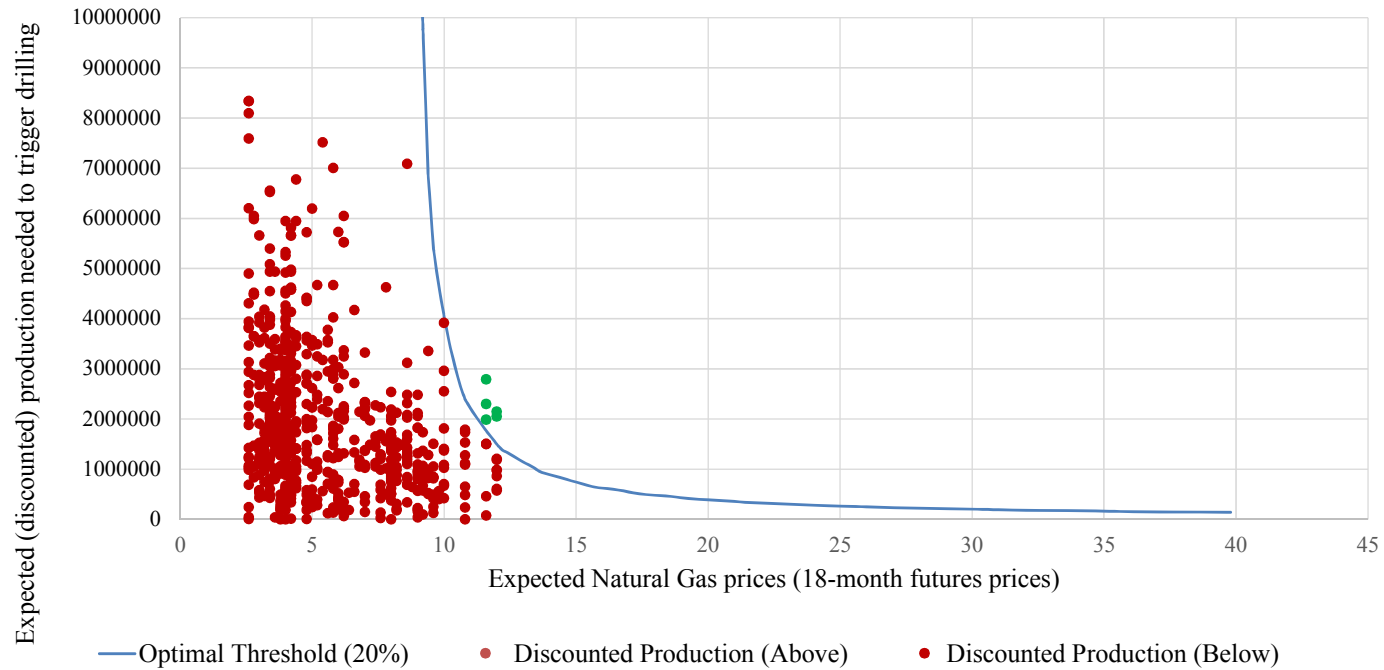


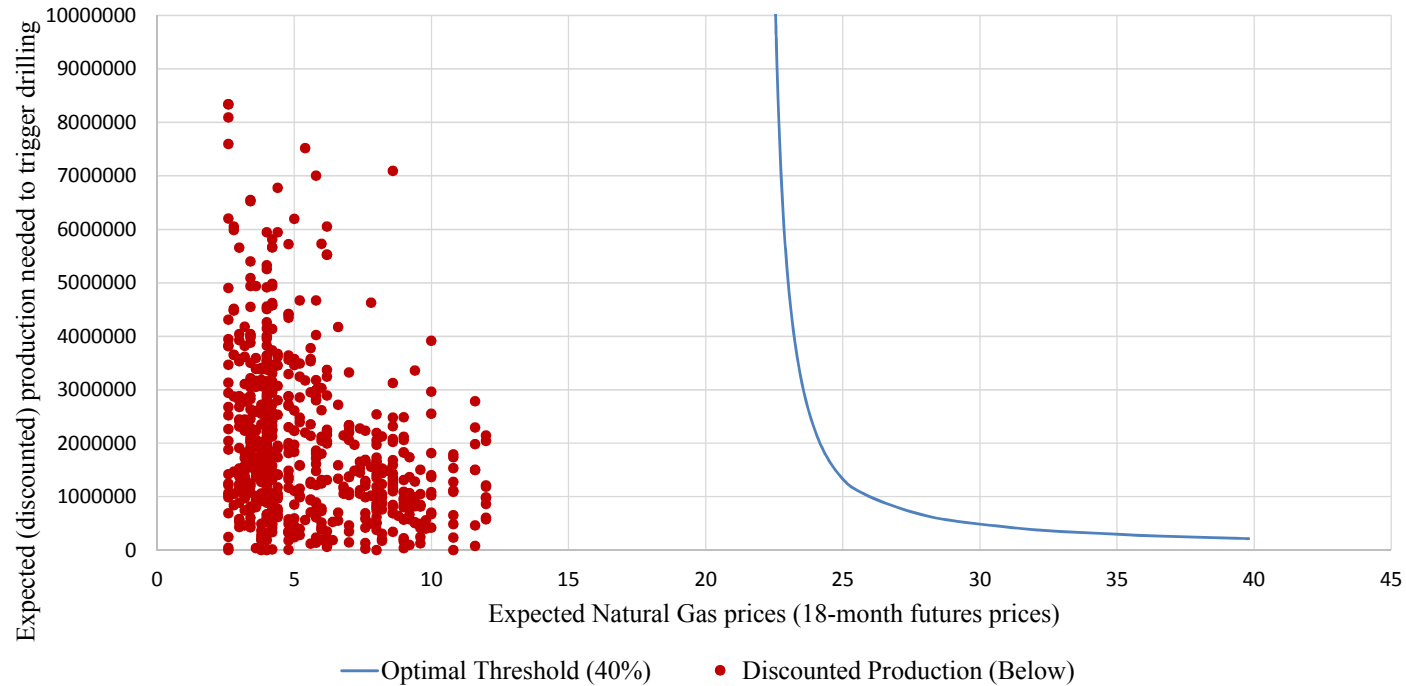
## Well Exercised Above/Below Dynamic Discrete Choice Model Optimal Threshold Curves (20% Implied Volatility Case)



### Appendix Figure 1A: Distribution of the realized Discounted Production of the Wells

This figure provides a comparison between the distribution of the realized discounted production of our sample wells and the Rust dynamic discrete choice model optimal exercise threshold line (see Figure 6 in Kellogg (2014)) computed at the lowest volatility value measured in our sample (20%). The x-axis shows natural gas 18-months futures prices at time of exercise. The y-axis shows expected discounted well production (in mcf). Overall, 99% of the exercised wells are exercised too early in this scenario.

