Strategic Learning and Corporate Investment



ABFER 9th Annual Conference

May 24/25, 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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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

May 24/25, 2022

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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: First to reveal how the anticipation of peers' information spillover impacts the timing of firms' corporate investment.

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

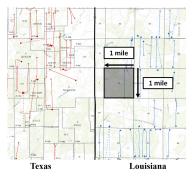
- (1) 537,093 option-month observations in Oklahoma and Louisiana (2005-2020)
- (2) Simple and homogeneous projects (mean investment = \$4.23 million)
 - \Rightarrow Output price
 - \Rightarrow Implied volatility
 - \Rightarrow Time-varying cost of drilling
 - \Rightarrow Risk-free rate
 - \Rightarrow Estimates of expected production
- (3) Standardized unit of observation for options
- (4) Clearly identify a firm and its peers

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

- (1) 537,093 option-month observations in Oklahoma and Louisiana (2005-2020)
- (2) Simple and homogeneous projects (mean investment = \$4.23 million)
- (3) Standardized unit of observation for options
 - \Rightarrow Land survey method
 - \Rightarrow Drilling and spacing requirements
- (4) Clearly identify a firm and its peers



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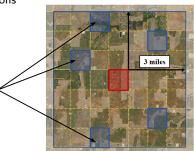
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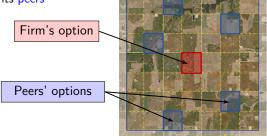
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Who are the peers? 1) Also engaged in O&G exploration and production 2) Own similar options exactly next to the firm's option



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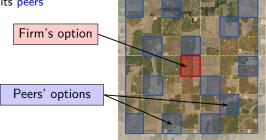


Theory (CG94) \longrightarrow Empirics:

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- (2) Quantity of anticipated information increases with the number of real options that could be exercised next to a firm

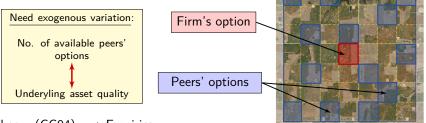
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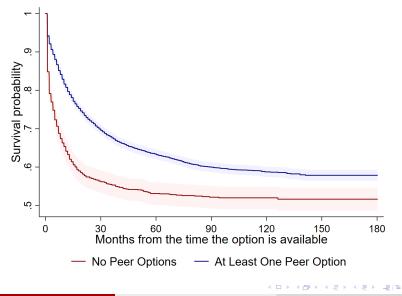
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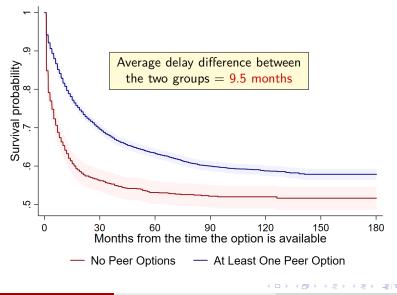
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Main Finding - In a nutshell



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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

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

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Aggregate Investment:

Regions with more dispersed options ownership are associated with 19% drilling \Rightarrow activity

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Aggregate Investment:

 $\Rightarrow\,$ Regions with more dispersed options ownership are associated with 19% drilling activity

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,
 Alt. variable def. and model specs.

Corporate Investment:

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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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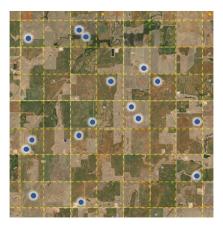
1. Real Options & Peers

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



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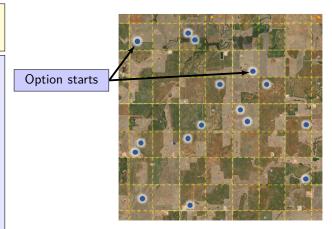
Sample properties

 \Rightarrow 442 firms

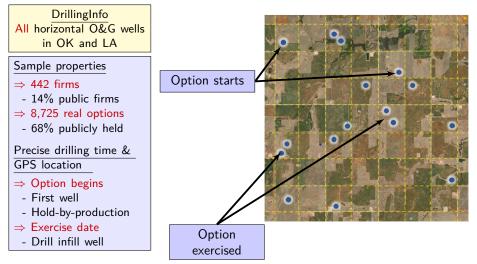
- 14% public firms
- \Rightarrow 8,725 real options
 - 68% publicly held

