

The Case of the Missing Negative Externality? Housing Market Effects of Fracking in the Niobrara Shale Play, Colorado

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Presented by Xuanhao He

Background

- Colorado is one of the US states with abundant shale gas reserves, and its production levels increased substantially from 18 billion cubic feet in 2013 to 236 billion cubic feet in 2014.
- Since 2013, Weld County has experienced the largest share of both annual horizontal drilling permits (e.g., 1,789 out of 2,016 totals in 2015), and active horizontal wells (e.g., 4,791 out of 5,270 totals as of 07/18/2016), of the state total in Colorado (COGCC 2016).

Shale Gas Activities

1. Oil and gas extraction companies lease mineral rights from the surface right owners (Gopalakrishnan and Klaiber 2014)
2. Upon signing the lease, a bonus is paid to the lessor, and a royalty rate is agreed on (McMahon 2017)
3. The companies obtain permits from state governments
4. On-site well preparation begins (e.g., vegetation removal, well-pad, reserve pits and access road construction) (UA and Argonne 2017)
5. Drilling activities start

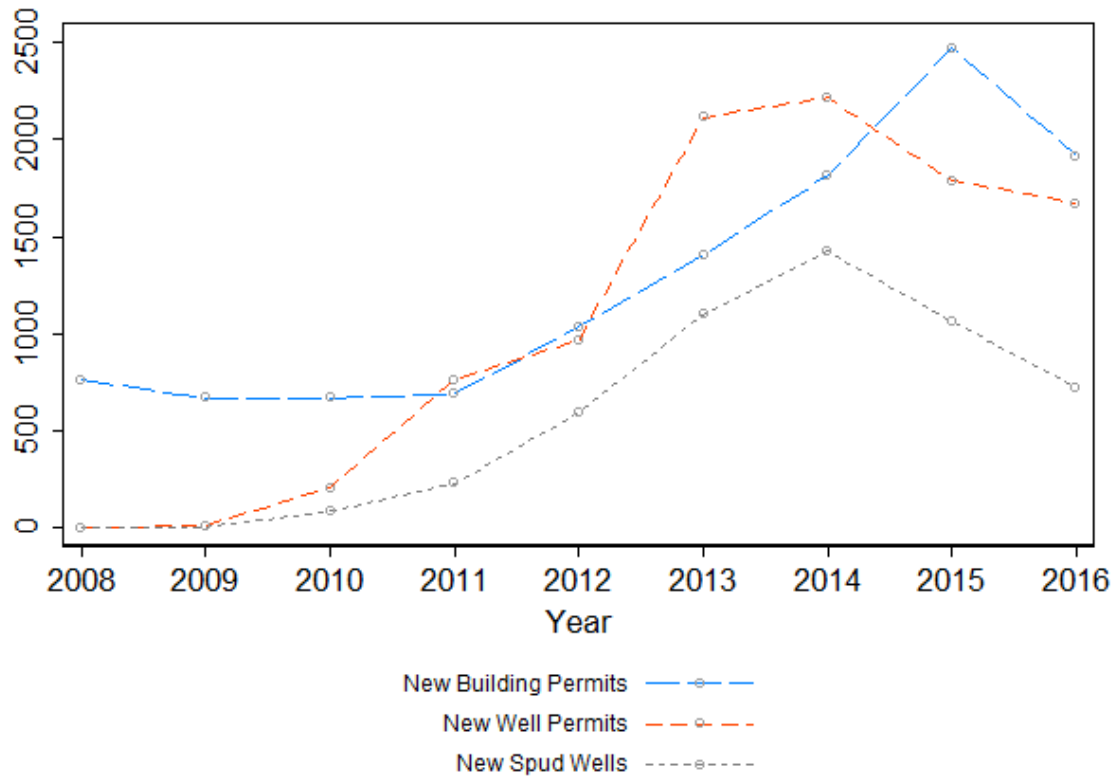
Benefits and Costs of Fracking

- Shale gas benefits:
 - Increase employment in the oil and gas sector
 - Increase tax, lease and royalty payment for governments
 - Generate royalty and lease payments to private property owners
- Shale gas environmental costs:
 - Air pollution: benzene, methane, VOCs, etc.
 - Water contamination: chloride, TSS, etc for groundwater and surface water
 - Congestion, noise pollution etc.
- Local policymakers and voters debate on the potential tradeoff (e.g., see review in Bennett and Loomis 2015)

Previous Hedonic Studies in Weld County

- Prior hedonic pricing method studies used housing data from 2012 and earlier and found negative impacts of shale gas exploration on residential property values.
- Housing value decreased by \$15,000 (roughly 7% of average house price) as its distance to the nearest wells reduces by 1 kilometre (James and James 2014).
- Housing price reduced by \$1,342 - \$1,936 (0.6 – 0.9% of average house value) as the number of wells within a half-mile increase by one during active drilling period in urban areas (Bennett and Loomis 2015).

