Strategic Learning and Corporate Investment



NBER Summer Institute Corporate Finance

July 12, 2022

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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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Empirical Evidence: Firms learn from their peers

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

Décaire and Wittry

Learning and Investment

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

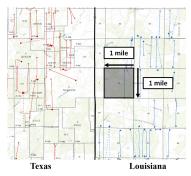
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Projects: 8,725 distinct real options in the oil and gas sector

- \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
- Clearly identify a firm and its peers (3)

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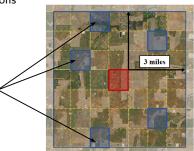


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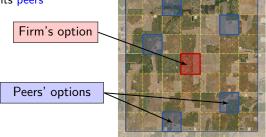
Who are the peers?1) Also engaged in O&G exploration and production2) Own similar options exactly next to the firm's option



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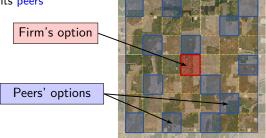


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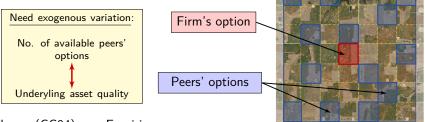
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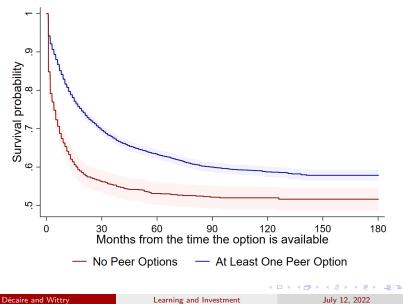
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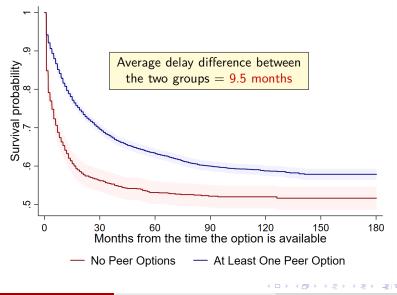
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Main Finding - In a nutshell



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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%
 - \Rightarrow Causality \rightarrow instrumental variable
- (2) Costs vs. benefits tradeoffs?
 - \Rightarrow Wait for more information when project is less likely to be profitable
 - \Rightarrow Wait less when it is financially costly to do so
- (3) What sources of information do firms focus on?
 - ⇒ Similar projects
 - \Rightarrow Skilled peers
- (4) When are these information spillovers most valuable?
 - \Rightarrow When information is scarce

Quantifying the cost-benefit tradeoff:

- \Rightarrow 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

Aggregate Investment:

Regions with more dispersed options ownership are associated with 19% less \Rightarrow 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.

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Identifying Real Options and Measuring Exercise Incentives



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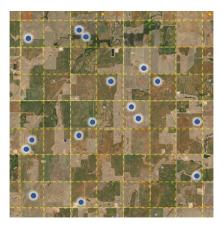
1. Real Options & Peers

DrillingInfo All horizontal O&G wells in OK and LA

Sample properties

- \Rightarrow 442 firms
 - 14% public firms
- \Rightarrow 8,725 real options
 - 68% publicly held

Precise drilling time & GPS location



1. Real Options & Peers

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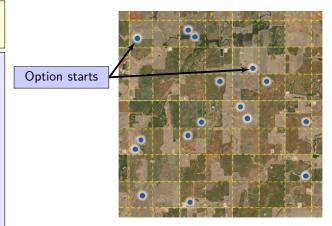
Sample properties

 \Rightarrow 442 firms

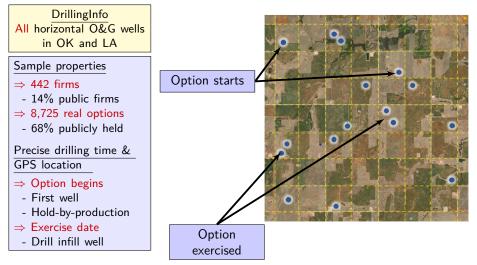
- 14% public firms
- \Rightarrow 8,725 real options
 - 68% publicly held

Precise drilling time & GPS location

- \Rightarrow Option begins
 - First well
 - Hold-by-production



1. Real Options & Peers



1. Real Options & Peers

DrillingInfo All horizontal O&G wells in OK and LA

Sample properties

- \Rightarrow 442 firms
- 14% public firms
- \Rightarrow 8,725 real options
 - 68% publicly held

Precise drilling time &

GPS location

2. Exercise Incentives

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

Cost of drilling

- \Rightarrow Time-varying estimate
- \Rightarrow Hand-collected

Bloomberg

- \Rightarrow Futures price
- \Rightarrow Implied volatility
- 18-month horizon

Cost of Equity

 \Rightarrow CAPM



3. Landownership Data

Bureau of Land Management

Historical landownership \Rightarrow Land assignments under various government programs during states' settlement period - Used for the IV

Ad for the Dawes Act of 1887

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1. Real Options & Peers

DrillingInfo All horizontal O&G wells in OK and LA

Sample properties

- \Rightarrow 442 firms
- 14% public firms
- \Rightarrow 8,725 real options
 - 68% publicly held

