Welfare and Distributional Implications of Shale Gas

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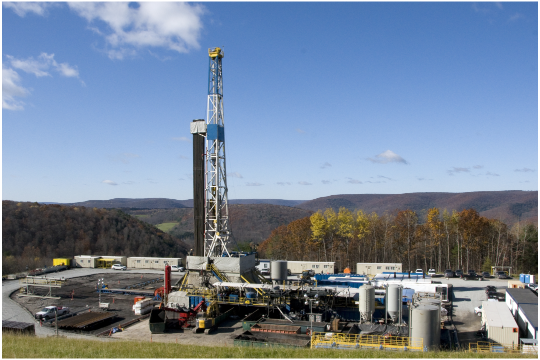

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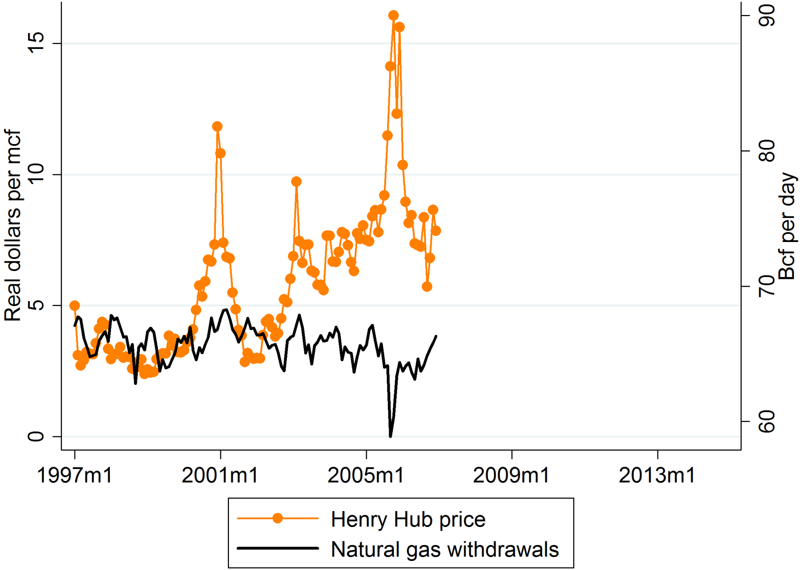
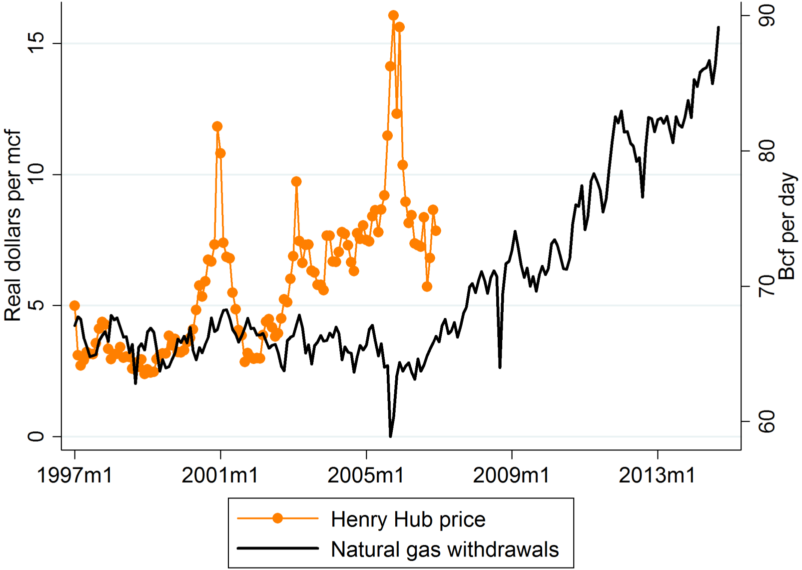
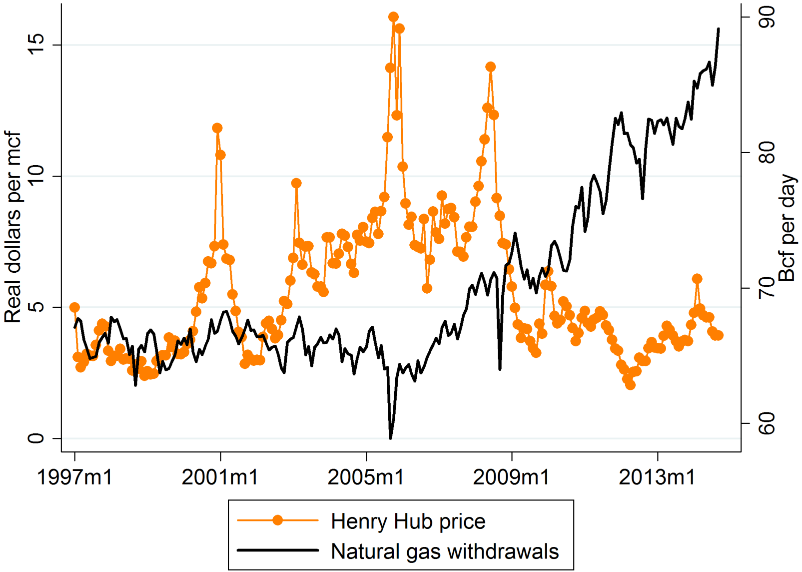
Economic impacts of shale gas



