Hydraulic Fracturing: The US Experience and Implications for the Rest of the World

Christopher R. Knittel

Sloan School of Management
Center for Energy Environmental Policy Research
Massachusetts Institute of Technology

July 2014

Motivation
Natural gas revolution

- This talk is based on two on-going projects that I have with two sets of co-authors
  - Dash for Gash: Fuel Switching Incentives Across Ownership and Market Structure
    - Christopher R. Knittel, Kostas Metaxoglou, and Andre Trindade
  - The Economic Consequences of Hydraulic Fracturing
    - Alexander W. Bartik, Janet Currie, Michael Greenstone, and Christopher R. Knittel
- My goal in this research program is to understand the costs and benefits of hydraulic fracturing, as well as how different market structures may alter fuel switching
- My short-term goal is to cover two sets of slide decks designed for 1:30-long seminars in 25 minutes!!

Dash for Gash: The Sequel

Christopher R. Knittel[1] Kostas Metaxoglou[2] Andre Trindade[3]

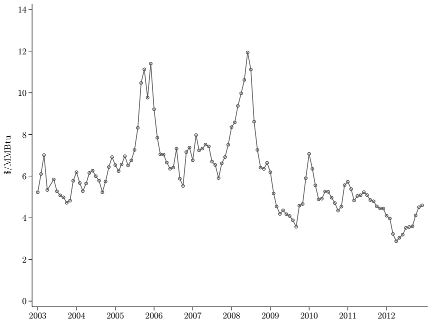
[1]MIT Sloan [2]Carleton University [3]Foundation Getulio Vargas

July 2014

Motivation
Natural gas revolution

- Hydraulic fracturing (fracking or fracing) has completely changed the relative prices of natural gas and coal
- These changes are expected to be long lasting

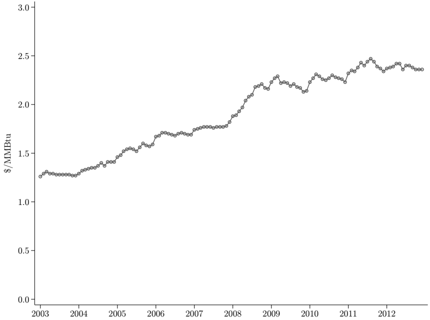
Figure 1 : Electric power sector price for natural gas



Motivation
The war on coal

- At the same time, coal prices have been trending upward

Figure 2 : Electric power sector price for coal



Research questions

"We are about halfway to the President's goal to cut greenhouse gas emissions and about half of that is because of the substitution of natural gas for coal in the power sector."

Ernest Moniz, August 26th, 2013

Research questions

"We are about halfway to the President's goal to cut greenhouse gas emissions and about half of that is because of the substitution of natural gas for coal in the power sector."

Ernest Moniz, August 26th, 2013

- We investigate how the electricity generators respond to changes in natural gas and coal prices

Research questions

"We are about halfway to the President's goal to cut greenhouse gas emissions and about half of that is because of the substitution of natural gas for coal in the power sector."

Ernest Moniz, August 26th, 2013

- We investigate how the electricity generators respond to changes in natural gas and coal prices
- Our focus is on whether differences exist among firm "types"

Research questions

"We are about halfway to the President's goal to cut greenhouse gas emissions and about half of that is because of the substitution of natural gas for coal in the power sector."

Ernest Moniz, August 26th, 2013

- We investigate how the electricity generators respond to changes in natural gas and coal prices
- Our focus is on whether differences exist among firm "types"
- We look at power plants that have burned both fuels and at firms that have burned both fuels

Research Questions

- Considerable variation in firm and market structure
- We classify firms into two general groups
  - *Utilities:* generally generate, transmit, and distribute electricity
  - *Non-utilities:* generally only generate electricity for sale to others, or own use
- We classify market-types into two groups
  - Some markets are organized around wholesale power markets
  - More traditional markets are organized around utilities that have a monopoly

	Utilities	
Wholesale Markets	Yes	No
No	1. Non-market utilites	3. ICs
Yes	2. Market utilites	4. IPPs