Precise drilling time &

GPS location

2. Exercise Incentives

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

Cost of drilling

Futures price and implied volatility

Cost of Equity

3. Landownership Data

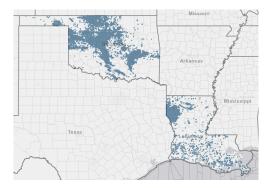
Bureau of Land Management

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

- Used for the IV

Clearly identify real options Precisely measure factors related to exercise

Number of Peer Options and the Timing of Corporate Investment



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	Hazard Model for Project Exercise						
		(1)		(2))
		Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Cox hazard rate model	Unexercised Investment Opportunities (Peers) _{j,t}	-0.030***	-2.93	-0.037***	-3.65	-0.037***	-3.62
	Cumulative Number of Wells Drilled _{j,t}	(0.011) 0.053***	5.41	(0.011) 0.048***	4.95	(0.010) 0.050***	5.18
\Rightarrow Enter when initial well is drilled	Unexercised Investment Opportunities $(Own)_{j,t}$	(0.004) -0.035***	-3.47	(0.004) -0.043***	-4.23	(0.004) -0.051***	-4.99
\Rightarrow Exit when infill well	Portfolio Concentration _{i,t}	(0.011) 0.188 (0.181)	20.72	(0.011) 0.096 (0.179)	10.06	(0.010) 0.076 (0.168)	7.94
is drilled	Mean Distance Between $Options_{i,t}$	-0.059 (0.037)	-5.75	-0.067* (0.035)	-6.46	-0.074** (0.034)	-7.17
Unit of cheenvetion	Firm Skill Level _{i,t}	-0.032 (0.057)	-3.14	-0.237*** (0.083)	-21.06	-0.192** (0.083)	-17.48
Unit of observation	Royalty Rate _k (%)	0.007 (0.007)	0.69	0.007 (0.007)	0.67	0.006 (0.007)	0.58
\Rightarrow Option-month level	Well Lateral Length _{j,t} (1,000 ft.)	(0.001)		-0.047** (0.023)	-4.56	-0.012 (0.020)	-1.22
	First Well's Market $Value_{j,t}$			0.233*** (0.068)	26.21	0.207*** (0.061)	23.00
	Peers' Wells' Mkt. Value _{j,t}			0.063*** (0.015)	6.48	0.058*** (0.014)	5.97
	Oil-to-Gas Ratio _j			0.308** (0.133)	36.03	0.340*** (0.124)	40.51
	Drilling Cost _{j,t}			-0.019 (0.042)	-1.90	-0.039 (0.030)	-3.84
	Futures Pricet			()		0.009*** (0.003)	0.90
	Implied Volatility _t (%)					-0.022*** (0.007)	-2.15
	10-Year Risk Free Rate _t (%)					0.176*** (0.057)	19.27
	County Strata	Yes		Yes		Ye	s
	<i>Pseudo — Loglikelihood</i> Wald Chi ²	-17,28 398	36	-17,1 541		-17,0	
	Observations 537,093		93	537,093		1,105 537,093	
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Décaire and Wittry	Learning and Investmen	nt		July	12, 202	22	8/13

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	Hazard Model for Project Exercise						
		(1)		(2)		(3	
		Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Variable of interest	Unexercised Investment Opportunities $(Peers)_{j,t}$	-0.030*** (0.011)	-2.93	-0.037*** (0.011)	-3.65	-0.037*** (0.010)	-3.62
	Cumulative Number of Wells Drilled _{i.t}	0.053***	5.41	0.048***	4.95	0.050***	5.18
\Rightarrow Number of peer	Unexercised Investment Opportunities (Own) _{i.t}	(0.004) -0.035***	-3.47	(0.004) -0.043***	-4.23	(0.004) -0.051***	-4.99
options within <u>three</u> miles	Portfolio Concentration _{i,t}	(0.011) 0.188 (0.181)	20.72	(0.011) 0.096 (0.179)	10.06	(0.010) 0.076 (0.168)	7.94
	Mean Distance Between Options _{i,t}	-0.059	-5.75	-`0.067*́	-6.46	-Ò.074* [*] *	-7.17
Robust to alternative	Firm Skill Level _{i,t}	(0.037) -0.032	-3.14	(0.035) -0.237***	-21.06	(0.034) -0.192**	-17.48
definitions	Royalty Rate _k (%)	(0.057) 0.007	0.69	(0.083) 0.007	0.67	(0.083) 0.006	0.58
\Rightarrow Two and four miles	Well Lateral Length _{i.t} (1,000 ft.)	(0.007)		(0.007) -0.047**	-4.56	(0.007) -0.012	-1.22
	First Well's Market Value _{i,t}			(0.023) 0.233***	26.21	(0.020) 0.207***	23.00
	FIRST WEILS MARKET VALUE;,t			(0.068)	20.21	(0.061)	23.00
	Peers' Wells' Mkt. Value _{j,t}			0.063*** (0.015)	6.48	0.058*** (0.014)	5.97
	Oil-to-Gas Ratioj			0.308**	36.03	0.340***	40.51
	Drilling Cost _{j,t}			(0.133) -0.019 (0.042)	-1.90	(0.124) -0.039 (0.030)	-3.84
	Futures Pricet			(0.042)		0.009***	0.90
	Implied Volatility: (%)					(0.003) -0.022***	-2.15
	10-Year Risk Free Rate $_t$ (%)					(0.007) 0.176*** (0.057)	19.27
	County Strata	Yes	5	Yes		Ye	s
	<i>Pseudo – Loglikelihood</i> Wald Chi ²	-17,2 398		-17,1 541		-17,0 1,1	
	Observations	537,0		537,0		537,	
Décaire and Wittry	Learning and Investment	nt		July	12, 202	22	8/13

	Hazard Model for Project Exercise						
		(1)		(2)		(3)
		Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Economic magnitude	Unexercised Investment Opportunities (Peers) _j	(0.011)	-2.93	-0.037*** (0.011)	-3.65	-0.037*** (0.010)	-3.62
\Rightarrow One SD increase in:	Cumulative Number of Wells Drilled _{j,t}	0.053*** (0.004)	5.41	0.048*** (0.004)	4.95	0.050*** (0.004)	5.18
,	Unexercised Investment Opportunities $(Own)_{j,t}$	-0.035*** (0.011)	-3.47	-0.043*** (0.011)	-4.23	-0.051*** (0.010)	-4.99
1) No. peer options	Portfolio Concentration _{i,t}	0.188 (0.181)	20.72	0.096 (0.179)	10.06	0.076	7.94
ightarrow 13% reduction in	Mean Distance Between $Options_{i,t}$	-0.059́	-5.75	-`0.067*́	-6.46	-Ò.074*´*	-7.17
exercise likelihood	Firm Skill Level _{i,t}	(0.037) -0.032	-3.14	(0.035) -0.237***	-21.06	(0.034) -0.192**	-17.48
	Royalty Rate _k (%)	(0.057) 0.007	0.69	(0.083) 0.007	0.67	(0.083) 0.006	0.58
	Well Lateral Length _{i,t} (1,000 ft.)	(0.007)		(0.007) -0.047**	-4.56	(0.007) -0.012	-1.22
	o <i>y</i> , (, <i>'</i> , , <i>'</i> , ,			(0.023) 0.233***	26.21	(0.020) 0.207***	23.00
	First Well's Market Value _{j,t}			(0.068)		(0.061)	
	Peers' Wells' Mkt. Value _{j,t}			0.063*** (0.015)	6.48	0.058*** (0.014)	5.97
	Oil-to-Gas Ratio _j			0.308** (0.133)	36.03	0.340*** (0.124)	40.51
	Drilling $Cost_{j,t}$			-0.019 (0.042)	-1.90	-0.039 (0.030)	-3.84
	Futures Price:			(0.042)		0.009***	0.90
	Implied Volatility _t (%)					(0.003) -0.022***	-2.15
	10-Year Risk Free Rate: (%)					(0.007) 0.176*** (0.057)	19.27
	County Strata	Yes		Yes	5	Ye	s
	Pseudo – Loglikelihood Wald Chi ²	-17,2		-17,1		-17,0	
	Wald Chi ² Observations	398 537,0		541 537,0		1,10 537,0	
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Décaire and Wittry	Learning and Investme	ent		July	12, 202	22	8/13