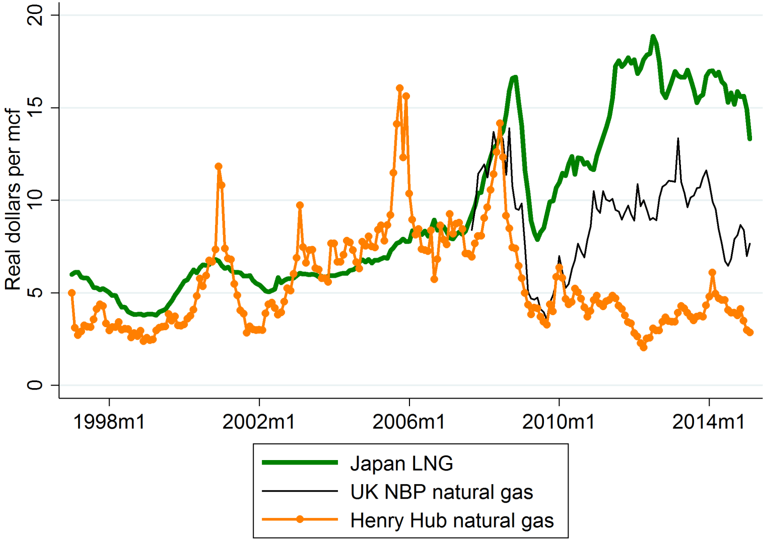
Economic impacts of shale gas



Economic impacts of shale gas



Price wedge


Real dollars per mcf
0
5
10
15
20
1998m1
2002m1
2006m1
2010m1
2014m1
Japan LNG
UK NBP natural gas
Henry Hub natural gas

Demand and supply estimation

- Using monthly data on prices (retail and wholesale), production, consumption, imports and exports,
- We estimate supply and demand elasticities.
- Separate demand elasticities for four types of users: residential, commercial, industrial, and electric power.
- Identification comes from weather shocks that draw down inventories.

Demand equation builds in simple dynamics via AR(1) process

$$\log C_{it} = \alpha_C \log P_{it} + \gamma_C \log C_{i,t-1} + \beta_C X_{Cit} + \varepsilon_{Cit}$$

- Gas consumption C_{it} in state i in month t depends on price P_{it}, lagged consumption $C_{i,t-1}$, weather X_{Cit}, and unobservable demand shifters ε_{Cit}
- AR(1) won't capture direct effects of long price lags, very long-run R&D / technology adoption effects, etc.
- Identification: need an instrument for price

Demand identification: empirical strategy relies on weather shocks

- Our strategy combines intuition from two previous papers: Davis and Muehlegger, 2010; Arora, 2014
- Instrument idea 1: weather in other states
    - Cold weather in Ohio drives up the price of natural gas, but does not directly affect demand in Michigan.
- Instrument idea 2: lagged weather
    - Theory of competitive storage: cold weather last month drove down inventories of natural gas.
- Our IV for gas price in state i in month t is lagged weather in other states: $\sum_{l=2}^{12} HDD_{t-l}$