Figure 3 : Natural gas shale plays

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

Tremendous Innovation in Fossil Fuel in the Last 5-10 Years

Top 10 countries with technically recoverable shale oil resources

Rank	Country	Shale oil (billion barrels)
1	Russia	75
2	U.S.	58
3	China	32
4	Argentina	27
5	Libya	26
6	Australia	18
7	Venezuela	13
8	Mexico	13
9	Pakistan	9
10	Canada	9
World Shale Oil		345
World Consumption of Liquids in 2010		32

Top 10 countries with technically recoverable shale gas resources

Rank	Country	Shale gas (trillion cubic feet)
1	China	1,115
2	Argentina	802
3	Algeria	707
4	U.S.	665
5	Canada	573
6	Mexico	545
7	Australia	437
8	South Africa	390
9	Russia	285
10	Brazil	245
World Shale Gas		7,299
World Consumption of Natural Gas in 2010		113

Source: EIA

Figure 4 : Natural gas production

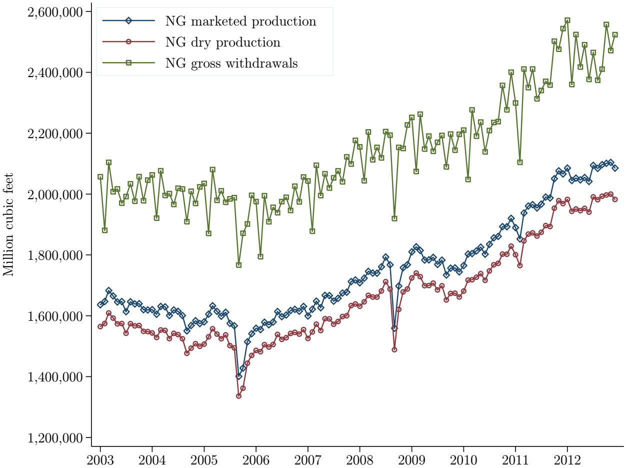
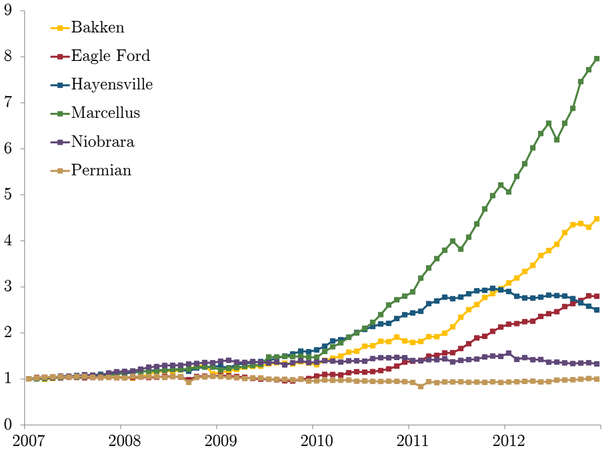


Figure 5 : Production (mcf/day) by major play, Jan-2007:1



US Electricity markets

- Electricity markets take one of two forms
- Traditional markets
  - Regulated monopoly utility
  - Utility generates, transmits, distributes and bills for the electricity
  - Periodic rate hearings set prices such that the utility earns a "fair rate of return"
- Restructured electricity markets
  - Designed around a wholesale market for electricity
  - Utilities and Independent Power Producers (IPPs) bid supply
  - Rate of return for utilities remained regulated

Empirical Analysis

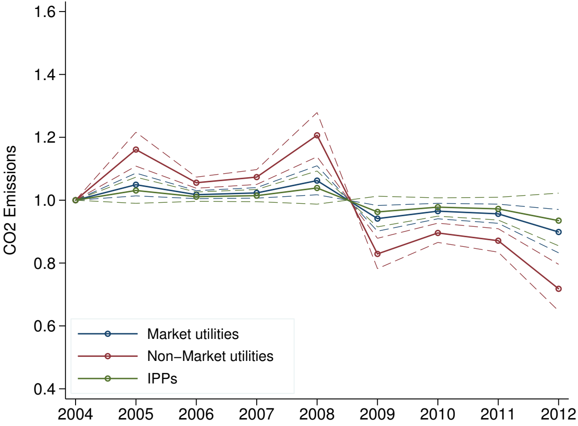
- We are interested in estimating how plants/firms alter their input mix when fuel prices change
- We focus on plants and firms (separately) that have burned both fuels. Our data start at 2003.
  - Many firms have both gas and coal power plants
  - Power plants also often have multiple "units"
    - May have both a gas and coal unit on site
- Findings
  - We find that traditionally regulated electric utilities are most sensitive to changes in natural gas prices—They are over twice as sensitive to natural gas prices than utilities operating in restructured markets
  - These differences have large implications for the greenhouse gas benefits from lower natural gas prices

