3	2	1
7	8	9	10	11	12	7	8	9	10	11	12	7	8	9	10	11	12
18	17	16	15	14	13	18	17	16	15	14	13	18	17	16	15	14	13
19	20	21	22	23	24	19	20	21	22	23	24	19	20	21	22	23	24
30	29	28	27	26	25	30	29	28	27	26	25	30	29	28	27	26	25
31	32	33	34	35	36	31	32	33	34	35	36	31	32	33	34	35	36
6	5	4	3	2	1	6	5	4	3	2	1	6	5	4	3	2	1
7	8	9	10	11	12	7	8	9	10	11	12	7	8	9	10	11	12
18	17	16	15	14	13	18	17	16	15	14	13	18	17	16	15	14	13
19	20	21	22	23	24	19	20	21	22	23	24	19	20	21	22	23	24
30	29	28	27	26	25	30	29	28	27	26	25	30	29	28	27	26	25
31	32	33	34	35	36	31	32	33	34	35	36	31	32	33	34	35	36

Reduced form identification

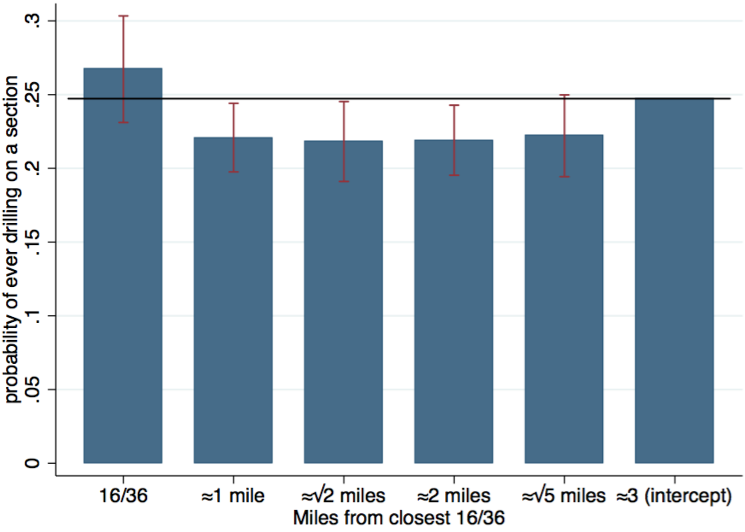
√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1
√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2
2	1	16	1	2	3	2	1	16	1	2	3	2	1	16	1	2	3
√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2
√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1
1	2	3	2	1	36	1	2	3	2	1	36	1	2	3	2	1	36
√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1
√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2
2	1	16	1	2	3	2	1	16	1	2	3	2	1	16	1	2	3
√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2
√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1	√2	√5	2	√5	√2	1
1	2	3	2	1	36	1	2	3	2	1	36	1	2	3	2	1	36

Reduced form specification

$$Y_i = \beta_{16/36} \cdot \mathbf{1}_i(16/36) \; + \; \beta_1 \cdot \mathbf{1}_i(\approx 1) \; + \; \beta_{\sqrt{2}} \cdot \mathbf{1}_i(\approx \sqrt{2})$$
$$+ \; \beta_2 \cdot \mathbf{1}_i(\approx 2) \; + \; \beta_{\sqrt{5}} \cdot \mathbf{1}_i(\approx \sqrt{5}) \; + \; \beta_0 \; + \; \varepsilon_i$$

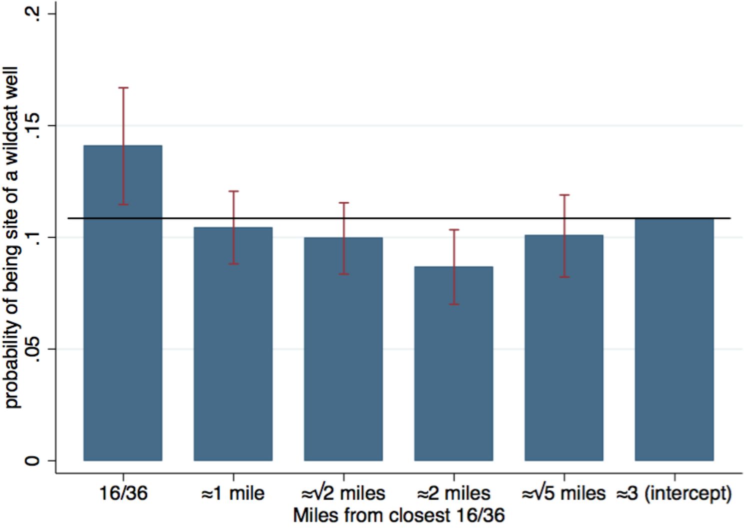
Inference using heteroskedasticity autocorrelation robust spatial standard errors (Conley, 1999)

How did land ownership patterns affect any drilling?