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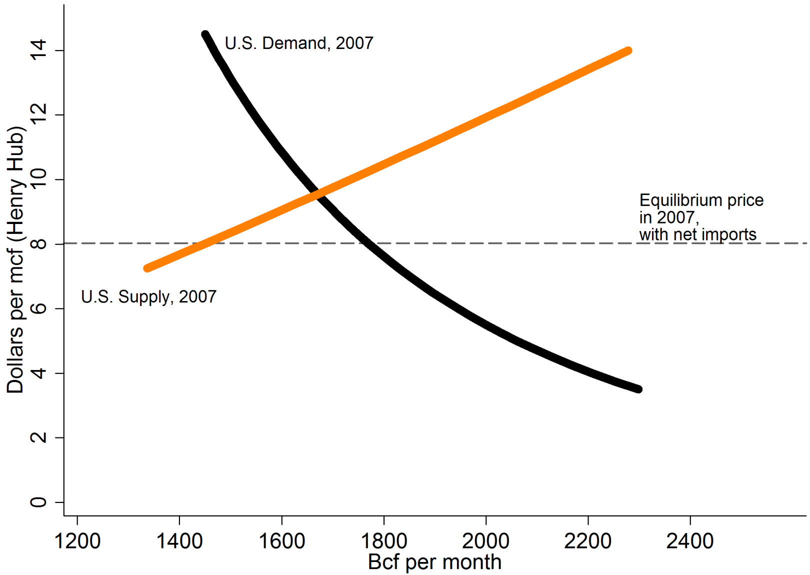
Strategy for supply estimation is similar to that for demand

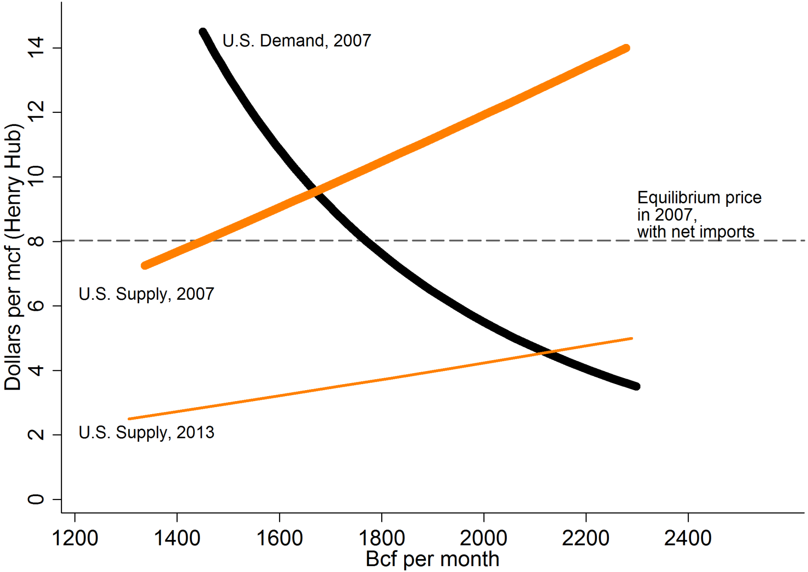
$$\log S_t = \alpha_S \log P_t + \gamma_S \log S_{t-1} + \beta_S X_{St} + \varepsilon_{St}$$

- Data are national
- Prices are wholesale (Henry Hub)
- Instrument: one-month lagged HDDs and CDDs
- Dependent variable is monthly drilling activity
    - Idea: The margin of adjustment is wells drilled, and in the long run, this is the relevant elasticity (Anderson, Kellogg and Salant 2014)