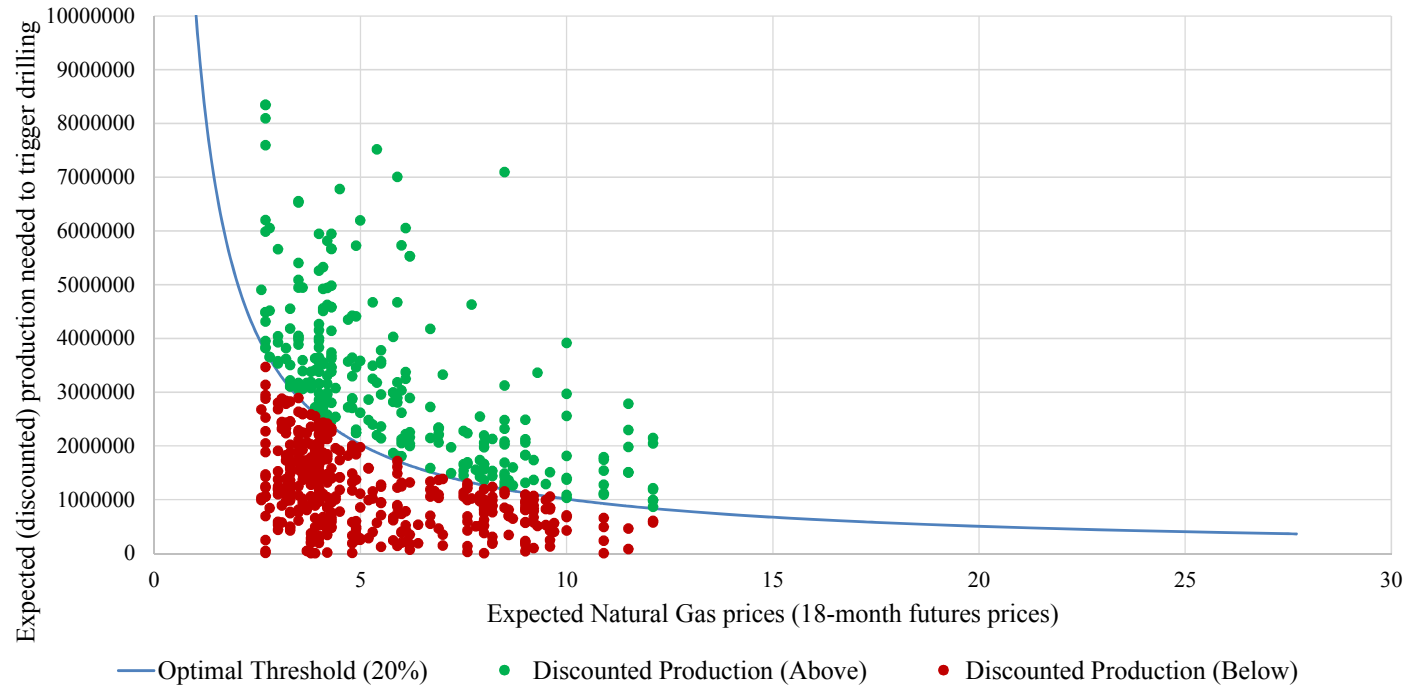
### Well Exercised Above/Below Dynamic Discrete Choice Model Optimal Threshold Curves (40% Implied Volatility Case)



#### Appendix Figure 1B: Distribution of the realized Discounted Production of the Wells

This figure provides a comparison between the distribution of the realized discounted production of our sample wells and the Rust dynamic discrete choice model optimal exercise threshold line (see Figure 