Strategic Learning and Corporate Investment

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NBER Summer Institute
Corporate Finance

July 12, 2022

Motivation

Empirical Evidence: Firms learn from their peers

Social learning is pervasive in information theory: A driving force explaining dynamics among economic agents

(1) Micro & Finance (Conley and Udry, AER 2010; Leary and Roberts, JF 2014)

(2) Macro (Fajgelbaum et al., QJE 2017)

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Econ. Theory: Anticipation of information spillover from peers $\longrightarrow$ war-of-attrition regarding the timing of investment and delays (Chamley and Gale, ECTA 1994)

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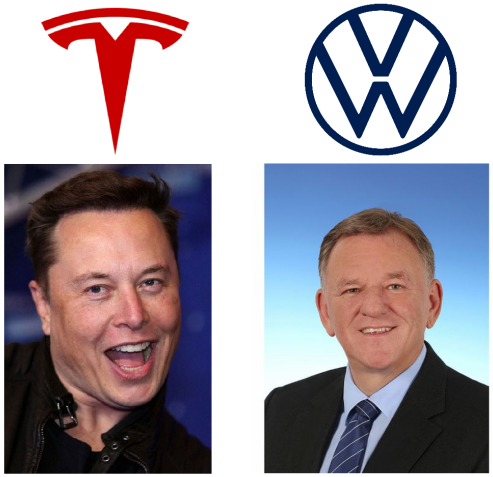

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Firms are willing to wait to learn from peers' decisions and outcomes.

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Studying how anticipation of peers' information revelation affects firms is challenging:

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(1) Identify peers
(2) Observe when real options are available and exercised
(3) Measure project-level inputs
(4) Separate the anticipation of peers' information spillover channel
(5) Quantify the amount anticipated information

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This paper: Reveals how the anticipation of peers' information spillover impacts the timing of firms' corporate investment.

Empirical Setting

Projects: 8,725 distinct real options in the oil and gas sector

$\Rightarrow$ 537,093 option-month observations in Oklahoma and Louisiana (2005-2020)

(1) Simple and homogeneous projects (mean investment = \$4.23 million)
   - $\Rightarrow$ Output price
   - $\Rightarrow$ Implied volatility
   - $\Rightarrow$ Time-varying cost of drilling
   - $\Rightarrow$ Risk-free rate
   - $\Rightarrow$ Estimates of expected production

(2) Standardized unit of observation for options

(3) Clearly identify a firm and its peers

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- ⇒ Land survey method
- ⇒ Drilling and spacing requirements

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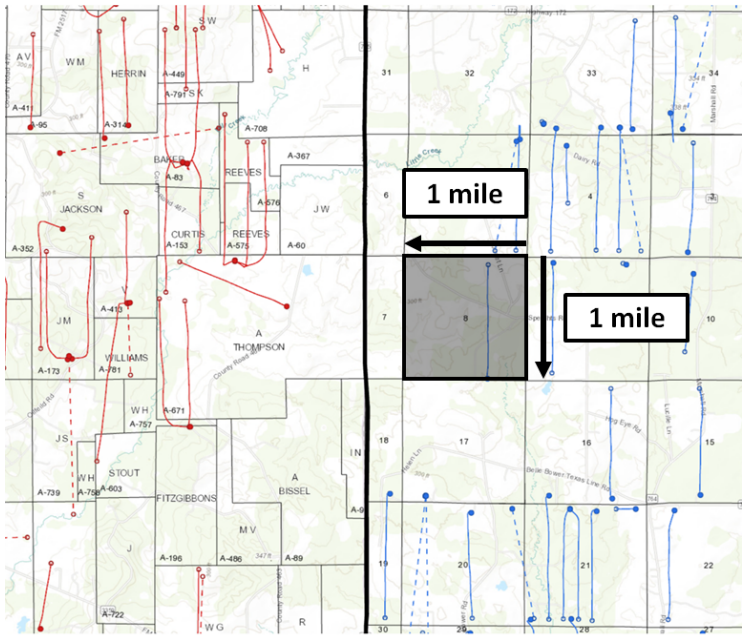

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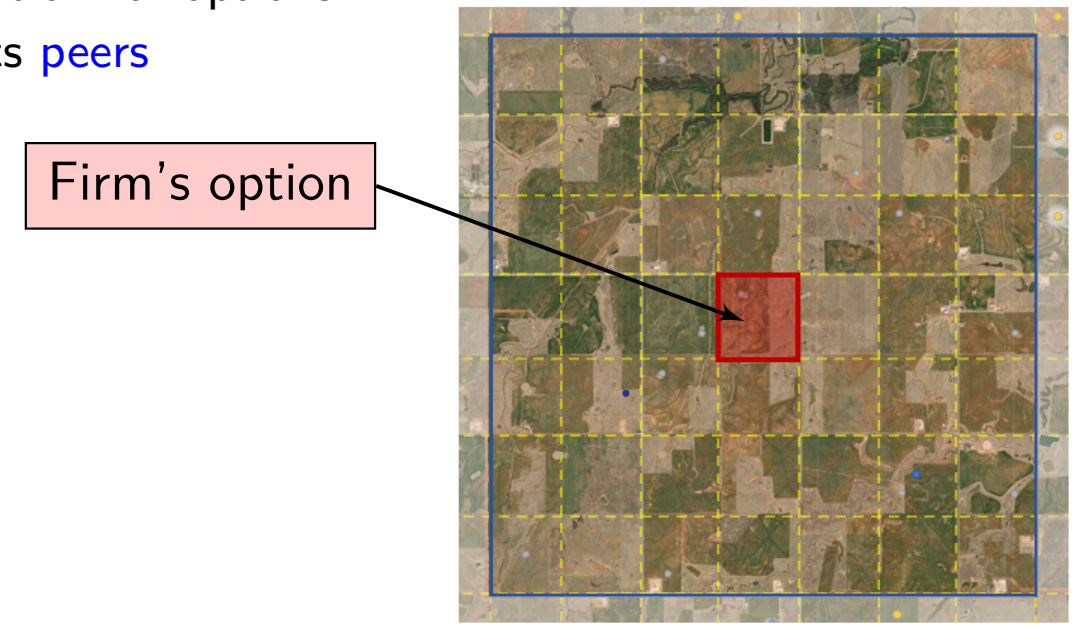

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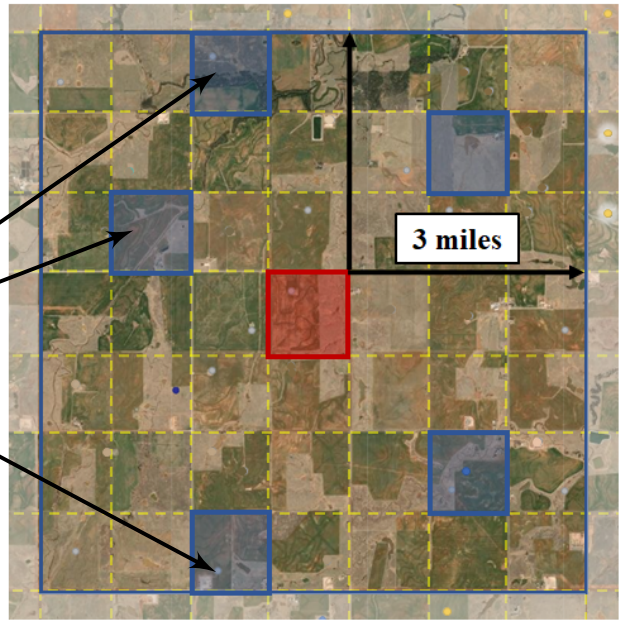
Who are the peers?
1) Also engaged in O&G exploration and production
2) Own similar options exactly next to the firm's option



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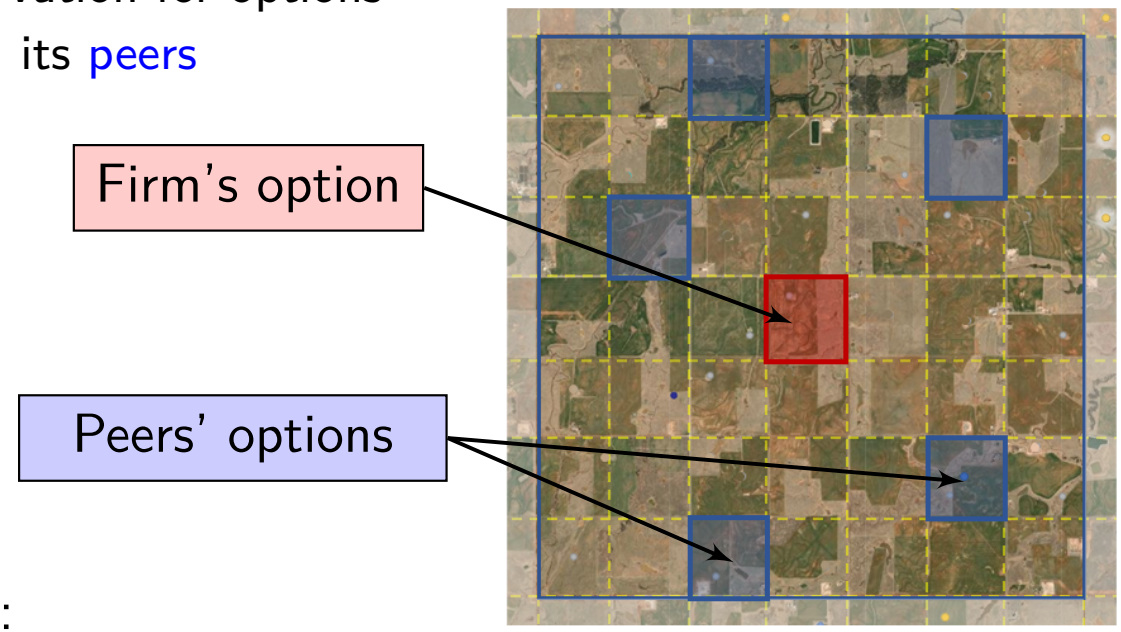