Motivation



Sources: Reported building permits for new home construction in Weld County obtained from U.S. Census Bureau. Newly approved shale gas permits and newly spud shale gas wells in Weld County are obtained from Colorado Oil & Gas Conservation Commission (COGCC).

Research Question

- What's the impact of shale gas activities on proximate residential property values in Weld County, CO?
 - Did the negative impacts found in previous literature grow stronger *after* 2012?

Data

1. Housing Transactions from October 20, 2014 to March 1, 2017 in Weld County, CO -- Weld County Assessor
2. Well permits approved between April 21, 2014 and July 28, 2017 -- Colorado Oil & Gas Conservation Commission
3. Designated Basin and Ground Water Management Area -- Colorado Ground Water Commission

Empirical Methodology -- Hedonic Pricing Method

- $P_{ijt} = \beta_0 + \beta_1 X_i + \beta_2 \alpha_j * \varphi_t + \gamma E_{ij} + \varepsilon_{ijt}$
 - i : property
 - j : census tract
 - t : year
 - X_i : control variables (housing characteristics, etc.)
 - $\alpha_j * \varphi_t$: census tract by year fixed effects
 - E_{ij} : the total number of approved well permits within a specific distance from a property and time window prior to its sales date
- Hypotheses
 - Ho: $\gamma = 0$
 - Ha: $\gamma < 0$

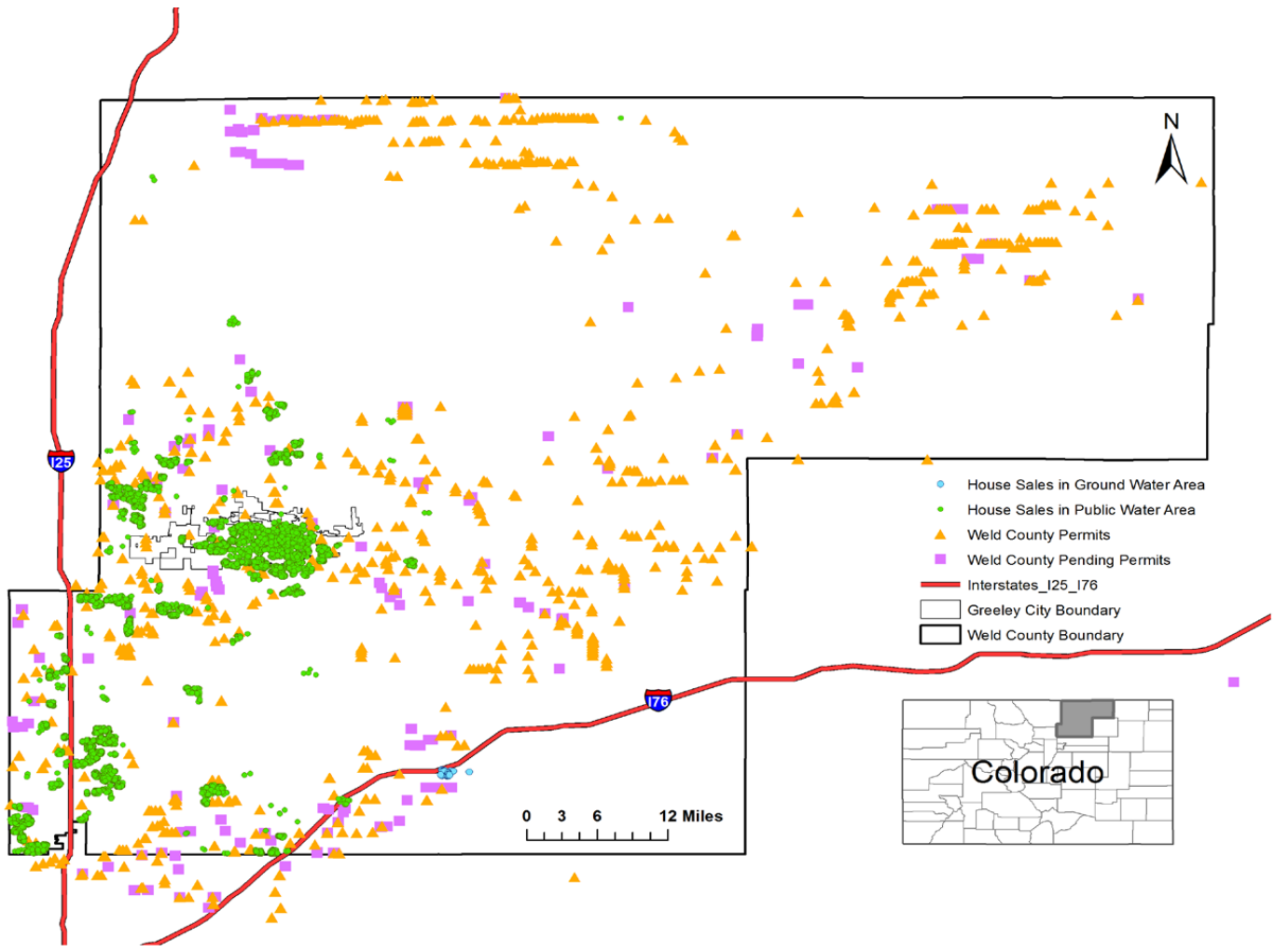
Spatial Temporal Variations of Well Permits