6 in Kellogg (2014)) computed at the highest volatility value measured in our sample (40%). The x-axis shows natural gas 18-months futures prices at time of exercise. The y-axis shows expected discounted well production (in mcf). Overall, 100% of the exercised wells are exercised too early in this scenario.

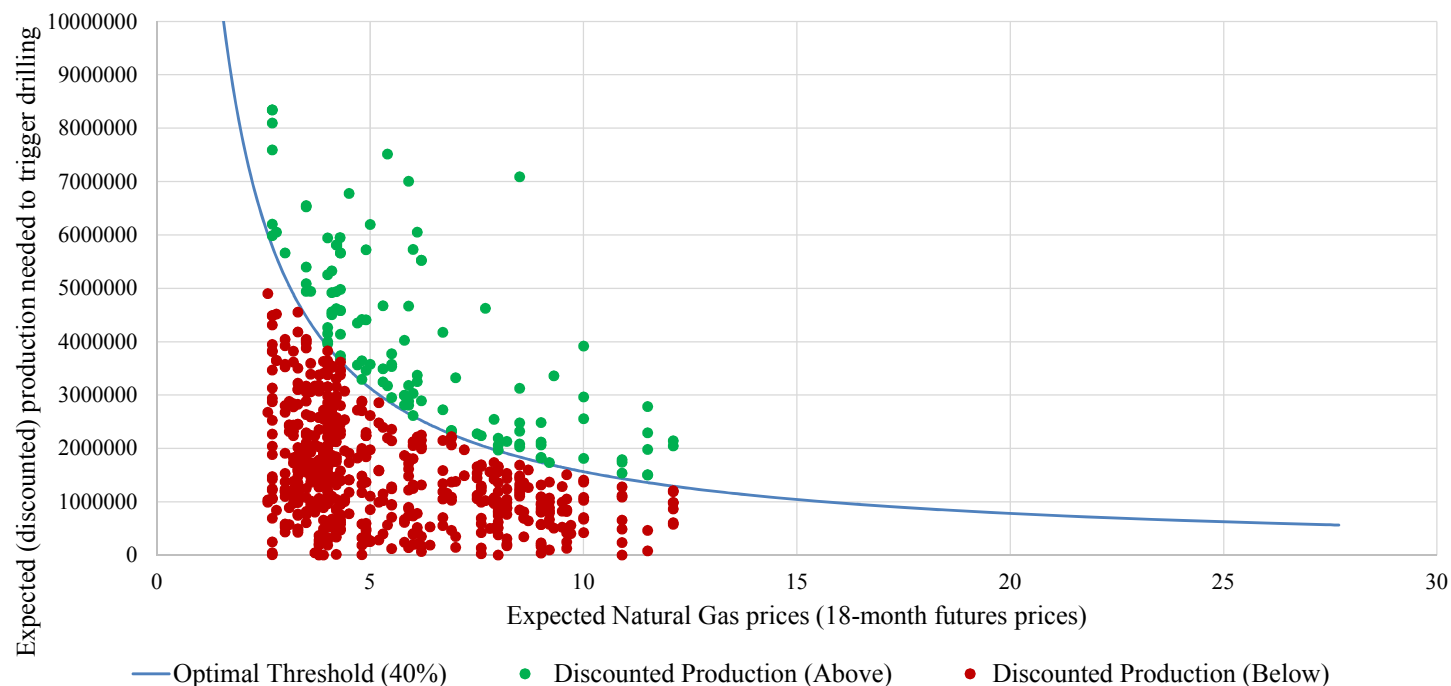
## Well Exercised Above/Below Dixit-Pindyck Optimal Threshold Curves (20% Implied Volatility Case)