Theory (CG94) $\longrightarrow$ Empirics:

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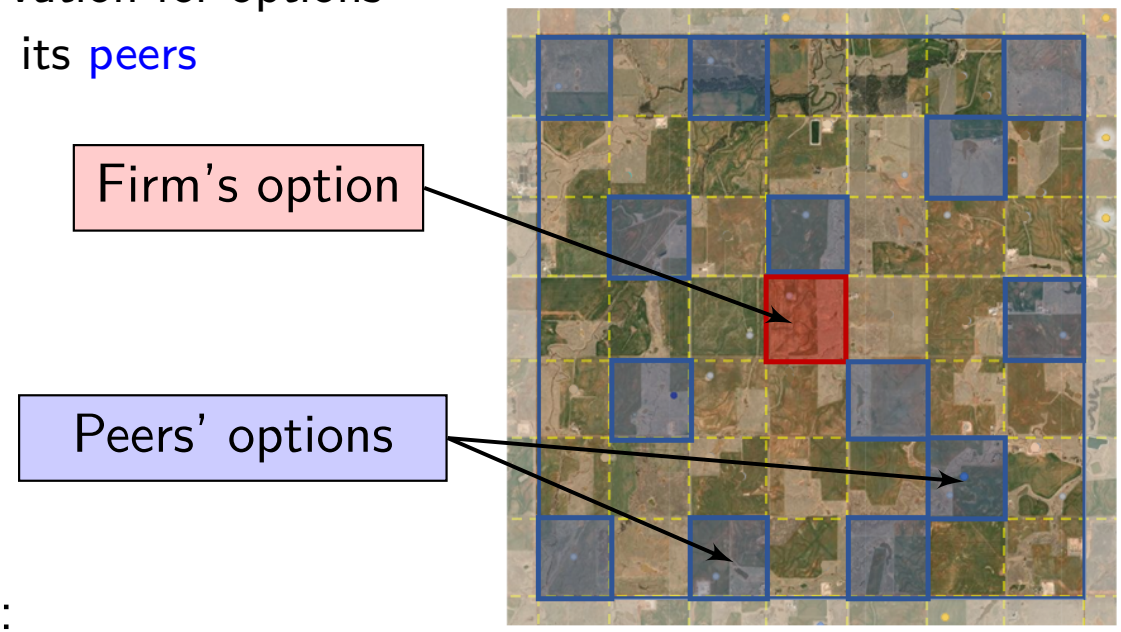

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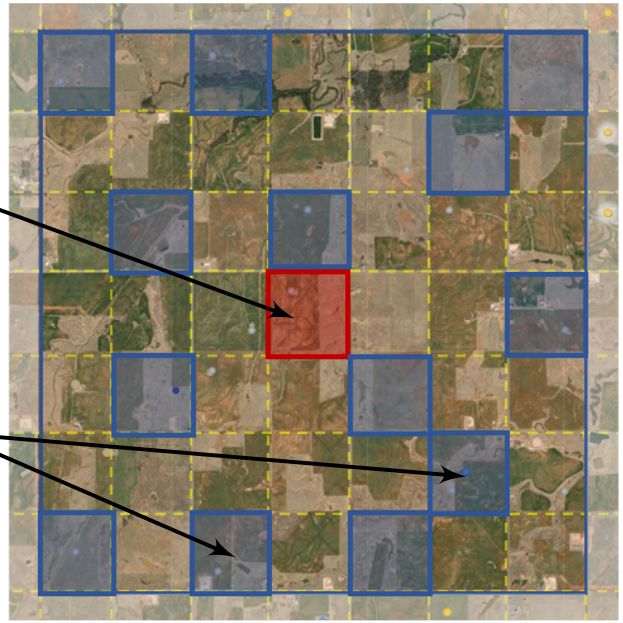
Need exogenous variation:

No. of available peers' options

$\Updownarrow$

Underyling asset quality



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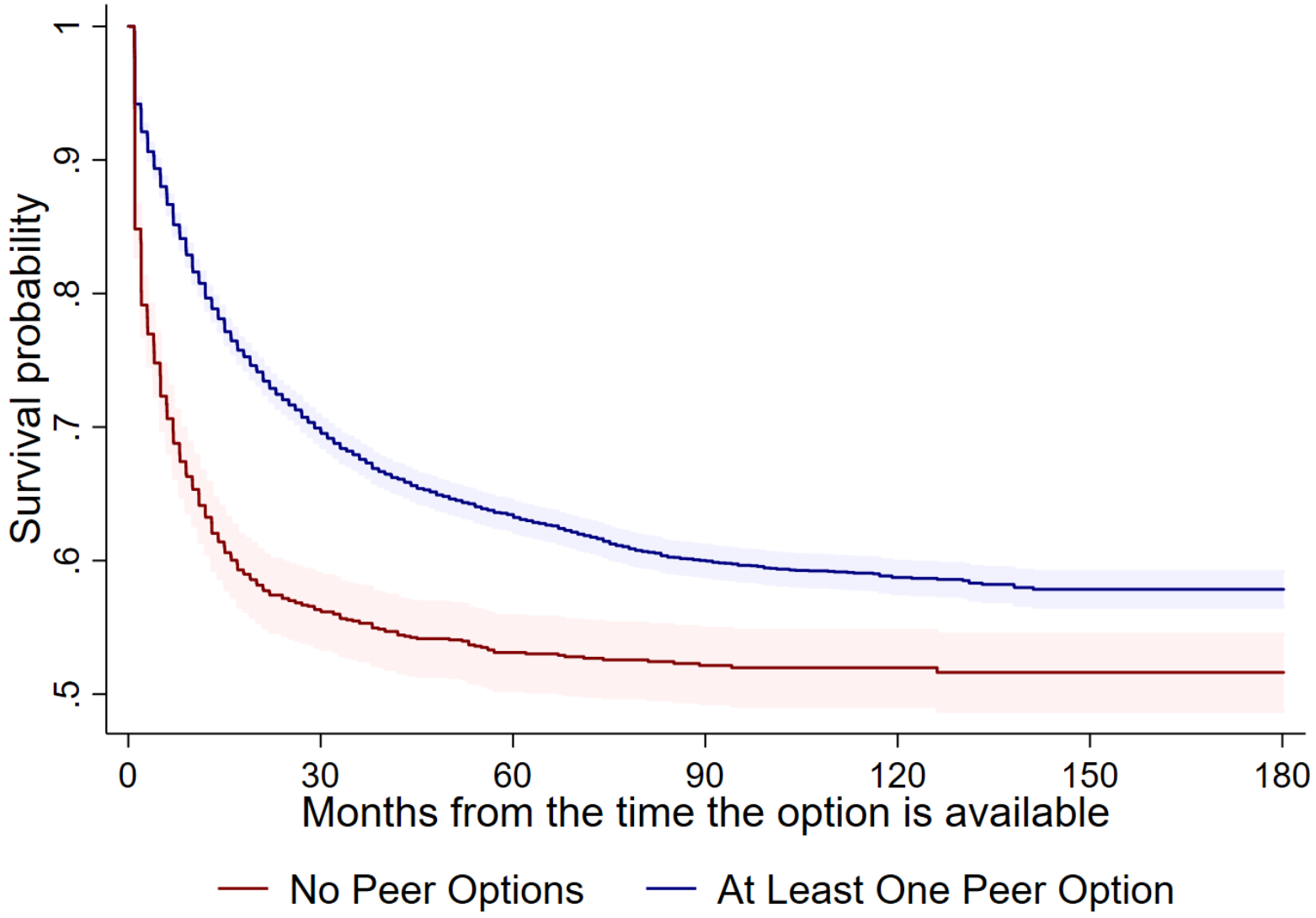

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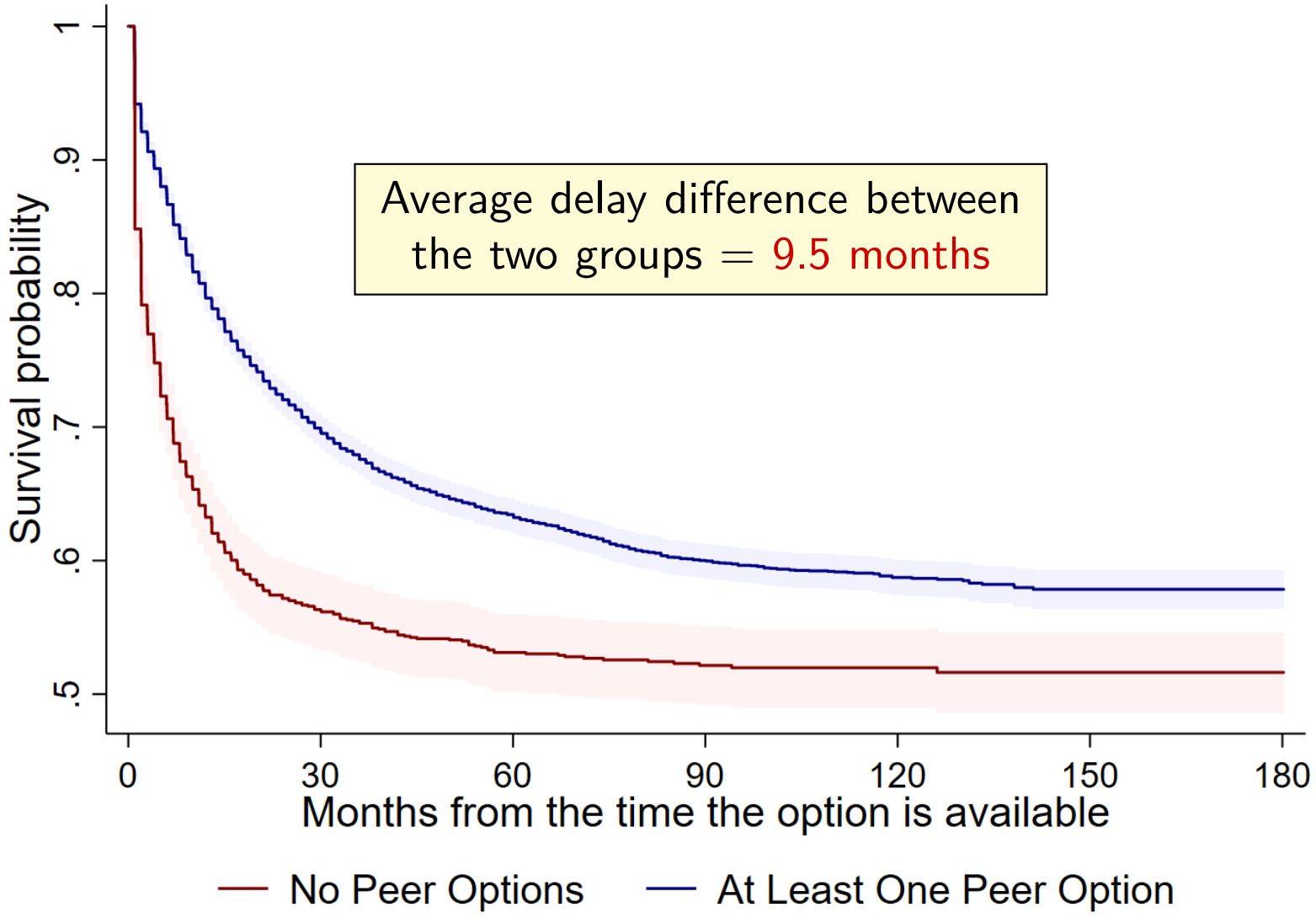