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 FRED

Cost of drilling

- $\Rightarrow \mathsf{Time-varying} \ \mathsf{estimate}$
- \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 ⇒ Land assignments under various government programs during states' settlement period - Used for the IV

Ad for the Dawes Act of 1887

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

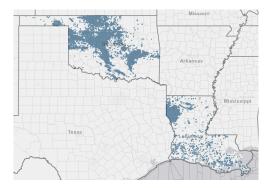
Historical landownership ⇒ Land assignments under various government programs during states' settlement period

- Used for the IV

Clearly identify real options Precisely measure factors related to exercise

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Number of Peer Options and the Timing of Corporate Investment



-		Hazard Model for Project Exercise					
		(1)	Thursday	(2)		(3)	
		Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Cox hazard rate model	Jnexercised Investment Opportunities (Peers) $_{j,t}$	-0.030***	-2.93	-0.037***	-3.65	-0.037***	-3.62
	Contraction New York (MARINE DO 1991	(0.011) 0.053***	F 41	(0.011) 0.048***	4.95	(0.010) 0.050***	F 10
\Rightarrow Enter when initial	Cumulative Number of Wells $Drilled_{j,t}$	(0.004)	5.41	(0.004)	4.95	(0.004)	5.18
	Jnexercised Investment Opportunities (Own) _{i,t}	-0.035***	-3.47	-0.043***	-4.23	-0.051***	-4.99
well is drilled		(0.011)		(0.011)		(0.010)	
\Rightarrow Exit when infill well	Portfolio Concentration _{i,t}	0.188 (0.181)	20.72	0.096 (0.179)	10.06	0.076 (0.168)	7.94
is drilled	Mean Distance Between Options _{i.t}	-0.059	-5.75	-0.067*	-6.46	-0.074**	-7.17
is unlied		(0.037)		(0.035)		(0.034)	
	Firm Skill Level _{i,t}	-0.032	-3.14	-0.237***	-21.06	-0.192**	-17.48
Unit of observation	Royalty Rate _k (%)	(0.057) 0.007	0.69	(0.083) 0.007	0.67	(0.083) 0.006	0.58
	(vyaity frates (70)	(0.007)	0.05	(0.007)	0.07	(0.007)	0.50
\Rightarrow Option-month level	Nell Lateral Length _{j,t} (1,000 ft.)	. ,		-0.047**	-4.56	-0.012	-1.22
	- irst Well's Market Value _{i.t}			(0.023) 0.233***	26.21	(0.020) 0.207***	23.00
	-Irst Well's Market Value _{j,t}			(0.068)	20.21	(0.061)	23.00
	Peers' Wells' Mkt. Value _{i.t}			0.063***	6.48	0.058***	5.97
				(0.015)		(0.014)	
	Dil-to-Gas Ratioj			0.308** (0.133)	36.03	0.340*** (0.124)	40.51
	Drilling Cost _{i.t}			-0.019	-1.90	-0.039	-3.84
	•			(0.042)		(0.030)	
	Futures Pricet					0.009***	0.90
	mplied Volatility, (%)					(0.003) -0.022***	-2.15
	inplied volutility? (70)					(0.007)	2.10
	10-Year Risk Free Rate: (%)					0.176***	19.27
						(0.057)	
	County Strata	Yes		Yes		Ye	s
	Pseudo – Loglikelihood	-17,286 -17,174 398 541		-17,074			
	Vald Chi ²						05
	Observations	537,09	93	537,0	93	537,0	093
		•			È► KÌ	e) × leta	. na
Décaire and Wittry	Learning and Investmer	nt		May 2	4/25, 2	022	8/19