Table 2 Spatial and Temporal Variations of Permitted Wells

PERMIT	Distance Buffer (miles)	Time Window (months)	Mean	SD	Min	Max
Permit_05_6	0.5	6	0.13	1.39	0	22
Permit_05_12	0.5	12	0.27	1.95	0	22
Permit_1_6	1	6	1.01	3.71	0	27
Permit_1_12	1	12	2.03	5.52	0	41
Permit_15_6	1.5	6	2.51	5.87	0	59
Permit_15_12	1.5	12	5.13	9.13	0	59
Permit_2_6	2	6	4.68	7.86	0	59
Permit_2_12	2	12	9.41	11.98	0	62

Spatial Autocorrelation of Housing Prices

- $COMPARABLE_i = \sum_{v=1}^n w_{iv} P_v = \sum_{v=1}^n \left[\frac{\frac{1}{d_{iv}}}{\sum_{v=1}^n \frac{1}{d_{iv}}} \right] P_v$
 - P_v : the v th neighbouring house price within a 1.8-mile distance from the subject house i and 6-months prior to its sale date.
 - d_{iv} : the distance between v th neighboring house and i th subject house
 - w_{iv} : the weight of v th neighboring house based on its inverse distance to the i th subject house. (See Can and Megbolugbe 1997)
- $COMPARABLE$ is part of X_i to account for both spatial and temporal autocorrelation.



Sources: House sales were obtained from Weld County Assessor and GIS Departments. Shale gas (pending) permits were obtained from Colorado Oil & Gas Conservation Commission (COGCC).

Table 1 Summary Statistics (N=11,453)

Variable	Description	Mean	SD	Min	Max
PRICE	Sale price (2015 dollars)	290892	88116	20024	1095900
COMPARABLE	Weighted average property prices within 1.8-mile of the subject property and 6-month before its transaction	293722	80337	65000	1094699
SQFT	Property size (squared feet)	1735	571	438	5781
ACRE	Lot size (acres)	0.20	0.23	0.01	9.35
ACRESQ	Squared Lot size	0.10	1.17	0.0001	87.42
BATH	Number of bathrooms	2.70	0.80	1	7
GARAGE	Equal to 1 if property has a garage, 0 otherwise	0.97	0.16	0	1
BALCONY	Equal to 1 if property has a balcony, 0 otherwise	0.19	0.39	0	1
FINBASE	Equal to 1 if property has a finished basement, 0 otherwise	0.37	0.48	0	1
RSTORY1	Equal to 1 if property is a 1 story ranch, 0 otherwise	0.48	0.50	0	1
BILEVEL	Equal to 1 if property is a bi level house, 0 otherwise	0.03	0.16	0	1
HARDBD	Equal to 1 if property is a frame house with hardboard exterior, 0 otherwise	0.43	0.49	0	1
VINYL	Equal to 1 if property is a frame house with vinyl exterior, 0 otherwise	0.05	0.22	0	1
MASONRY	Equal to 1 if property is a frame house with masonry veneer exterior, 0 otherwise	0.05	0.21	0	1
AGE	Age of property (years)	17.03	23.16	0	166
NEW	Equal to 1 if property is sold in the same year as being built, 0 otherwise	0.20	0.40	0	1
INDISTRD	Inverse of minimum distance to US highway or Interstate (1/miles)	2.28	69.14	0.04	7114.86
EMPLOYMENT	Monthly employee counts of oil and gas extraction sector in Weld County	1108	21	1081	1152