Main Findings

Corporate Investment:

(1) A one-standard deviation increase in the number of nearby peer options reduces the likelihood of project exercise at a given point in time by 13%

⇒ Causality ⟶ instrumental variable

(2) Costs vs. benefits tradeoffs?

⇒ Wait for more information when project is less likely to be profitable

⇒ Wait less when it is financially costly to do so

(3) What sources of information do firms focus on?

⇒ Similar projects

⇒ Skilled peers

(4) When are these information spillovers most valuable?

⇒ When information is scarce

Main Findings

Corporate Investment:

⇒ A one-standard deviation increase in the number of nearby peer options reduces the likelihood of project exercise at a given point in time by 13%

– Causality ⟶ instrumental variable

Quantifying the cost-benefit tradeoff:

⇒ Back-of-the-envelope calculation:

– When firms can learn from their peers, they select projects that are 8.3% more productive

– Costs 7.4% of NPV in pure time-value-of-money

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⇒ Regions with more dispersed options ownership are associated with 19% less drilling activity

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Robustness:

⇒ Aggregate demand shock/Local coord. gains → falsification test,
Local resource constraints → Local rig utilization rates,
Firm-region matching → HDFE, Local prod. optimization → Short wells,
Exclude JV and SAs, Alt. variable def. and model specs.

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A novel mechanism through which information externalities impact corporate investment.

Identifying Real Options and Measuring Exercise Incentives

Data

1. Real Options & Peers

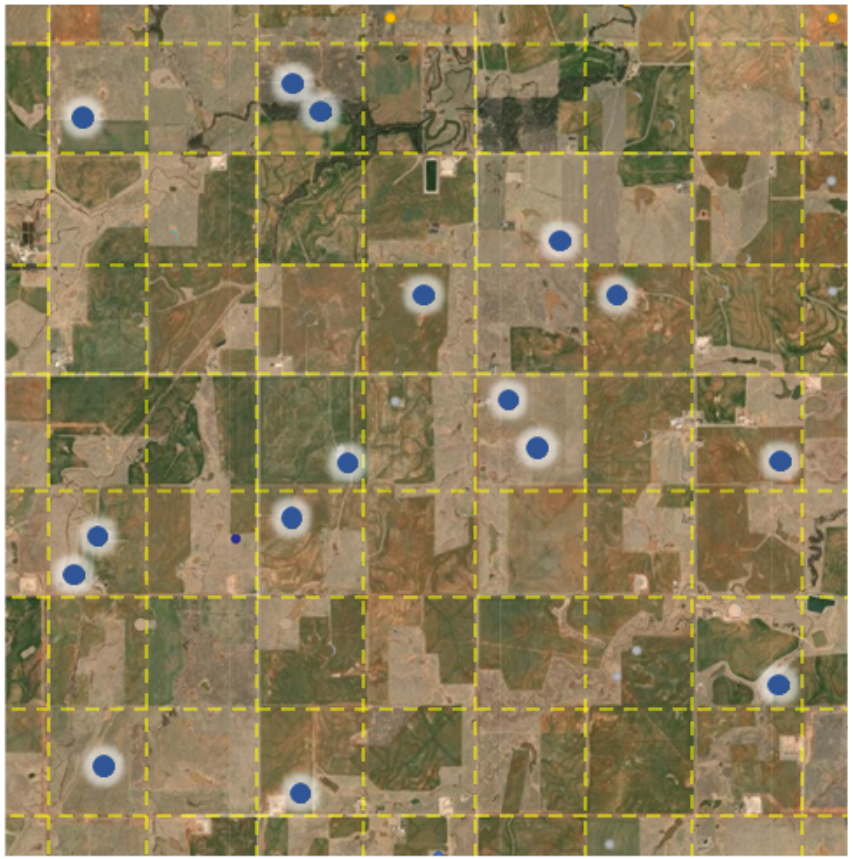
DrillingInfo
All horizontal O&G wells in OK and LA

Sample properties

⇒ 442 firms
- 14% public firms

⇒ 8,725 real options
- 68% publicly held

Precise drilling time & GPS location



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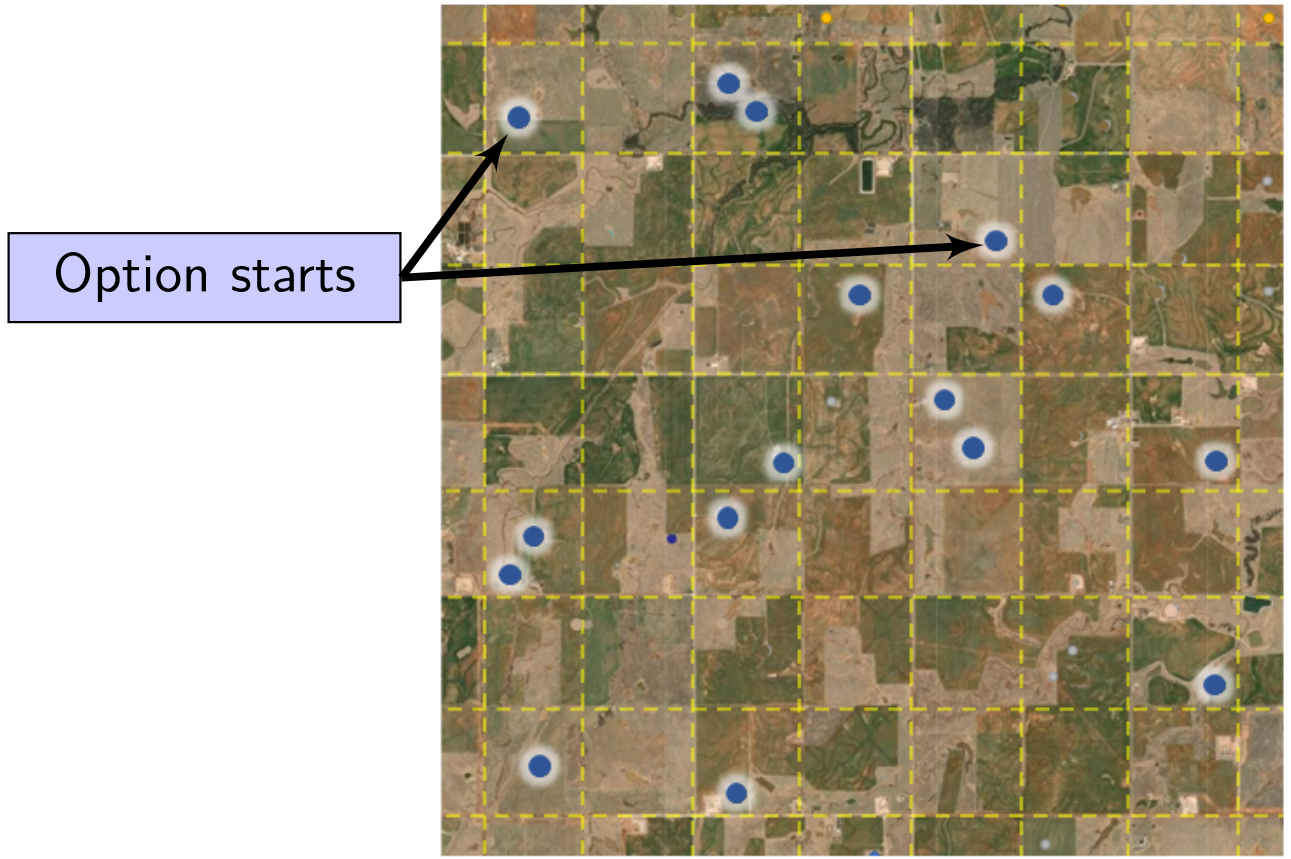

