The Incidence of Environmental Policy

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Often interested not just in efficiency, but also distributional impacts.

- Are cigarette taxes paid for by smokers or big tobacco?
- Do tariffs fall primarily on consumers or firms?
- Are subsidies for green products captured mainly by consumers or producers?

Many different levels of incidence

1. Producer vs. consumer (tax on cigarettes)
2. Source of income (labor vs. capital)
3. Income level (rich vs. poor)
4. Region or country (local property taxes)
5. Across generations (social security reform)

ˆ *[Much of the first part of this draws on Raj Chetty's excellent public economics lectures.]*

Simple econ 101 treatment of tax incidence

■ FIGURE 19-3

The Side of the Market Is Irrelevant • A 50¢ tax levied on gas consumers (the statutory burden) leads to a decrease in demand from D_1 to D_2 and to a 20¢ fall in the price of gas from P_1 to P_3 (with the market moving from the pre-tax equilibrium at point *A* to the post-tax equilibrium at point *D*). The real burden of the tax is borne primarily by consumers, who pay the 50¢ tax to the government but receive an offsetting price reduction of only 20¢; producers bear that 20¢ of the tax.

Incidence is independent of statutory burden.

Simple version assumes:
- Single price (homogenous good)
- Firms price takers

Consumer incidence:

$$\frac{\epsilon_S}{\epsilon_S + \epsilon_D}$$

Weyl and Fabinger (2013) extend this to oligopoly

$$\rho = \frac{1}{1 + \frac{\theta}{\epsilon_\theta} - \frac{\theta + \epsilon_D}{\epsilon_S} + \frac{\theta}{\epsilon_{MS}}}$$

[see Michael's notes for details]

Empirical studies of incidence

Reduced Form

- Use quasi-experimental variation in dp/dt (or dp/dc)
  - Event study
  - Difference in differences
  - Regression discontinuity

Structural

- Assume nature of conduct
- Estimate demand and supply functions (typically MC)
- Change costs and recompute prices and welfare

Example: Subsidies for hybrid vehicles

- Hybrid electric vehicles introduced to the US market in 2000
    - Early entrant: Toyota Prius
- 2005 Energy Policy Act Introduced a substantial tax credit (up to $2,650) for purchasing these vehicles
- Two papers estimate the incidence using different methods

Sallee (AEJ Policy, 2008)

TABLE 1—VARIATION IN FEDERAL TAX INCENTIVES FOR THE TOYOTA PRIUS

Date effective	Tax incentive
January 1, 2001 to December 31, 2005	\$2,000 deduction (up to \$700 value in 2005)
January 1, 2006 to September 30, 2006	\$3,150 credit
October 1, 2006 to March 31, 2007	\$1,575 credit
April 1, 2007 to September 30, 2007	\$787.50 credit
October 1, 2007 forward	no credit

Uses *transaction-level* data from JD Power and Associates
- a representative sample of dealers (15% all final new car sales)
- data includes price of each vehicle sold, the exact date of the sale, and the truncated Vehicle Identification Number (VIN).

Sallee finds that consumers captured most of the subsidy

- Simple comparison of means finds *zero* price increase
- Even extreme assumptions place lower bound of consumer surplus capture at 73%
- This was a very surprising result, as it seems clear that Prius's were supply constrained at this time
  - Simple model suggests prices should fully adjust to offset subsidy
- Sallee suggests that a dynamic model of demand can rationalize this

Beresteneu and Li (IER, 2011)

- Have aggregate data: annual vehicle registrations by model for 22 MSAs (from RL Polk)
- no retail prices .. use MSRP
- Use BLP to estimate demand
    - fuel costs and tax bill vary across MSA, allowing them to include product fixed effects
    - variation from MSRP in the error term
- Use demand system to simulate counterfactual prices and shares without subsidy
    - Find prices drop such that consumers captured 50-60% of the subsidy

What are some pros and cons of these approaches?

Ganapati, Shapiro and Walker (*AEJ:Applied*, 2020)

- What is the research question in this paper?
- Why don’t they use one of the previous two methods?

What is the incidence of a carbon tax on energy inputs?

Challenges:

– No widespread tax exists, so can't estimate directly

– Taxes (or other price shifts) that affect *output* will not have the same effect as an input cost shock if firm's can substitute between inputs.

This paper develops a partial equilibrium framework for estimating the incidence of a hypothetical input tax that uses only cost variation.

Data: Census of Manufacturers

Conducted every five years (ending in 2 or 7)

- Use 1972 - 1997 (due to reporting changes)

Observe:

- Labor hours
- Book value of capital (price less depreciation)
- material and energy *expenditures* (PQ)
- Output revenue and quantity observed

Challenge: unobserved product quality

Restrict sample to homogenous, single product (-ish) industries: boxes, bread, cement, concrete, gasoline and plywood.