Table 3 Full Sample Analysis (N = 11,453, R-squared = 0.92)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	0.5 Mile 6 Month	0.5 Mile 12 Month	1 Mile 6 Month	1 Mile 12 Month	1.5 Mile 6 Month	1.5 Mile 12 Month	2 Mile 6 Month	2 Mile 12 Month
SQFT	57.60*** (2.124)	57.60*** (2.130)	57.59*** (2.127)	57.61*** (2.125)	57.63*** (2.108)	57.67*** (2.080)	57.60*** (2.120)	57.61*** (2.108)
ACRE	33,539*** (7,751)	33,515*** (7,733)	33,525*** (7,737)	33,446*** (7,743)	33,575*** (7,701)	33,448*** (7,710)	33,592*** (7,711)	33,505*** (7,716)
ACRESQ	-4,133*** (1,560)	-4,130*** (1,556)	-4,129*** (1,559)	-4,120** (1,560)	-4,137*** (1,557)	-4,122** (1,561)	-4,140*** (1,559)	-4,131*** (1,560)
BATH	7,372*** (697.7)	7,379*** (698.7)	7,395*** (699.8)	7,388*** (700.2)	7,399*** (701.2)	7,382*** (694.9)	7,378*** (699.2)	7,369*** (697.5)
GARAGE	11,065*** (2,052)	11,054*** (2,056)	11,103*** (2,047)	11,093*** (2,045)	11,148*** (2,059)	11,126*** (2,067)	11,096*** (2,055)	11,089*** (2,059)
BALCONY	4,149*** (1,240)	4,138*** (1,240)	4,119*** (1,243)	4,121*** (1,245)	4,133*** (1,251)	4,154*** (1,251)	4,155*** (1,254)	4,169*** (1,258)
FINBASE	14,598*** (1,269)	14,602*** (1,274)	14,611*** (1,275)	14,628*** (1,275)	14,593*** (1,272)	14,620*** (1,265)	14,592*** (1,271)	14,617*** (1,269)
RSTORY1	23,316*** (1,789)	23,320*** (1,790)	23,305*** (1,790)	23,306*** (1,790)	23,350*** (1,785)	23,344*** (1,780)	23,333*** (1,792)	23,315*** (1,790)

Notes: All the regressions use linear sale prices as dependent variables. They include year by census tract fixed effects. Robust standard errors clustered by census tract. *** p<0.01, ** p<0.05, * p<0.1

Table 3 Continued Full Sample Analysis (N = 11,453, R-squared = 0.92)

VARIABLES	(1) 0.5 Mile 6 Month	(2) 0.5 Mile 12 Month	(3) 1 Mile 6 Month	(4) 1 Mile 12 Month	(5) 1.5 Mile 6 Month	(6) 1.5 Mile 12 Month	(7) 2 Mile 6 Month	(8) 2 Mile 12 Month
BILEVEL	20,653*** (2,308)	20,675*** (2,312)	20,716*** (2,313)	20,720*** (2,299)	20,734*** (2,296)	20,707*** (2,295)	20,681*** (2,306)	20,639*** (2,318)
HARDBD	-4,435** (1,688)	-4,448** (1,691)	-4,431** (1,683)	-4,459*** (1,674)	-4,461*** (1,665)	-4,498*** (1,640)	-4,444*** (1,679)	-4,451*** (1,682)
VINYL	-5,549*** (1,996)	-5,557*** (1,998)	-5,511*** (1,989)	-5,479*** (1,984)	-5,554*** (1,996)	-5,579*** (1,990)	-5,553*** (1,998)	-5,562*** (2,002)
MASONRY	-5,686** (2,217)	-5,704** (2,233)	-5,635** (2,202)	-5,651** (2,208)	-5,743** (2,196)	-5,733** (2,182)	-5,729** (2,194)	-5,801*** (2,194)
AGE	-333.9*** (46.64)	-334.0*** (46.78)	-333.8*** (46.90)	-333.4*** (47.02)	-333.0*** (46.73)	-332.4*** (46.94)	-333.3*** (46.90)	-332.6*** (47.11)
NEW	3,854 (2,887)	3,877 (2,878)	3,939 (2,844)	3,949 (2,827)	3,910 (2,859)	3,962 (2,832)	3,861 (2,888)	3,894 (2,862)
INDISTRD	2.871*** (0.444)	2.869*** (0.443)	2.874*** (0.441)	2.867*** (0.439)	2.874*** (0.441)	2.877*** (0.442)	2.868*** (0.441)	2.871*** (0.443)
COMPARABLE	0.659*** (0.0276)	0.659*** (0.0276)	0.659*** (0.0276)	0.659*** (0.0277)	0.659*** (0.0274)	0.659*** (0.0274)	0.659*** (0.0273)	0.659*** (0.0275)
PERMIT	-133.5 (379.0)	-171.1 (300.8)	-189.1 (194.2)	-140.7 (125.9)	-120.9 (97.42)	-116.3 (87.48)	-45.72 (64.12)	-55.91 (51.44)

