

The Local Economic and Welfare Consequences of Hydraulic Fracturing

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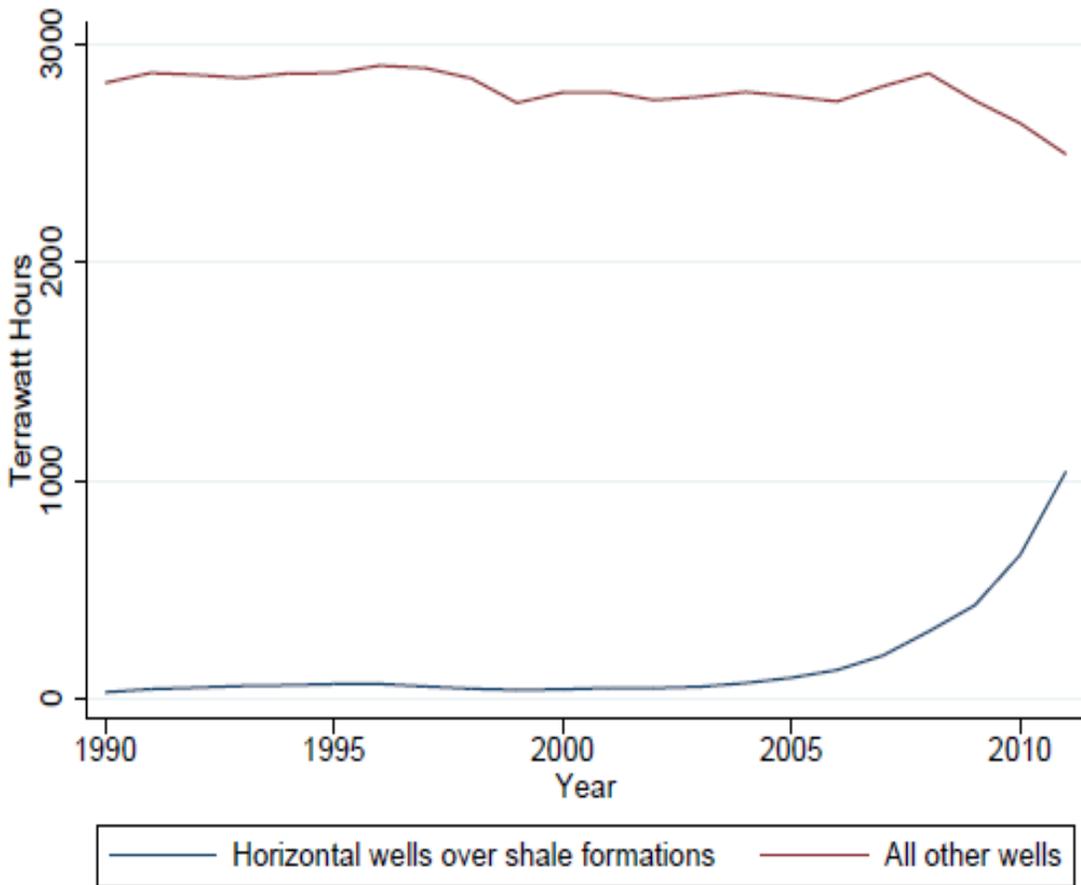
Policies Permitting or Banning Polluting Industries are Among the Most Important Place-Based Policies

- A large literature documents negative health effects, especially for children and the elderly.
- There is still much uncertainty about exact magnitudes and scope of the effects.
- Industry brings jobs, higher property values, spillover effects.

This Study: Investigates the Local Costs and Benefits of Fracking

- Interesting in part because it is a new industry often coming into poor largely rural locations.
- Drilling brings royalty payments and economic activity.
- But also concerns about quality of life, pollution, congestion, crime.
- Substantial heterogeneity in communities' reactions
 - Pennsylvania, Texas, and North Dakota embrace fracking.
 - New York, New Jersey, Vermont, and some countries such as Germany and France, have banned it.

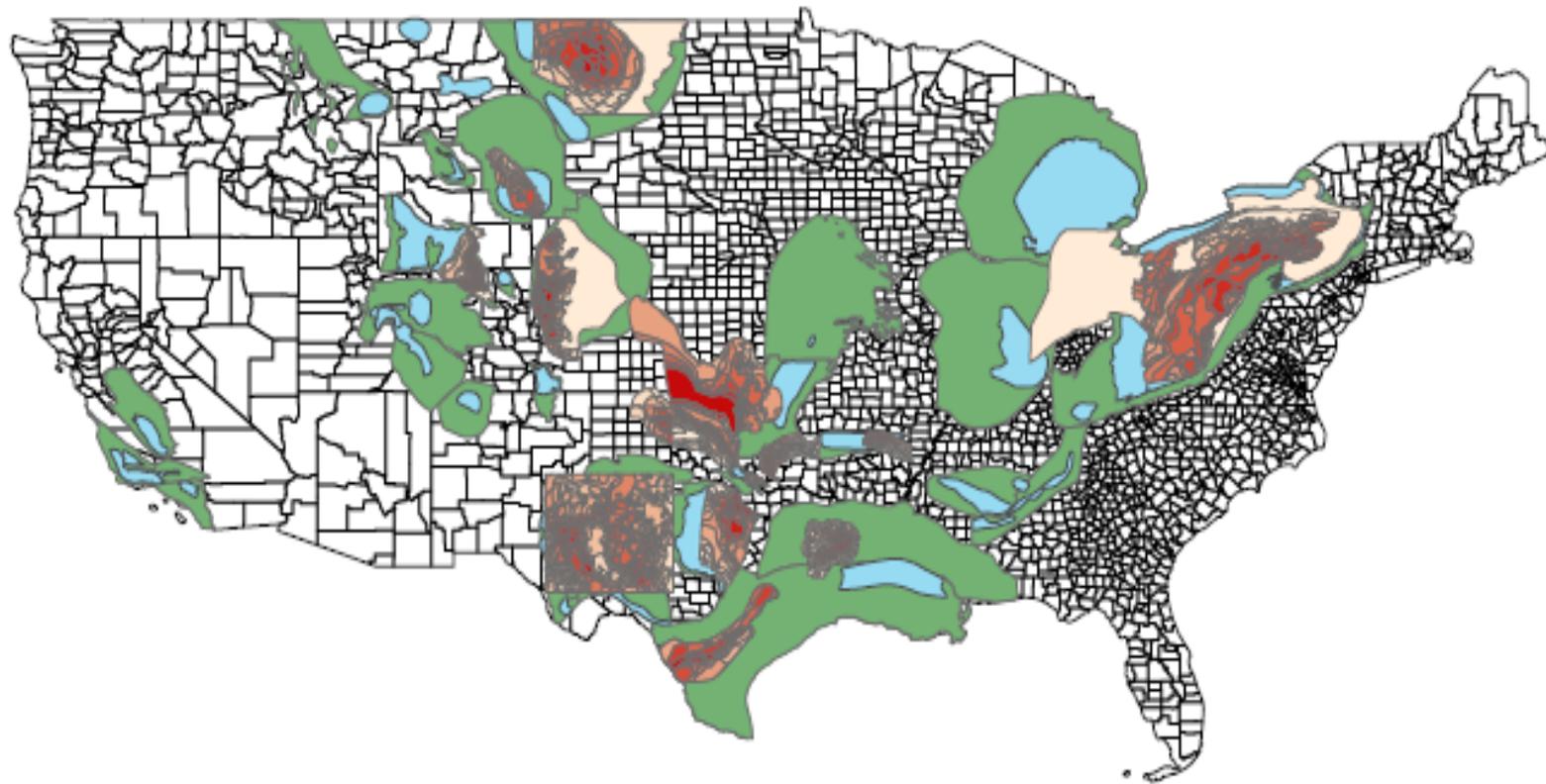
Figure 1: Hydrocarbon production from horizontal wells over shale play