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		(1)		(2)		(0		
					(2)		3)	
N/ · · · · · · · · ·		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 (0.037)	-5.75	-0.067* (0.035)	-6.46	-0.074** (0.034)	-7.17	
Robust to alternative	Firm Skill Level _{i,t}	-0.032	-3.14	-0.237***	-21.06	-0.192**	-17.48	
<u>definitions</u>	Royalty Rate _k (%)	(0.057) 0.007	0.69	(0.083) 0.007	0.67	(0.083) 0.006	0.58	
\Rightarrow <u>Two</u> and <u>four</u> miles	Well Lateral Length _{j,t} (1,000 ft.)	(0.007)		(0.007) -0.047**	-4.56	(0.007) -0.012	-1.22	
	First Well's Market Value _{j,t}			(0.023) 0.233***	26.21	(0.020) 0.207***	23.00	
	Peers' Wells' Mkt. Value _{j,t}			(0.068) 0.063***	6.48	(0.061) 0.058***	5.97	
	Oil-to-Gas Ratioj			(0.015) 0.308**	36.03	(0.014) 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*** (0.003)	0.90	
	Implied Volatility _t (%)					-0.022***	-2.15	
	10-Year Risk Free Rate: (%)					(0.007) 0.176*** (0.057)	19.27	
	County Strata	Yes		Yes		Ye	s	
	<i>Pseudo – Loglikelihood</i> Wald Chi ²	-17,286 -17,174 398 541		-17,074 1,105				
	Observations	537,0		537,0		537,0		
Décaire and Wittry	Learning and Investmen				8/1			

		Hazard Model for Project Exercise					
		(1)		(2)		(3)
		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
	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 (0.168)	7.94
\rightarrow 13% reduction in	Mean Distance Between Options _{i,t}	-0.059 [´]	-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
	0 <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: (%)					(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
	<i>Pseudo – Loglikelihood</i> Wald Chi ²	-17,2 398	:	-17,174 541		-17,074 1,105	
	Observations	537,0		537,0		537,	
Décaire and Wittry	Learning and Investme	nt		May 2	24/25, 2	022	8 / 19

	Hazard Model for Project Exercise						
		(1)		(2)		(3)
		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
	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´ (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
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.)	· · /		-0.047** (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 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 Price:					0.009*** (0.003)	0.90
	Implied Volatility _t (%)					-0.022***	-2.15
	10-Year Risk Free Rate $_{t}$ (%)					(0.007) 0.176*** (0.057)	19.27
	County Strata	Yes		Yes		Ye	s
	<i>Pseudo</i> — <i>Loglikelihood</i> Wald Chi ²	-17,28 398		-17,1 541		-17,0 1,1	
	Observations	537,0	93	537,0	93	537,	093
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Décaire and Wittry	Learning and Investme	nt		May 2	4/25, 2	022	8/19

		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	-17,286 398				-17,074		
	Observations	398 537,093		537,093		1,105 537,093		
		•			€ > < 0	e) × leta	• na	