Theoretical framework

Incidence (I) of a tax change:

$$I \equiv \frac{dCS/d\tau}{dPS/d\tau}$$

Applying the envelope theorem, a marginal tax increase reduces consumer surplus by the resulting equilibrium quantity times the change in price.

$$\frac{dCS}{d\tau} = \rho Q^{\star}$$

Where $\rho \equiv \frac{dP}{d\tau}$ is the **pass-through rate**

Deriving the change in producer surplus

$$\pi = (P - MC)Q_i$$

Taking the derivative with respect to τ yields

$$\frac{d\pi}{d\tau} = Q_i[(1 - L\epsilon_D)\rho - \gamma]$$

- Lerner index: $L = (P - MC)/P$
- Elasticity of demand ϵ_D
- Cost shift rate $\gamma \equiv dMC/d\tau$

Derivation:

$$
\begin{aligned}
\frac{d\pi}{d\tau} &= \frac{dP}{d\tau}Q + \frac{dQ}{dP}\frac{dP}{d\tau}P - \frac{dMC}{d\tau}Q - \frac{dQ}{dP}\frac{dP}{d\tau}MC \\
&= \frac{dP}{d\tau}Q + \frac{dQ}{dP}\frac{dP}{d\tau}[P - MC] - \frac{dMC}{d\tau}Q \\
&= \rho[Q + Q[\frac{dQ}{dP}\frac{P}{Q}][\frac{P - MC}{P}]] - \gamma Q \\
&= Q[\rho(1 - L\epsilon_D) - \gamma]
\end{aligned}
$$

From tax pass-through to cost pass-through

$$\frac{dP}{d\tau} = \frac{dP}{dMC}\frac{dMC}{d\tau} = \rho_{MC}\gamma$$

Final result:

$$I = \frac{\rho_{MC}}{1-(1-L\epsilon_D)\rho_{MC}}$$

Requires just three parameters:

1. marginal cost pass-through
2. Lerner index (percent markups)
3. elasticity of demand

Challenge: Prices easily observed, but marginal costs rarely are.

Want to estimate market power: $L = (p - mc)/p$

Modern empirical IO developed machinery to solve this problem by focusing on the **demand side**.

Under Bertrand, optimal price solves:

$$Q(P) + PQ'(P) = MC(Q(P))Q'(P)$$

Inverse elasticity rule:

$$\frac{P - MC(Q(P))}{P} = -\frac{1}{\epsilon_D}$$

This says that if we can estimate demand, can infer markups.

A new approach to estimating markups

De Loecker and Warzynski (AER, 2012) develop an alternative approach which does not require demand estimation.

- Assumes only cost minimization.

THE RISE OF MARKET POWER AND THE MACROECONOMIC IMPLICATIONS*

JAN DE LOECKER
JAN EECKHOUT
GABRIEL UNGER

We document the evolution of market power based on firm-level data for the U.S. economy since 1955. We measure both markups and profitability. In 1980, aggregate markups start to rise from 21% above marginal cost to 61% now. The increase is driven mainly by the upper tail of the markup distribution: the upper percentiles have increased sharply. Quite strikingly, the median is unchanged. In addition to the fattening upper tail of the markup distribution, there is reallocation of market share from low- to high-markup firms. This rise occurs mostly

Setup

Firms produce output using variable inputs (V), dynamic inputs (D), and productivity (Ω)

Production technology $Q = Q(V, D, \Omega)$

Variable inputs chosen to minimize costs:

$$\mathcal{L}(V, D, \lambda) = P^V V + RK + \lambda[Q - Q(V, D, \Omega)]$$

FOC:

$$\frac{\partial \mathcal{L}}{\partial V} = P^V - \lambda \frac{\partial Q()}{\partial V}$$

Derivation

$$P^V = \lambda \frac{\partial Q()}{\partial V}$$

- Multiply numerator and denominator by V/Q on RHS
- Multiply both sides by P

Recovering markups

$$\frac{P}{\lambda} = [\frac{\partial Q()}{\partial V}\frac{V}{Q}][\frac{P^V V}{PQ}]^{-1}$$

- First term: Elasticity of output w.r.t. a variable input
- Second term: Total cost of the input divided by revenue (“revenue share”)

If we can estimate these two, then recover marginal costs from observed price.

- Intuition for identification (footnote 30): In imperfectly competitive markets, output growth must be associated with disproportionate revenue growth.

Elasticity of output does a LOT of work in this framework

$$\lambda_{it} = P_{it}^{V} \frac{V_{it}}{Q_{it}} \frac{1}{\theta_{it}^{V}}$$

- Otherwise markups just average price over average cost
- So want this elasticity to be very flexible rationalize price and cost movements

Estimating the elasticity of output

Long literature on production function estimation.

- for basic intuition of IO approach, see ABBP.
- Dan Ackerberg has some notes on subsequent lit here.