Back-of-the envelope calculations
Emissions

- We estimate firm-level regressions of CO_2, NO_x, and SO_2 emissions on natural gas and coal prices
- This allow us to estimate how emissions change with changes in input prices
  - Given the noisiness of the coal price coefficients, we focus on natural gas prices
- How would emissions have evolved if every firm's response was that of type XX?
  - We can construct emission paths assuming that all firms have the same set of input-price coefficients
  - *Note:* Not a counterfactual, since we are ignoring demand side
- We can monetize the reductions in CO_2 with additional assumptions on which plants are affected and a social cost of carbon

Back-of-the envelope calculations
CO_2 Emissions

Figure 6 : CO_2 emissions



Implications for international markets

- There has been a lot of discussion about whether the US will begin exporting LNG
- Currently there are large price differences between the US and both Europe and Asia—larger than the estimated cost of liquefaction
- However, there is an **indirect** way to export US natural gas
- Fracking has shifted out the US supply curve of BTUs
- We can think about exporting natural gas or exporting BTUs

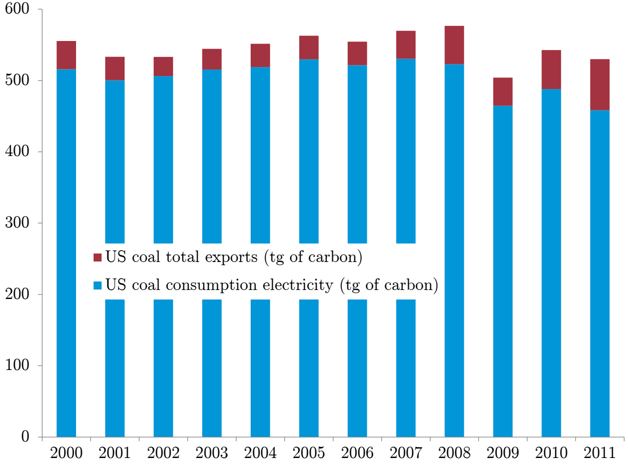
Implications for international markets

- At present, the cheapest way to export BTUs is to export coal, instead of natural gas
  - Three reasons why exporting coal-BTUs are currently the most profitable option:
    1. A number of recent regulatory changes in the US have increased the cost of burning coal
    2. Low ETS prices make burning coal in Europe less expensive than before
    3. China's appetite for coal appears to be ever-growing

Circling back to Moniz quote

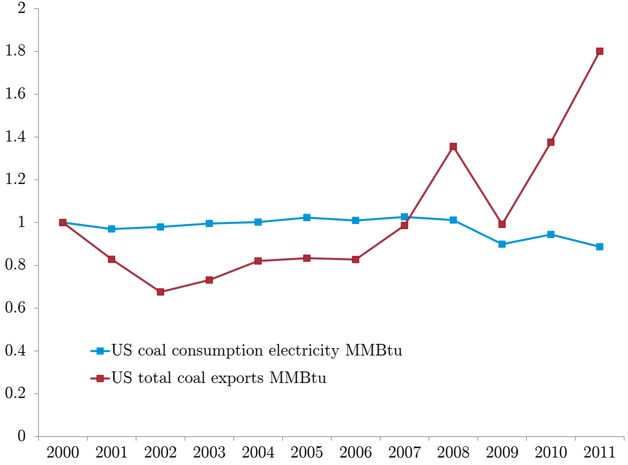
Annual US coal consumption and exports

Figure 7 : Coal consumption and exports



Annual US coal consumption and exports

Figure 8 : Percentage changes in consumption and exports



US coal exports

- US coal exports to China in 2001 1.0 million short tons, 2012 exports were 10 million short tons!
- US coal exports to Japan in 2003 0 million short tons (2.0 million short tons in 2001), 2012 exports were 5.6 million short tons
- US coal exports to Germany in 2003 0.5 million short tons (0.9 million short tons in 2001), 2012 exports were 5.2 million short tons
- US coal exports to Europe in 2003 15 million short tons, 2013 exports were 54 million million short tons