Difficult to Identify the Effects of Fracking

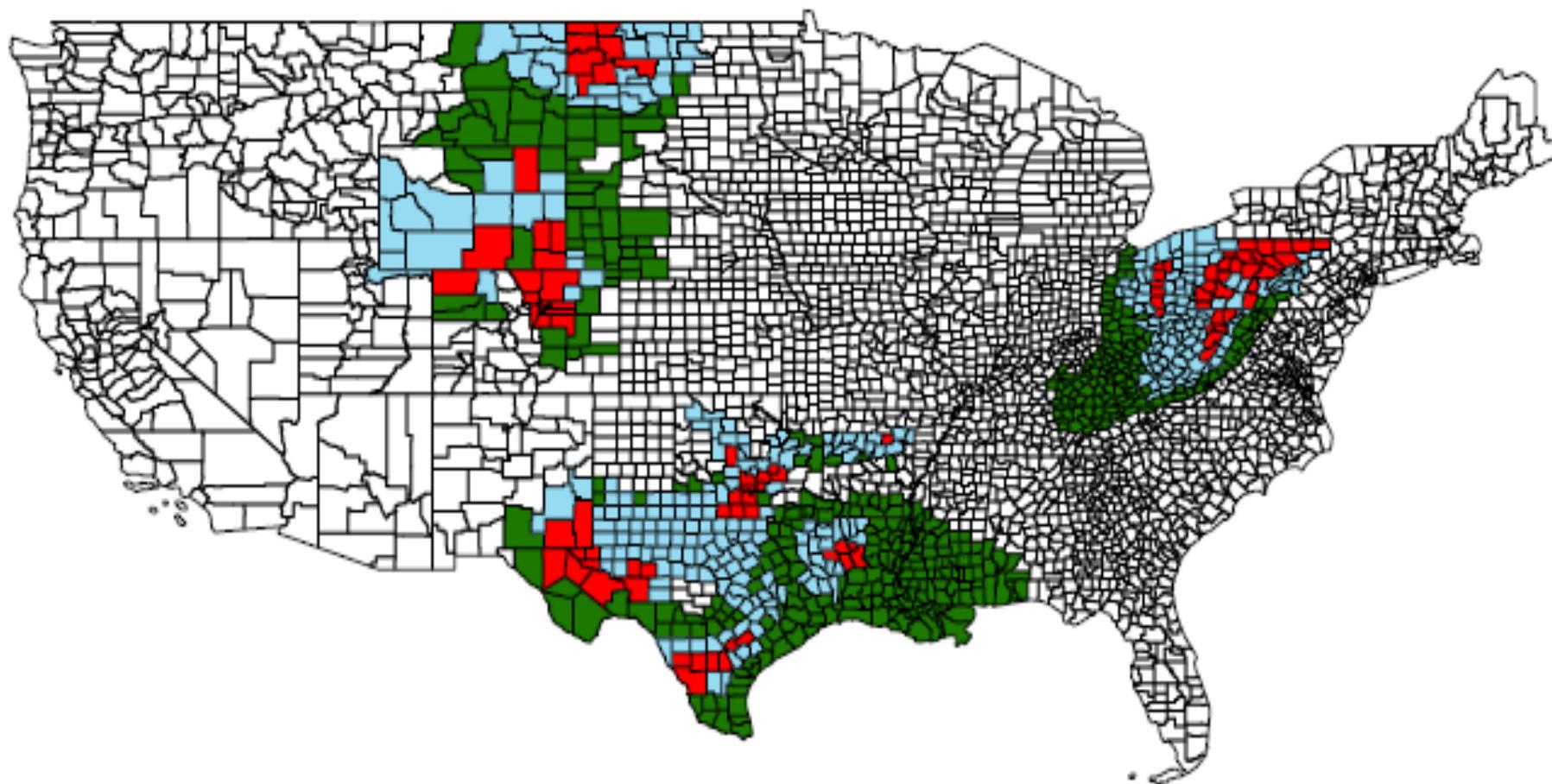
- Many underlying differences between communities with and without
- We use underlying geology to predict fracking activity
 - thickness, depth, and thermal maturity of the shale deposit
 - Use prospectivity index from Rystad Energy, an international oil and gas consulting company
- Also differences in timing of exploitation of deposits

Figure 2: Shale basins, plays, and prospectivity scores



- Aggregate the Rystad prospectivity measure to the county level by computing the maximum Rystad score within each county.
- Divide counties within a shale play into Rystad score quartiles.
- Use the maximum prospectivity score in each county because the quality of a county's best resources impacts hydrocarbon production more than the average quality.
- We also explored the sensitivity of the results to alternative measures of fracking exposure.

Figure 3: County prospectivity score classifications



Compare to previous research designs:

- The fracking literature generally compares areas over shale formations to areas without shale formations underneath them (see e.g., Cascio and Narayan (2015); Fetzer (2015); Manilo and Mastromonaco (2014); Weber (2012); Weinstein (2014)).
- But these places differ in many ways.
- Boslett et al. (2015) compare border areas in Pennsylvania where fracking has been embraced versus New York where it has been banned.

Table 1: Treatment and control counties by shale basin

Shale Play	Shale Basin	Play First Frac Year	Top Quartile Counties	Outside Top Quartile Counties
(1)	(2)	(3)	(4)	(5)
Woodford-Anadarko	Anadarko	2008	1	10
Marcellus	Appalachian	2008	28	95
Utica	Appalachian	2012	7	18
Woodford-Ardmore	Ardmore	2007	4	5
Fayetteville	Arkoma	2005	1	13
Woodford-Arkoma	Arkoma	2006	2	7
Niobrara-Denver	Denver	2010	13	4
Barnett	Forth Worth	2001	5	41
Niobrara-Greater Green River	Greater Green River	2012	2	9
Permian All Plays	Permian	2005	11	34
Niobrara-Powder River	Powder River	2010	1	5
Haynesville	TX-LA-MS Salt	2008	5	21
Eagle Ford	Western Gulf	2009	7	21
Bakken	Williston Basin	2007	8	27
Total			95	310

Outcomes

- Total employment and total annual earnings (Bureau of Economic Analysis' Regional Economic and Information Systems (REIS)).
- Wages by industry are (Quarterly Census of Employment and Wages, QCEW).
- Housing price data for 2009-2013 (American Community Survey, ACS); housing price data and #units for previous decades (decennial Census, 1990 and 2000).
- Housing permits (Census Bureau's New Residential Construction data-series).
- Monetary variables inflation adjusted using the Consumer Price Index (CPI) to \$2010.
- Migration data (IRS county-county migration dataset, released as part of the Statistics on Income).