Décaire and Wittry

Learning and Investment

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			Haza	rd Model for	Project E	xercise	
		(1)		(2)			
		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
	Cumulative Number of Wells Drilled _{i.t}	(0.011) 0.053***	5.41	(0.011) 0.048***	4.95	(0.010) 0.050***	5.18
1) Local drilling		(0.004)		(0.004)		(0.004)	
activity	Unexercised Investment Opportunities $(Own)_{j,t}$	-0.035*** (0.011)	-3.47	-0.043*** (0.011)	-4.23	-0.051*** (0.010)	-4.99
detivity	Portfolio Concentration, t	0.188	20.72	0.096	10.06	0.076	7.94
2) Opportunity set		(0.181)		(0.179)		(0.168)	
,	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's ability	Firm Skill Level _{i,t}	-0.032	-3.14	-0.237***	-21.06	-0.192**	-17.48
4) Geographic footprint		(0.057)		(0.083)		(0.083)	
4) Geographic Tootprint	Royalty Rate _k (%)	0.007 (0.007)	0.69	0.007 (0.007)	0.67	0.006 (0.007)	0.58
	Well Lateral Length _{i.t} (1,000 ft.)	(0.001)		-0.047**	-4.56	-0.012	-1.22
				(0.023)		(0.020)	
	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***	6.48	0.058***	5.97
	O'LL C. D. L			(0.015) 0.308**	26.02	(0.014) 0.340***	40.51
	Oil-to-Gas Ratioj			(0.133)	36.03	(0.124)	40.51
	Drilling Cost _{j,t}			-0.019	-1.90	-0.039	-3.84
	Futures Price			(0.042)		(0.030) 0.009***	0.90
	rutures rifter					(0.003)	0.90
	Implied Volatility _t (%)					-0.022***	-2.15
	10-Year Risk Free Rate _t (%)					(0.007) 0.176***	19.27
	10= Teal Misk Tree Mate: (76)					(0.057)	19.21
	County Strata	Yes		Yes		Ye	s
	Pseudo – Loglikelihood Wald Chi ²		36	-17,17	74	-17.0	074
				541		1,10)5
	Observations	537,09	93	537,0	93	537,0	093
					E ▶ 4 I	리로 세계	na
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			Haza	rd Model for	Project E	xercise	
		(1)		(2)		(3	
		Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Firm-level controls	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 $Drilled_{j,t}$	(0.011) 0.053*** (0.004)	5.41	(0.011) 0.048*** (0.004)	4.95	0.050*** (0.004)	5.18
Drainet lavel controls	Unexercised Investment Opportunities $(Own)_{j,t}$	-0.035*** (0.011)	-3.47	-0.043*** (0.011)	-4.23	-0.051*** (0.010)	-4.99
Project-level controls	Portfolio Concentration _{i,t}	0.188 (0.181)	20.72	0.096 (0.179)	10.06	(0.010) 0.076 (0.168)	7.94
1) Signal of project	Mean Distance Between $Options_{i,t}$	-0.059 (0.037)	-5.75	-0.067* (0.035)	-6.46	-0.074** (0.034)	-7.17
quality (own and	Firm Skill Level _{i,t}	-0.032 (0.057)	-3.14	-0.237*** (0.083)	-21.06	-0.192** (0.083)	-17.48
peers)	Royalty Rate _k (%)	0.007	0.69	0.007 (0.007)	0.67	0.006 (0.007)	0.58
2) Time-varying-costs	Well Lateral Length _{j,t} (1,000 ft.)	(0.007)		-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			(0.012)		0.009*** (0.003)	0.90
	Implied Volatility _t (%)					-0.022*** (0.007)	-2.15
	10-Year Risk Free Rate _r (%) County Strata					0.176*** (0.057)	19.27
				Yes		Ye	s
	Pseudo – Loglikelihood Wald Chi² Observations	-17,2 398 537.0		-17,1 541 537.0		-17,0 1,1 537,0	05
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Décaire and Wittry	Learning and Investment	nt		May 2	4/25, 2	022	8 / 19

Décaire and Wittry

			Haza	rd Model for	Project E	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
	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) _{i,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	-5.75	-0.067*	-6.46	-Ò.074* [*] *	-7.17
Market-level controls	Firm Skill Level _{i,t}	(0.037) -0.032 (0.057)	-3.14	(0.035) -0.237*** (0.083)	-21.06	(0.034) -0.192** (0.083)	-17.48
1) Expected level and	Royalty Rate _k (%)	0.007 (0.007)	0.69	0.007	0.67	0.006 (0.007)	0.58
volatility of cash flows	Well Lateral Length _{j,t} (1,000 ft.)	(0.007)		-0.047** (0.023)	-4.56	-0.012 (0.020)	-1.22
2) Time value of	First Well's Market Value _{j,t}			0.233***	26.21	0.207***	23.00
money	Peers' Wells' Mkt. Value _{j,t}			(0.068) 0.063***	6.48	(0.061) 0.058***	5.97
	Oil-to-Gas Ratioj			(0.015) 0.308**	36.03	(0.014) 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*** (0.003)	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
	Pseudo – Loglikelihood	-17,2		-17,1		-17,0	
	Wald Chi ² Observations	398 537.0		541 537.0		1,1 537,	

Learning and Investment

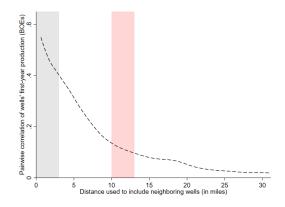
May 24/25, 2022

8/19

			Haza	rd Model for	Project E	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
	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
Duris et level sentende	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 (0.007)	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
. ,	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 Price _t			(0.042)		0.009*** (0.003)	0.90
	Implied Volatility: (%)					-0.022*** (0.007)	-2.15
	10-Year Risk Free Rate: (%) County Strata Pseudo – Loglikelihood Wald Chi ² Observations					0.176*** (0.057)	19.27
				Yes		Ye	s
			36	-17,1 541 537,0		-17,074 1,105	
	Observations	537,0		537,0		537,	
Décaire and Wittry	Learning and Investmen	nt		May 2	4/25, 2	022	8/19

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

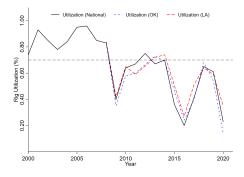


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Confounding cases:

- (1) Is the effect driven by a regional shock or coordination gains with peers? \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



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 matching between firms and regions? Include a firm-county strata

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 → 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 matching between firms and regions?