	Hazard Model for Project Exercise						
		(1)	(1)		(2))
		Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Economic magnitude	Unexercised Investment Opportunities $(Peers)_{j,t}$	-0.030*** (0.011)	-2.93	-0.037*** (0.011)	-3.65	-0.037*** (0.010)	-3.62
\Rightarrow One SD increase in:	Cumulative Number of Wells $Drilled_{j,t}$	0.053*** (0.004)	5.41	0.048*** (0.004)	4.95	0.050*** (0.004)	5.18
1) No	Unexercised Investment Opportunities $(Own)_{j,t}$	-0.035*** (0.011)	-3.47	-0.043*** (0.011)	-4.23	-0.051*** (0.010)	-4.99
1) No. peer options \rightarrow 13% reduction in	Portfolio Concentration _{i,t}	0.188 (0.181)	20.72	0.096 (0.179)	10.06	0.076 (0.168)	7.94
\rightarrow 13% reduction in exercise likelihood	Mean Distance Between Options _{i,t}	-0.059 (0.037)	-5.75	-0.067* (0.035)	-6.46	-0.074** (0.034)	-7.17
	Firm Skill Level _{i,t}	-0.032 (0.057)	-3.14	-0.237*** (0.083)	-21.06	-0.192** (0.083)	-17.48
2) Futures price \rightarrow	Royalty Rate _k (%)	0.007 (0.007)	0.69	0.007 (0.007)	0.67	0.006 (0.007)	0.58
17% increase in exer-	Well Lateral Length _{j,t} (1,000 ft.)			-0.047** (0.023)	-4.56	-0.012 (0.020)	-1.22
cise likelihood	First Well's Market Value _{j,t}			0.233*** (0.068)	26.21	0.207*** (0.061)	23.00
3) Volatility \rightarrow 12%	Peers' Wells' Mkt. Value _{j,t}			0.063*** (0.015)	6.48	0.058*** (0.014)	5.97
reduction in exercise	Oil-to-Gas Ratio			0.308** (0.133)	36.03	0.340*** (0.124)	40.51
likelihood	Drilling Cost _{j,t}			-0.019 (0.042)	-1.90	-0.039 (0.030) 0.009***	-3.84
	Futures Price:					(0.003)	0.90
	Implied Volatility _t (%)					-0.022***	-2.15
	10-Year Risk Free Rate _t (%)					0.176*** (0.057)	19.27
	County Strata	Yes		Yes		Ye	s
	Pseudo — Loglikelihood Wald Chi ²	-17,28 398		-17,1 541		-17,0	
	Observations	537,09	93	537,0	93	537,	093
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Décaire and Wittry	Learning and Investme	nt		July	12, 202	22	8/13

		Hazard Model for Project Exercise						
		(1)		(2)		(3		
		Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)	
Economic magnitude	Unexercised Investment Opportunities $(Peers)_{j,t}$	-0.030***	-2.93	-0.037***	-3.65	-0.037***	-3.62	
\Rightarrow One SD increase in:	Cumulative Number of Wells $Drilled_{j,t}$	(0.011) 0.053*** (0.004)	5.41	(0.011) 0.048*** (0.004)	4.95	(0.010) 0.050*** (0.004)	5.18	
	Unexercised Investment Opportunities $(Own)_{j,t}$	-0.035* ^{**}	-3.47	-0.043***	-4.23	-0`.051***	-4.99	
1) No. peer options	Portfolio Concentration _{i,t}	(0.011) 0.188 (0.181)	20.72	(0.011) 0.096 (0.179)	10.06	(0.010) 0.076 (0.168)	7.94	
\rightarrow 13% reduction in	Mean Distance Between $Options_{i,t}$	-0.059 (0.037)	-5.75	-0.067*	-6.46	-0.074** (0.034)	-7.17	
exercise likelihood	Firm Skill Level _{i,t}	-0.032 (0.057)	-3.14	-0.237*** (0.083)	-21.06	-0.192** (0.083)	-17.48	
2) Futures price \rightarrow	Royalty Rate _k (%)	`0.007´ (0.007)	0.69	0.007 (0.007)	0.67	`0.006´ (0.007)	0.58	
17% increase in exer-	Well Lateral Length _{j,t} (1,000 ft.)	(0.007)		-Ò.047*´*	-4.56	-0.012 (0.020)	-1.22	
cise likelihood	First Well's Market Value _{j,t}			(0.023) 0.233*** (0.068)	26.21	(0.020) 0.207*** (0.061)	23.00	
3) Volatility \rightarrow 12%	Peers' Wells' Mkt. Value $_{j,t}$			0.063*** (0.015)	6.48	0.058*** (0.014)	5.97	
reduction in exercise	Oil-to-Gas Ratioj			0.308** (0.133)	36.03	0.340*** (0.124)	40.51	
likelihood	Drilling $Cost_{j,t}$			-0.019 (0.042)	-1.90	-0.039 (0.030)	-3.84	
	Futures Pricet			(0.042)		0.009*** (0.003)	0.90	
Alternative models	Implied Volatility _f (%)					-0.022*** (0.007)	-2.15	
\Rightarrow Results are robust	10-Year Risk Free $Rate_t$ (%)					(0.007) 0.176*** (0.057)	19.27	
to OLS and Probit	County Strata	Yes		Yes		Ye	s	
models	Pseudo – Loglikelihood Wald Chi ²	-17,2		-17,1 541		-17,0		
	Observations	398 537,093		537,093		1,105 537,093		
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Décaire and Wittry