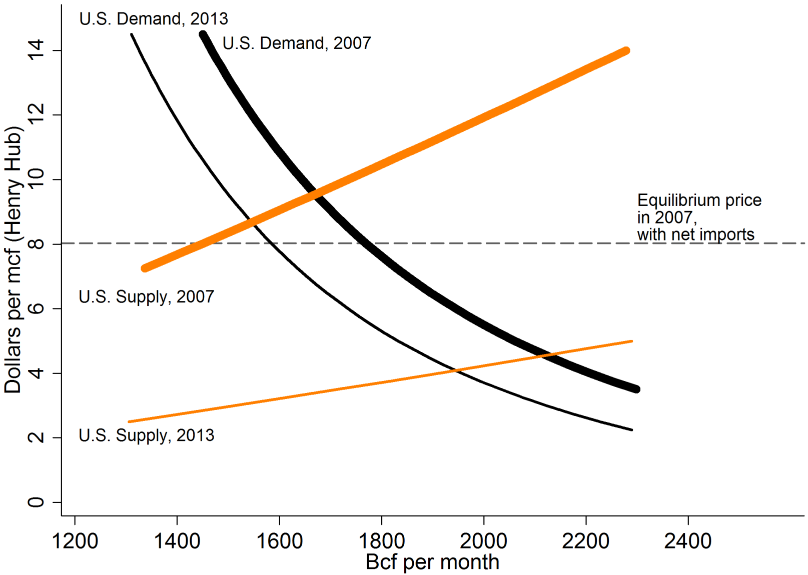
Demand and supply picture for 2007



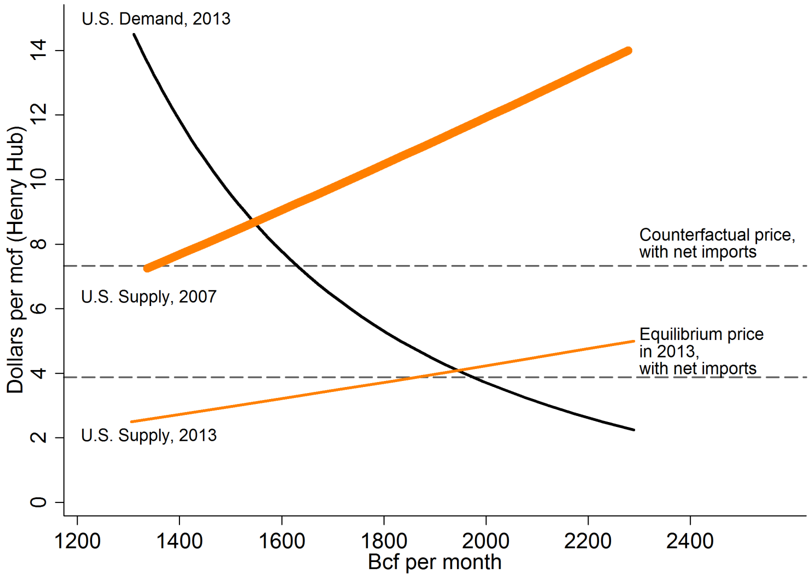
Supply expands due to fracking



Demand was contracting during 2007–2013



Causal price fall: \$3.45/mcf, almost 50%



Consumer surplus impacts for 2013

- Total consumer surplus increase of $74 billion per year.
  - Residential: $17 billion
  - Commercial: $11 billion
  - Industrial: $22 billion
  - Electric power: $25 billion
- Commercial, industrial, electric power sectors: gains split between firms and customers
- Gains are largest in "West South Central Region" (AK, LA, OK, TX)

Overall, we estimate a *decrease* in producer surplus of $26 billion for 2013, driven by conventional gas producers

	2007 supply, bcf	2013 supply, bcf	Change in annual PS, billion $	Percent change in PS
Arkansas	232	980	1.1	104%
Colorado	1069	1380	-1.6	-32%
Louisiana	1174	2070	-0.6	-12%
New Mexico	1305	1028	-3	-52%
Oklahoma	1534	1844	-2.5	-36%
Pennsylvania	157	2803	5.4	758%
Texas	5266	6489	-8.3	-35%
Utah	324	405	-0.5	-34%
West Virginia	199	617	0.5	51%
Wyoming	1761	1598	-3.8	-48%

Impact on total surplus for 2013 is $48 billion per year

- Approximately 1/3 of 1% of GDP.
- Approximately $150 per capita.
- Varies by up to 20% when we double/halve the elasticities.