### Appendix Figure 2A: Distribution of the realized Discounted Production of the Wells

This figure provides a comparison between the distribution of the realized discounted production of our sample wells with the Dixit-Pindyck optimal exercise threshold curve computed at the minimum volatility value measured in our sample (20%). The x-axis shows natural gas 18-months futures prices at time of exercise. The y-axis shows expected discounted well production (in mcf). Overall, 61% of the exercised wells are exercised too early in this scenario.

## Well Exercised Above/Below Dixit-Pindyck Optimal Threshold Curves (40% Implied Volatility Case)



**Appendix Figure 2B: Distribution of the realized Discounted Production of the Wells**

This figure provides a comparison between the distribution of the realized discounted production of our sample wells with the Dixit-Pindyck optimal exercise threshold curve computed at the maximum volatility value measured in our sample (40%). The x-axis shows natural gas 18-months futures prices at time of exercise. The y-axis shows expected discounted well production (in mcf). Overall, 82.3% of the exercised wells are exercised too early in this scenario.

**Appendix Table 1: Real Option Exercise and Exogenous Peer Effects - IV Probit Model, Cluster by Township**

This table reports results of the main instrumental variable tests reported in Table 4 Panel A using IV Probit as the estimation model. Variable definitions and panel structure match what is used in Table 4. Standard errors are clustered by Township.

**Table 4: Panel A - IV Probit Model, Cluster by Township**

	IV Probit model		
	Instrumented - Number of adjacent exercised options (peer)		
	(1)	(2)	(3)
	Estimate	Estimate	Estimate
( $\beta_1$ ) Implied volatility of natural gas (percent) <sub>t</sub>	-0.0088*	-0.0097*	-0.0046
	[-1.79]	[-1.94]	[-0.76]
( $\beta_2$ ) Natural gas price (\$/mcf) <sub>t</sub>	0.0241	0.0093	0.0867***
	[1.05]	[0.42]	[3.51]
( $\beta_3$ ) Log drilling cost <sub>t</sub>	-0.0373	-0.0592	0.1389
	[-0.35]	[-0.57]	[1.13]
( $\beta_4$ ) 5 year risk free interest rate <sub>t</sub>	0.0581*	0.07*	0.0958**
	[1.65]	[1.92]	[1.97]
( $\beta_5$ ) Log first well production <sub>i</sub>	0.0436	-0.0103	-0.0099
	[1.34]	[-0.48]	[-0.39]
( $\beta_6$ ) Instrumented - Number of adjacent exercised options (peer) <sub>i,t</sub>	0.5688***	0.5697***	0.5476***
	[4.14]	[4.22]	[2.69]
( $\beta_7$ ) Average log first well production adjacent options (peer) <sub>i,t</sub>	-0.014*	-0.0182***	-0.0154
	[-1.86]	[-2.68]	[-1.25]
( $\beta_8$ ) Number of adjacent exercised options (own) <sub>i,t</sub>		0.15***	0.2567***
		[3.91]	[7.95]
( $\beta_9$ ) Relative rank percentile (own project) <sub>i,t</sub>		0.0707	0.0686
		[1.39]	[1.01]
Township FE	No	No	Yes
<i>N</i>	103,451	103,451	103,451

