

All the DUCs in a Row: Natural Gas Production in US - Appendix

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Abstract

Using data from seven shale gas regions in the United States, we examine natural gas production in terms of drilling rig activity and well completion rates. Our objectives are to examine the role and determinants of well completion decisions in the US natural gas production. We observe that in recent years, the explanatory power of drilling rig count has declined. On the other hand, the number of producing wells remain a significant factor in explaining the variation in gas production. We find that an increase in the number of drilled but uncompleted wells (DUCs) has a significant role in natural gas supply. The number of DUCs depends on drilling rig activity and futures prices of oil and natural gas. Also, our results indicate that well completion decisions and the duration of DUC status depend on oil and gas prices, pipeline capacity, producing well type and well depth.

Keywords: Natural Gas Production, Rigs, Drilling, Completion, Pipelines, Prices.

JEL codes: D24, L71, Q35, Q47

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Appendix Tables

In this appendix we show: (i) estimation results with region specific break points in Tables A1 to A4, (ii) time series diagnostic test results in Tables A5 to A8, and (iii) vector autoregressive model results in Tables A9 and.

Dependent – NGP	Before Break(i)	After Break(i)
Rig Count _{t-1}	0.461 (0.02)***	-0.080 (0.02)***
Constant	12.47 (0.12)***	15.97 (0.07)***
R-sq	0.45	0.05
Observations	n=7, N=444	n=7, N=522

Table A1: Split Sample Regional Fixed Effects Results for Aggregate NGP

*Note: Significance values 1%***, 5%***, 10%*, Standard errors in parenthesis*

Table A2: Region and Time Fixed Effects Results for Aggregate NGP

NGP-Dep	Model 1	Model 2	Model 3
Rig Count _{t-1}	0.298 (0.03)***		0.247 (0.03)***
Producing Wells		0.512 (0.04)***	0.467 (0.04)***
Break(i)	0.427 (0.05)***	0.423 (0.05)***	0.378 (0.05)***
Constant	13.10 (0.22)***	10.01 (0.40)***	9.266 (0.40)***
R-sq	0.61	0.64	0.66
Observations	Balanced Panel n=7, T=138, N=966		

*Note: Significance values 1%***, 5%***, 10%*, Standard errors in parenthesis; Data from 2007-2018*

Table A3: Regional Regression Results (Determinants of NGP)

Region	Model 1	Model 2	Model 3
Anadarko			
Rig Count _{t-1}	-0.084 (0.02)***		-0.020 (0.02)
Producing Wells		0.510 (0.08)***	0.484 (0.09)***
B_7 May 2010	0.259 (0.03)***	0.084 (0.03)***	0.097 (0.03)***
Adj R-sq	0.543	0.618	0.614
Appalachia			
Rig Count _{t-1}	0.421 (0.10)***		0.180 (0.09)*
Producing Wells		2.114 (0.30)***	1.902 (0.30)***
B_2 August 2012	1.972 (0.08)***	1.501 (0.09)***	1.551 (0.09)***
Adj R-sq	0.831	0.871	0.871
Bakken			
Rig Count _{t-1}	0.121 (0.05)**		-0.060 (0.02)***
Producing Wells		0.676 (0.02)***	0.711 (0.02)***
B_3 December 2012	1.597 (0.15)***	0.377 (0.05)***	0.311 (0.05)***
Adj R-sq	0.814	0.974	0.976
Eagle Ford			
Rig Count _{t-1}	0.238 (0.03)**		0.147 (0.02)***
Producing Wells		1.072 (0.06)***	0.921 (0.06)***
B_7 February 2013	1.044 (0.04)***	0.292 (0.06)***	0.381 (0.04)***
Adj R-sq	0.873	0.933	0.958
Haynesville			
Rig Count _{t-1}	0.077 (0.02)***		0.160 (0.03)***
Producing Wells		0.177 (0.14)	0.771 (0.17)***
B_3 February 2009	0.653 (0.05)***	0.490 (0.08)***	0.391 (0.07)***
Adj R-sq	0.587	0.571	0.638
Niobrara			
Rig Count _{t-1}	-0.046 (0.01)***		-0.034 (0.01)***
Producing Wells		0.184 (0.02)***	0.161 (0.02)***
B_6 January 2014	-0.015 (0.01)	-0.066 (0.02)***	-0.077 (0.02)***
Adj R-sq	0.061	0.284	0.283
Permian			
Rig Count _{t-1}	-0.019 (0.03)		-0.011 (0.03)
Producing Wells		-0.073 (0.07)	-0.065 (0.08)
B_7 January 2014	0.462 (0.02)***	0.484 (0.04)***	0.481 (0.03)***
Adj R-sq	0.750	0.752	0.749