Are we Fracked? The Economic Consequences of Hydraulic Fracturing

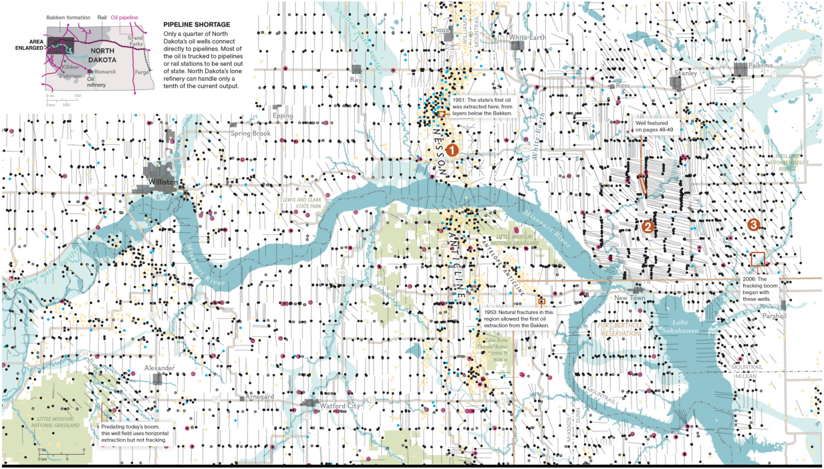
Alexander W. Bartik, Janet Currie, Michael Greenstone, and Christopher R. Knittel

[1]MIT Economics [2]Princeton Economics [3]MIT Economics [4]MIT Sloan

July 2014

Motivation

Drilling activity in North Dakota



Motivation
Not without controversy

- "Farmers who once lived check to check are now extremely comfortable, if not downright wealthy. New cars, recreational vehicles and trailers are parked in nearly every driveway." (NY Times, 2010)

- "...But by the fall of 2008, homes around the well begain producing muddy water at the faucet...Mrs Shager,...and a dozen nearby residents contended that [the oil/gas firm] somehow managed to pollute their water with drilling or fracking fluids" (NY Times, 2010)

Motivation

Controversy Continued

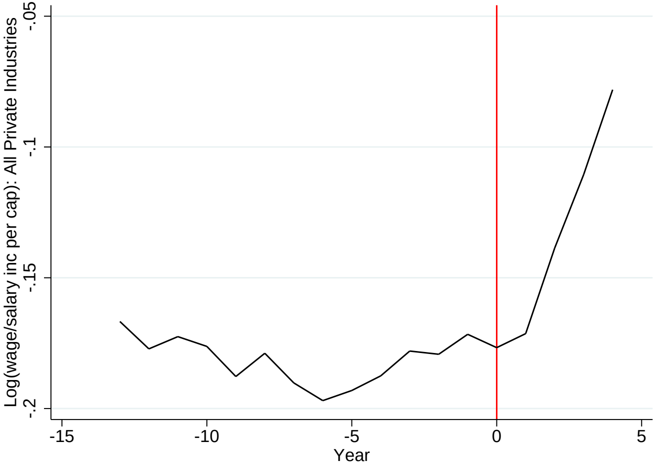
- A number of states, countries, and cities have responded to these concerns by banning or significantly restricting fracing activity.
  - New York State (currently has a moratorium pending an environmental review)
  - Vermont State
  - Delaware River Basin (includes parts of Pennsylvania, New York, New Jersey, and Delaware)
  - France