**Appendix Table 2: Real Option Exercise and Exogenous Peer Effects - IV-2SLS Model, Cluster by Township**

This table reports results of the main instrumental variable tests reported in Table 4 Panel A using IV-2SLS as the estimation model. Variable definitions and panel structure match what is used in Table 4. Standard errors are clustered by Township.

**Table 4: Panel A - IV-2SLS Regression Model, Cluster by Township**

	IV 2SLS regression model		
	Instrumented - Number of adjacent exercised options (peer)		
	(1)	(2)	(3)
	Estimate	Estimate	Estimate
( $\beta_1$ ) Implied volatility of natural gas (percent) <sub>t</sub>	-0.0001 [-1.63]	-0.0001* [-1.70]	-0.0001 [-1.04]
( $\beta_2$ ) Natural gas price (\$/mcf) <sub>t</sub>	0.0009** [2.04]	0.0008* [1.85]	0.0017*** [3.04]
( $\beta_3$ ) Log drilling cost <sub>t</sub>	-0.0007 [-0.44]	-0.0008 [-0.49]	0.0013 [0.86]
( $\beta_4$ ) 5 year risk free interest rate <sub>t</sub>	0.0006 [0.92]	0.0007 [1.03]	0.0007 [0.98]
( $\beta_5$ ) Log first well production <sub>i</sub>	0.0003 [1.54]	-0.0002 [-1.13]	-0.0002 [-0.79]
( $\beta_6$ ) Instrumented - Number of adjacent exercised options (peer) <sub>i,t</sub>	0.0071*** [2.97]	0.0046** [2.10]	0.0052* [1.65]
( $\beta_7$ ) Average log first well production adjacent options (peer) <sub>i,t</sub>	-0.0001 [-0.75]	-0.0001 [-0.71]	0.0000 [0.17]
( $\beta_8$ ) Number of adjacent exercised options (own) <sub>i,t</sub>		0.0032*** [4.89]	0.0039*** [4.04]
( $\beta_9$ ) Relative rank percentile (own project) <sub>i,t</sub>		0.0018*** [3.13]	0.0019*** [2.71]
Township FE	No	No	Yes
<i>N</i>	103,451	103,451	103,451

**Appendix Table 3: Real Option Exercise and Exogenous Peer Effects - IV Probit Model (Cluster by Township and by Year)**

This table reports results of the main instrumental variable tests reported in Table 4 Panel A using IV Probit as the estimation model. Variable definitions and panel structure match what is used in Table 4. Standard errors are clustered by Township and by Year.

**Table 4: Panel A - IV Probit Model (Cluster by Township and by Year)**

	IV Probit model		
	Instrumented - Number of adjacent exercised options (peer)		
	(1)	(2)	(3)
	Estimate	Estimate	Estimate
( $\beta_1$ ) Implied volatility of natural gas (percent) <sub>t</sub>	-0.0088*	-0.0097**	-0.0046
	[-1.80]	[-2.05]	[-0.51]
( $\beta_2$ ) Natural gas price (\$/mcf) <sub>t</sub>	0.0241	0.0093	0.0867***
	[1.04]	[0.38]	[3.19]
( $\beta_3$ ) Log drilling cost <sub>t</sub>	-0.0373	-0.0592	0.1389
	[-0.29]	[-0.44]	[1.16]
( $\beta_4$ ) 5 year risk free interest rate <sub>t</sub>	0.0581*	0.07*	0.0958**
	[1.68]	[1.91]	[2.30]
( $\beta_5$ ) Log first well production <sub>i</sub>	0.0436	-0.0103	-0.0099
	[1.61]	[-0.47]	[-0.44]
( $\beta_6$ ) Instrumented - Number of adjacent exercised options (peer) <sub>i,t</sub>	0.5688***	0.5697***	0.5476***
	[4.88]	[4.66]	[2.79]
( $\beta_7$ ) Average log first well production adjacent options (peer) <sub>i,t</sub>	-0.014*	-0.0182***	-0.0154
	[-1.90]	[-2.64]	[-1.15]
( $\beta_8$ ) Number of adjacent exercised options (own) <sub>i,t</sub>		0.15***	0.2567***
		[3.95]	[7.55]
( $\beta_9$ ) Relative rank percentile (own project) <sub>i,t</sub>		0.0707	0.0686
		[1.31]	[0.97]
Township FE	No	No	Yes
<i>N</i>	103,451	103,451	103,451

