The importance of accounting for market power and the production process in environmental policy: evidence from U.S. oil refineries

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Introduction and Motivation

- Policy makers are increasingly concerned with regulating emissions from transportation fuels
- Two key features of the transportation sector make it exceptionally difficult to regulate
  - Imperfect competition
    - When firms are imperfectly competitive, regulation can exacerbate market power (Seade, 1986)
  - Regulation in a multi-product setting
    - Incomplete regulation can lead to production reallocation that results in emissions leakage as well as inefficient production (Fowlie, 2009, Auffhammer and Kellogg, 2011, Brown et al., 2006)
- When these features are not accounted for, introducing regulation can lead to a wide range of unintended welfare effects.

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Contributions

- I test whether these conditions occur in the oil refining industry as a result of the national U.S. Renewable Fuel Standard
- I implement a novel production function approach combined with very detailed data to estimate markups and marginal costs for all refineries in the U.S.
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Findings

- I find significant variation in markups across firms, products, and locations
- In 2013, a shock to renewable fuel credit prices (RIN's) *increased* markups for gasoline and ultra low-sulfur diesel
- In 2013, credit prices (RIN's) were excessively passed onto wholesale gasoline and diesel prices
- The policy had spillover effects to non-regulated fuels
  - Firms reallocated production to non-regulated fuels (aviation fuel), leading to potential emissions leakage
  - Non-regulated fuel prices, markups, and marginal costs were also affected
- I intend to evaluate the welfare effects of failing to account for market power and multi-product production process in policy making

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Data

- Confidential Production and Sales Data From Energy Information Administration (2004 - 2014)
  - Monthly Inputs
    - Crude quantities (refinery level)
    - Imported and Domestic Crude Prices (firm-PADD level)
    - Crude quality - API gravity and sulfur content
    - Distillation capacity (refinery level)
    - Labor inputs (state level)
  - Monthly Outputs
    - Quantities of all production outputs (used for production function estimation)
    - Shipments of all outputs by refinery (used in the markup estimation)
    - Sales prices of all products by state (firm level)
- Renewable Fuel Standard Credit Prices (RIN's)

Methodology: Markup Definition (De Loecker and Goldberg et al. 2014)

$$\mu_j = \frac{P_j}{mc_j} = \theta_j^c \left(\frac{P_j Q_j}{(p^c q^c)\rho_j} \right)$$

- θ_j^c is the output elasticity with respect to crude oil input
- $\frac{P_j Q_j}{(p^c q^c)}$ is the revenue share of product j relative to input expenditure on product j
- ρ_j is share of sales of product j

Production Function

$$q_{ijt} = \alpha + \beta_k \boldsymbol{k}_{ijt} + \theta_j^c c_{ijt} + \beta_l l_{st} + g_t(\omega_{it}) + \varepsilon_{ijt}$$

- $q_{ijt} = \log(Q_{ijt})$ outputs
- $\boldsymbol{k}_{ijt} = \log(\rho_{ijt} \boldsymbol{K}_{it})$ vector of capacity measures multiplied by product share
- $c_{ijt} = \log(\rho_{ijt} C_{it})$ crude oil input multiplied by product share
- l_{st} is a measure of labor usage
- $g_t(\omega_{it})$ is refinery specific unobserved productivity

Key Challenge:

Addressing potential correlation between ω_{it} and c_{ijt}

Solution

- Structural Approach - Olley and Pakes (1996), Levinsohn and Petrin (2003), Ackerberg, Caves, and Frazer (2006)

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Production Function Estimates

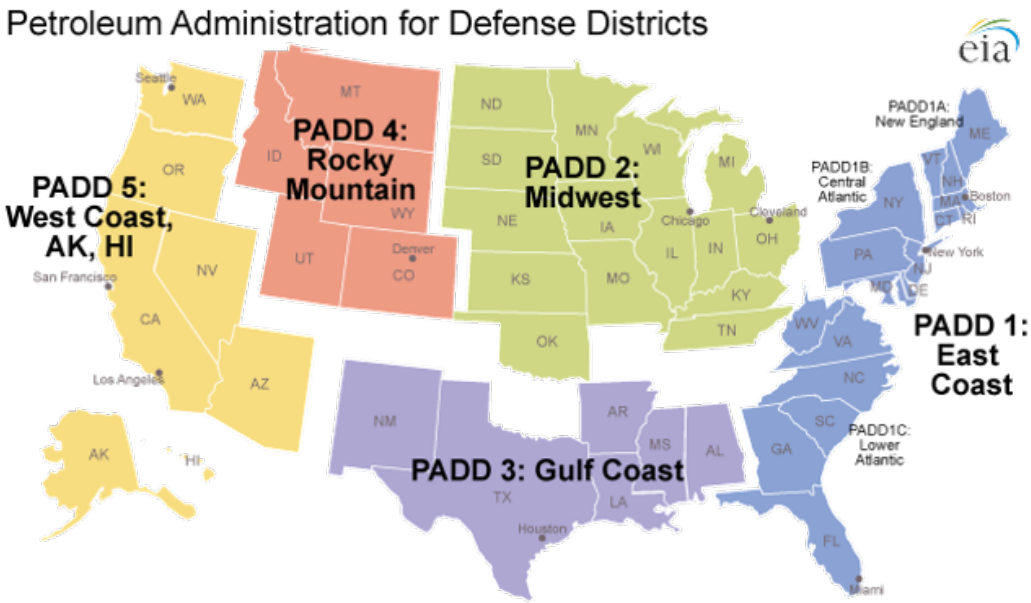
	Gasoline	Diesel	Aviation	Other
Crude Inputs	0.807**	0.779***	0.771***	0.747***
	(0.401)	(0.214)	(0.112)	(0.214)
Capital	0.113	0.188	0.148	0.189
	(0.395)	(0.222)	(0.117)	(0.151)
Labor	0.065***	0.024***	0.018***	0.058***
	(0.008)	(0.005)	(0.005)	(0.015)
PADD FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
N	19870	19968	10040	15349