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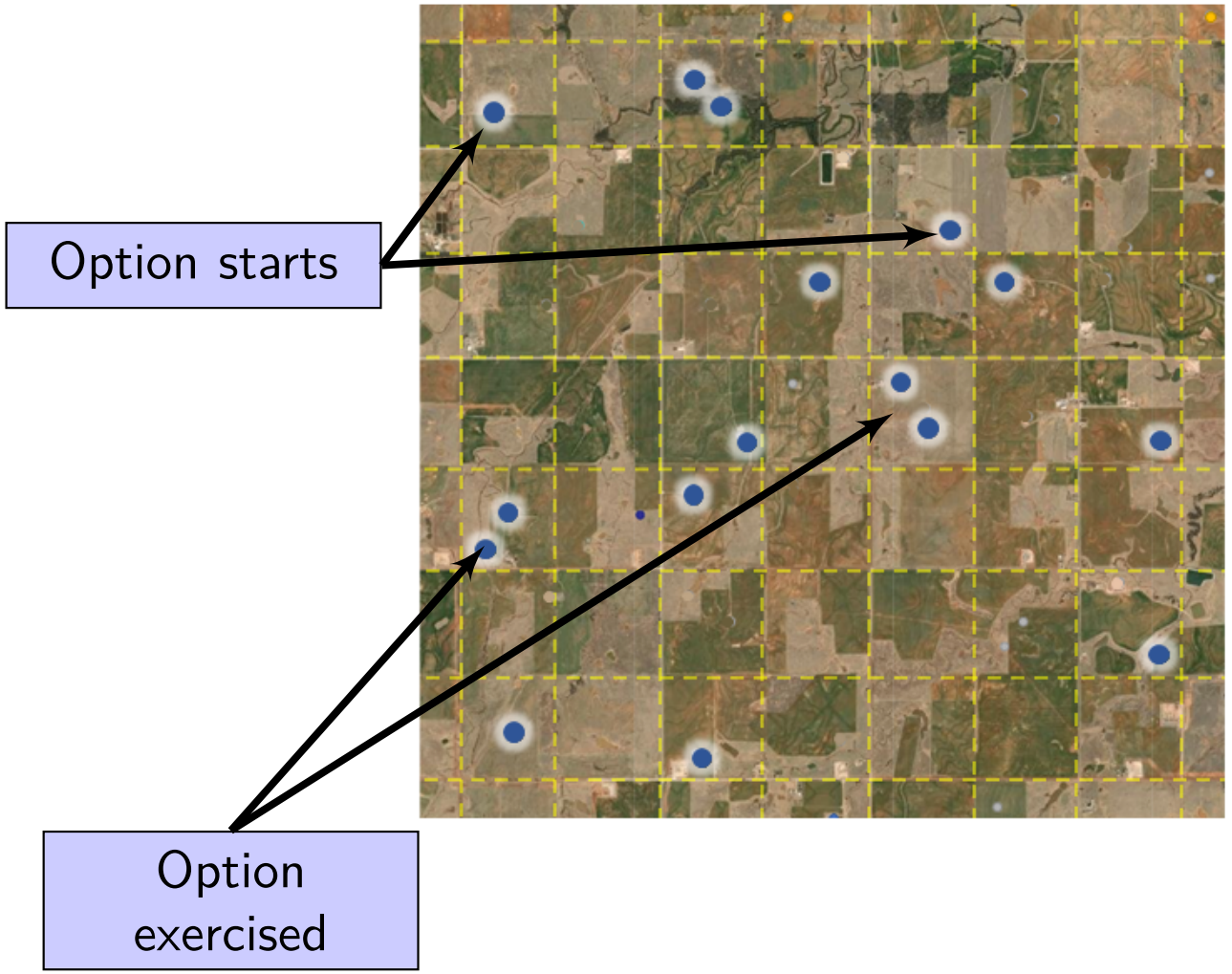
⇒ Option begins
- First well
- Hold-by-production

⇒ Exercise date
- Drill infill well



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2. Exercise Incentives

Public filings, regulatory documents, Bloomberg, St. Louis FRED

Cost of drilling
⇒ Time-varying estimate
⇒ Hand-collected

Bloomberg
⇒ Futures price
⇒ Implied volatility
- 18-month horizon

Cost of Equity
⇒ CAPM

Data

Ad for the *Dawes Act* of 1887

3. Landownership Data

Bureau of Land Management

Historical landownership

⇒ Land assignments under various government programs during states' settlement period

- Used for the IV

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Cost of drilling

Futures price and implied volatility

Cost of Equity

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Historical landownership

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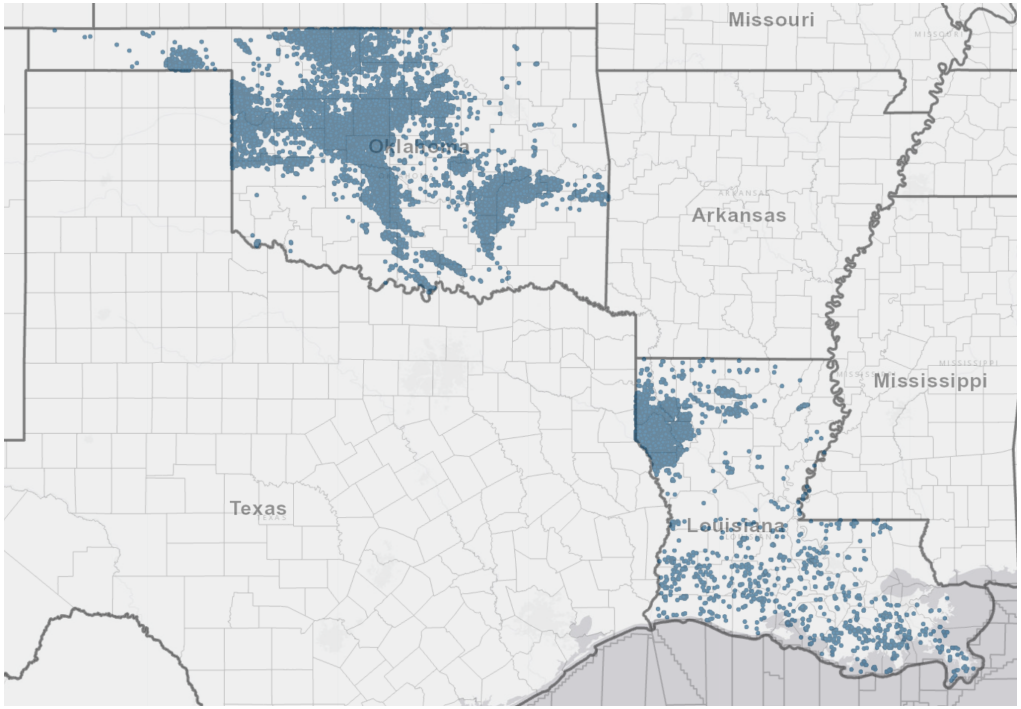
1) Clearly identify real options
2) Precisely measure factors related to exercise

Number of Peer Options and the Timing of Corporate Investment



Baseline Cox Model Results

Cox hazard rate model

⇒ Enter when initial well is drilled

⇒ Exit when infill well is drilled

Unit of observation

⇒ Option-month level

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.030***	-2.93	-0.037***	-3.65	-0.037***	-3.62
	(0.011)		(0.011)		(0.010)	
Cumulative Number of Wells Drilled$_{j,t}$	0.053***	5.41	0.048***	4.95	0.050***	5.18
	(0.004)		(0.004)		(0.004)	
Unexercised Investment Opportunities (Own)$_{j,t}$	-0.035***	-3.47	-0.043***	-4.23	-0.051***	-4.99
	(0.011)		(0.011)		(0.010)	
Portfolio Concentration$_{i,t}$	0.188	20.72	0.096	10.06	0.076	7.94
	(0.181)		(0.179)		(0.168)	
Mean Distance Between Options$_{i,t}$	-0.059	-5.75	-0.067*	-6.46	-0.074**	-7.17
	(0.037)		(0.035)		(0.034)	
Firm Skill Level$_{i,t}$	-0.032	-3.14	-0.237***	-21.06	-0.192**	-17.48
	(0.057)		(0.083)		(0.083)	
Royalty Rate$_{k}$ (%)	0.007	0.69	0.007	0.67	0.006	0.58
	(0.007)		(0.007)		(0.007)	
Well Lateral Length$_{j,t}$ (1,000 ft.)			-0.047**	-4.56	-0.012	-1.22
			(0.023)		(0.020)	
First Well's Market Value$_{j,t}$			0.233***	26.21	0.207***	23.00
			(0.068)		(0.061)	
Peers' Wells' Mkt. Value$_{j,t}$			0.063***	6.48	0.058***	5.97
			(0.015)		(0.014)	
Oil-to-Gas Ratio$_{j}$			0.308**	36.03	0.340***	40.51
			(0.133)		(0.124)	
Drilling Cost$_{j,t}$			-0.019	-1.90	-0.039	-3.84
			(0.042)		(0.030)	
Futures Price$_{t}$					0.009***	0.90
					(0.003)	
Implied Volatility$_{t}$ (%)					-0.022***	-2.15
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10-Year Risk Free Rate$_{t}$ (%)					0.176***	19.27
					(0.057)	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-17,286		-17,174		-17,074	
Wald Chi^2	398		541		1,105	
Observations	537,093		537,093		537,093	

Baseline Cox Model Results

Variable of interest

⇒ Number of peer options within three miles

Robust to alternative definitions

⇒ Two and four miles

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Economic magnitude

⇒ One SD increase in:

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2) Futures price → 17% increase in exercise likelihood