Note: Significance values 1%***, 5%***, 10%*; Standard errors in parenthesis;
Data from 2007-2018

Table A4: Region and Time Fixed Effects Results (NGP and New Wells)

Dependent – ΔNGP	Log-log form
Legacy Wells	-0.012 (0.00)***
New Wells	0.009 (0.00)***
Break(i)	0.002 (0.02)
Constant	0.072 (0.03)**
R-sq	0.26

Note: Significance values 1%***, 5%***, 10%*; Standard errors in parenthesis

Table A5: Unit Root Tests

Variables	With trend	Without trend	With trend	Without trend
	Phillips-Perron		Augmented Dickey-Fuller	
Regional Aggregate				
ΔNG Production	-50.060***	-48.412***	-35.003***	-34.928***
ΔRig Count	-5.636***	-5.629***	-5.087***	-5.085***
ΔNG Futures price	-12.862***	-12.866***	-12.903***	-12.903***
ΔOil Futures prices	-5.621***	-5.617***	-7.071***	-7.094***
Levin-Lin-Chu				
Anadarko				
ΔRig Count	-4.987***	-4.985***	-4.912***	-4.929***
ΔNG Production	-12.601***	-12.451***	-12.412***	-12.311***
ΔProducing Wells	96.47	63.152	-18.883***	-18.164***
Appalachia				
ΔRig Count	-5.702***	-5.585***	-5.617***	-5.522***
ΔNG Production	-8.416***	-7.270***	-8.290***	-7.188***
ΔProducing Wells	-14.339***	-12.918***	-19.903***	-19.919***
Bakken				
ΔRig Count	-4.820***	-4.679***	-4.747***	-4.626***
ΔNG Production	-10.783***	-10.031***	-10.620***	-9.918***
ΔProducing Wells	157.528	126.49	2.733	2.262
Eagle Ford				
ΔRig Count	-4.860***	-4.758***	-4.786***	-4.705***
ΔNG Production	-5.759***	-5.758***	-5.672***	-5.693***
ΔProducing Wells	3.407	1.672	-9.951***	-9.76***
Haynesville				
ΔRig Count	-4.813***	-4.800***	-4.741***	-4.746***
ΔNG Production	-4.571***	-4.565***	-4.502***	-4.514***
ΔProducing Wells	-17.226***	-6.157***	-9.597***	-8.984***
Niobrara				
ΔRig Count	-5.781***	-5.776***	-5.694***	-5.711***
ΔNG Production	-8.550***	-8.428***	-8.421***	-8.333***
ΔProducing Wells	30.459	23.813	-21.602***	-20.942***
Permian				
ΔRig Count	-4.185***	-4.182***	-4.122**	-4.135***
ΔNG Production	-9.870***	-8.215***	-9.721***	-8.122***
ΔProducing Wells	-9.036***	-7.827***	-17.335***	-16.921***

Note: Significance values ***1%; **5%; *10%

Table A6: Variable Lag Length

Series→	NGP & RC		NGP & PW		NGP, RC & PW	
Region	#of lags (AIC)	#of lags (HQIC)	#of lags (AIC)	#of lags (HQIC)	#of lags (AIC)	#of lags (HQIC)
Anadarko	4 (-7.13)	3 (-6.99)	4 (-7.79)	4 (-7.61)	4 (-10.70)	3(-10.36)
Appalachia	3 (-7.14)	2 (-7.02)	4 (-5.87)	1 (-5.75)	2 (-8.94)	2(-8.75)
Bakken	3 (-6.57)	2 (-6.45)	1 (-4.00)	1 (-3.93)	3(-6.76)	2(-6.57)
Eagle Ford	2 (-7.14)	2 (-7.03)	4 (-9.20)	4 (-9.03)	4 (-11.54)	4 (-11.20)
Haynesville	2 (-7.22)	2 (-7.12)	4 (-10.03)	4 (-9.85)	3 (-12.29)	3 (-12.03)
Niobrara	2 (-7.69)	2 (-7.58)	2 (-7.90)	2 (-7.79)	2 (-10.26)	2 (-10.07)
Permian	2 (-7.30)	2 (-7.19)	2 (-7.80)	2 (-7.69)	2 (-10.85)	2 (-10.66)

AIC/HQIC level in parenthesis

Table A7: Pedroni Panel Test for Cointegration

Test Statistic	Panel Statistics	Group Statistics
v	-1.782 (1.93)	.
rho	-7.322 (2.00)	-17.73 (2.00)
PP	-3.066 (2.00)	-5.013 (2.00)
adf	2.084 (0.04)**	2.084 (0.01)***