Notes: All the regressions use linear sale prices as dependent variables. They include year by census tract fixed effects. Robust standard errors clustered by census tract. *** p<0.01, ** p<0.05, * p<0.1

Table 3 Continued Full Sample Analysis (N = 11,453, R-squared = 0.92)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	0.5 Mile 6 Month	0.5 Mile 12 Month	1 Mile 6 Month	1 Mile 12 Month	1.5 Mile 6 Month	1.5 Mile 12 Month	2 Mile 6 Month	2 Mile 12 Month
BILEVEL	20,653*** (2,308)	20,675*** (2,312)	20,716*** (2,313)	20,720*** (2,299)	20,734*** (2,296)	20,707*** (2,295)	20,681*** (2,306)	20,639*** (2,318)
HARDBD	-4,435** (1,688)	-4,448** (1,691)	-4,431** (1,683)	-4,459*** (1,674)	-4,461*** (1,665)	-4,498*** (1,640)	-4,444*** (1,679)	-4,451*** (1,682)
VINYL	-5,549*** (1,996)	-5,557*** (1,998)	-5,511*** (1,989)	-5,479*** (1,984)	-5,554*** (1,996)	-5,579*** (1,990)	-5,553*** (1,998)	-5,562*** (2,002)
MASONRY	-5,686** (2,217)	-5,704** (2,233)	-5,635** (2,202)	-5,651** (2,208)	-5,743** (2,196)	-5,733** (2,182)	-5,729** (2,194)	-5,801*** (2,194)
AGE	-333.9*** (46.64)	-334.0*** (46.78)	-333.8*** (46.90)	-333.4*** (47.02)	-333.0*** (46.73)	-332.4*** (46.94)	-333.3*** (46.90)	-332.6*** (47.11)
NEW	3,854 (2,887)	3,877 (2,878)	3,939 (2,844)	3,949 (2,827)	3,910 (2,859)	3,962 (2,832)	3,861 (2,888)	3,894 (2,862)
INDISTRD	2.871*** (0.444)	2.869*** (0.443)	2.874*** (0.441)	2.867*** (0.439)	2.874*** (0.441)	2.877*** (0.442)	2.868*** (0.441)	2.871*** (0.443)
COMPARABLE	0.659*** (0.0276)	0.659*** (0.0276)	0.659*** (0.0276)	0.659*** (0.0277)	0.659*** (0.0274)	0.659*** (0.0274)	0.659*** (0.0273)	0.659*** (0.0275)
PERMIT	-133.5 (379.0)	-171.1 (300.8)	-189.1 (194.2)	-140.7 (125.9)	-120.9 (97.42)	-116.3 (87.48)	-45.72 (64.12)	-55.91 (51.44)

Notes: All the regressions use linear sale prices as dependent variables. They include year by census tract fixed effects. Robust standard errors clustered by census tract. *** p<0.01, ** p<0.05, * p<0.1

Table 3 Continued Full Sample Analysis (N = 11,453, R-squared = 0.92)