Basic idea (Cobb-Douglas case):

$$y_{it} = \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \omega_{it} + \epsilon_{it}$$

Want: β_m

Challenge: ω_{it} observed by firm not econometrician.

Ackerberg, Caves and Frazer (2015, ECMA) I

Step 1: Purge output of shocks

$$y_{it} = \phi_t(k_{it}, l_{it}, m_{it}) + \epsilon_{it}$$

Where ϕ is a flexible functional form.

– This first step removes measurement error and ϵ

Can then recover ω_{it} under assumed functional form:

$$\omega_{it}(\tilde{\beta}) = \hat{\phi}_{it} - \tilde{\beta}_k k_{it} - \tilde{\beta}_l l_{it} - \tilde{\beta}_m m_{it}$$

Ackerberg, Caves and Frazer (2015, ECMA) II

Step 2: Use timing assumption to estimate β

- Productivity innovation: $\xi_{it} = \omega_{it} - E[\omega_{it}|\mathcal{I}_{it-1}]$
- Suggests moments: $E[\xi_{it}(\beta)d_{it}] = 0$
- GSW assuming ξ orthogonal to current and lagged capital and labor and lagged materials.
- Assume translog functional form, which gives output elasticities:

$$\theta_{it} = \theta(\tilde{\beta}, l_{it}, m_{it}, k_{it})$$

Estimating cost pass-through

- Could just project prices onto estimated marginal costs.

$$p_{it} = X'\alpha + \rho_{mc}\lambda_{it} + \epsilon_{it}$$

- GWS concerned that marginal costs are estimated with error.
- Even if costs were observed, might be worried about endogeneity. Why?

Construct 2 “shift-share” instruments (Bartik 1991)

ZA: Lagged share of fuels used to generate electricity in a state-year (σ) interacted with national prices for these fuels (e).

$$z^A_{s,t} = [e^A_{-s,t,f} \cdot \sigma^A_{s,t-k,f}], f \in \{coal, gas, oil\}$$

ZB: Lagged industry (n) fuel shares with national mean energy prices

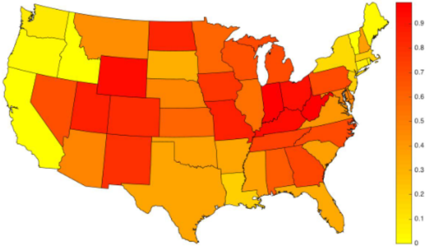
$$z^B_{n,t} = [e^B_{-n,t,f} \cdot \sigma^B_{s,t-k,f}], f \in \{coal, gas, oil\}$$

Question: Why are these good instruments?

Regional energy mix variation

Figure 3: Electricity Fuel Mix by Region

(a) Coal



(b) Natural Gas

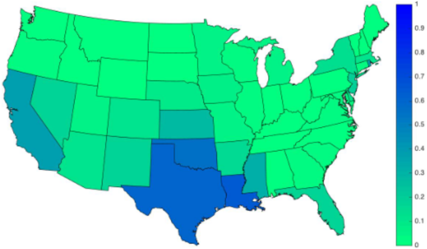
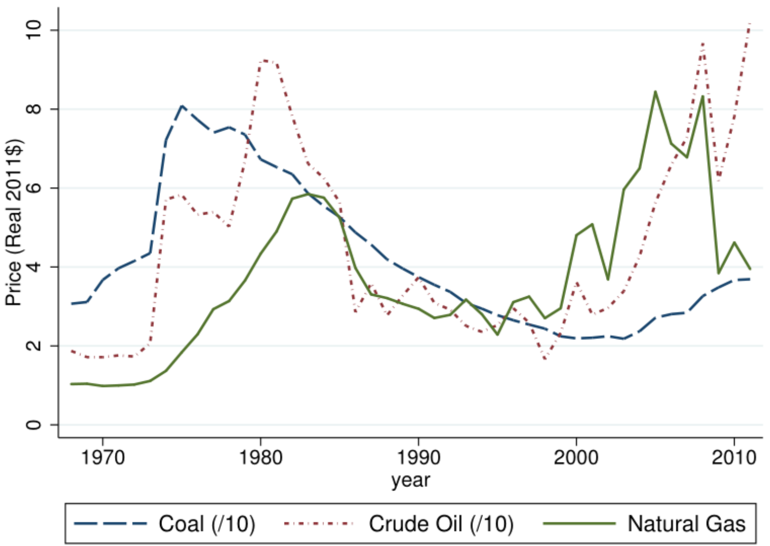


Figure 4: National Fuel Prices, 1967-2012



A note on Bartik Instruments

- These instruments have become quite popular.
  - Prominent example: Autor et al 2013
- A recent literature attempts to formalize what exactly these instruments do: Paul Goldsmith-Pinkham et al, AER 2020.
- DI Blog has an accessible summary
- Takeway is that identification is really coming from the cross-sectional variation (in ADH, industry share variation across markets), not the time-series.