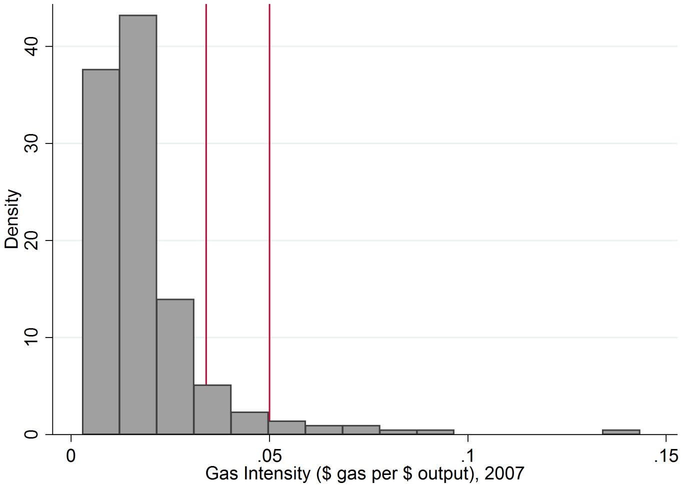
How would LNG exports change the picture?

- Impact of expanding LNG permits:
- We quantify the price increase and changes to surplus:
- Small net gain; some of the producer surplus accrues to Canada.

Have low natural gas prices led to a "manufacturing renaissance"?

- Our analysis considers gas-consuming sectors, not suppliers of inputs to the oil & gas sector
- Data on natural gas intensity by sector
  - BEA input-output tables: 2007
- Data on establishment count, employment, compensation, and capital expenditure
  - Economic Censes: 2002, 2007, 2012
- 230 manufacturing sectors

Natural gas manufacturing intensity, by sector



Red lines at the 90th and 95th percentiles. Data include direct and indirect gas inputs.

List of 95th percentile natural gas intensive industries

NAICS Code	Sector	Gas Intensity ($ of gas per $ of output)
325190	Other basic organic chemical manufacturing	0.052
322120	Paper mills	0.054
322110	Pulp mills	0.060
322130	Paperboard mills	0.067
327310	Cement manufacturing	0.069
325110	Petrochemical manufacturing	0.073
311221	Wet corn milling	0.082
327400	Lime and gypsum product manufacturing	0.094
325310	Fertilizer manufacturing	0.143

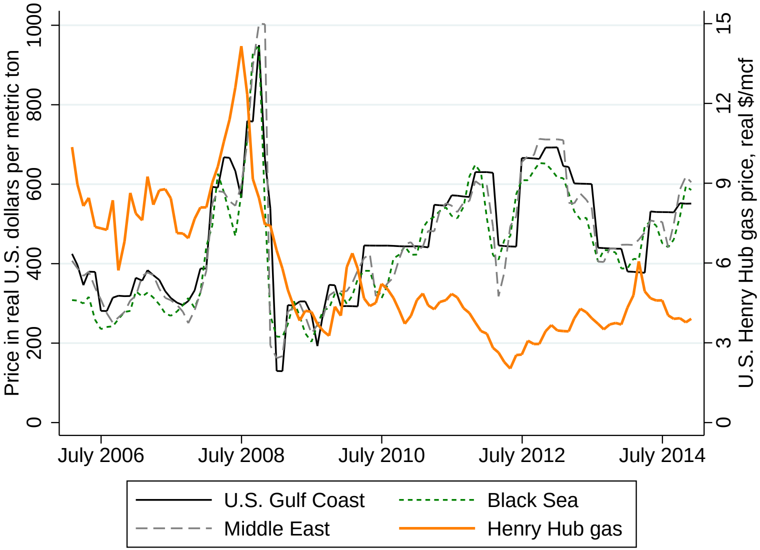
Economic activity in gas intense vs. non-intense sectors

Years	Number of Establishments	Employment	Employee Compensation	Capital Expenditure
Sectors with natural gas intensity $<$ 90th percentile				
2002 to 2007	-5.8%	-9.0%	9.9%	21.3%
2007 to 2012	-10.6%	-16.5%	-3.7%	4.9%
Sectors with natural gas intensity $\geq$ 90th percentile				
2002 to 2007	-3.5%	-14.7%	-1.9%	36.8%
2007 to 2012	-6.2%	-13.1%	4.3%	8.5%
Sectors with natural gas intensity $\geq$ 95th percentile				
2002 to 2007	-0.6%	-14.3%	-1.0%	46.5%
2007 to 2012	1.7%	-8.6%	9.1%	2.5%
Fertilizer manufacturing (NAICS 325310)				
2002 to 2007	-9.5%	-15.8%	8.5%	20.4%
2007 to 2012	8.3%	8.6%	24.8%	232.7%

A manufacturing renaissance?