**Appendix Table 4: Real Option Exercise and Exogenous Peer Effects - IV 2SLS Regression Model (Cluster by Township and by Year)**

This table reports results of the main instrumental variable tests reported in Table 4 Panel A using IV 2SLS as the estimation model. Variable definitions and panel structure match what is used in Table 4. Standard errors are clustered by Township and by Year.

**Table 4: Panel A - IV 2SLS Regression Model (Cluster by Township and by Year)**

	IV 2SLS regression model		
	Instrumented - Number of adjacent exercised options (peer)		
	(1)	(2)	(3)
	Estimate	Estimate	Estimate
( $\beta_1$ ) Implied volatility of natural gas (percent) <sub>t</sub>	-0.0001 [-1.38]	-0.0001 [-1.38]	-0.0001 [-0.74]
( $\beta_2$ ) Natural gas price (\$/mcf) <sub>t</sub>	0.0009 [1.49]	0.0008 [1.32]	0.0017*** [4.19]
( $\beta_3$ ) Log drilling cost <sub>t</sub>	-0.0007 [-0.32]	-0.0008 [-0.34]	0.0013 [0.77]
( $\beta_4$ ) 5 year risk free interest rate <sub>t</sub>	0.0006 [0.88]	0.0007 [0.98]	0.0007 [1.01]
( $\beta_5$ ) Log first well production <sub>i</sub>	0.0003* [1.71]	-0.0002 [-1.09]	-0.0002 [-0.90]
( $\beta_6$ ) Instrumented - Number of adjacent exercised options (peer) <sub>i,t</sub>	0.0071*** [3.49]	0.0046*** [2.82]	0.0052*** [1.96]
( $\beta_7$ ) Average log first well production adjacent options (peer) <sub>i,t</sub>	-0.0001 [-0.84]	-0.0001 [-0.79]	0.0000 [0.16]
( $\beta_8$ ) Number of adjacent exercised options (own) <sub>i,t</sub>		0.0032*** [3.65]	0.0039*** [3.74]
( $\beta_9$ ) Relative rank percentile (own project) <sub>i,t</sub>		0.0018** [2.39]	0.0019** [2.15]
Township FE	No	No	Yes
<i>N</i>	103,451	103,451	103,451



**Appendix Table 5: Real Option Exercise and Exogenous Peer Effects - IV Cox Model (Cluster by Township and by Year)**

This table reports results of the main instrumental variable tests reported in Table 4 Panel A with standard errors double clustered by Township and by Year. Variable definitions and panel structure match what is used in Table 4.