Cost-pass through then estimated using 2SLS

Second stage projects log price onto log marginal cost (estimated),

$$p_{it} = \rho_{mc,\epsilon} mc_{it} + X'_{nst}\gamma + \eta_i + \pi_t + \epsilon_{ist}$$

which, by construction, is equivalent to:

$$p_{it} = \rho_{mc,\epsilon}[p^V_{it} + v_{it} - q_{it} - \hat{\theta}^V_{it}] + X'_{nst}\gamma + \eta_i + \pi_t + \epsilon_{ist}$$

Excluded instruments are Z1, Z2

– Also estimate the reduced form.

Table A1: Pass-Through Rate of Marginal Costs into Unit Prices, by Product: Instrumental Variables

	(1) Boxes	(2) Bread	(3) Cement	(4) Concrete	(5) Gasoline	(6) Plywood
Marginal Costs	0.946***	0.214	0.706***	0.743***	0.491***	0.825***
	(0.031)	(0.443)	(0.067)	(0.098)	(0.139)	(0.076)
N	1414	248	229	3369	284	139
First Stage F-Statistic	12.60	4.25	18.50	15.22	4.73	77.18
Year FE	X	X	X	X	X	X
Plant FE	X	X	X	X	X	X
State-Trends FE	X	X	X	X	X	X

[see tables in text for comparison across specs]

Demand Estimation follows Foster, Haltiwanger and Syverson (2008)

- Project log quantity on to log price
- Challenge: prices can reflect unobserved product quality

GSW solution:
– limit analysis to single-product plants in six industries that produce homogenous products: Boxes, Bread, Cement, Concrete, Gasoline,and Plywood.

- Instrument for price with TFPQ: Physical output / Physical inputs

Table B4: Demand Elasticity Estimates

	(1) Boxes	(2) Bread	(3) Cement	(4) Concrete	(5) Gas	(6) Plywood
	Panel A: OLS					
Demand Elasticity (ϵ_D)	-0.377**	-0.273	-0.387	-0.657	-0.0454	0.00469
	(0.121)	(0.211)	(0.286)	(0.505)	(0.0748)	(0.196)
	Panel B: Productivity IV Estimates					
Demand Elasticity (ϵ_D)	-2.762**	-5.233	-2.902**	-4.275*	-0.131	-1.926*
	(0.894)	(9.187)	(1.054)	(1.980)	(0.111)	(0.820)
N	100	25	25	25	25	50
First Stage F-Statistic	11.71	0.267	9.312	5.209	8.673	8.181
Year Trend	X	X	X	X	X	X

Table 8: Incidence: Change in Consumer Surplus as Share of Change in Total Surplus

	(1) Boxes	(2) Bread	(3) Cement	(4) Concrete	(5) Gasoline	(6) Plywood
	Panel A: Incidence Components					
MC Pass-Through (ρ_{MC})	1.44	0.68	1.81	0.78	0.32	1.07
Demand Elasticity (ϵ_D)	2.76	5.23	2.90	4.28	0.13	1.93
Mean Lerner Index (L)	0.32	0.17	0.57	0.11	0.10	0.32
	Panel B: Consumer Share of Burden (by Market Structure)					
Oligopoly	0.63	0.43	0.46	0.58	0.31	0.64
	(0.03)	(0.17)	(0.09)	(0.07)	(0.22)	(0.18)
Monopoly	0.59	0.41	0.64	0.44	0.24	0.52
	(0.02)	(0.17)	(0.17)	(0.05)	(0.12)	(0.16)
Perfect Competition	1.44	0.68	1.81	0.78	0.32	1.07
	(0.12)	(0.71)	(2.04)	(0.16)	(0.23)	(0.53)

Previous paper employed a common panel strategy to estimate pass-through

– Get a panel of firms before and after some regulation or input cost change

– Some firms are exposed, others aren't

– Pass-through estimated off differential price change between firms that were and weren't exposed in

Challenge: Rival cost pass-through

– In imperfectly competitive markets, firm prices respond *directly* to changes in their own costs, but also *indirectly* to changes in their competitor's costs

This has two immediate implications:

1) Important to account for rival cost changes in estimation.
   – worse than OVB; SUTVA assumption violated

2) Important to pick variation that matches the policy application
   – price responses vary based on the scope of the cost shock, even after conditioning on a firm's own costs.