Learning and Investment

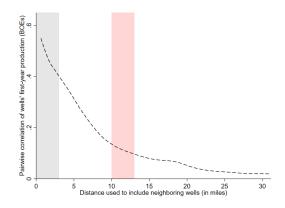
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Baseline Cox Model Results

			Haza	rd Model for	Project B	xercise	
		(1)		(2)		(3)
		Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Firm-level controls	Unexercised Investment Opportunities (Peers) _{j,t}	-0.030***	-2.93	-0.037***	-3.65	-0.037***	-3.62
<u>Fimi-level controls</u>	Cumulative Number of Wells $Drilled_{j,t}$	(0.011) 0.053*** (0.004)	5.41	(0.011) 0.048*** (0.004)	4.95	(0.010) 0.050*** (0.004)	5.18
	Unexercised Investment Opportunities $(Own)_{j,t}$	-0.035***	-3.47	-0.043***	-4.23	-0.051***	-4.99
Project-level controls	Portfolio Concentration $_{i,t}$	(0.011) 0.188 (0.181)	20.72	(0.011) 0.096 (0.179)	10.06	(0.010) 0.076 (0.168)	7.94
	Mean Distance Between $Options_{i,t}$	-0.059 (0.037)	-5.75	-0.067* (0.035)	-6.46	-0.074** (0.034)	-7.17
Market-level controls	Firm Skill Level _{i,t}	-0.032 (0.057)	-3.14	-0.237*** (0.083)	-21.06	-0.192** (0.083)	-17.48
	Royalty Rate _k (%)	0.007	0.69	0.007	0.67	0.006 (0.007)	0.58
County Stratification	Well Lateral Length _{j,t} (1,000 ft.)	(0.007)		-Ò.047*´*	-4.56	-0.012	-1.22
1) Underlying asset	First Well's Market Value _{j,t}			(0.023) 0.233***	26.21	(0.020) 0.207***	23.00
quality	Peers' Wells' Mkt. Value _{j,t}			(0.068) 0.063*** (0.015)	6.48	(0.061) 0.058*** (0.014)	5.97
100.0	Oil-to-Gas Ratioj			(0.015) 0.308** (0.133)	36.03	(0.014) 0.340*** (0.124)	40.51
	Drilling Cost _{j,t}			-0.019 (0.042)	-1.90	-0.039 (0.030)	-3.84
	Futures Pricet			(0.042)		0.009*** (0.003)	0.90
	Implied Volatility: (%)					-0.022***	-2.15
	10-Year Risk Free Rate $_t$ (%)					(0.007) 0.176*** (0.057)	19.27
	County Strata	Yes		Yes		Ye	s
	Pseudo – Loglikelihood Wald Chi ²	-17,28		-17,1		-17,0	
	Wald Chi ² Observations	398 537,093		541 537,093		1,105 537,093	
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Décaire and Wittry	Learning and Investment	nt		July 12, 202		22	8 / 13

Confounding cases:

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



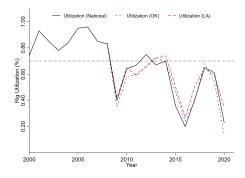
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Confounding cases:

- (1) Is the effect driven by a regional shock or coordination gains with peers?
 → Falsification test with peer options located within 10-13 miles
- (2) Is the effect driven by local resources constraints?
 - Subsample with low local rig utilization rate



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Confounding cases:

- (1) Is the effect driven by a regional shock or coordination gains with peers? \rightarrow Falsification test with peer options located within 10-13 miles
- (2) Is the effect driven by local resources constraints?
 - Subsample with low local rig utilization rate
- (3) Is the effect driven by projects with poor prospects?
 - Subsample test in prolific regions
- (4) Is the effect driven by firms' optimization constraints?
 - Subsample with short wells
- (5) Is the effect driven by JV or SA information sharing (Beshears, 2013)? Subsample with no JVs/SAs
- (6) Is the effect driven by matching between firms and regions?
 - Include a firm-county strata

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
- (2) Is the effect driven by local resources constraints?
 - Subsample with low local rig utilization rate
- (3) Is the effect driven by projects with poor prospects?
 - Subsample test in prolific regions
- (4) Is the effect driven by firms' optimization constraints?
 - Subsample with short wells
- (5) Is the effect driven by JV or SA information sharing (Beshears, 2013)?
 Subsample with no JVs/SAs
- (6) Is the effect driven by matching between firms and regions?
 - Include a firm-county strata

Introduce an instrumental variable

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Learning and Investment

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Challenge:

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

Challenge:

⇒ 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

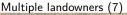


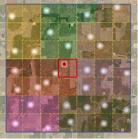
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Challenge:

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







Challenge:

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

- ⇒ Exogenous variation in the number of surrounding options that are held by any of a firm's peers
- ⇒ 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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Main concern: Number of peers is correlated with the underlying asset quality

 \Rightarrow A remaining challenge: Contemporaneous landownership structure may be correlated with land potential (Libecap and Lueck, JPE 2011).