VARIABLES	(1) 0.5 Mile 6 Month	(2) 0.5 Mile 12 Month	(3) 1 Mile 6 Month	(4) 1 Mile 12 Month	(5) 1.5 Mile 6 Month	(6) 1.5 Mile 12 Month	(7) 2 Mile 6 Month	(8) 2 Mile 12 Month
BILEVEL	20,653*** (2,308)	20,675*** (2,312)	20,716*** (2,313)	20,720*** (2,299)	20,734*** (2,296)	20,707*** (2,295)	20,681*** (2,306)	20,639*** (2,318)
HARDBD	-4,435** (1,688)	-4,448** (1,691)	-4,431** (1,683)	-4,459*** (1,674)	-4,461*** (1,665)	-4,498*** (1,640)	-4,444*** (1,679)	-4,451*** (1,682)
VINYL	-5,549*** (1,996)	-5,557*** (1,998)	-5,511*** (1,989)	-5,479*** (1,984)	-5,554*** (1,996)	-5,579*** (1,990)	-5,553*** (1,998)	-5,562*** (2,002)
MASONRY	-5,686** (2,217)	-5,704** (2,233)	-5,635** (2,202)	-5,651** (2,208)	-5,743** (2,196)	-5,733** (2,182)	-5,729** (2,194)	-5,801*** (2,194)
AGE	-333.9*** (46.64)	-334.0*** (46.78)	-333.8*** (46.90)	-333.4*** (47.02)	-333.0*** (46.73)	-332.4*** (46.94)	-333.3*** (46.90)	-332.6*** (47.11)
NEW	3,854 (2,887)	3,877 (2,878)	3,939 (2,844)	3,949 (2,827)	3,910 (2,859)	3,962 (2,832)	3,861 (2,888)	3,894 (2,862)
INDISTRD	2.871*** (0.444)	2.869*** (0.443)	2.874*** (0.441)	2.867*** (0.439)	2.874*** (0.441)	2.877*** (0.442)	2.868*** (0.441)	2.871*** (0.443)
COMPARABLE	0.659*** (0.0276)	0.659*** (0.0276)	0.659*** (0.0276)	0.659*** (0.0277)	0.659*** (0.0274)	0.659*** (0.0274)	0.659*** (0.0273)	0.659*** (0.0275)
PERMIT	-133.5 (379.0)	-171.1 (300.8)	-189.1 (194.2)	-140.7 (125.9)	-120.9 (97.42)	-116.3 (87.48)	-45.72 (64.12)	-55.91 (51.44)

Notes: All the regressions use linear sale prices as dependent variables. They include year by census tract fixed effects. Robust standard errors clustered by census tract. *** p<0.01, ** p<0.05, * p<0.1

Table 4 Full Sample Temporal Variations at 2-Mile (N = 11,453, R-squared = 0.92)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	2 Mile 6 Month	2 Mile 9 Month	2 Mile 12 Month	2 Mile 15 Month	2 Mile 18 Month	2 Mile 21 Month	2 Mile 24 Month	2 Mile 26 Month
PERMIT	-45.72 (64.12)	-30.47 (43.47)	-55.91 (51.44)	-17.45 (53.19)	1.676 (55.67)	-16.71 (57.30)	1.376 (57.55)	-2.595 (57.21)

Notes: All the regressions use linear sale prices as dependent variables. They include year by census tract fixed effects. Robust standard errors clustered by census tract. *** p<0.01, ** p<0.05, * p<0.1

Subsample around Pending Permits

- Unobserved heterogeneity between properties near wells and not might exist
 - Time-invariant (i.e., different landscapes)
 - Time-varying (i.e., changed local economic activities)
- To account for these heterogeneity, we restrict our sample to properties within 2-miles of a pending permit for a subsample analysis.
- Pending well permits applied between February 25, 2015 and July 27, 2017 -- Colorado Oil & Gas Conservation Commission

Table 5 Subsample Analysis (N = 5,060, R-squared = 0.90)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	0.5 Mile 6 Month	0.5 Mile 12 Month	1 Mile 6 Month	1 Mile 12 Month	1.5 Mile 6 Month	1.5 Mile 12 Month	2 Mile 6 Month	2 Mile 12 Month
PERMIT	-113.9 (475.9)	-87.48 (397.0)	-363.4 (299.3)	-177.5 (196.2)	-269.5 (176.4)	-230.8 (193.3)	-92.05 (115.3)	-65.17 (82.14)

Notes: All the regressions use linear sale prices as dependent variables. They all include year by census tract fixed effects. Robust standard errors clustered by census tract. *** p<0.01, ** p<0.05, * p<0.1