Motivating example

- As an illustration, consider a simple Cournot model
- Linear demand: $p_i = a - bQ$, constant (heterogenous) mc: c_i

$$p_i \quad = \frac{a}{N+1} + \frac{c_i}{N+1} + \frac{\sum_{j \neq i}^{N} c_j}{N+1}$$

- Point 1: Omitting competitors' costs, biases own-cost PT estimate: $\hat{\beta} = \frac{1}{N+1} + \frac{N-1}{N+1} Cov(c_i, \bar{c}_{-i})$
- Point 2: PT varies for different types of cost shocks
  - Pass-through of a shock to only firm i: $\frac{1}{N+1}$
  - Pass-through of a shock common to all firms: $\frac{N}{N+1}$
  - Depending on the policy question, one might be more relevant

Addressing this emprically is difficult

Need good data on input costs and prices (generally)

Now need to know which firms are competing

And need independent variation in the costs of close competitors

In Muehlegger & Sweeney, we overcome this by focusing on the US refining industry during the fracking boom

A structural approach to pass-through does not have this problem!

– If you estimate BLP, and recompute prices with, for example, subsidies changed, then you have incorporated rival cost pass-through

– Of course we know from Weyl and Fabinger that pass-through is fully determined by structural assumptions that would be imposed on the model

– For this reason, the overwhelming majority of pass-through papers prefer the reduced form.

– Note this too imposes structural assumptions, so you would want to be careful applying any estimates externally

Overview of the refining industry

Middle of supply chain

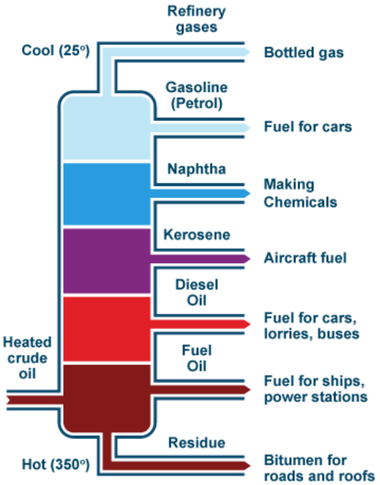
- Buy crude, convert it into end products

Joint production

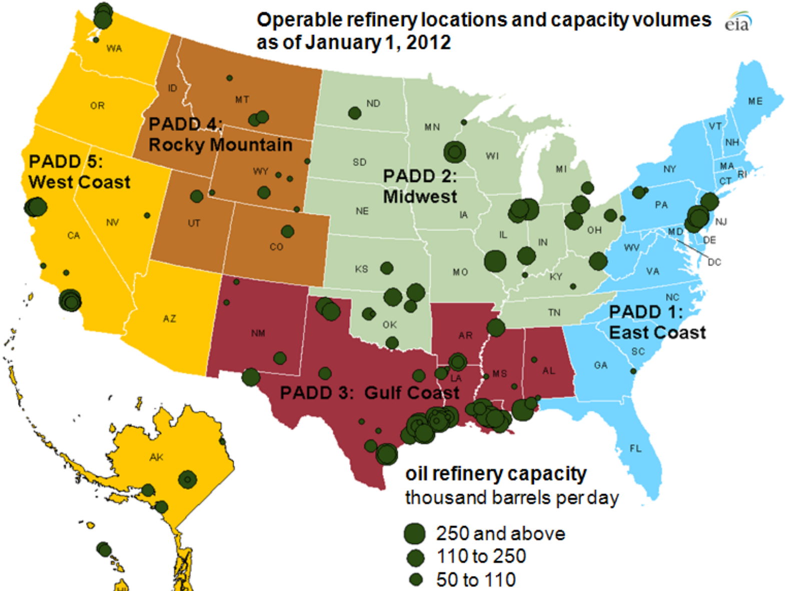
- Gasoline
- No.2 distillate
- Jet fuel

Not all crudes are the same

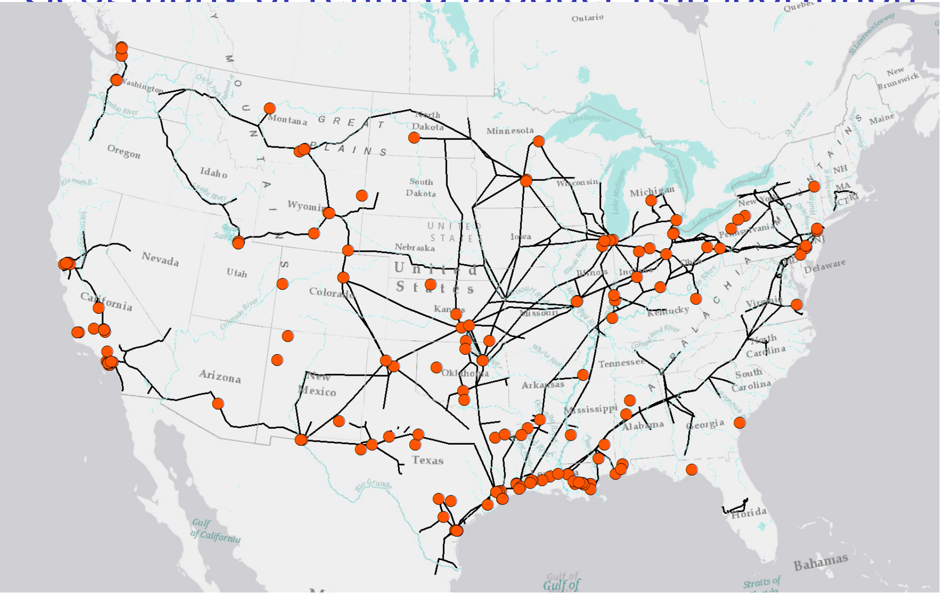
- ↑ API gravity =↑ light products
- "Upgrading" technology ↑ light yields
- **Refineries tailored to specific crudes**