3) Volatility → 12% reduction in exercise likelihood

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.030***	-2.93	-0.037***	-3.65	-0.037***	-3.62
	(0.011)		(0.011)		(0.010)	
Cumulative Number of Wells Drilled$_{j,t}$	0.053***	5.41	0.048***	4.95	0.050***	5.18
	(0.004)		(0.004)		(0.004)	
Unexercised Investment Opportunities (Own)$_{j,t}$	-0.035***	-3.47	-0.043***	-4.23	-0.051***	-4.99
	(0.011)		(0.011)		(0.010)	
Portfolio Concentration$_{i,t}$	0.188	20.72	0.096	10.06	0.076	7.94
	(0.181)		(0.179)		(0.168)	
Mean Distance Between Options$_{i,t}$	-0.059	-5.75	-0.067*	-6.46	-0.074**	-7.17
	(0.037)		(0.035)		(0.034)	
Firm Skill Level$_{i,t}$	-0.032	-3.14	-0.237***	-21.06	-0.192**	-17.48
	(0.057)		(0.083)		(0.083)	
Royalty Rate$_{k}$ (%)	0.007	0.69	0.007	0.67	0.006	0.58
	(0.007)		(0.007)		(0.007)	
Well Lateral Length$_{j,t}$ (1,000 ft.)			-0.047**	-4.56	-0.012	-1.22
			(0.023)		(0.020)	
First Well's Market Value$_{j,t}$			0.233***	26.21	0.207***	23.00
			(0.068)		(0.061)	
Peers' Wells' Mkt. Value$_{j,t}$			0.063***	6.48	0.058***	5.97
			(0.015)		(0.014)	
Oil-to-Gas Ratio$_{j}$			0.308**	36.03	0.340***	40.51
			(0.133)		(0.124)	
Drilling Cost$_{j,t}$			-0.019	-1.90	-0.039	-3.84
			(0.042)		(0.030)	
Futures Price$_{t}$					0.009***	0.90
					(0.003)	
Implied Volatility$_{t}$ (%)					-0.022***	-2.15
					(0.007)	
10-Year Risk Free Rate$_{t}$ (%)					0.176***	19.27
					(0.057)	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-17,286		-17,174		-17,074	
Wald Chi^2	398		541		1,105	
Observations	537,093		537,093		537,093	

Baseline Cox Model Results

Economic magnitude

⇒ One SD increase in:

1) No. peer options → 13% reduction in exercise likelihood

2) Futures price → 17% increase in exercise likelihood

3) Volatility → 12% reduction in exercise likelihood

Alternative models

⇒ Results are robust to OLS and Probit models

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Baseline Cox Model Results

Firm-level controls

Project-level controls

Market-level controls

County Stratification

1) Underlying asset quality

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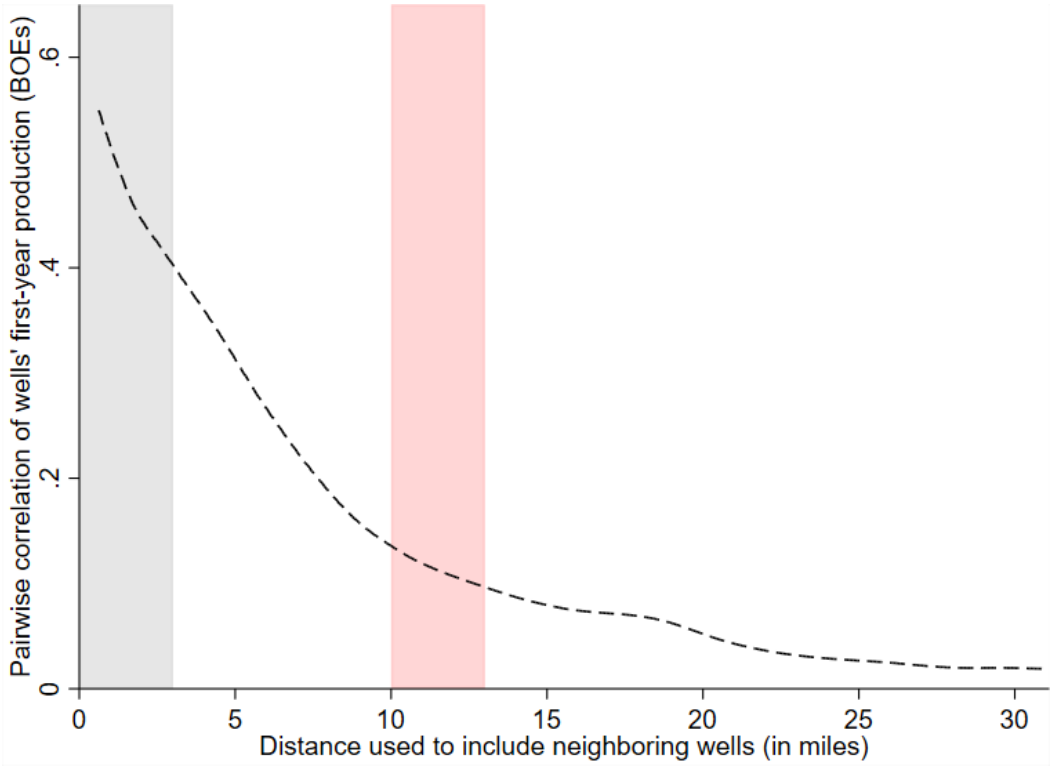
Robustness

Confounding cases:

(1) Is the effect driven by a regional shock or coordination gains with peers?
→ Falsification test with peer options located within 10-13 miles



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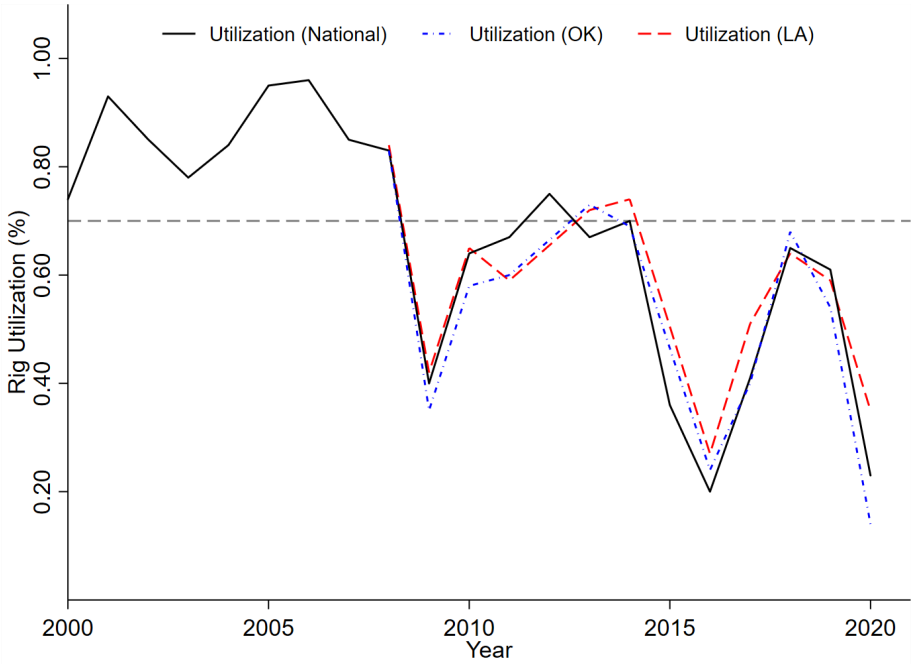
  – Subsample with low local rig utilization rate



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Introduce an instrumental variable

Instrumental Variables Analysis

Challenge:

$\Rightarrow$ Exogenous variation in the number of surrounding options that are held by any of a firm's peers

Instrumental Variables Analysis

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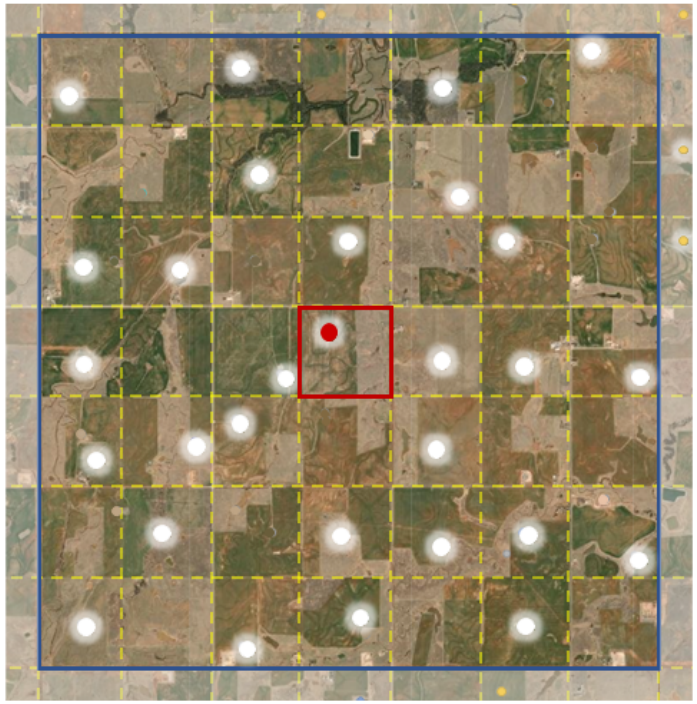
⇒ Exogenous variation in the number of surrounding options that are held by any of a firm's peers

Main concern: Number of peers is correlated with the underlying asset quality

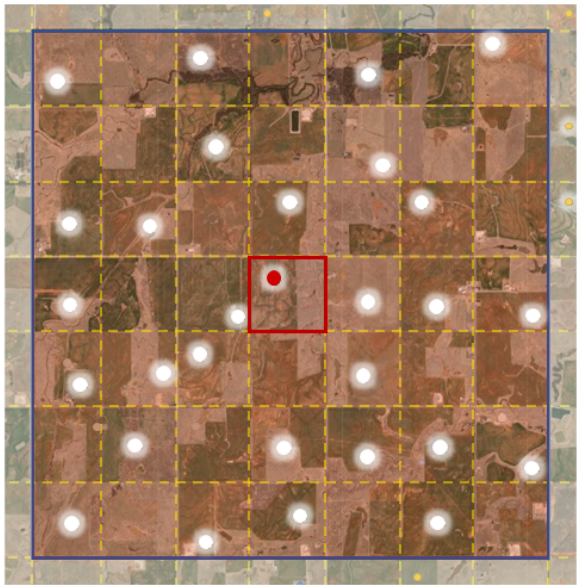


Instrumental Variables Analysis

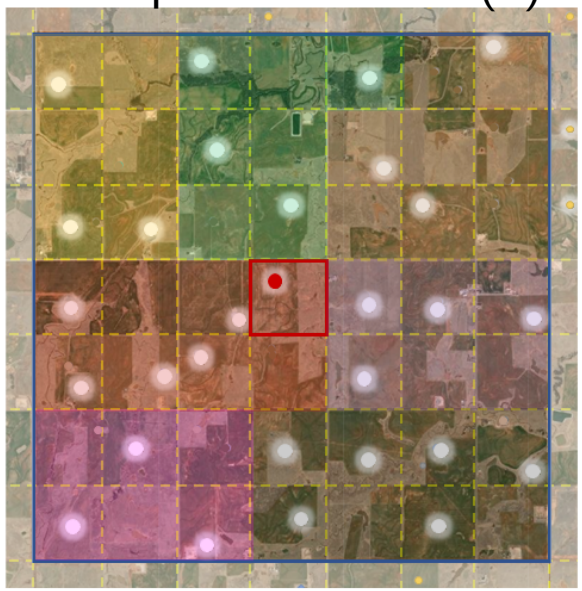
Challenge:

- ⇒ Exogenous variation in the number of surrounding options that are held by any of a firm's peers
- ⇒ Solution: Fragmentation of landownership

One landowner



Multiple landowners (7)



Instrumental Variables Analysis

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- ⇒ Solution: Fragmentation of landownership
- ⇒ Intuition: Areas with fragmented landownership make it harder for a single firm to acquire all the leases, before any of its peers

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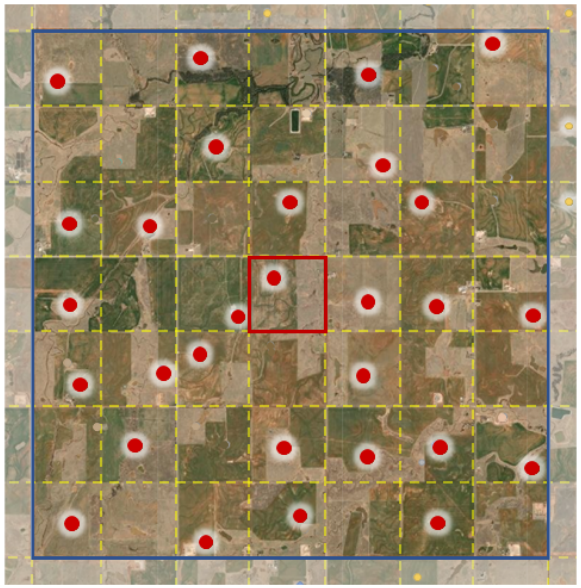

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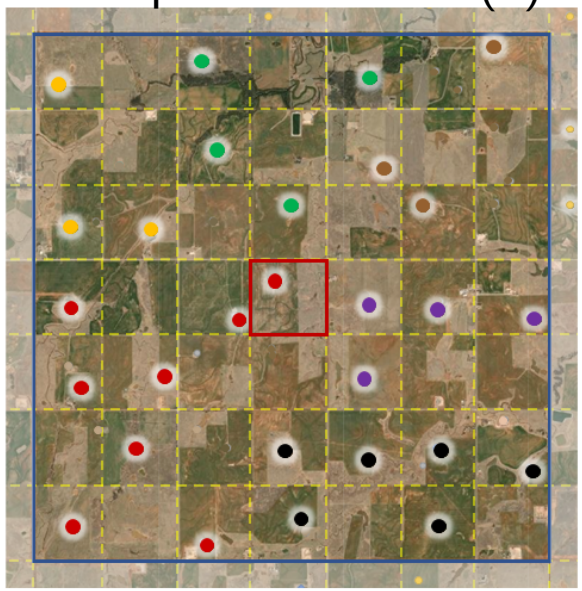

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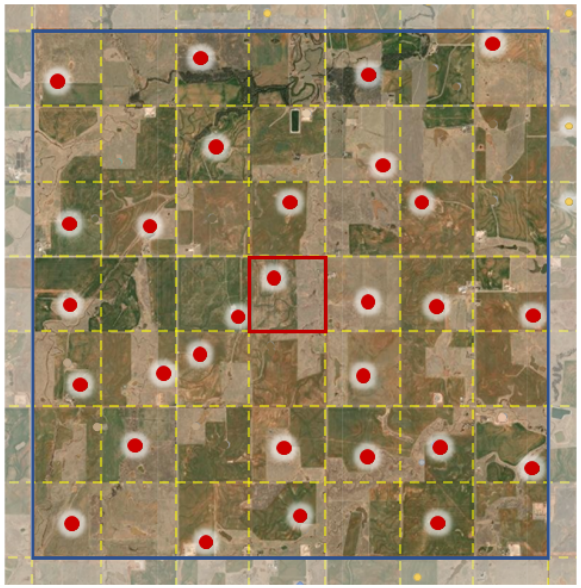

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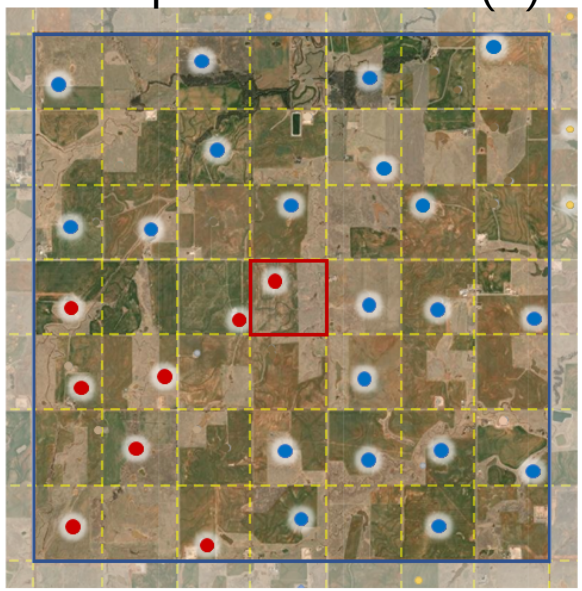

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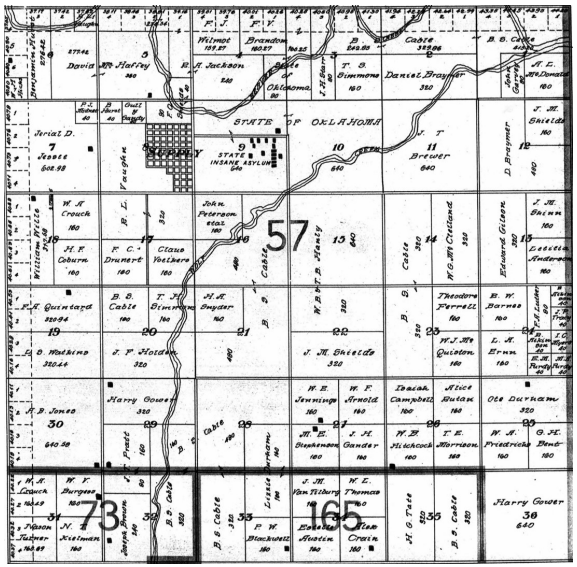
⇒ Solution: Historical landownership (Bureau of Land Management)

(1) Homestead Act (42%)
(2) Dawes Act (11%)
(3) Script Warrant Acts (4%)
(4) Cash entry programs (39%)

Settling, farming, and rewarding soldiers



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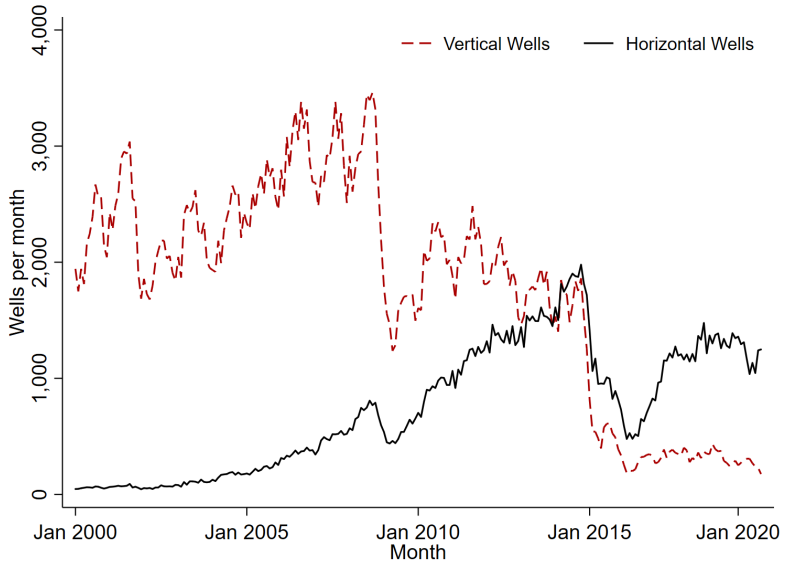

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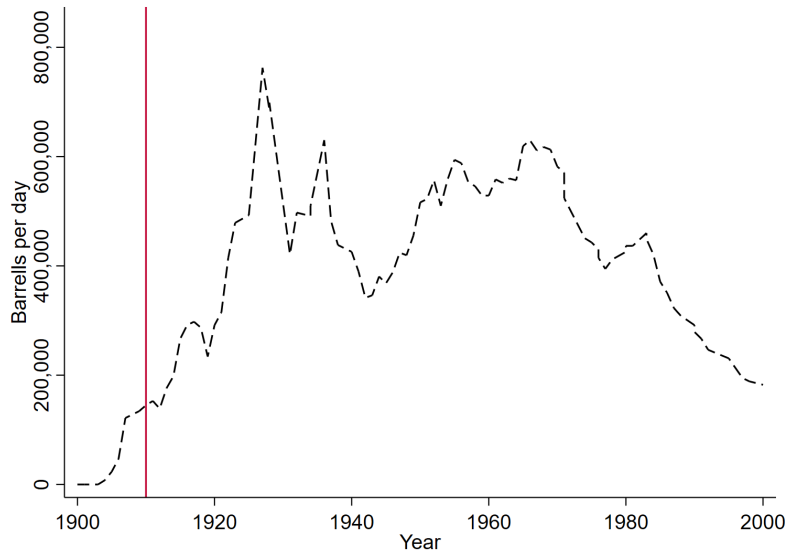