More Outcomes

- Crime data come from FBI (2015) Uniform Crime Reporting program (includes murder, rape, aggravated assault, robbery, burglary, larceny, and motor-vehicle theft).
- Local government spending and revenues from the Census of Governments conducted every 5 years (years ending in 2 and 7).
- School district-level enrollment data from the Common Core.

Table 2: Comparison of pre-trends and levels across treatment and control counties

	Mean Value in US	Basin vs. Rest of US	Play vs. Basin	Rystad Top Quartile vs. Play
	(1)	(2)	(3)	(4)
Panel A: Covariate Balance (All Variables measured in 2000 unless noted)				
<i>Panel A1: Non-Crime Variables</i>				
Log(Real Median Home Values)	11.897	-0.402*** (0.037)	-0.071** (0.031)	0.039 (0.050)
Log(Real Median Home Rental Prices)	6.621	-0.179*** (0.032)	-0.023 (0.030)	0.055 (0.045)
Log(Total Housing Units)	9.427	-0.159*** (0.055)	0.413*** (0.087)	0.082 (0.143)
Log(Total Employment)	9.533	-0.242*** (0.060)	0.402*** (0.104)	0.057 (0.161)
Log(Total Income per capita)	13.594	-0.279*** (0.062)	0.416*** (0.103)	0.032 (0.171)
Share of Population with Bachelor's Degree or more	0.241	-0.041*** (0.010)	0.003 (0.016)	0.042* (0.025)
Share of Population Ages 18-64	0.619	-0.003 (0.003)	-0.011** (0.004)	-0.003 (0.007)
Log(Real Total Government Revenue: 2002 - 1992)	11.512	-0.273*** (0.059)	0.374*** (0.101)	0.050 (0.159)
Log(Real Total Government Expenditures: 2002 - 1992)	11.515	-0.283*** (0.060)	0.373*** (0.102)	0.063 (0.162)
Total Value of Hydrocarbon Production: 2000 - 1992	56.238	81.559*** (19.990)	78.570*** (17.698)	108.280* (58.527)

	Mean Value in US	Basin vs. Rest of US	Play vs. Basin	Rystad Top Quartile vs. Play
	(1)	(2)	(3)	(4)
Panel B: Pre-Trends (Change 1990 - 2000 unless noted)				
<i>Panel B1: Non-Crime Variables</i>				
Log(real median home values)	0.110	0.020 (0.026)	-0.022 (0.014)	-0.011 (0.028)
Log(real median home rental prices)	0.012	0.055*** (0.016)	-0.027*** (0.006)	0.003 (0.008)
Log(Total Housing Units)	0.124	-0.035*** (0.005)	-0.054*** (0.008)	0.009 (0.012)
Log(Total Employment)	0.179	-0.040*** (0.007)	-0.028** (0.012)	0.028* (0.016)
Log(Total Income per capita)	0.268	-0.044*** (0.007)	-0.068*** (0.014)	0.034* (0.018)
Share of Population with Bachelor's Degree or more	0.040	-0.012*** (0.003)	0.002 (0.003)	0.013*** (0.005)
Share of Population Ages 18-64	0.001	0.005*** (0.002)	0.000 (0.003)	-0.006 (0.004)
Log(Real Total Government Revenue: 2002 - 1992)	0.286	-0.063*** (0.011)	-0.113*** (0.019)	0.042 (0.027)
Log(Real Total Government Expenditures: 2002 - 1992)	0.290	-0.029*** (0.011)	-0.124*** (0.020)	0.034 (0.029)
Total Value of Hydrocarbon Production: 2000 - 1992	7.934	6.845* (4.150)	4.036 (7.246)	28.929 (18.096)

When annual data are available, we estimate the following equation for outcome variable y_{cpt} , where the subscripts refer to county (c), shale play (p), and year (t):

$$y_{cpt} = \mu_{pt} + \gamma_c + \delta \left(1[\text{Post Fracing}]_{pt} \cdot 1[\text{Rystad Top Quartile}]_c \right) + \epsilon_{cpt}. \quad (5.1)$$

The specification includes year-by-play, μ_{pt} , and county fixed effects, γ_c . The two key covariates are: 1) $1[\text{Post Fracing}]_{pt}$, which is an indicator that equals 1 in the year that fracing is initiated in shale play p and remains 1 for all subsequent years;³⁷ 2) $1[\text{Rystad Top Quartile}]_c$ is an indicator for whether the maximum prospectivity value within county c is in the top quartile for counties in shale play p . The model is fit on the sample of counties that intersect at least one of the 14 US shale plays listed in Table 1.