**Table 4: Panel A - IV Cox Model (Cluster by Township and by Year)**

	Hazard model					
	Instrumented - Number of adjacent exercised options (peer)					
	(1)		(2)		(3)	
	Estimate	HI (%)	Estimate	HI (%)	Estimate	HI (%)
( $\beta_1$ ) Implied volatility of natural gas (percent) <sub>t</sub>	-0.0245	-2.42	-0.0281	-2.77	-0.0166	-1.64
	[-1.39]		[-1.55]		[-0.61]	
( $\beta_2$ ) Natural gas price (\$/mcf) <sub>t</sub>	0.2062**	22.90	0.1546	16.72	0.2801**	32.33
	[2.23]		[1.63]		[2.45]	
( $\beta_3$ ) Log drilling cost <sub>t</sub>	0.0494	5.06	-0.0319	-3.14	0.4462	56.24
	[0.15]		[-0.08]		[0.96]	
( $\beta_4$ ) 5 year risk free interest rate <sub>t</sub>	0.1325	14.17	0.1564	16.93	0.2168	24.21
	[1.11]		[1.19]		[1.15]	
( $\beta_5$ ) Log first well production <sub>i</sub>	0.2432***	27.54	-0.0064	-0.64	-0.0565**	-5.50
	[3.10]		[-0.08]		[-2.44]	
( $\beta_6$ ) Instrumented - Number of adjacent exercised options (peer) <sub>i,t</sub>	0.595***	81.31	0.5825***	79.06	0.6623***	93.93
	[3.65]		[3.11]		[2.79]	
( $\beta_7$ ) Average log first well production adjacent options (peer) <sub>i,t</sub>	-0.0671*	-6.49	-0.0746**	-7.18	-0.0236	-2.33
	[-1.82]		[-2.00]		[-0.96]	
( $\beta_8$ ) Number of adjacent exercised options (own) <sub>i,t</sub>			0.3731***	45.22	0.7649***	114.88
			[3.41]		[5.03]	
( $\beta_9$ ) Relative rank percentile (own project) <sub>i,t</sub>			0.311**	36.48	0.2563*	29.21
			[2.04]		[1.68]	
Township FE		No		No		Yes
<i>N</i>		103,451		103,451		103,451

**Appendix Table 6: (Table 4 Panel B) - Reduced Form (Cluster by Township and by Year)**

This table reports results of the main reduced form tests reported in Table 4 Panel B with standard errors double clustered by Township and by Year. Variable definitions and panel structure match what is used in Table 4.

	Hazard model					
	Reduced form - Relative rank percentile (adjacent peer projects)					
	(1)		(2)		(3)	
	Estimate	HI (%)	Estimate	HI (%)	Estimate	HI (%)
( $\beta_1$ ) Implied volatility of natural gas (percent) <sub>t</sub>	-0.0242 [-1.33]	-2.39	-0.028* [-1.67]	-2.76	-0.0211 [-1.09]	-2.09
( $\beta_2$ ) Natural gas price (\$/mcf) <sub>t</sub>	0.1838*** [3.95]	20.18	0.1301** [2.54]	13.90	0.1588*** [4.11]	17.21
( $\beta_3$ ) Log drilling cost <sub>t</sub>	0.1768 [0.50]	19.34	0.0805 [0.22]	8.39	0.2025 [0.58]	22.45
( $\beta_4$ ) 5 year risk free interest rate <sub>t</sub>	0.0704 [1.02]	7.30	0.1022 [1.34]	10.76	0.0441 [0.44]	4.51
( $\beta_5$ ) Log first well production <sub>i</sub>	0.295*** [3.45]	34.31	0.0045 [0.05]	0.45	-0.0446 [-0.81]	-4.36
( $\beta_6$ ) Relative rank percentile (adjacent peer projects) <sub>i,t</sub>	0.3043*** [4.38]	35.57	0.2676*** [4.42]	30.69	0.2417*** [2.96]	27.34
( $\beta_7$ ) Average log first well production adjacent options (peer) <sub>i,t</sub>	0.0567*** [3.51]	5.84	0.0365** [2.24]	3.72	0.0566*** [3.13]	5.82
( $\beta_8$ ) Number of adjacent exercised options (own) <sub>i,t</sub>			0.5002*** [11.93]	64.90	0.3985*** [7.60]	48.96
( $\beta_9$ ) Relative rank percentile (own project) <sub>i,t</sub>			0.4146*** [3.55]	51.37	0.4256*** [3.77]	53.05
Township FE	No		No		Yes	
<i>N</i>	103,451		103,451		103,451	

**Appendix Table 7: Effect of Adjacent First Wells**

This table reports results of the main instrumental variable and reduced form tests reported in Table 4 Panel A (specification (3)) and Table 4 Panel B (specification (3)) with the inclusion of an additional control variable for the number of adjacent peer unexercised real options (number of adjacent first wells drilled (peers)). Other variable definitions and panel structure match what is used in Table 4. Standard errors are clustered by Township.