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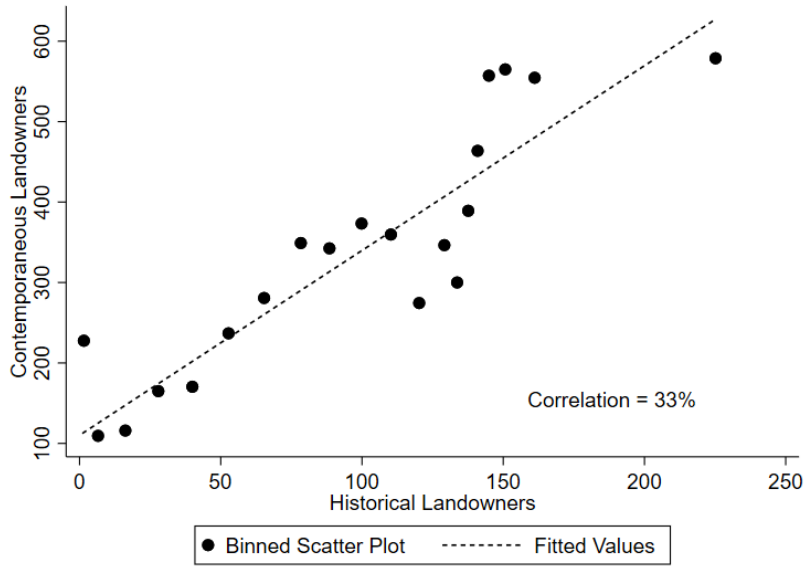
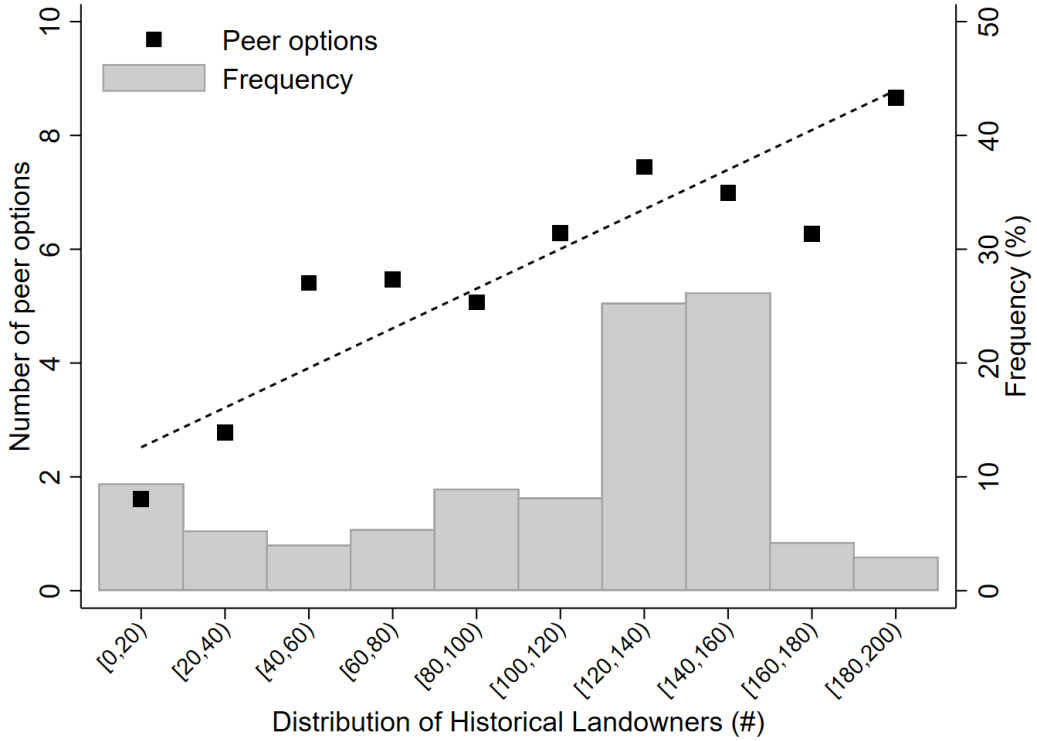
Historical landownership patterns explain today's patterns (Curry-Roper, 1987)



Instrumental Variables Analysis

Relevance condition:

- ⇒ First stage is positive
  - ⇒ Consistent with intuition
- ⇒ First-stage F-tests > 12 (Staiger and Stock, ECTA 1997; Stock and Yogo, 2006)



Instrumental Variables Analysis

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Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo – Loglikelihood	-13,651		-13,564		-13,481	
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A potential case of affirmative bias:

⇒ Positive correlation between the number of peers' options and the quality of the underlying asset

⇒ Higher quality assets should get exercised faster (i.e, $E[\beta_{\text{quality}}] \geq 0$)

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Suggests that the coefficient in the endogenous regression is biased upward

Conclusion

Methodological contribution

⇒ Introduce a novel instrument

Key result

Firms anticipate information spillover and delay their investment decision to learn from their peers

Additional Results

⇒ Firms appear to trade off costs with benefits of waiting for peers' information

⇒ Firms' incentive to wait for peers' information is greater when the source of information is more relevant

⇒ Results suggest that the anticipation of information has an aggregate level effect on investment

When are information spillovers most valuable?

Spillovers matter most when information is scarce!

	Hazard Model for Project Exercise	
	(1)	
Quantity of Prior Information Released =	Small	
	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.506***	-39.68
	(0.056)	
Firm-level controls	Yes	
Project-level controls	Yes	
Market level controls	Yes	
County Strata	Yes	
Pseudo − Loglikelihood	-3,936	
Wald Chi^2	365	
Observations	183,015	

Small amount of prior information

$\Rightarrow$ Median number of options drilled $= 0$

$\Rightarrow$ Mean number of options drilled $= 0.6$

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Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.506***	-39.68	-0.052	-5.03
	(0.056)		(0.053)	
Firm-level controls	Yes		Yes	
Project-level controls	Yes		Yes	
Market level controls	Yes		Yes	
County Strata	Yes		Yes	
Pseudo – Loglikelihood	-3,936		-4,882	
Wald Chi^2	365		978	
Observations	183,015		166,972	

Small amount of prior information

$\Rightarrow$ Median number of options drilled = 0

$\Rightarrow$ Mean number of options drilled = 0.6

Large amount of prior information

$\Rightarrow$ Median number of options drilled = 8

$\Rightarrow$ Mean number of options drilled = 9.1

Spillovers matter most when information is scarce!

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
Quantity of Prior Information Released =	Small		Medium		Large	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.506***	-39.68	-0.326***	-27.83	-0.052	-5.03
	(0.056)		(0.040)		(0.053)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	Yes		Yes		Yes	
Market level controls	Yes		Yes		Yes	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-3,936		-4,875		-4,882	
Wald Chi^2	365		453		978	
Observations	183,015		187,106		166,972	

Small amount of prior information

⇒ Median number of options drilled = 0

⇒ Mean number of options drilled = 0.6

Large amount of prior information

⇒ Median number of options drilled = 8

⇒ Mean number of options drilled = 9.1

⇒ Effect gradually decreases with the quantity of information already revealed

Spillovers matter most when information is scarce!

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
Quantity of Prior Information Released =	Small		Medium		Large	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
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Firm-level controls	Yes		Yes		Yes	
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⇒ Mean number of options drilled = 0.6

Large amount of prior information

⇒ Median number of options drilled = 8

⇒ Mean number of options drilled = 9.1

⇒ Effect gradually decreases with the quantity of information already revealed

⇒ Incentives to wait are concentrated in cases with limited available information

Costs vs. Benefits Tradeoffs

Costs of Waiting

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.095**	-9.07	-0.107***	-10.14	-0.115***	-10.83
	(0.038)		(0.038)		(0.038)	
Unexercised Inv. Opp. (Peers)$_{j,t}\times$ Cost of Equity$_{i,t}$	0.007*	0.68	0.008**	0.77	0.009**	0.86
	(0.004)		(0.004)		(0.004)	
Cost of Equity$_{i,t}$ (%)	-0.049**	-4.74	-0.065***	-6.25	-0.069***	-6.69
	(0.023)		(0.024)		(0.026)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-7,033		-6,981		-6,943	
Wald Chi^2	532		671		1,390	
Observations	273,427		273,427		273,427	

Costs of Waiting

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.095**	-9.07	-0.107***	-10.14	-0.115***	-10.83
	(0.038)		(0.038)		(0.038)	
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	(0.004)		(0.004)		(0.004)	
Cost of Equity$_{i,t}$ (%)	-0.049**	-4.74	-0.065***	-6.25	-0.069***	-6.69
	(0.023)		(0.024)		(0.026)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-7,033		-6,981		-6,943	
Wald Chi^2	532		671		1,390	
Observations	273,427		273,427		273,427	

Costs of Waiting

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.095**	-9.07	-0.107***	-10.14	-0.115***	-10.83
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Wald Chi^2	532		671		1,390	
Observations	273,427		273,427		273,427	

1) Cross-partial derivative coefficient (CPDC) at the mean = 0.003
2) CPDCs are positive over the full support of the variable of interest
3) Interaction term is positive in the OLS case

Costs of Waiting

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
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Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
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County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-7,033		-6,981		-6,943	
Wald Chi^2	532		671		1,390	
Observations	273,427		273,427		273,427	