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

- A remaining challenge: Contemporaneous landownership structure may be \Rightarrow correlated with land potential (Libecap and Lueck, JPE 2011).
- Solution: Historical landownership (Bureau of Land Management)
 - Homestead Act (42%) (1)
 - Dawes Act (11%) (2)
 - Script Warrant Acts (4%) (3)
 - Cash entry programs (39%) (4)

Settling, farming, and rewarding soldiers

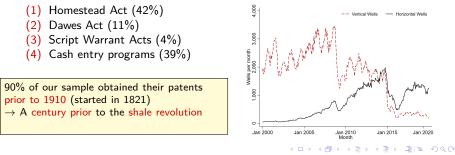


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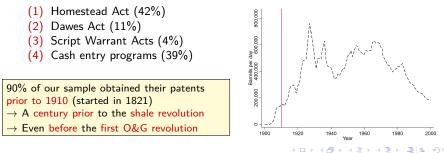


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Main concern: Number of peers is correlated with the underlying asset quality

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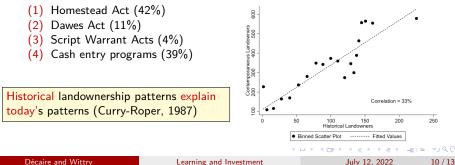


Challenge:

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

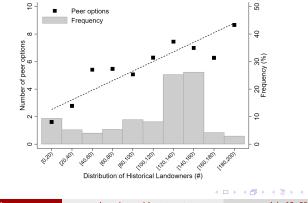
Main concern: Number of peers is correlated with the underlying asset quality

- ⇒ A remaining challenge: Contemporaneous landownership structure may be correlated with land potential (Libecap and Lueck, JPE 2011).
- ⇒ Solution: Historical landownership (Bureau of Land Management)



Relevance condition:

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



	Hazard Model for Project Exercise									
	(1)		(2)	(2))				
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)				
Instrumented Unexercised Investment Opportunities $(Peers)_{j,t}$	-0.262** (0.120)	-23.02	-0.253** (0.114)	-22.39	-0.249** (0.113)	-22.02				
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Yes Yes Yes					
County Strata	Yes		Yes		Yes					
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-13,651 84 414,176		-13,564 112 414,176		-13,481 190 414,176					

	Hazard Model for Project Exercise									
	(1)		(2)		(3)					
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)				
Instrumented Unexercised Investment Opportunities (Peers) _{j,t}	-0.262** (0.120)	-23.02	-0.253** (0.114)	-22.39	-0.249** (0.113)	-22.02				
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Yes Yes Yes					
County Strata	Yes		Yes		Yes					
<i>Pseudo – Loglikelihood</i> Wald Chi ²	-13,651 84		-13,564 112		-13,481 190					
Observations	414,1	76	414,1	76	414,176					

Validates the reduced-form result: firms delay exercise to learn from their peers

	Hazard Model for Project Exercise									
	(1)		(2)		(3)					
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)				
Instrumented Unexercised Investment Opportunities (Peers) _{j,t}	-0.262** (0.120)	-23.02	-0.253** (0.114)	-22.39	-0.249** (0.113)	-22.02				
Firm-level controls Project-level controls Market level controls	No Y		Yes	Yes Yes No		Yes Yes Yes				
County Strata	Yes	5	Yes		Yes					
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-13,651 84 414.176		-13,564 112 414,176		-13,481 190 414,176					

Validates the reduced-form result: firms delay exercise to learn from their peers

A potential case of affirmative bias:

- $\Rightarrow\,$ Positive correlation between the number of peers' options and the quality of the underlying asset
- \Rightarrow Higher quality assets should get exercised faster (i.e, $E[\beta_{quality}] \ge 0$)

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	Hazard Model for Project Exercise									
	(1)		(2)		(3)					
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)				
Instrumented Unexercised Investment Opportunities (Peers) _{j,t}	-0.262** (0.120)	-23.02	-0.253** (0.114)	-22.39	-0.249** (0.113)	-22.02				
Firm-level controls Project-level controls Market level controls	No Y		Yes	Yes Yes No		Yes Yes Yes				
County Strata	Yes	5	Yes		Yes					
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-13,651 84 414.176		-13,564 112 414,176		-13,481 190 414,176					

Validates the reduced-form result: firms delay exercise to learn from their peers

A potential case of affirmative bias:

- \Rightarrow Positive correlation between the number of peers' options and the quality of the underlying asset
- ⇒ Higher quality assets should get exercised faster (i.e, $E[\beta_{quality}] \ge 0$)

Suggests that the coefficient in the endogenous regression is biased upward

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Conclusion

Methodological contribution

 \Rightarrow 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 \Rightarrow
- Firms' incentive to wait for peers' information is greater when the source of \Rightarrow information is more relevant
- \Rightarrow Results suggest that the anticipation of information has an aggregate level effect on investment

When are information spillovers most valuable?



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Spillovers matter most when information is scarce!

	Haza	ard Model for Project Exerci
	(1)	
Quantity of Prior Information Released $=$	Small	
	Estimates HI(%)	
Inexercised Investment Opportunities $(Peers)_{j,t}$	-0.506*** -39.68 (0.056)	
irm-level controls roject-level controls 1arket level controls	Yes Yes Yes	
County Strata	Yes	
Pseudo – Loglikelihood Vald Chi ²	-3,936	
bservations	365 183,015	

Small amount of prior information	I
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\Rightarrow Median number	of	options	drilled	= 0
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 \Rightarrow Mean number of options drilled = 0.6

Spillovers matter most when information is scarce!

	Hazard Model for	r Project Exercise		
	(1)	(3)		
Quantity of Prior Information Released =	Small	Large		
	Estimates HI(%)	Estimates HI(%)		
Unexercised Investment Opportunities $(\text{Peers})_{j,t}$	-0.506*** -39.68 (0.056)	-0.052 -5.03 (0.053)		
Firm-level controls Project-level controls Market level controls	Yes Yes Yes	Yes Yes Yes		
County Strata	Yes	Yes		
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-3,936 365 183,015	-4,882 978 166,972		
Small amount of prior information	Large amount of	prior information		
\rightarrow Median number of options drilled	$= 0 \rightarrow$ Median numbe	r of options drilled = 8		
\Rightarrow Mean number of options drilled =	$0.6 \Rightarrow$ Mean number	of options drilled $= 9.1$		

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Spillovers matter most when information is scarce!