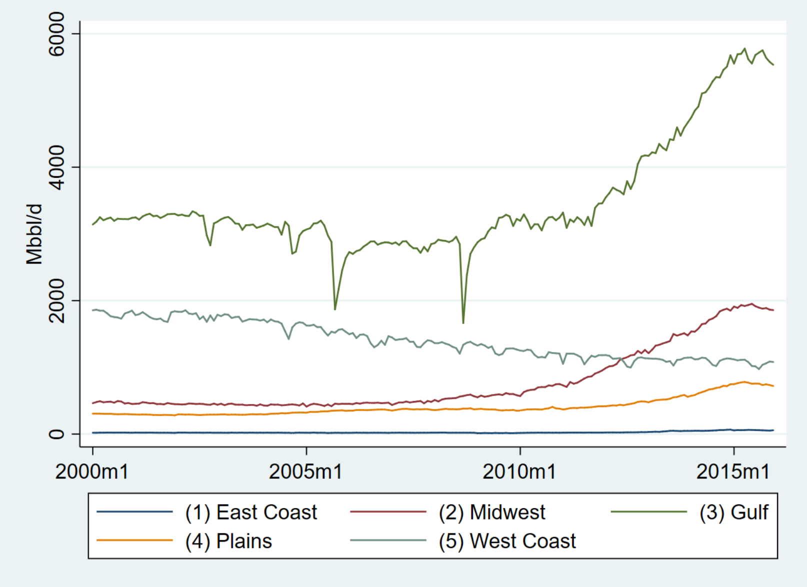
Geography of refining industry



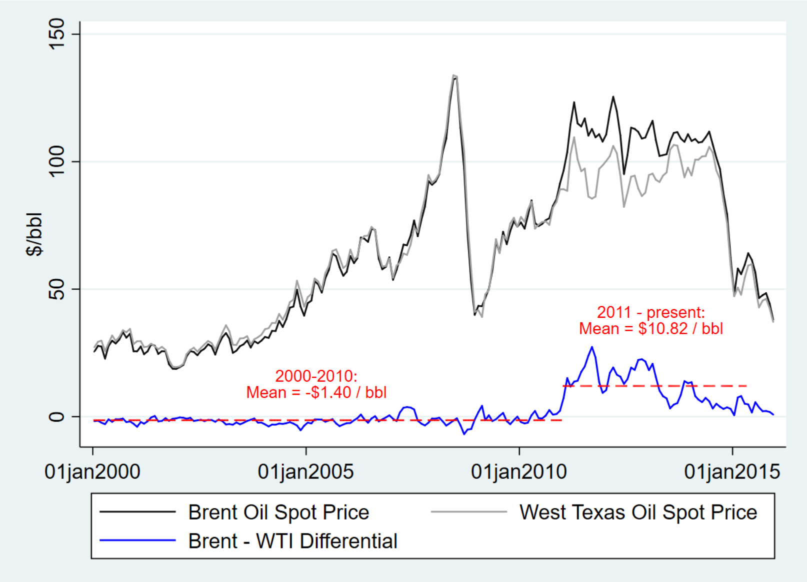
Geography of refined product transportation



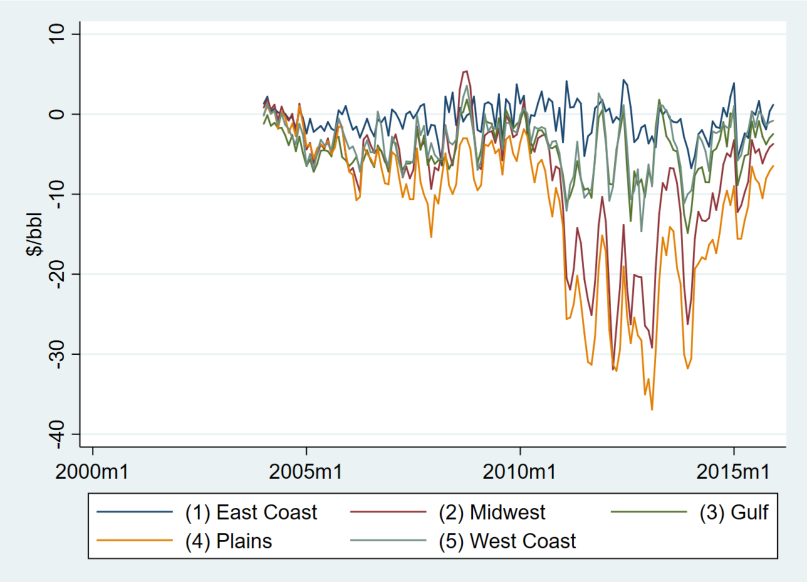
Fracking substantially increased US oil production



U.S. oil spot prices diverged from global prices



Input costs diverged within the U.S.