Potential local effects
Complicated trade-offs

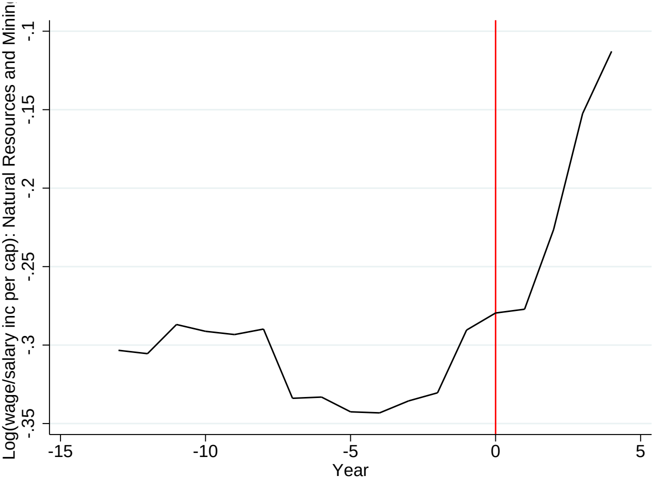
- Potential Benefits
  - Income from leasing land or mineral rights
  - Rising local labor demand
- Potential Costs
  - Water contamination
    - Chemicals from the fracing process or fossil fuels may leak into groundwater
  - Seismic activity
  - Air pollution/Noise/Other disturbances
  - Negative social externalities (i.e. man camps)

Regression-free evidence

Income per capita before and after fracing

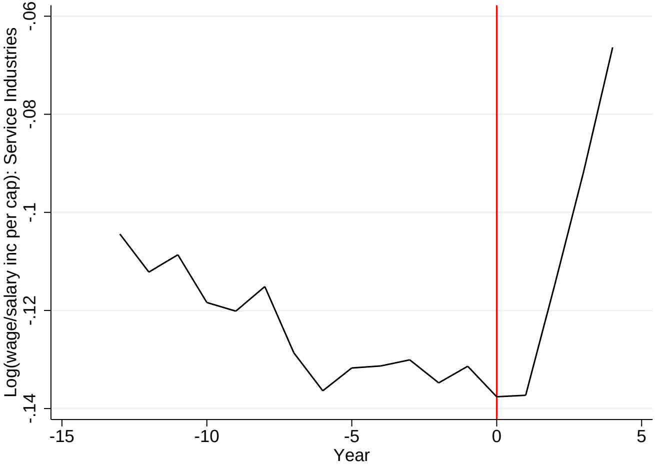


Regression-free evidence
Mining industry income



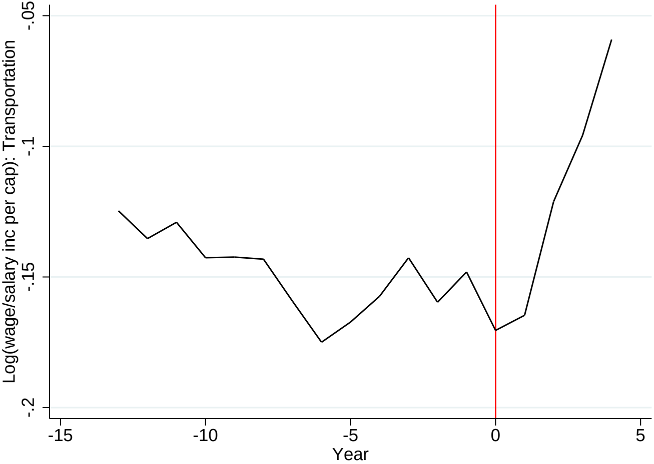
Regression-free evidence

Spillovers? Service industry income



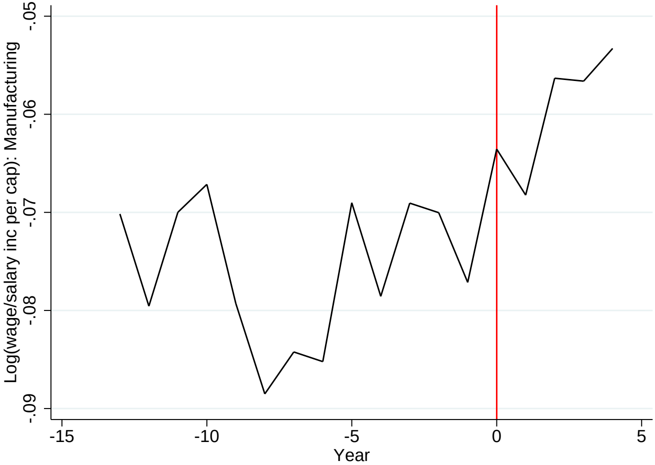
Regression-free evidence

Spillovers? Transportation sector income



Regression-free evidence

Spillovers? Manufacturing income



Regression results

Wage and Salary Income: 7% Higher

	Base Specification (4)	Year-Basin FE (5)	County Trends + Year-Basin FE (6)
All Industries: Log(Wage and Salary Income)			
Treatment Effect at t=3	0.102***	0.069***	0.071***
	(0.020)	(0.017)	(0.017)