	Hazard Model for Project Exercise							
	(1)	(2)		(3)		
Quantity of Prior Information Released $=$	Sm	Small		Medium		ge		
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)		
Unexercised Investment Opportunities $(Peers)_{j,t}$	-0.506*** (0.056)	-39.68	-0.326*** (0.040)	-27.83	-0.052 (0.053)	-5.03		
Firm-level controls	Y		Yes		Yes			
Project-level controls Market level controls	Y		Yes		Yes			
Market level controls	Y	es	Yes		Yes			
County Strata	Y	es	Yes		Yes			
Pseudo – Loglikelihood	-3,9	936	-4,875		-4,882			
Wald Chi ²	36		453		978			
Observations	183	015	187,1	06	166,	972		
Small amount of prior information	Small amount of prior information							
\Rightarrow Median number of options drilled :	= 0 =	\Rightarrow Median number of options drilled =						
\Rightarrow Mean number of options drilled =	0.6 =	\Rightarrow Mean number of options drilled = 9.						

 \Rightarrow Effect gradually decreases with the quantity of information already revealed

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Spillovers matter most when information is scarce!

	Hazard Model for Project Exercise								
	-	(1)	(2)	(3	5)			
Quantity of Prior Information Released $=$	S	Small		Medium		ge			
	Estimate	es HI(%)	Estimates	HI(%)	Estimates	HI(%)			
Unexercised Investment Opportunities $(Peers)_{j,t}$	-0.506** (0.056)		-0.326*** (0.040)	-27.83	-0.052 (0.053)	-5.03			
Firm-level controls		Yes		Yes		es			
Project-level controls Market level controls		res res		Yes Yes		es es			
		105	10	165		5			
County Strata	•	Yes	Ye	Yes		es			
Pseudo – Loglikelihood	-3	,936	-4,875		-4,8	882			
Wald Chi ²		365		453		'8			
Observations	18	3,015	187,	106	166,	972			
Small amount of prior information		Large a	mount of p	orior inf	ormation				
\Rightarrow Median number of options drilled	= 0	$0 \Rightarrow$ Median number of options drilled =							
\Rightarrow Mean number of options drilled =	0.6	\Rightarrow Mean number of options drilled = 9.1							

 \Rightarrow Effect gradually decreases with the quantity of information already revealed \Rightarrow Incentives to wait are concentrated in cases with limited available information

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Costs vs. Benefits Tradeoffs



	Hazard Model for Project Exercise							
	(1)		(2)		(3)		
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)		
Unexercised Investment Opportunities $(Peers)_{j,t}$	-0.095** (0.038)	-9.07	-0.107*** (0.038)	-10.14	-0.115*** (0.038)	-10.83		
Unexercised Inv. Opp. (Peers) $_{j,t} \times$ Cost of Equity $_{i,t}$	0.007* (0.004)	0.68	0.008** (0.004)	0.77	0.009** (0.004)	0.86		
Cost of Equity _{i,t} (%)	-0.049* ^{**} (0.023)	-4.74	-0.065*** (0.024)	-6.25	-0̀.069**́* (0.026)	-6.69		
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Yes Yes Yes			
County Strata	Yes		Yes		Yes			
Pseudo – Loglikelihood	-7,033		-6,981		-6,943			
Wald Chi ² Observations	532 273,427		671 273,427		1,390 273,427			

	Hazard Model for Project Exercise								
	(1)		(2)		(3)			
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)			
Unexercised Investment Opportunities $(Peers)_{j,t}$	-0.095** (0.038)	-9.07	-0.107*** (0.038)	-10.14	-0.115*** (0.038)	-10.83			
Unexercised Inv. Opp. (Peers) _{<i>j</i>,<i>t</i>} × Cost of Equity _{<i>i</i>,<i>t</i>}	0.007* (0.004)	0.68	0.008** (0.004)	0.77	0.009** (0.004)	0.86			
Cost of Equity _{i,t} (%)	-0.049** (0.023)	-4.74	-0.065*** (0.024)	-6.25	-0.069*** (0.026)	-6.69			
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Yes Yes Yes				
County Strata	Yes		Yes		Yes				
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-7,033 532 273,427		671	-6,981 671 273,427		43 90 427			

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

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

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	Hazard Model for Project Exercise								
	(1)		(2)		(3)			
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)			
Unexercised Investment Opportunities $(Peers)_{j,t}$	-0.095** (0.038)	-9.07	-0.107*** (0.038)	-10.14	-0.115*** (0.038)	-10.83			
Unexercised Inv. Opp. (Peers) _{<i>j</i>,<i>t</i>} × Cost of Equity _{<i>i</i>,<i>t</i>}	0.007* (0.004)	0.68	0.008** (0.004)	0.77	0.009** (0.004)	0.86			
Cost of Equity _{i,t} (%)	-0.049** (0.023)	-4.74	-0.065*** (0.024)	-6.25	-0.069*** (0.026)	-6.69			
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Yes Yes Yes				
County Strata	Yes		Yes		Yes				
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-7,033 532 273,427		-6,98 671 273,4	671		-6,943 1,390 273,427			

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

		Hazard Model for Project Exercise						
	(1)		(2)		(3)		
	Estimates	HI(%)	Estimates	HI(%)	Estimates	(3) Estimates HI(%)		
Unexercised Investment Opportunities (Peers) _{i,t}	-1.106***	-66.91	-0.980***	-62.49	-0.816***	-55.77		
	(0.158)		(0.145)		(0.141)			
Unexercised Inv. Opp. (Peers) _{i,t}	0.071***	7.31	0.062***	6.41	0.051***	5.27		
\times Peers' Wells' Mkt. Value _{i.t}	(0.011)		(0.010)		(0.009)			
Peers' Wells' Value _{i.t}	0.062***	6.42	0.058***	5.92	0.054***	5.54		
3 7	(0.015)		(0.013)		(0.013)			
Firm-level controls	Yes		Yes		Yes			
Project-level controls	No		Yes		Yes			
Market level controls	No		No		Ye	s		
County Strata	Yes		Yes		Yes			
Pseudo – Loglikelihood	-17,1	-17,194		32	-17,0)46		
Wald Chi ²	775		884	ļ	1,63	36		
Observations	537,0	93	537,0	93	537,0	093		