 - Include a firm-county strata

Introduce an instrumental variable

Challenge:

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

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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



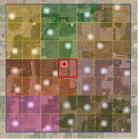
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Challenge:

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



Multiple landowners (7)



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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



Multiple landowners (7)



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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







Learning and Investment

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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).

Challenge:

 $\Rightarrow\,$ 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)
 - (1) Homestead Act (42%)
 - (2) Dawes Act (11%)
 - (3) Script Warrant Acts (4%)
 - (4) Cash entry programs (39%)

Settling, farming, and rewarding soldiers



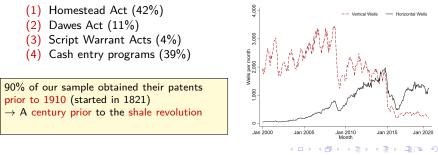
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Challenge:

 $\Rightarrow\,$ 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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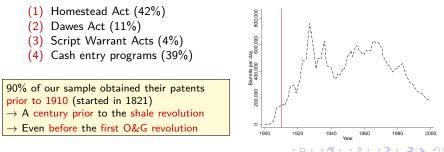


Challenge:

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

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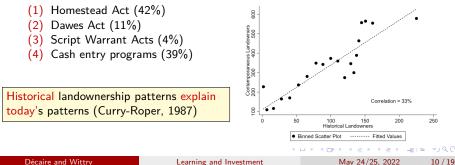


Challenge:

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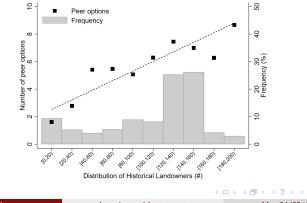
Main concern: Number of peers is correlated with the underlying asset quality

- ⇒ 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)	(3)			
	Estimates HI(%) Estimates HI(%)	Estimates HI(%)			
Instrumented Unexercised Investment Opportunities $(Peers)_{j,t}$	-0.262** -23.0 (0.120)	2 -0.253** -22.39 (0.114)	-0.249** -22.02 (0.113)			
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			
Pseudo – Loglikelihood Wald Chi ² Observations	-13,651 84 414.176		-13,5 112 414.1		-13,481 190 414,176			

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

Image: A matrix

	Hazard Model for Project Exercise						
	(1)	(1)			(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	i	Yes		
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-13,651 84 414,176		-13,564 112 414,176		-13,481 190 414,176		

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)	(1)			(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	5	Yes Yes Yes		
County Strata	Yes		Yes	5	Yes		
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-13,651 84 414,176		-13,5 112 414,1	2	-13,481 190 414,176		

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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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		Ye	s
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)	(2))	
	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		
Pseudo – Loglikelihood Wald Chi ² Observations	-7,033 532 273,427		-6,981 671 273,427		-6,943 1,390 273,427		

	Hazard Model for Project Exercise					
	(1)		(2)	(2))
	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		-6,981 671 273,427		-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				
Pseudo – Loglikelihood Wald Chi ² Observations	-7,033 532 273,427		-6,981 671 273,427		-6,943 1,390 273,427				

Costs of	Waiting for	Info.	Spillovers
	wait less or		

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	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		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	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

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*** (0.158)	-66.91	-0.980*** (0.145)	-62.49	-0.816*** (0.141)	-55.77		
Unexercised Inv. Opp. (Peers) _{<i>j</i>,t} \times Peers' Wells' Mkt. Value _{<i>j</i>,t}	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		Yes Yes Yes			
County Strata	Yes		Yes	Yes		s		
<i>Pseudo – Loglikelihood</i> Wald Chi ²	-17,194 775		884	-17,132 884		-17,046 1,636		
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