Figure 4: Event study analysis of county-level value of hydrocarbons

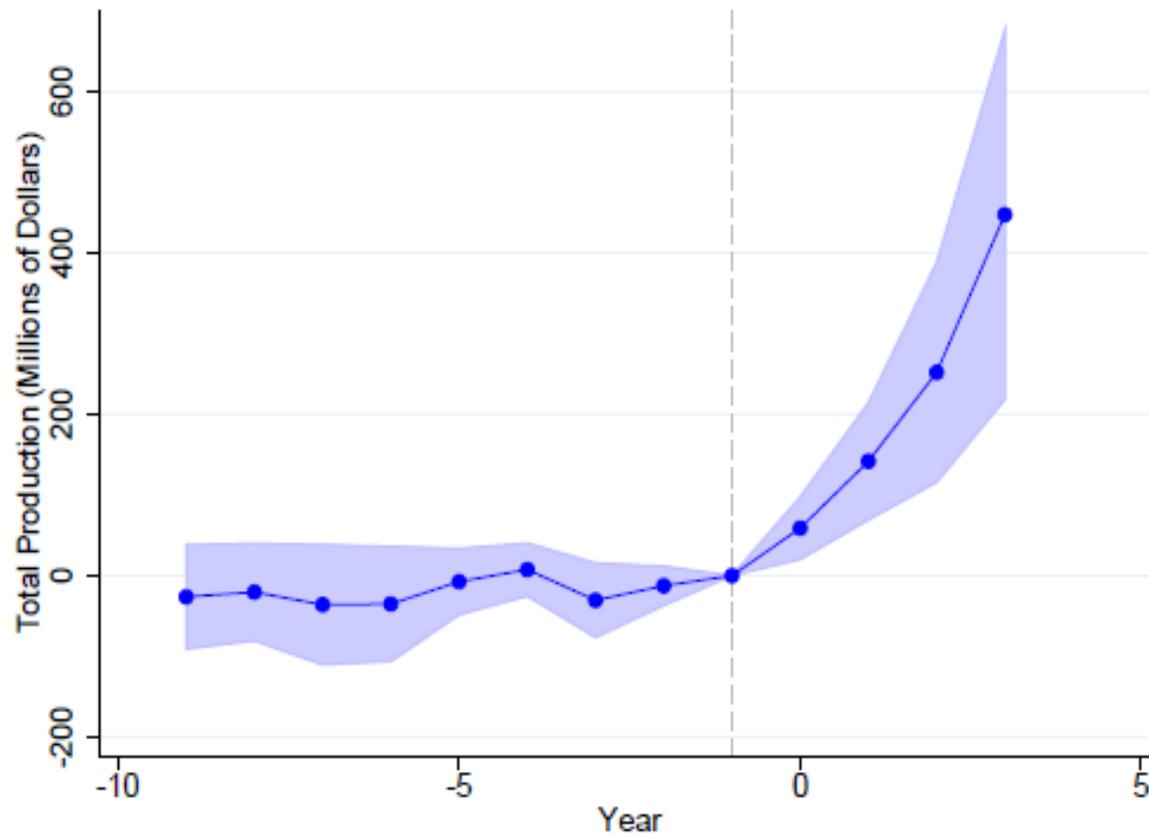
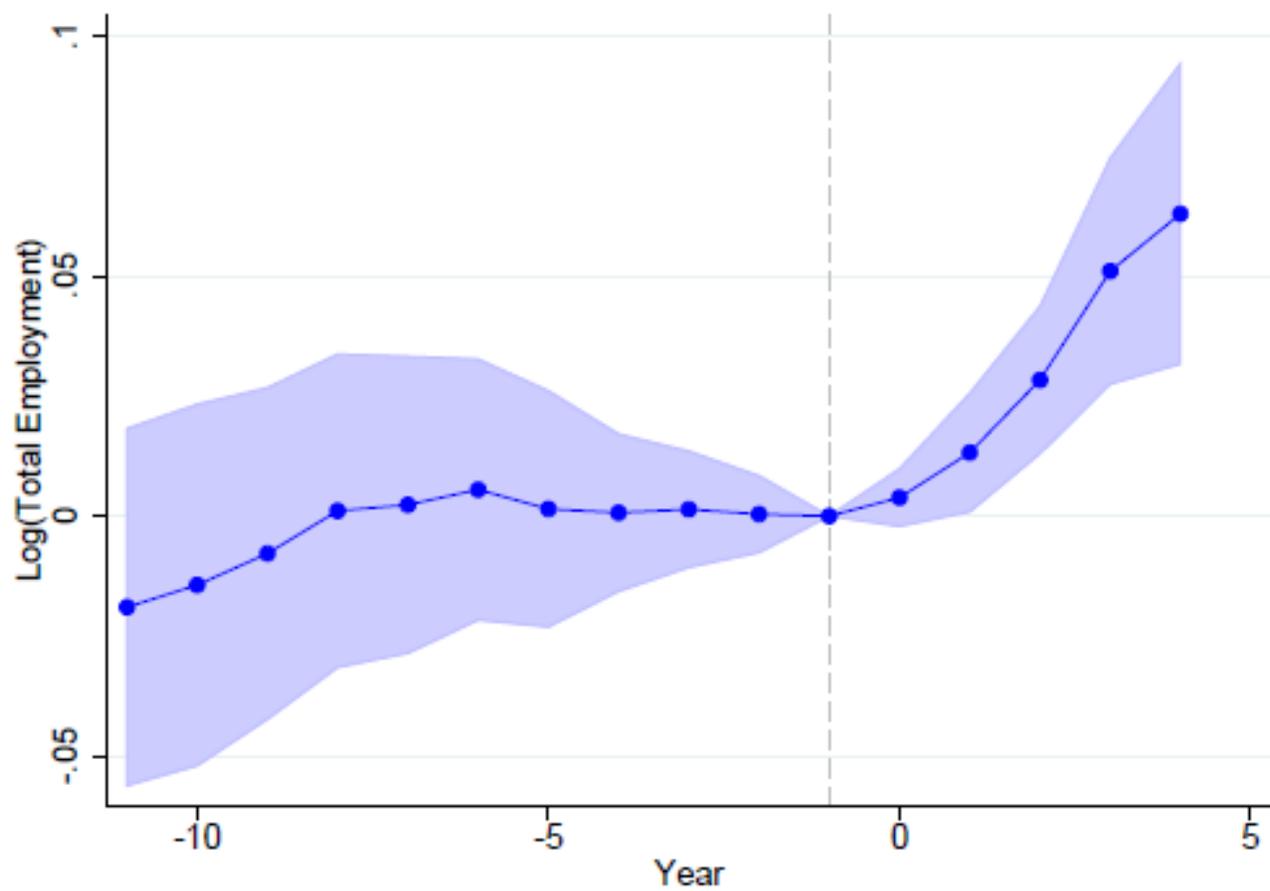


Table 3: Impact of fracing on the value of hydrocarbon production

	(1)	(2)	(3)
Panel A: Total Value of Oil and Gas Production			
1(Fracing Exposure)*1(Post)	242*** (68)	36 (47)	36 (23)
t*1(Fracing Exposure)		3 (6)	
t*1(Fracing Exposure)*1(Post)		124*** (37)	125*** (38)
Fracing Exposure Effect at tau=3	242*** (68)	409*** (123)	410*** (115)
Fracing Exposure Group	Top Quartile	Top Quartile	Top Quartile
Control Group	Quartiles 1-3	Quartiles 1-3	Quartiles 1-3
Fracing Exposure Level Shift	Y	Y	Y
Fracing Exposure Trend	N	Y	Y
Fracing Exposure Trend Break	N	Y	Y
County Fixed Effects	Y	Y	Y
County-Specific Trends	N	N	Y
Year-Play Fixed Effects	Y	Y	Y
Restricted to Balanced Sample	N	N	Y