- Diff-in-diff (or triple-differenced) analysis finds association between natural gas intensity and increases from 2007 to 2012:
  - In manufacturing establishments, employment, compensation, and capital expenditure.
  - Especially for fertilizer manufacturing.
- Total effect depends on whether this led to increases or decreases in employment in other industries.

Part of story: little pass-through to ammonia (fertilizer) prices



Environmental externalities

Global environmental externalities: climate change

- Scale effect: more fossil fuels consumed, so more CO2.
  - Also methane leaks: a powerful GHG.
- Substitution effect: coal displaced (and renewables/nuclear).
  - Mitigated by increased coal exports.
- Bounding exercise: short-run climate change cost for 2013 ranges from 3 billion to 28 billion dollars.
- Long-run impact on transition to low-carbon energy?

Local environmental externalities

- Groundwater and surface water contamination
  - Natural gas migrating into water
  - Toxic fluids used in fracking process
  - Naturally occurring toxic chemicals released by process
- Water depletion
- Air quality
  - From the well, compressor stations, and transport equipment
  - Some benefits from coal displacement in electricity
- Trucking accidents
- Earthquakes
- Habitat fragmentation
- "Boomtown" disamenities: crime and noise

Conclusion: fracking a game-changer for prices, consumers, and producers

- Total surplus impact of $150 per capita in 2013
  - Almost 50% price fall.
  - Consumer surplus increase of $74 billion in 2013.
  - Producer surplus decrease of $26 billion in 2013.
- Downstream manufacturing employment effects.
- Under some assumptions, climate change costs can erase up to half the private gains.
- Better data on environmental impacts would help both valuation and cost-effective regulation.

Thank you!

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Demand elasticity estimates by sector

	Dependent variable: log(consumption)			
	Residential	Commercial	Industrial	Electric Power
log(Price)	-0.11	-0.09	-0.16	-0.15
	(0.11)	(0.08)	(0.07)	(0.14)
y_{t-1}	0.43	0.59	0.72	0.68
	(0.05)	(0.04)	(0.09)	(0.03)
Long-run elasticity	-0.20	-0.23	-0.57	-0.47
	(0.19)	(0.18)	(0.17)	(0.43)
First-stage F	10.01	10.55	10.33	11.85
Observations	6912	6912	6912	6849

Controls include state-by-month effects, a linear time trend, and current and one-month lagged weather (HDDs and CDDs).

Estimated long-run supply elasticity is 0.81

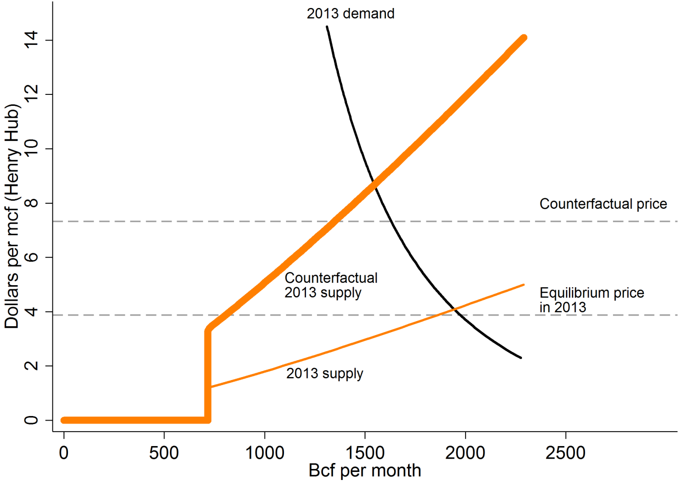
	Dependent var: log(drilling)
log(Price)	0.09
	(0.05)
y_{t-1}	0.89
	(0.04)
Long-run elasticity	0.81
	(0.16)
First-stage F	4.46
Observations	108

Controls include month effects and a linear time trend.

Producer surplus: Need to capture entire shift in the supply curve, not just change at equilibrium quantity

- Once you drill a well, the MC of production is approximately zero (Anderson, Kellogg, Salant 2014).
- And the well will produce for years/decades
- Implication: wells drilled prior to the fracking boom are still producing, with MC $= 0$.