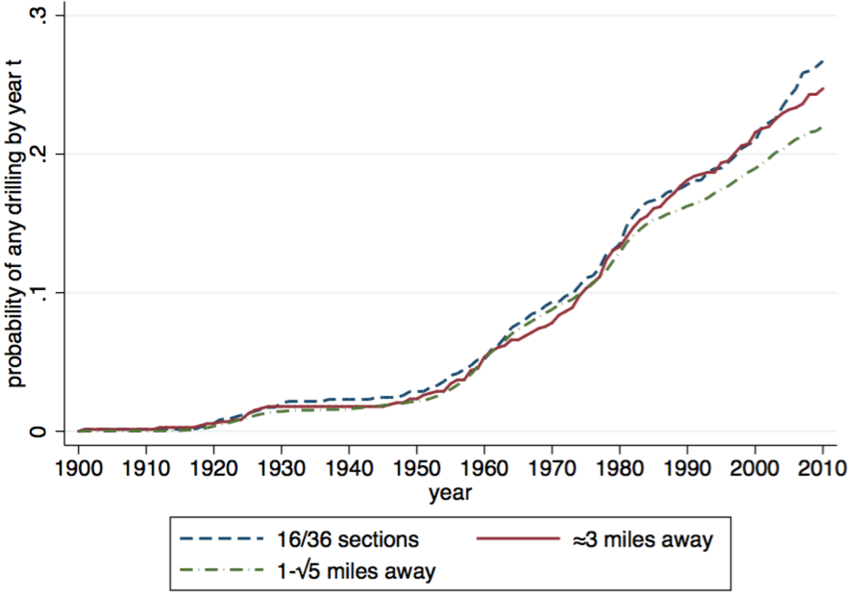
- $1 - \sqrt{5}$ miles is statistically different from $16/36$ with p value < 0.01.

How did land ownership patterns affect exploratory drilling?



- Test 1-3 miles are all equal is rejected with $p < 0.1$

Probability of drilling diverged in about 1980



Section-level production, wells drilled 1980 and later

MacKinnon-Magee transformation: $log(q + \sqrt{q^2 + 1})$

	(1) BOE	(2) BOE
is 16/36	0.05	0.05
	(0.15)	(0.15)
$\approx$ 1 mile away	-0.23*	-0.25**
	(0.13)	(0.11)
$\approx \sqrt{2}$ miles away	-0.21	-0.21*
	(0.14)	(0.12)
$\approx$ 2 miles away	-0.18*	-0.19*
	(0.10)	(0.11)
$\approx \sqrt{5}$ miles away	-0.21*	-0.21**
	(0.12)	(0.10)
constant	1.48***	
	(0.44)	
township FE	No	Yes
Observations	12549	12549

Log production for first 12, 24, and 36 months of production

With drilling year and field fixed effects.

	(1) BOE 12	(2) BOE 24	(3) BOE 36
is 16/36	-0.44***	-0.42***	-0.41***
	(0.10)	(0.13)	(0.15)
$\approx$ 1 mile away	-0.21**	-0.17	-0.14
	(0.09)	(0.11)	(0.12)
$\approx \sqrt{2}$ miles away	-0.23**	-0.23**	-0.22*
	(0.09)	(0.11)	(0.12)
$\approx$ 2 miles away	-0.13	-0.09	-0.07
	(0.08)	(0.10)	(0.12)
$\approx \sqrt{5}$ miles away	-0.21***	-0.21**	-0.21**
	(0.08)	(0.09)	(0.10)
R squared	0.50	0.48	0.46
Observations	7684	7237	6738

Conclusion

- Spatial patterns of mineral ownership have a significant effect on drilling and production
- Results consistent with a model where federal government land imposes higher costs
- Federal land has different outcomes depending on proximity to state land
- Divergence in drilling in 1980's consistent with stronger environmental protection starting in 1970's