Figure 5: Event study analysis of total employment



Appendix Figure G.4: Event study analysis of county-level total income

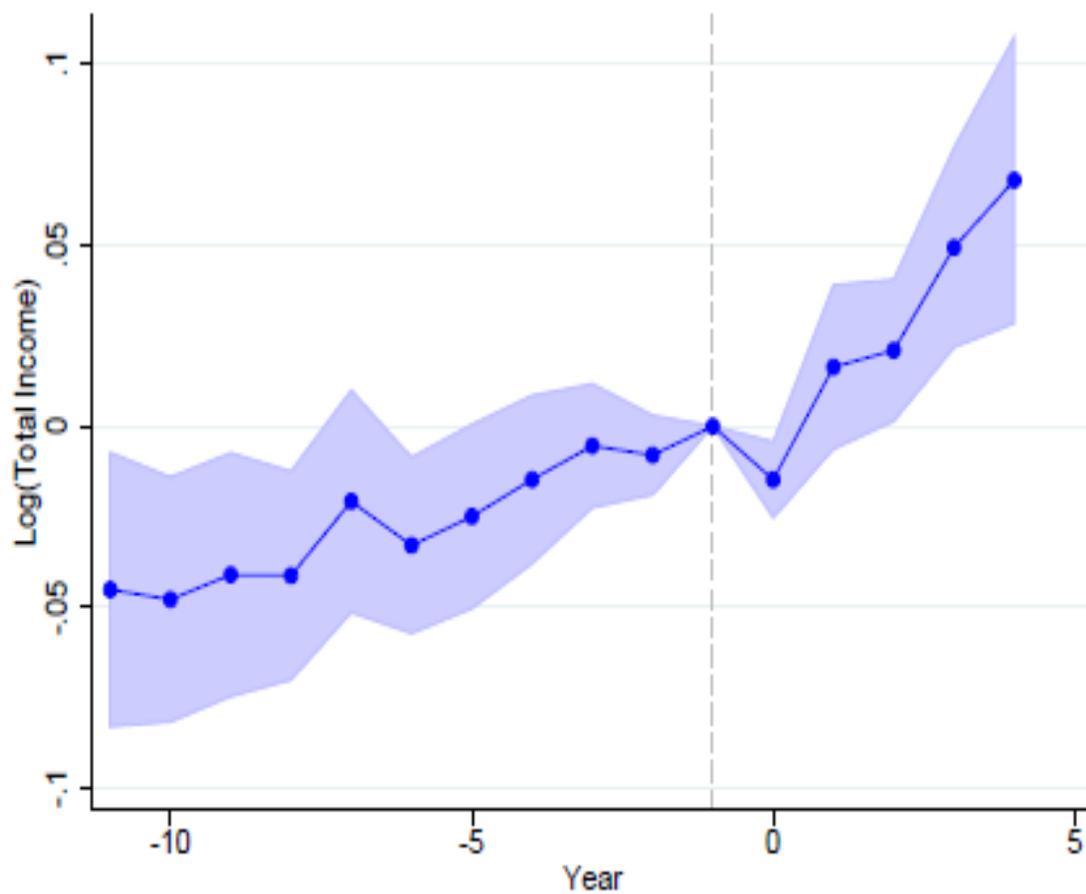
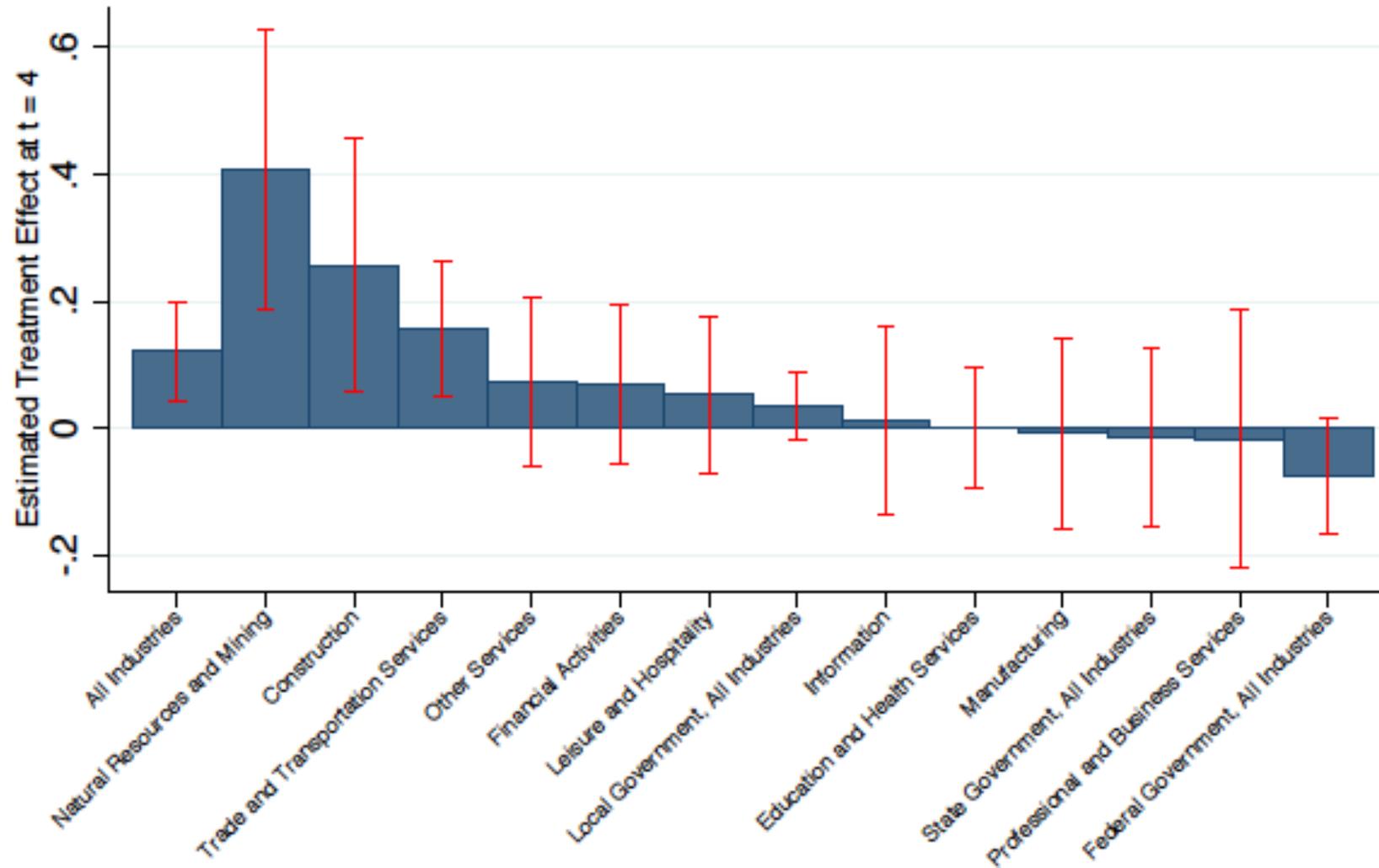


Table 4: Impact of fracing on employment and aggregate income: time-series specifications