Table 6 Subsample Temporal Variations at 2-Mile (N = 5,060, R-squared = 0.90)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	2 Mile 6 Month	2 Mile 9 Month	2 Mile 12 Month	2 Mile 15 Month	2 Mile 18 Month	2 Mile 21 Month	2 Mile 24 Month	2 Mile 26 Month
PERMIT	-92.05 (115.3)	-37.14 (71.65)	-65.17 (82.14)	-35.28 (88.15)	-61.10 (89.20)	-71.63 (83.74)	-39.29 (85.93)	-31.58 (87.36)

Notes: All the regressions use linear sale prices as dependent variables. They all include year by census tract fixed effects. Robust standard errors clustered by census tract. *** p<0.01, ** p<0.05, * p<0.1

Employment of Oil and Gas Extraction Sector

- Rising jobs in oil and gas sector might increase the demand for housing in the local area, thus raising housing prices (Bennett and Loomis 2015).
- Monthly employment counts in the oil and gas extraction sector in Weld County from Bureau of Labor Statistics was matched to house sales 60 days later
- If our result is robust, then we would expect no change to the sign and significance of the estimated coefficient of interest, γ .

Table 7 Employment Effect Using Full Sample (N = 11,453, R-squared = 0.92)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	0.5 Mile 6 Month	0.5 Mile 12 Month	1 Mile 6 Month	1 Mile 12 Month	1.5 Mile 6 Month	1.5 Mile 12 Month	2 Mile 6 Month	2 Mile 12 Month
EMPLOYMENT	-65.28*** (16.67)	-65.06*** (16.67)	-64.85*** (16.78)	-65.33*** (16.83)	-64.23*** (16.96)	-65.83*** (16.88)	-64.78*** (16.73)	-65.79*** (16.77)
PERMIT	-108.9 (355.9)	-149.8 (289.1)	-180.4 (191.0)	-139.3 (122.0)	-108.4 (94.38)	-118.6 (86.86)	-32.03 (59.99)	-58.48 (51.80)

Notes: All the regressions use linear sale prices as dependent variables. They all include year by census tract fixed effects. Robust standard errors clustered by census tract. *** p<0.01, ** p<0.05, * p<0.1

Case of Missing Externality

- Expected a substantial increase in negative externalities from shale exploration *after* 2012, because of much high levels of
 - shale gas production, well-preparation activities
 - population growth, new housing construction
- However, our HPM model does not support this expectation
 - With data from October 20th, 2014 to March 1st, 2017, the effect of well-permitting shows no evidence of negative externalities on home prices, regardless of the utilized spatial and temporal cut-offs.
- We call this a “case of missing externality”

Coase Theorem

- “It is always possible to modify by transactions on the market the initial legal delimitation of rights. And, of course, if such market transactions are costless, such a rearrangement of rights will always take place if it will lead to an increase in the value of production.” -----
-- (Coase 1960, p. 15)
- Induced equilibrium is capable of weakly pareto-dominating the original Nash equilibrium between parties without side payments (Bigelow 1993).

Descriptive Evidence of Side Payments

- Side payments could be
 - Property owners (lessors) receiving bonus payments or expecting to receive lease payments from oil and gas companies (lessees)
 - Compensation received from the lessee accessing subsurface minerals from surface area
- Local landowners could receive from several dollars to thousands of dollars per acre bonus payments, upon signing a lease with oil and gas companies (Brasier et al. 2011; Muehlenbachs, Spiller, and Timmins 2012).

Public Support Against Fracking Muted

- 2016.3, the Greeley City Council reversed the Planning Commission's denial to a permit to drill 22 wells west of the city.
 - This reversal protected the private property rights of 1,800 citizens with mineral rights in Greeley (Aguilar 2016).
- 2016.11, Weld County commissioners created a county permit for oil and gas projects in the unincorporated Weld County
 - Oil and gas companies are no longer required to have landowners signed off (hold public hearing in most cases), even if wells are near homes or schools (Sweeney 2016).

Public Support Against Fracking Muted

- 2016.4, House Bill 1355 was voted down by the Colorado House of Representatives
 - It would give local governments the ability to exercise land use authority over fracking (Alford 2016).
- 2016.8, Ballot Initiative #78 couldn't make the November 2016 state ballot.
 - It proposed to shift control of oil and gas development to local government, and add a mandatory setback zone of 2,500 feet around occupied buildings and in open public spaces, making roughly 90% of surface acreage in Colorado (85% of surface acreage in Weld County) unavailable for future oil and gas facility development (Alford 2016).