	Reduced Form		Instrumented	
	Peer Effects		Peer Effects	
	(1)		(2)	
	Estimate	HI (%)	Estimate	HI (%)
( $\beta_1$ ) Implied volatility of natural gas (percent) <sub>t</sub>	-0.0200 [-1.34]	-1.98	-0.0179 [-1.09]	-1.77
( $\beta_2$ ) Natural gas price (\$/mcf) <sub>t</sub>	0.1621*** [3.28]	17.60	0.249** [2.41]	28.27
( $\beta_3$ ) Log drilling cost <sub>t</sub>	0.1969 [0.54]	21.76	0.4256 [1.00]	53.05
( $\beta_4$ ) 5 year risk free interest rate <sub>t</sub>	0.0782 [0.78]	8.13	0.1981 [1.20]	21.90
( $\beta_5$ ) Log first well production <sub>i</sub>	-0.0436 [-0.61]	-4.27	-0.0520 [-0.65]	-5.07
( $\beta_6$ ) Relative rank percentile (adjacent peer projects) <sub>i,t</sub>	0.2633*** [3.18]	30.12		
( $\beta_7$ ) Average log first well production adjacent options (peer) <sub>i,t</sub>	0.0270 [1.44]	2.74	0.0261 [1.40]	2.64
( $\beta_8$ ) Number of adjacent exercised options (own) <sub>i,t</sub>	0.4724*** [9.52]	60.39	0.5556*** [6.22]	74.30
( $\beta_9$ ) Relative rank percentile (own project) <sub>i,t</sub>	0.4157*** [3.73]	51.55	0.2627* [1.83]	30.04
( $\beta_{10}$ ) Number of adjacent first wells drilled (peer) <sub>i,t</sub>	0.312*** [5.82]	36.61	-0.7108* [-1.66]	-50.88
( $\beta_{11}$ ) Instrumented - Number of adjacent exercised options (peer) <sub>i,t</sub>			1.1168** [2.29]	205.50
Township FE	Yes		Yes	
<i>N</i>	103,451		103,451	

**Appendix Table 8: Operator Fixed Effects**

This table reports results of the main instrumental variable and reduced form tests reported in Table 4 Panel A (specification (3)) and Table 4 Panel B (specification (3)) with the inclusion of operator fixed effects. Other variable definitions and panel structure match what is used in Table 4. Standard errors are clustered by Township.

	Reduced Form		Instrumented	
	Peer Effects		Peer Effects	
	(1)		(2)	
	Estimate	HI (%)	Estimate	HI (%)
( $\beta_1$ ) Implied volatility of natural gas (percent) <sub>t</sub>	-0.0229 [-1.43]	-2.26	0.0130* [-1.72]	1.31
( $\beta_2$ ) Natural gas price (\$/mcf) <sub>t</sub>	0.1636*** [2.80]	17.77	0.0906*** [2.43]	9.48
( $\beta_3$ ) Log drilling cost <sub>t</sub>	0.2906 [0.74]	33.72	0.3216 [1.63]	37.93
( $\beta_4$ ) 5 year risk free interest rate <sub>t</sub>	-0.0543 [-0.56]	-5.29	0.0670 [0.34]	6.93
( $\beta_5$ ) Log first well production <sub>i</sub>	-0.0509 [-0.48]	-4.96	0.0885 [-0.32]	9.25
( $\beta_6$ ) Relative rank percentile (adjacent peer projects) <sub>i,t</sub>	0.1619* [1.87]	17.58		
( $\beta_7$ ) Average log first well production adjacent options (peer) <sub>i,t</sub>	0.0524*** [2.76]	5.38	0.0171 [0.14]	1.72
( $\beta_8$ ) Number of adjacent exercised options (own) <sub>i,t</sub>	0.3205*** [6.15]	37.78	0.1894*** [2.58]	20.85
( $\beta_9$ ) Relative rank percentile (own project) <sub>i,t</sub>	0.5406*** [4.15]	71.70	0.1664*** [2.52]	18.11
( $\beta_{10}$ ) Instrumented - Number of adjacent exercised options (peer) <sub>i,t</sub>			0.1466*** [2.39]	15.78
Township FE		Yes		Yes
Operator FE		Yes		Yes
<i>N</i>	103,451		103,451	