	(1)	(2)	(3)
Panel A: Log(Total Employment)			
Fracing Exposure Effect at tau=4	0.036** (0.016)	0.054* (0.029)	0.049*** (0.019)
Panel B: Income			
<i>Log(Total Income)</i>			
Fracing Exposure Effect at tau=4	0.056*** (0.015)	0.069** (0.028)	0.044** (0.021)
<i>B1. Log(Total Wage/Salary Income): 56 percent of total personal income</i>			
Fracing Exposure Effect at tau=4	0.076*** (0.021)	0.130*** (0.035)	0.089*** (0.030)
<i>B2. Log(Total Rents/Dividends): 19 percent of total personal income</i>			
Fracing Exposure Effect at tau=4	0.070*** (0.019)	0.080** (0.038)	0.068** (0.028)
<i>B3. Log(Total Transfers): 10 percent of total personal income</i>			
Fracing Exposure Effect at tau=4	0.012 (0.012)	0.001 (0.020)	-0.005 (0.008)
<i>B4. Log(Total Proprieter's Income): 18 percent of total personal income</i>			
Fracing Exposure Effect at tau=4	0.036 (0.040)	-0.101 (0.064)	-0.041 (0.069)

Effects on Employment by Industry (t=4, percent)



Panel C: Migration

C1. Log(In Migration)

Fracing Exposure Effect at tau=4	0.044** (0.017)	0.073* (0.038)	0.005 (0.042)
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C2. Log(Out Migration)

Fracing Exposure Effect at tau=4	-0.001 (0.013)	0.007 (0.031)	-0.047 (0.035)
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Fracing Exposure Group	Top Quartile	Top Quartile	Top Quartile
Control Group	Quartiles 1-3	Quartiles 1-3	Quartiles 1-3
Fracing Exposure Level Shift	Y	Y	Y
Fracing Exposure Trend	N	Y	Y
Fracing Exposure Trend Break	N	Y	Y
County Fixed Effects	Y	Y	Y
County-Specific Trends	N	N	Y
Year-Play Fixed Effects	Y	Y	Y
Restricted to Balanced Sample	N	N	Y

The Impact of Fracking on Local Expenditures, 2002-2012

A1. Direct Expenditures by Type

A1a. Log(Current Operating Expenditure):

[84%]

0.107***

(0.028)

A1b. Log(Capital Outlays):

[12%]

0.181

(0.135)

The Impact of Fracking on Local Expenditures, 2002-2012

A2. Direct Expenditures by Purpose

A2a. Log(Education Expenditures): [48%]	0.025 (0.032)
A2b. Log(Public Safety Expenditures): [8%]	0.195*** (0.063)
A2c. Log(Welfare and Hospital Expenditures): [10%]	0.240 (0.154)
A2d. Log(Infrastructure and Utility Expenditures): [18%]	0.242*** (0.071)
A2e. Log(Other Expenditures): [16%]	0.122* (0.063)

The Impact of Fracking on Local Revenues, 2002-2012

B1a. Log(Property Tax Revenues): [24%]	0.133*** (0.042)
B1b. Log(Sales Tax Revenues): [4%]	0.594*** (0.120)
B1c. Log(Other Tax Revenues): [2%]	0.038 (0.155)
B1d. Log(Intergovernmental Revenues): [42%]	0.100 (0.081)
B1e. Log(Charges Revenues): [14%]	0.095 (0.079)
B1f. Log(Other Revenues): [14%]	0.261*** (0.066)

Table 7: Impact of fracing on housing outcomes

	(1)
Panel A: House Values	
A1. Log(Median House Value)	0.057*** (0.018)
A2. Log(Mean Housing Value)	0.057*** (0.018)
A3. Log(Mobile Housing Units: Median Housing Value)	0.079** (0.037)
Panel B: Rental Prices	
B1. Log(Median Rental Price)	0.020* (0.010)
B2. Log(Mean Rental Price)	0.029*** (0.011)
Panel C: Housing Quantities	
C1. Log(Total Housing Units)	0.011 (0.012)