Costs of Waiting for Info. Spillovers	Benefits of Waiting for Info. Spillovers
\Rightarrow Firms wait less on peers when the	\Rightarrow Wait for more information when the
TVM increases	project is less likely to be profitable
\Rightarrow Back-of-the-envelope: 7.4% drop in	\Rightarrow When firms can learn from their
NPV due to pure TVM	peers, they select projects that are 8.3%
	more productive

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Benefits of Waiting

		Haza	rd Model for	Project E	Exercise	
	(1)		(2)		(3)
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities $(Peers)_{j,t}$	-1.106*** (0.158)	-66.91	-0.980*** (0.145)	-62.49	-0.816*** (0.141)	-55.77
Unexercised Inv. Opp. (Peers) _{<i>j</i>,<i>t</i>} × Peers' Wells' Mkt. Value _{<i>j</i>,<i>t</i>}	0`.071**** (0.011)	7.31	0`.062*** (0.010)	6.41	0`.051*** (0.009)	5.27
Peers' Wells' Value _{j,t}	0`.062*** (0.015)	6.42	0`.058**** (0.013)	5.92	0`.054*** (0.013)	5.54
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Ye Ye Ye	s
County Strata	Yes Yes		Yes			
<i>Pseudo – Loglikelihood</i> Wald Chi ²	-17,1 775	i	884	-17,132 884)46 36
Observations	537,0	93	537,0	93	537,	093

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

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Relevance of Information Sources



Décaire and Wittry

Learning and Investment

July 12, 2022

6/19

Project Similarity

		Haza	rd Model for	Project E	Exercise	
	(1)		(2)		(3)
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Same Resource)_{j,t}	-0.112*** (0.035)	-10.60	-0.136*** (0.034)	-12.75	-0.138*** (0.032)	-12.87
Unexercised Investment Opportunities (Different Resource)_{j,t}	-0.026 (0.025)	-2.58	-0.040 (0.027)	-3.91	-0.036 (0.025)	-3.49
Chi² (Same Resource—Different Resource) (p-Value)	8.25*** 17.25*** (0.004) (0.000)		15.90 (0.00			
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No	;	Ye Ye Ye	s
County Strata	Yes		Yes		Yes	
Pseudo – Loglikelihood	-17,285		-17,1	74	-17,0)74
Wald Chi ² Observations	474 537,0		563 537,0		1,1 537,0	

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Which peer	/project	characteristics	matter?
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Project Similarity

	Hazard Model for Project Exercise							
	(1)		(2)		(3)		
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)		
Unexercised Investment Opportunities (Same Resource) _{<i>i</i>,<i>t</i>}	-0.112***	-10.60	-0.136***	-12.75	-0.138***	-12.87		
Unexercised Investment Opportunities (Different Resource)_{j,t}	(0.035) -0.026 (0.025)	-2.58	(0.034) -0.040 (0.027)	-3.91	(0.032) -0.036 (0.025)	-3.49		
Chi² (Same Resource—Different Resource) (p-Value)	8.25*** (0.004)		17.25*** (0.000)		15.90*** (0.000)			
Firm-level controls Project-level controls Market level controls	No	Yes Yes No Yes No No		Ye Ye Ye	s			
County Strata	Yes		Yes		Yes			
Pseudo – Loglikelihood	-17,2	85	-17,1	74	-17,0)74		
Wald Chi ² Observations	474 537,0		563 537,0		1,1 537,0			

How do we do it?	Which peer/project characteristics matter?
\Rightarrow Split variable into options producing	
the same and different majority resources	
(oil vs. gas)	

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*** (0.035)	-10.60	-0.136*** (0.034)	-12.75	-0.138*** (0.032)	-12.87		
Unexercised Investment Opportunities (Different Resource)_{j,t}	-0.026 (0.025)	-2.58	-0.040 (0.027)	-3.91	-0.036 (0.025)	-3.49		
Chi ² (Same Resource—Different Resource) (p-Value)	8.25*** (0.004)		17.25*** (0.000)		15.90*** (0.000)			
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Yes Yes Yes			
County Strata	Yes		Yes		Yes			
Pseudo – Loglikelihood	-17,285		-17,174		-17,074			
Wald Chi ² Observations	474 537,0		563 537,093		1,161 537,093			

$\begin{array}{l} \label{eq:how-do-we-do-it} \hline How do we do it? \\ \Rightarrow \mbox{ Split variable into options producing the same and different majority resources (oil vs. gas)} \end{array}$
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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*** (0.035)	-10.60	-0.136*** (0.034)	-12.75	-0.138*** (0.032)	-12.87	
Unexercised Investment Opportunities (Different Resource)_{j,t}	-0.026 (0.025)	-2.58	-0.040 (0.027)	-3.91	-0.036 (0.025)	-3.49	
Chi ² (Same Resource—Different Resource) (p-Value)	8.25*** 17.25*** (0.004) (0.000)		15.90*** (0.000)				
Firm-level controls Project-level controls Market level controls	Yes Yes No Yes No No		Ye Ye Ye	s			
County Strata	Yes		Yes		Yes		
Pseudo – Loglikelihood	-17,285		-17,174		-17,074		
Wald Chi ² Observations	474 537,0		563 537,0		1,10 537,0		

How do we do it?	Which peer/project characteristics matter?
\Rightarrow Split variable into options producing the same and different majority resources	\Rightarrow Focus on options producing the same resource
(oil vs. gas)	
\Rightarrow Magnitudes are statistically different	

	Hazard Model for Project Exercise						
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)	
Unexercised Investment Opportunities (High-Skill Peers) $_{j,t}$	-0.125*** (0.041)	-11.77	-0.154*** (0.044)	-14.23	-0.148*** (0.040)	-13.79	
Unexercised Investment Opportunities (Low-Skill Peers)_{j,t}	0.026 (0.024)	2.65	0.021 (0.024)	2.16	0.007 (0.024)	0.70	
Chi ² (High Skill—Low Skill) (p-Value)	11.40*** 12.54*** (0.001) (0.000)		11.94*** (0.001)				
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Ye Ye Ye	s	
County Strata	Yes Yes		Yes				
Pseudo – Loglikelihood	-17,280		-17,168		-17,071		
Wald Chi ² Observations	435 537,0		580 537,0		1,2 537,0		