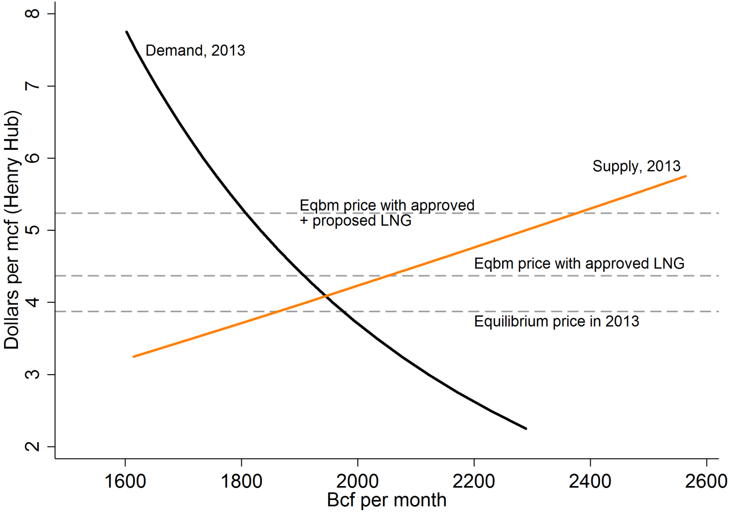
We calculate the *inframarginal quantity* of gas production for 2013 and draw supply curves back to the origin



How would LNG exports change the picture?

- Large U.S. vs. Asia differential had spurred interest in LNG export, despite high costs
  - NERA (2014) cost estimates: $6.65 to Korea and Japan, $7.79 to China and India
- We consider two scenarios for LNG export:
  - Exports equal to all FERC-approved terminals as of 5 February, 2015 (9.2 bcf per day)
  - Exports equal to all FERC approved + proposed terminals as of 5 February, 2015 (24.6 bcf per day)

Counterfactual price increases: \$0.49 per mcf for approved LNG, \$1.36 per mcf for approved + proposed LNG



We carry out a bounding exercise for global climate change impacts

- We consider three channels for GHG impacts
  1. Scale effect: more fossil fuels consumed, so more CO2
  2. Substitution effect: coal displaced (and renewables/nuclear). Offset by coal exports?
  3. Methane leaks
- Analysis ignores long-run effects, R&D, etc.
- Newell and Raimi (2014): Substitution effect outweighs scale effect; total effect unclear after accounting for methane leaks.

Upper bound for global climate change impacts

- Scenario for upper bound:
    - Kill the substitution effect: All displaced coal is exported; no effect on global coal production
    - Scale effect includes Canadian and Mexican gas consumption
    - Methane leak rate: 7.9% (Howarth 2014)
    - SCC = $40 per metric ton CO2. Methane 100 year GWP = 34.
- Scale effect drives GHG externalities of $13 billion per year
- Methane leaks add $15 billion per year

Lower bound for global climate change impacts

- Scenario for lower bound:
  - Substitution effect: Entire increase in electric power gas consumption displaces coal. Coal stays in the ground.
  - Scale effect includes domestic gas consumption only
  - Methane leak rate: 0.42% (Allen et al. 2013)
  - SCC = \$40 per metric ton CO_2. Methane 100 year GWP = 34.
- Substitution effect reduces GHG externalities by \$2.8 billion per year
- Scale effect drives increase of \$5.3 billion per year
- Methane leaks add \$0.5 billion per year

Valuation of Environmental Externalities

- Valuation not currently possible:
  - Data are limited.
  - Some evidence of very heterogeneous impacts.
  - Revealed preference valuation approach (e.g. housing prices) limited because of incomplete information.
- Heterogeneity problematic for two reasons:
  - Difficult to scale up case studies to estimate magnitude of overall problem.
  - Difficult for regulators to rapidly target biggest issues.

Cost-Effective Regulation In This Context?

- Cap-and-trade or emissions taxes require high quality monitoring and attribution.
- Instead, we've seen ex-post liability through judicial system.
- And technology standards.
- One possibility: treat like non-point source pollution: ambient environmental standards and joint liability (Segerson)
- Perhaps with opt-out through voluntary monitoring (Millock, Sunding and Zilberman 2002)