Shale boom lead to a glut of “light” (high API) oil

Empirical strategy

- Shale boom exogenously caused crude input costs to fall for:
  - refiners in the upper midwest
  - refiners not specialized to process heavy crude
- End markets vary with respect to how many refiners were affected by the shale boom
- We compare pass-through in locations where many firms experience shocks to locations where few firms experience shocks.

We use monthly microdata from EIA (2004-2015)

- **Crude price** observed by Firm-PADD
  - crude price and quantity, fraction domestic / foreign
- **Product price** observed by Firm-State
  - price and quantity, by product & channel (e.g., for resale)
- **Production** observed by refinery
  - all input and output volumes
  - crude characteristics
  - capacity, technology
- State level demographic, weather, economic covariates.

Empirical specification

$$Price_{fmt} = \alpha Cost_{fmt} + \sum_{i \neq f} \beta_{im} Cost_{imt} + X\delta + \eta_t + \epsilon_{fmt}$$

- $Price_{fmt}$ is the price firm f receives in month t in market m
- $Cost_{fmt}$ is the average crude cost for firm f in the PADD (or nearest PADD).
- X is a vector of demand and supply shifters: HDD/ CDD, Income/pc, population, # firms (state, region), capacity
- Three considerations:

1. Incorporating competitors' cost shocks
2. Choice of time fixed effects
3. Instrumenting for cost endogeneity

Empirical consideration 1: Rival cost shocks

$$Price_{fmt} = \alpha Cost_{fmt} + \beta_R \overline{\mathbf{Cost}}^{R}_{imt} + \beta_{NR} \overline{\mathbf{Cost}}^{NR}_{imt} + X\delta + \eta_t + \epsilon_{fmt}$$

- We take a reduced-form approach to mirror the Cournot model
- Separate firms that sell into market m ("rivals") from those that do not ("non-rivals")
  - Average cost of f's rivals, $R(f,m)$: $\overline{Cost}^{R}_{imt} = \frac{\sum_{i \in R(f,m)} Cost_{imt}}{N_{R(f,m)}}$
  - Average cost, weighted by inverse transportation costs (t_{imt}) across non-rivals, $NR(m)$: $\overline{Cost}^{NR}_{imt} = \frac{\sum_{i \in NR(f,m)} Cost_{imt}/t_{imt}}{\sum_{i \in NR(f,m)} 1/t_{imt}}$

Empirical consideration 2: Time fixed effects

$$Price_{fmt} = \alpha Cost_{fmt} + \beta_R \overline{\mathbf{Cost}}^R_{imt} + \beta_{NR} \overline{\mathbf{Cost}}^{NR}_{imt} + X\delta + \eta_t + \epsilon_{fmt}$$

- Given reduced form approach, natural to include fine FEs
- But time FE subsume input cost shocks common to all firms
  - Preclude estimating the PT of an economy-wide shock
- We consider specifications with time FE, and others with year FE and month FE

Empirical consideration 3: Cost endogeneity

$$Price_{fmt} = \alpha Cost_{fmt} + \beta_R \overline{\mathbf{Cost}}^R_{imt} + \beta_{NR} \overline{\mathbf{Cost}}^{NR}_{imt} + X\delta + \eta_t + \epsilon_{fmt}$$

- Cost changes could be correlated with other price determinants
- Nature of fracking shock suggests “Bartik” instruments
- We instrument for input costs using:
  - Pre-period API gravity interacted with time-varying crude index, by API gravity
  - Pre-period domestic fraction interacted with crude index
  - Upper-midwest interacted with crude index

Main Results - State level

Table 1: Fixed Effect Comparison Table

	(1)	(2)	(3)	(4)	(5)
Own	0.0668	0.0534	0.0521	0.0393	0.0447
	(0.0131)	(0.0133)	(0.0131)	(0.0141)	(0.0133)
Rival			0.173	0.938	0.282
			(0.0427)	(0.0147)	(0.0164)
Brent Spot					0.625
					(0.0113)
Time FE	MoS	MoS-St	MoS	Y,M	Y,M
N	71570	71489	71570	71570	71570
r2	0.962	0.973	0.962	0.939	0.945