Regression results

Mining and Natural Resources Wage and Salary Income: 14% Higher

	Base Specification (4)	Year-Basin FE (5)	County Trends + Year-Basin FE (6)
Natural Resources and Mining Industries: Log(Wage and Salary Income)			
Treatment Effect at t=3	0.212***	0.156***	0.144***
	(0.039)	(0.040)	(0.045)

Regression results

Spillovers: Wage and Salary Income in Service Industries - 5.5% Higher

	Base Specification	Year-Basin FE	County Trends + Year-Basin FE
	(4)	(5)	(6)
Service Industries: Log(Wage and Salary Income)			
Treatment Effect at t=3	0.076***	0.056***	0.055***
	(0.016)	(0.014)	(0.015)

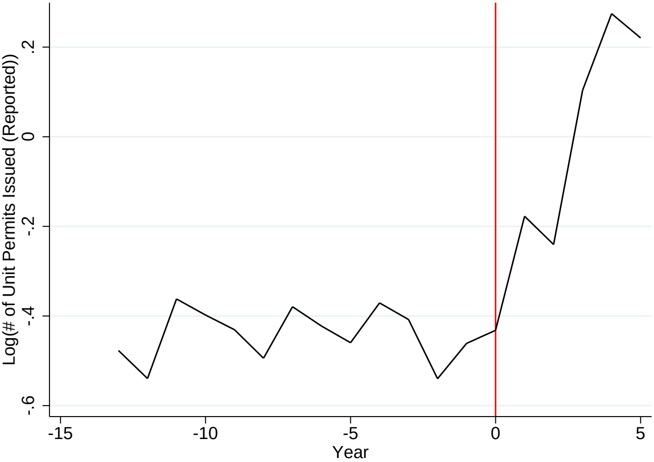
Regression results

Spillovers: Wage and Salary Income in Manufacturing Industries - Not Significantly Different

	Base Specification	Year-Basin FE	County Trends + Year-Basin FE
	(4)	(5)	(6)
Manufacturing Industries: Log(Wage and Salary Income)			
Treatment Effect at t=3	0.022	0.006	0.010
	(0.019)	(0.019)	(0.020)

Regression-free evidence

Log(Building Permits)



Regression results

Building Permits - 50% Higher

	Base Specification (4)	Year-Basin FE (5)	County Trends + Year-Basin FE (6)
	Log(Building Permits)		
Treatment Effect at t=3	0.717***	0.510***	0.496***
	(0.161)	(0.138)	(0.136)

Potential negative effects

Complicated trade-offs

- We also look at two potential negative effects of fracing
- Potential Costs
  - Negative social externalities (i.e. man camps)
    - We may think that having lots of 20-something year old men with pockets of cash may not be desirable
    - We find little evidence that crime rates increase after fracing activity begins
  - Air pollution
    - We find some evidence that air quality reduces after fracing
    - However, the reduction doesn't lead to increases in the number of "poor quality" days

Summarizing the Results

- Fracing significantly shifts local labor demand, increasing wages by 7%, and 14% within natural resources and mining industries
- Housing prices increase roughly 7% overall.
- The local population increaes by 1.5%
- Agricultural land is converted to other purposes and new construction booms by 50%
- Estimates of the effects of fracing on crime and air pollution do not suggest increases in crime and large reductions in air quality

Wrapping up

- Paper 1: Hydraulic fracturing has led to large reductions in greenhouse gas emissions within the US
- However, it has also led to large US exports of GHGs
- The net effect is difficult to measure, but important
- Paper 2: Hydraulic fracturing has led to large increases in wealth
- These wealth increases have gone to both land/property owners and workers
- We do not find evidence of increases in crime, however, these are statistically noisy
- There is some evidence of increases in pollution