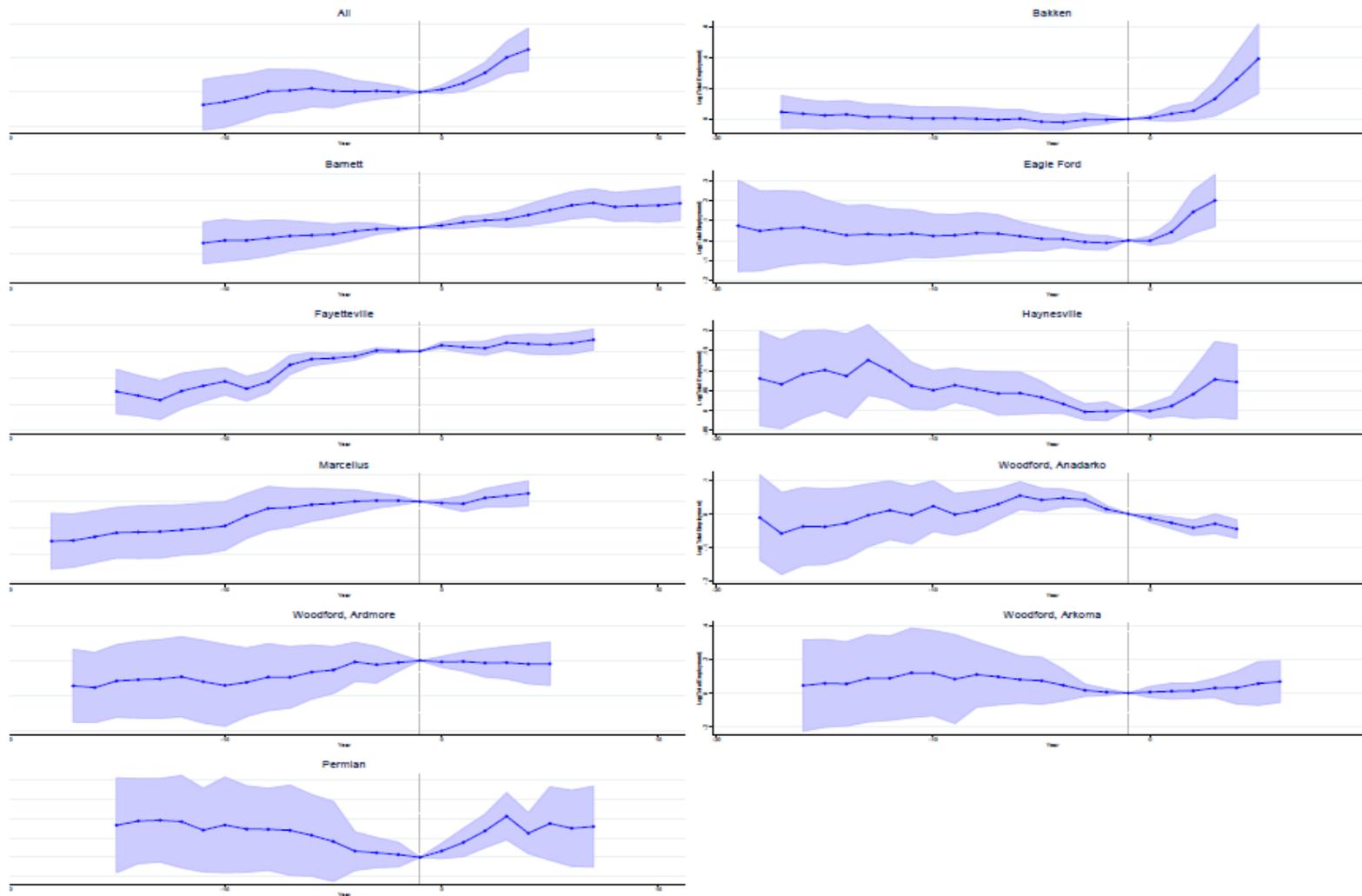
Table 8: Impact of fracing on crime

	(1)	(2)	(3)
Panel A: Log(Total Crime)			
Top Quartile Effect at tau=5	0.072 (0.056)	-0.042 (0.082)	-0.004 (0.101)
Panel B: Log(Violent Crime)			
Top Quartile Effect at tau=5	0.116* (0.068)	0.208* (0.124)	0.109 (0.142)
Panel C: Log(Property Crime)			
Top Quartile Effect at tau=5	0.065 (0.057)	-0.057 (0.087)	0.000 (0.106)
Fracing Exposure Group	Top Quartile	Top Quartile	Top Quartile
Control Group	Quartiles 1-3	Quartiles 1-3	Quartiles 1-3
Fracing Exposure Level Shift	Y	Y	Y
Fracing Exposure Trend	N	Y	Y
Fracing Exposure Trend Break	N	Y	Y
County Fixed Effects	Y	Y	Y
County-Specific Trends	N	N	Y
Year-Play Fixed Effects	Y	Y	Y
Restricted to Balanced Sample	N	N	Y

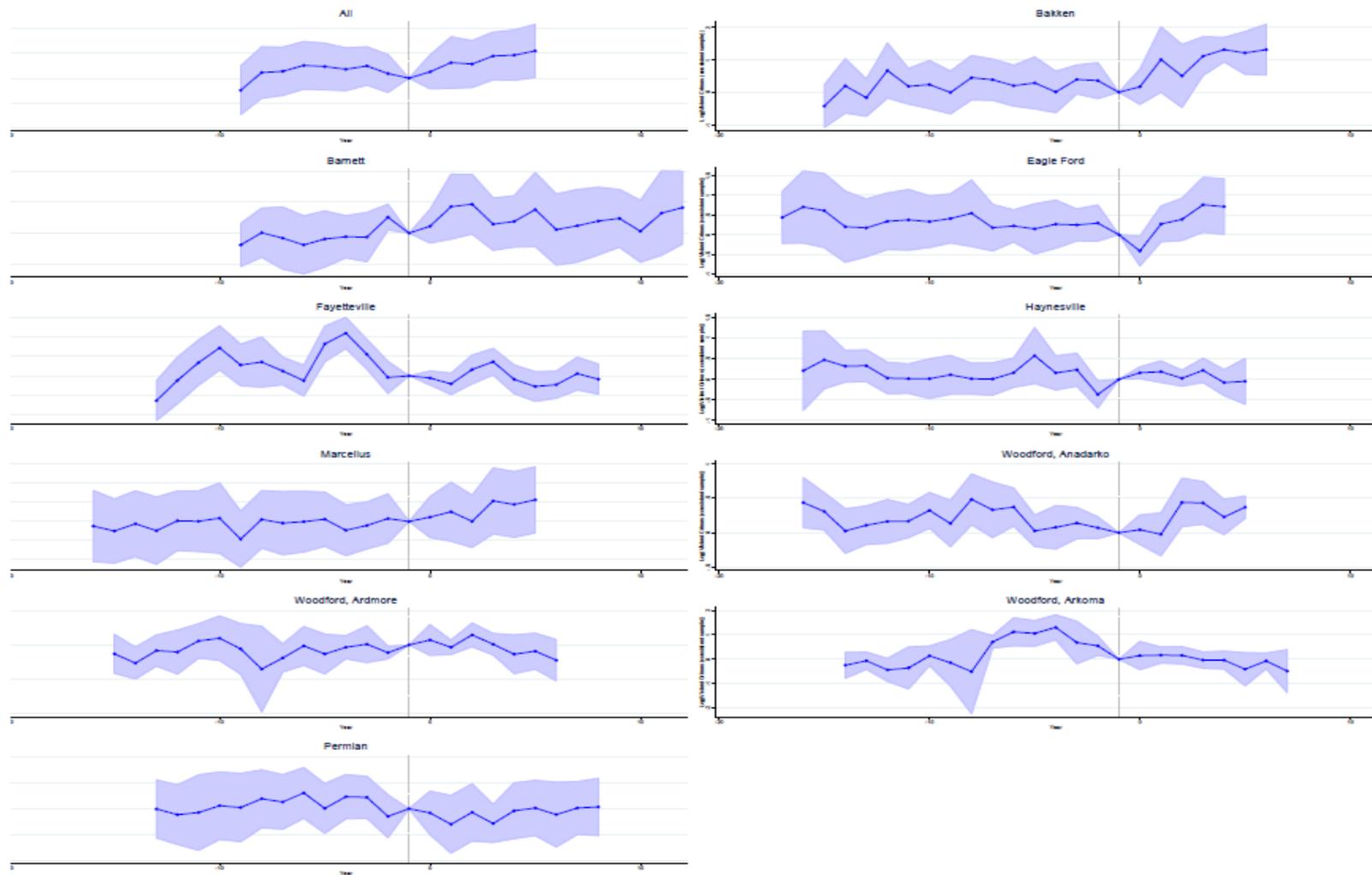
Table 9: Play specific Estimates

	All (1)	Bakken (2)	Barnett (3)	Fayetteville (4)	Haynesville (5)	Marcellus (6)
Panel A: Average Characteristics of Top Quartile Counties						
Population (2000)	64,860	6,307	109,202	24,046	24,576	112,911
Oil Share of Hydrocarbon Production Value (2011)	0.33	0.94	0.42	0.00	0.01	0.07
Panel B: Hydrocarbon Production						
B1. Total Value of Hydrocarbon Production						
	409*** (123)	972** (414)	322* (183)	69 (78)	1,730* (903)	185*** (70)
Panel C: Labor Markets						
C1. Log(Total Income)						
	0.069** (0.028)	0.399*** (0.089)	0.007 (0.038)	-0.049*** (0.015)	0.036 (0.044)	-0.019 (0.017)
Panel D: Housing Prices						
D1. Log(Median Home Values)						
	0.057*** (0.012)	0.228*** (0.086)	-0.046 (0.030)	0.018 (0.111)	-0.071 (0.057)	0.089*** (0.014)
Top Quartile Counties	65	8	5	1	5	28
Outside Top Quartile Counties ^a	253	27	41	13	21	95

Appendix Figure G.9: Event study analysis of county-level employment by play



Appendix Figure G.10: Event study analysis of county-level log(violent crime) by play



Welfare calculations

- Intuition: In spatial equilibrium, the marginal resident must be indifferent to relocating. Hence, local housing prices respond to changes in local wages and amenities.
- Response depends on the elasticity of local housing supply and on moving costs (or location preferences).
- Using estimates from the literature on the relationship between productivity shocks and house prices, we back out the change in local amenities and use these estimates to infer the total change in local welfare.