Rival cost pass-through - State level

(a) State Level Results

	(1)	(2)	(3)	(4)
Own	0.0447	0.0485	0.0606	0.0704
	(0.0133)	(0.0134)	(0.0255)	(0.0252)
Rival	0.282	0.128	0.146	0.0357
	(0.0164)	(0.0214)	(0.0299)	(0.0387)
Fringe		0.159		0.112
		(0.0220)		(0.0357)
Brent Spot	0.625	0.617	0.732	0.722
	(0.0113)	(0.0101)	(0.0124)	(0.0105)
Rival Measure		Avg		Avg
IV			Yes	Yes
fstat			4651	3137
N	71570	71529	71570	71529

Rival cost pass-through - Firm level

(b) Firm Level Results

	(1)	(2)	(3)	(4)
Own	0.0493	0.0552	-0.00498	0.0102
	(0.0312)	(0.0286)	(0.0517)	(0.0501)
Rival	0.285	0.204	0.211	0.163
	(0.0368)	(0.0408)	(0.0663)	(0.0858)
Fringe		0.0604		0.00838
		(0.0379)		(0.0654)
Brent Spot	0.622	0.635	0.736	0.757
	(0.0181)	(0.0168)	(0.0252)	(0.0235)
Rival Measure		Avg		Avg
IV			Yes	Yes
fstat			288	190
N	9169	9169	9169	9169

Implications for incidence

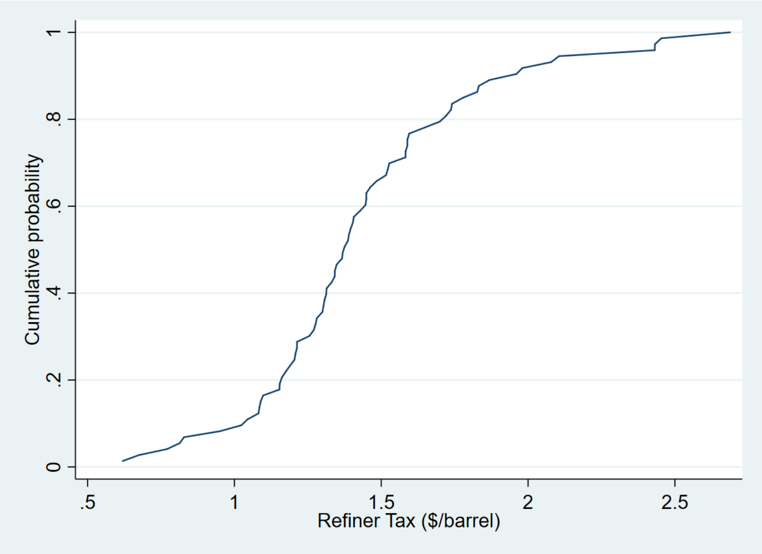
Consistent with two recent refinery PT papers:

- Ganapati, Shapiro & Walker (2017): PT ~ .24
- Knittel, Meiselman & Stock (2015): PT = 1

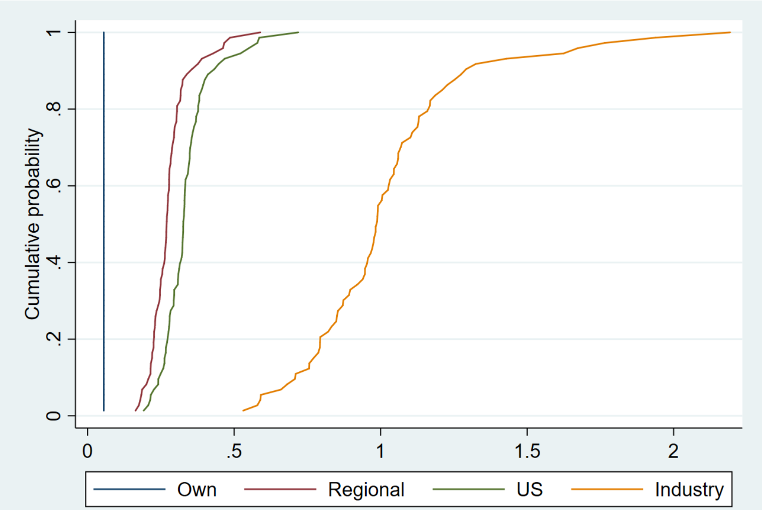
Application: Carbon tax on refining industry

- Over 20% of well-to-wheel gasoline emissions prior to the pump
- Roughly 10% from refining
- Second highest ranked sector in terms of GHG emissions per facility (behind Power Plant Sector)
    - average of 1.22 MMT CO2e
- 145 facilities ~ 3% total US GHG emissions (EPA GHGRP)
- We consider a $51/ton CO2 tax on refineries
    - Hold aside taxing the carbon content of fuels

Significant heterogeneity in carbon intensity



Translates into heterogeneity in pass-through



A value of 1 denotes full pass-through of a firm's cost shock onto consumers.