May 24/25, 2022

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	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	
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	Yes No No		Yes Yes No		Yes Yes Yes		
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		

How do we do it?	Which peer

Which pee	r/project	characteristics	matter?
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	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		
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		
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		Ye Ye Ye	s		
County Strata	Yes		Yes		Yes			
Pseudo – Loglikelihood	-17,285		-17,174		-17,0)74		
Wald Chi ² Observations	474 537,0		563 537,0		1,10 537,0			

$\begin{array}{l} \label{eq:how-do-we-do-it?} \\ \Rightarrow \mbox{ Split variable into options producing the same and different majority resources (oil vs. gas)} \end{array}$	Which peer/project characteristics matter?
(

	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		563 537,0		1,10 537,0		

$\begin{array}{ c c c c c } \hline How & do & we & do & it? \\ \Rightarrow & Split variable into options producing \\ the same and different majority resources \\ (oil vs. gas) \end{array}$	Which peer/project characteristics matter?
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	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	474 537,093		563 537,093		1,161 537,093	

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	

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*** (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*** (0.001)		12.54*** (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	435 537,093		580 537,093		1,254 537,093	

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*** (0.001)		12.54*** (0.000)		11.94*** (0.001)			
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	-17,280		-17,168		-17,071			
Wald Chi ² Observations	435 537,093		580 537,093		1,254 537,093			

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*** (0.001)		12.54*** (0.000)		11.94*** (0.001)			
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	-17,280 435		-17,168 580		-17,071 1,254			
Observations	537,0	93	537,0	93	537,093			

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

Which peer/project characteristics matter?

How do we do it?

	Hazard Model for Project Exercise							
	(1)	(1)		(2))		
	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*** (0.001)		12.54*** (0.000)		11.94*** (0.001)			
Firm-level controls Project-level controls Market level controls	Yes No No		Yes Yes No		Yes Yes Yes			
County Strata	Yes	i	Yes		Yes			
Pseudo – Loglikelihood	-17,2	80	-17,168		-17,071			
Wald Chi ² Observations	435 537,093		580 537,093		1,254 537,093			

How do we do it?	Which peer/project characteristics matter?
\Rightarrow Split variable into options owned by	\Rightarrow Focus on options producing the same
skilled and unskilled peers	resource
\Rightarrow Magnitudes are statistically different	\Rightarrow Focus on peers that are better at selecting and designing wells

	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*** (0.001)		12.54*** (0.000)		11.94*** (0.001)			
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 Wald Chi ² Observations	-17,280 435 537,093		580		-17,071 1,254 537,093			

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

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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

Appendix

Falsification Tests - Peer Options 10-13 Miles Away

	Hazard Model for Project Exercise									
	(1)		(2)		(3)					
	Estimates HI(%) E		Estimates	Estimates HI(%)		HI(%)				
Falsified Unexercised Investment Opportunities (Peers) _{j,t}	-0.002 -0.20 (0.003)		-0.003 (0.003)			-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					
<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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Subsample of Periods with Low Rig Utilization Rates

		Hazar	d Model for	Project I	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		Yes Yes Yes	
County Strata	Yes		Yes		Yes	
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-11,733 367 465,960		-11,670 571 465,960		-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)	(1)			(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		Yes Yes Yes			
County Strata	Yes		Yes		Yes			
Pseudo — Loglikelihood Wald Chi ² Observations	-11,014 272 268,547		-10,897 892 268,547		-10,860 1,306 268,547			

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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 $(\text{Peers})_{j,t}$	-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		Yes Yes Yes			
County Strata	Yes		Yes		Yes			
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-16,041 307 509,632		-15,929 446 509,632		-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		Yes Yes Yes	
County-Firm Strata	Yes		Yes		Yes	
<i>Pseudo – Loglikelihood</i> Wald Chi ² Observations	-10,058 498 537,093		-9,953 664 537,093		-9,900 1,009 537,093	

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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	(3)	
Peers Distance Definition =	2 Miles		3 Miles		4 Miles		
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)	
Unexercised Investment Opportunities $(\text{Peers})_{j,t}$	-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				

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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)	0.040***	0.015*	
	(0.009)	(800.0)	
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 R^2	3,462	3,462	3,462	
	0.40	0.47	0,47	

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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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