How do we do it?	Which peer/project characteristics matter?
	\Rightarrow Focus on options producing the same resource

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	Hazard Model for Project Exercise						
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)	
Unexercised Investment Opportunities (High-Skill Peers) _{j,t}	-0.125*** (0.041)	-11.77	-0.154*** (0.044)	-14.23	-0.148*** (0.040)	-13.79	
Unexercised Investment Opportunities (Low-Skill Peers) _{j,t}	0.026 (0.024)	2.65	0.021 (0.024)	2.16	0.007 (0.024)	0.70	
Chi ² (High Skill—Low Skill) (p-Value)	11.40 [°] (0.00		12.54 (0.00		11.94 (0.00		
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Ye Ye Ye	s	
County Strata	Yes		Yes		Ye	s	
Pseudo – Loglikelihood	-17,2		-17,1	68	-17,0		
Wald Chi ² Observations	435 537,0		580 537,0		1,2 537,0		

\Rightarrow Split variable into options owned by
\rightarrow Split variable into options owned by
skilled and unskilled peers

Which peer/project characteristics matter?

How do we do it?

	Hazard Model for Project Exercise						
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)	
Unexercised Investment Opportunities (High-Skill Peers) _{j,t}	-0.125*** (0.041)	-11.77	-0.154*** (0.044)	-14.23	-0.148*** (0.040)	-13.79	
Unexercised Investment Opportunities (Low-Skill Peers) $_{j,t}$	0.026 (0.024)	2.65	0.021 (0.024)	2.16	0.007 (0.024)	0.70	
Chi ² (High Skill—Low Skill) (p-Value)	11.40*** 12.54 (0.001) (0.00			11.94 (0.00			
Firm-level controls Project-level controls Market level controls	Yes Yes No Yes No No			Yes Yes Yes			
County Strata	Yes		Yes		Yes		
Pseudo – Loglikelihood	-17,280		-17,168		-17,071		
Wald Chi ² Observations	435 537,0		580 537,0		1,2 537,0		

\Rightarrow Split variable into options owned by
skilled and unskilled peers

Which peer/project characteristics matter?

How do we do it?

	HI(%) -11.77 2.65	(2) Estimates -0.154*** (0.044) 0.021	HI(%) -14.23	(3) Estimates -0.148*** (0.040)) HI(%) -13.79
125*** .041) .026	-11.77	-0.154*** (0.044) 0.021	-14.23	-0.148***	
.041) .026		(0.044) 0.021			-13.79
.026	2.65	`0.021´	0.4.6		
		(0.024)	2.16	0.007 (0.024)	0.70
11.40*** 12.54*** (0.001) (0.000)		11.94*** (0.001)			
Yes Yes No Yes No No			Yes Yes Yes		
Yes Yes		Yes			
-17,280 -17,168 435 580 537,093 537,093		-17,071 1,254 537,093			
,	Yes No No Yes -17,28 435 537,09	Yes No No Yes -17,280 435 537,093	Yes Yes No Yes No No Yes Yes -17,280 -17,10 435 580 537,093 537,09	Yes Yes No Yes No No Yes Yes -17,280 -17,168 435 580 537,093 537,093	Yes Yes Yes No Yes Yes No No Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes 17,280 -17,168 -17,0 435 580 1,25

 \Rightarrow Split variable into options owned by skilled and unskilled peers

 \Rightarrow Magnitudes are statistically different

 \Rightarrow Focus on options producing the same resource

 \Rightarrow Focus on peers that are better at selecting and designing wells

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	Hazard Model for Project Exercise						
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)	
Unexercised Investment Opportunities (High-Skill Peers)_{j,t}	-0.125*** (0.041)	-11.77	-0.154*** (0.044)	-14.23	-0.148*** (0.040)	-13.79	
Unexercised Investment Opportunities (Low-Skill Peers)_{j,t}	0.026 (0.024)	2.65	0.021 (0.024)	2.16	0.007 (0.024)	0.70	
Chi ² (High Skill—Low Skill) (p-Value)	11.40 [°] (0.00		12.54 (0.00		11.94 (0.00		
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Ye Ye Ye	s	
County Strata	Yes		Yes		Ye	s	
Pseudo – Loglikelihood Wald Chi ² Observations	-17,280 435 537,093		435 580		-17,0 1,29 537,0	54	

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

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Appendix

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 (0.003)	-0.20	-0.003 (0.003)	-0.28	-0.001 (0.002)	-0.11	
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Yes Yes Yes		
County Strata	Yes		Yes	Yes		S	
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-17,296 461 537,093		-17,19 527 537,0		-17,091 1,257 537,093		

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Appendix

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 $(\text{Peers})_{j,t}$	-0.026** (0.012)	-2.52	-0.031** (0.012)	-3.03	-0.033*** (0.011)	-3.29	
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Ye Ye Ye	5	
County Strata	Yes		Yes		Yes		
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-11,733 367 465,960		571		-11,598 621 465,960		

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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** (0.013)	-2.86	-0.029** (0.014)	-2.90	-0.031** (0.012)	-3.04	
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Ye Ye Ye	s	
County Strata	Yes		Yes		Yes		
Pseudo — Loglikelihood Wald Chi ² Observations	-11,0 272 268,5		-10,8 892 268,5		-10,8 1,30 268,5)6	

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Appendix

Subsample of Projects with Initial Well Drilled on a Single Section

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

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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*** (0.010)	-3.18	-0.035*** (0.011)	-3.40	-0.038*** (0.010)	-3.74
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Ye Ye Ye	5
County-Firm Strata	Yes		Yes		Yes	
Pseudo – Loglikelihood Wald Chi ² Observations	-10,058 498 537,093		664		664 1,009	

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		

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		

Alternative Peer Distance Definitions

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

Direction of Observed Bias

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

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 R^2	3,462	3,462	3,462		
	0.40	0.47	0,47		

Source of Drilling Costs per Lateral Foot

Cause CD No. 202001656-T Calyx Energy III, LLC Final Order of the Commission Pooling

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

7.1 <u>Participate</u>: 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 <u>25</u> 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 ta below and thereafter fails or refuses to pay or



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