*Note: P-values in parenthesis; Significance values ***1%; **5%; *10%*

Table A8: Johansen Test for Cointegration

Region	Model 1	Model 2	Model 3
	NGP & RC	NGP & PW	NGP, RC & PW
Rank	Rank	Rank	Rank
Anadarko	0 (6.97)*	0 (13.44)*	2 (0.59)*
Appalachia	1 (2.76)*	1 (2.15)*	2 (3.22)*
Bakken	1 (1.66)*	0 (10.12)*	1 (11.99)*
Eagle Ford	1 (2.31)*	0 (10.33)*	1 (6.23)*
Haynesville	1 (3.57)*	0 (13.98)*	1 (12.82)*
Niobrara	0 (14.47)*	1 (1.17)*	0 (22.86)*
Permian	1 (3.25)*	1 (0.01)*	1 (6.24)*

Trace statistic levels in parenthesis

Table A9: Region Panel Vector Autoregressive (PVAR) Model Results

	Model 1	Model 2	Model 3	Model 4
ΔNatural Gas Production				
LD	-0.012 (0.04)	-0.013 (0.04)	-0.021 (0.04)	-0.038 (0.04)
L2D		0.067 (0.04)	0.072 (0.04)*	0.063 (0.04)
L3D			0.150 (0.04)***	0.157 (0.04)***
L4D				0.114 (0.04)***
ΔRig Count				
LD	0.002 (0.01)	-0.010 (0.02)	-0.009 (0.02)	-0.009 (0.02)
L2D		0.021 (0.02)	0.015 (0.02)	0.014 (0.02)
L3D			0.010 (0.01)	-0.011 (0.01)
				0.025 (0.01)**
ΔProducing Wells				
LD	0.036 (0.02)**	0.040 (0.02)**	0.034 (0.02)	0.027 (0.02)
L2D		0.006 (0.02)	0.010 (0.02)	-0.003 (0.03)
L3D			0.005 (0.02)	-0.001 (0.02)
				-0.003 (0.01)

Note: Significance values 1%***, 5%***, 10%*, Standard errors in parenthesis

Table A10: Regional Vector Error Correction (VEC) Model Results

Variables	Anadarko	Appalachia	Bakken	Eagle Ford	Haynesville	Niobrara	Permian
Error	-1.730***	0.005	-0.779***	-0.365***	-0.140**	-0.648***	-0.799***
Correction	(0.24)	(0.01)	(0.18)	(0.09)	(0.06)	(0.15)	(0.17)
ΔNatural Gas Production							
LD	0.411***	-0.979***	-0.137	-0.471***	-0.588***	-0.490***	-0.364**
	(0.20)	(0.09)	(0.16)	(0.10)	(0.09)	(0.14)	(0.16)
L2D	0.051	-0.570***	-0.146	-0.380***	-0.455***	-0.354***	-0.227
	(0.14)	(0.12)	(0.13)	(0.10)	(0.10)	(0.12)	(0.14)
L3D	-0.013	-0.176	-0.010	-0.194**	-0.158	-0.143	-0.043
	(0.09)	(0.09)	(0.09)	(0.08)	(0.09)	(0.08)	(0.09)
ΔRig Count							
LD	0.064	0.005	-0.098	-0.100***	-0.027	-0.053**	-0.114**
	(0.04)	(0.05)	(0.05)	(0.03)	(0.03)	(0.03)	(0.05)
L2D	-0.022	0.079	-0.156***	-0.037	-0.005	-0.016	-0.008
	(0.04)	(0.06)	(0.05)	(0.03)	(0.03)	(0.03)	(0.05)
L3D	-0.078	0.048	-0.057	-0.010	-0.023	-0.022	-0.013
	(0.04)	(0.05)	(0.05)	(0.02)	(0.03)	(0.02)	(0.05)
ΔProducing Wells							
LD	0.606***	-0.056	-0.026	-0.647***	0.076	-0.330***	0.840***
	(0.11)	(0.09)	(0.66)	(0.20)	(0.18)	(0.08)	(0.16)
L2D	0.407	-0.035	0.244	0.372	-0.510	-0.246**	0.565***
	(0.86)	(0.06)	(0.70)	(0.38)	(0.38)	(0.12)	(0.12)
L3D	1.622	-0.011	0.037	-0.129	-0.949	-0.127	0.223***
	(0.86)	(0.03)	(0.65)	(0.63)	(1.04)	(0.10)	(0.07)
R-sq	0.70	0.57	0.49	0.46	0.38	0.59	0.65

Note: Significance values 1%***, 5%***, 10%*, Standard errors in parenthesis