Costs of Waiting for Info. Spillovers

⇒ Firms wait less on peers when the TVM increases

⇒ Back-of-the-envelope: 7.4% drop in NPV due to pure TVM

Benefits of Waiting

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-1.106***	-66.91	-0.980***	-62.49	-0.816***	-55.77
	(0.158)		(0.145)		(0.141)	
Unexercised Inv. Opp. (Peers)$_{j,t}$	0.071***	7.31	0.062***	6.41	0.051***	5.27
$\times$ Peers' Wells' Mkt. Value$_{j,t}$	(0.011)		(0.010)		(0.009)	
Peers' Wells' Value$_{j,t}$	0.062***	6.42	0.058***	5.92	0.054***	5.54
	(0.015)		(0.013)		(0.013)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo – Loglikelihood	-17,194		-17,132		-17,046	
Wald Chi^2	775		884		1,636	
Observations	537,093		537,093		537,093	

Costs of Waiting for Info. Spillovers

$\Rightarrow$ Firms wait less on peers when the TVM increases

$\Rightarrow$ Back-of-the-envelope: 7.4% drop in NPV due to pure TVM

Benefits of Waiting for Info. Spillovers

$\Rightarrow$ Wait for more information when the project is less likely to be profitable

$\Rightarrow$ When firms can learn from their peers, they select projects that are 8.3% more productive

Benefits of Waiting

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-1.106***	-66.91	-0.980***	-62.49	-0.816***	-55.77
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Pseudo – Loglikelihood	-17,194		-17,132		-17,046	
Wald Chi^2	775		884		1,636	
Observations	537,093		537,093		537,093	

Firms appear to trade off the benefits of collecting additional information from peers with the costs of waiting

Relevance of Information Sources

Project Similarity

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Same Resource)$_{j,t}$	-0.112***	-10.60	-0.136***	-12.75	-0.138***	-12.87
	(0.035)		(0.034)		(0.032)	
Unexercised Investment Opportunities (Different Resource)$_{j,t}$	-0.026	-2.58	-0.040	-3.91	-0.036	-3.49
	(0.025)		(0.027)		(0.025)	
Chi^2 (Same Resource—Different Resource)	8.25***		17.25***		15.90***	
(p-Value)	(0.004)		(0.000)		(0.000)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-17,285		-17,174		-17,074	
Wald Chi^2	474		563		1,161	
Observations	537,093		537,093		537,093	

How do we do it?

Which peer/project characteristics matter?

Project Similarity

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Same Resource)$_{j,t}$	-0.112***	-10.60	-0.136***	-12.75	-0.138***	-12.87
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How do we do it?

⇒ Split variable into options producing the same and different majority resources (oil vs. gas)

Which peer/project characteristics matter?

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	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
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Observations	537,093		537,093		537,093	

How do we do it?

⇒ Split variable into options producing the same and different majority resources (oil vs. gas)

⇒ Magnitudes are statistically different

Which peer/project characteristics matter?

⇒ Focus on options producing the same resource

Peer Quality

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (High-Skill Peers)$_{j,t}$	-0.125***	-11.77	-0.154***	-14.23	-0.148***	-13.79
	(0.041)		(0.044)		(0.040)	
Unexercised Investment Opportunities (Low-Skill Peers)$_{j,t}$	0.026	2.65	0.021	2.16	0.007	0.70
	(0.024)		(0.024)		(0.024)	
Chi^2 (High Skill—Low Skill)	11.40***		12.54***		11.94***	
(p-Value)	(0.001)		(0.000)		(0.001)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo – Loglikelihood	-17,280		-17,168		-17,071	
Wald Chi^2	435		580		1,254	
Observations	537,093		537,093		537,093	

How do we do it?

Which peer/project characteristics matter?

⇒ Focus on options producing the same resource

Peer Quality

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
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Observations	537,093		537,093		537,093	

How do we do it?

⇒ Split variable into options owned by skilled and unskilled peers

Which peer/project characteristics matter?

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Peer Quality

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	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
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(p-Value)	(0.001)		(0.000)		(0.001)	
Firm-level controls	Yes		Yes		Yes	
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Observations	537,093		537,093		537,093	

How do we do it?

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Which peer/project characteristics matter?

⇒ Focus on options producing the same resource

Peer Quality

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	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
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	(0.024)		(0.024)		(0.024)	
Chi^2 (High Skill—Low Skill)	11.40***		12.54***		11.94***	
(p-Value)	(0.001)		(0.000)		(0.001)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
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County Strata	Yes		Yes		Yes	
Pseudo – Loglikelihood	-17,280		-17,168		-17,071	
Wald Chi^2	435		580		1,254	
Observations	537,093		537,093		537,093	

How do we do it?

⇒ Split variable into options owned by skilled and unskilled peers

⇒ Magnitudes are statistically different

Which peer/project characteristics matter?

⇒ Focus on options producing the same resource

⇒ Focus on peers that are better at selecting and designing wells

Peer Quality

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (High-Skill Peers)$_{j,t}$	-0.125***	-11.77	-0.154***	-14.23	-0.148***	-13.79
	(0.041)		(0.044)		(0.040)	
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(p-Value)	(0.001)		(0.000)		(0.001)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-17,280		-17,168		-17,071	
Wald Chi^2	435		580		1,254	
Observations	537,093		537,093		537,093	

Firms appear to wait more to obtain information from sources that are more relevant

Falsification Tests - Peer Options 10-13 Miles Away

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Falsified Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.002	-0.20	-0.003	-0.28	-0.001	-0.11
	(0.003)		(0.003)		(0.002)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-17,296		-17,190		-17,091	
Wald Chi^2	461		527		1,257	
Observations	537,093		537,093		537,093	

Back

Subsample of Periods with Low Rig Utilization Rates

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.026**	-2.52	-0.031**	-3.03	-0.033***	-3.29
	(0.012)		(0.012)		(0.011)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo – Loglikelihood	-11,733		-11,670		-11,598	
Wald Chi^2	367		571		621	
Observations	465,960		465,960		465,960	

Back

Subsample of Projects likely to be Valuable if Exercised Immediately

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.029**	-2.86	-0.029**	-2.90	-0.031**	-3.04
	(0.013)		(0.014)		(0.012)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-11,014		-10,897		-10,860	
Wald Chi^2	272		892		1,306	
Observations	268,547		268,547		268,547	

Back

Subsample of Projects with Initial Well Drilled on a Single Section

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.029**	-2.83	-0.036***	-3.52	-0.035***	-3.48
	(0.011)		(0.012)		(0.011)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-16,041		-15,929		-15,829	
Wald Chi^2	307		446		893	
Observations	509,632		509,632		509,632	

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County-Firm Strata

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.032***	-3.18	-0.035***	-3.40	-0.038***	-3.74
	(0.010)		(0.011)		(0.010)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County-Firm Strata	Yes		Yes		Yes	
Pseudo – Loglikelihood	-10,058		-9,953		-9,900	
Wald Chi^2	498		664		1,009	
Observations	537,093		537,093		537,093	

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Probit Model

Dependent variable =	Project Exercise		
	(1)	(2)	(3)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.005	-0.009	-0.012**
	(0.005)	(0.006)	(0.005)
Firm-level controls	Yes	Yes	Yes
Project-level controls	No	Yes	Yes
Market-level controls	No	No	Yes
County FE	Yes	Yes	Yes
Pseudo – Loglikelihood	-20384.91	-19692.98	-19011.27
Observations	530,251	530,251	530,251

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OLS Model

Dependent variable =	Project Exercise		
	(1)	(2)	(3)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.0001	-0.0002**	-0.0002***
	(0.0001)	(0.0001)	(0.0001)
Firm-level controls	Yes	Yes	Yes
Project-level controls	No	Yes	Yes
Market-level controls	No	No	Yes
County FE	Yes	Yes	Yes
Observations	540,765	540,765	540,765
R^2	0.00	0.00	0.01

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Alternative Peer Distance Definitions

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
Peers Distance Definition =	2 Miles		3 Miles		4 Miles	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.065***	-6.28	-0.037***	-3.62	-0.015***	-1.54
	(0.016)		(0.010)		(0.005)	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Pseudo − Loglikelihood	-17,075		-17,074		-17,084	
Wald Chi^2	1,140		1,105		1,040	
Observations	537,093		537,093		537,093	

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Direction of Observed Bias

Panel B: Direction of Bias		
Dependent variable =	log(First Well's Market Value$_j$)	
	(1)	(2)
Unexercised Investment Opportunities (Peers)$_j$	0.040***	0.015*
	(0.009)	(0.008)
Controls	No	Yes
County FE	Yes	Yes
Observations	8,718	8,718
R^2	0.33	0.47

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Gain From Waiting

Dependent variable =	log(Second Well's Market Value$_j$)		
	(1)	(2)	(3)
Number of Peer Options Firm Waited For$_j$	0.033	0.067**	0.068**
	(0.032)	(0.029)	(0.028)
Firm-level controls	Yes	Yes	Yes
Project-level controls	Yes	Yes	Yes
Market level controls	Yes	Yes	Yes
County FE	Yes	Yes	Yes
Observations	3,462	3,462	3,462
R^2	0.40	0.47	0.47

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Source of Drilling Costs per Lateral Foot

Said owners named in Exhibit "A" attached hereto must make one or any combination of the following elections within 20 days from the date of this Order.

7.1 Participate: To participate in the development of the unit and common source of supply by agreeing to pay such owner's proportionate part of the actual cost of the well and unit covered hereby and by paying, as set out below, to Operator such owner's proportionate part of the estimated completed for production cost thereof, or by providing the Operator with an irrevocable letter of credit for such payment satisfactory to the Operator, within 25 days from the date of this Order, as follows:

Completed as a dry hole	$ 962,323
Completed for production	$4,013,194

Provided further, however, that in the event an owner elects to participate in said unit well or wells by paying his proportionate part of the costs thereof and further does not elect to defer payment of well costs as set out in paragraph 7.1a below and thereafter fails or refuses to pay or

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