Assumptions for Welfare Calculations

- The first row reports estimates where the share of household income spent on housing, β , is 0.65, following Albouy (2008) and $s=0.40$, the standard deviation of idiosyncratic location preferences or moving costs, (see Diamond (2016)).
- Subsequent rows are based on alternative assumptions for β and s .
- Throughout, we assume a 6.0 percent change in income and a 2.7 percent change in population.

Welfare calculations

	Δ in housing costs = 2.9%		Δ in housing costs = 5.7%	
	Amenities (1)	WTP for change in: Welfare (2)	Amenities (3)	Welfare (4)
Panel A: Annual Impacts per household				
$s = 0.4$ and $\beta = 0.65$	-\$1,225	\$1,173	-\$510	\$1,888
$s = 0.2$ and $\beta = 0.33$	-\$1,806	\$592	-\$1,443	\$955
$s = 0.4$ and $\beta = 0.33$	-\$1,594	\$804	-\$1,231	\$1,167
$s = 0.6$ and $\beta = 0.33$	-\$1,382	\$1,016	-\$1,019	\$1,379
$s = 0.2$ and $\beta = 0.65$	-\$1,437	\$961	-\$722	\$1,676
$s = 0.4$ and $\beta = 0.65$	-\$1,225	\$1,173	-\$510	\$1,888
$s = 0.6$ and $\beta = 0.65$	-\$1,013	\$1,385	-\$298	\$2,100

Findings from the Fracking Boom

- Counties experienced average gains in total income (4.4 - 6.9%), employment (3.6 - 5.4%), and wages (7.6 - 13.0%).
- Local governments saw 15.5% increases in revenues and 12.9% average increases in expenditures, but no increase in expenditures on social welfare (education, health).
- Higher violent crime rates (?), and a 20% increase in public safety expenditures.
- Overall change in welfare among households that lived in these communities before fracking's initiation is about \$1,200-\$1,900 per household annually.

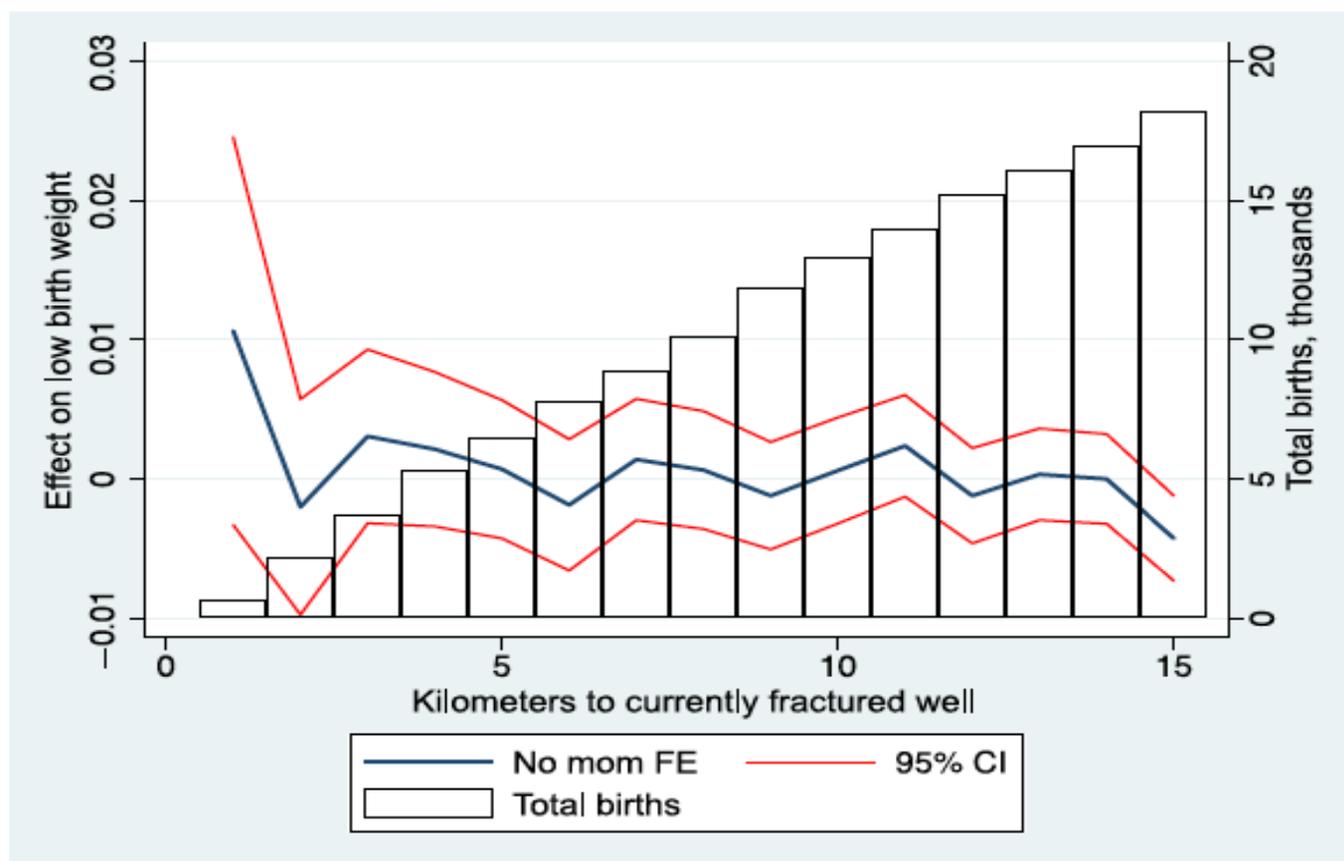
Findings

- Substantial regional heterogeneity: Some areas have banned fracking while others have embraced it. This may be entirely reasonable.
- Even in areas with positive mean increases in welfare, fracking may not make the majority of residents better off.
- Individuals who are not in the labor force won't benefit. Renters who aren't in the labor force fare especially poorly.
- Homeowners who don't own the mineral rights will not benefit from drilling royalties, but may experience negative impacts of drilling activity.

Imperfect Information about Pollution

- Housing values are the basis of the revealed preference approach to measuring welfare impacts.
- If households learn that the negative environmental and quality of life impacts of fracking are larger than they thought, then the welfare impacts will be smaller (i.e. housing values will fall).
- Resolution of uncertainty and pollution and its effects and sensible zoning could increase the welfare benefits of fracking.

Currie, Greenstone, and Meckel (2017) show that effects of pollution on infant health are detected at residences <2km from a fracking site (but not further away).



Overall takeaway for place-based policy

- To make local policy sensibly may require more information than most local government have the ability to acquire.
- Providing technical assistance in procuring such information might be one way to support informed local place-based policy (roll of EPA?).
- Policies to “share the wealth” may also be needed.