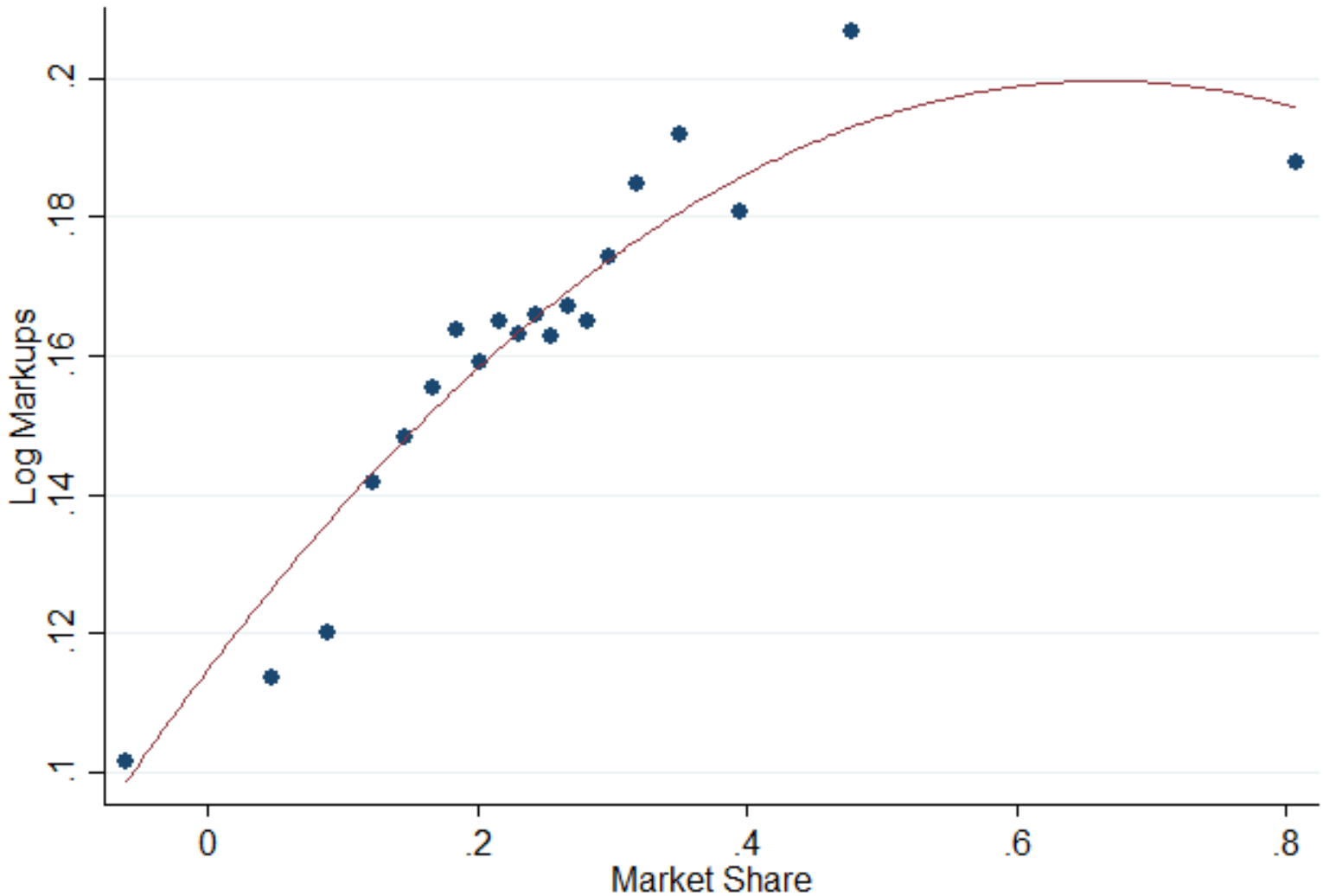
* p<0.1, ** p<0.05,*** p<0.01

Instruments: lagged crude inputs, current capital and labor, lagged market share, interactions (lagged crude inputs x lagged market share)
Controls: API gravity and sulfur content, PADD dummies, market share

Markup Summary Statistics by Region

PADD	Median	Mean	Min	Max	N
1	1.180	1.204	0	3.344	20063
2	1.141	1.186	0	58.702	53004
3	1.229	1.512	0	167.607	20702
4	1.192	1.207	0	6.250	10768
5	1.212	1.260	0	3.692	16008
Total	1.173	1.257	0	167.607	120545





Inner 98th Percentile of Markups. Absorbing firm, fuel, time fixed effects.

Application to the National Renewable Fuel Standard (2007)

- Policy Goals
  - Ensure gasoline and diesel are blended with renewable fuels
  - Reduce greenhouse gas emissions from transportation fuels
  - Reduce petroleum imports
- Takeaways for today's presentation
  - Conventional fuel (gasoline and diesel) is taxed (called the RIN obligation)
  - Renewable fuel is subsidized e.g., ethanol, biodiesel, advanced biodiesel

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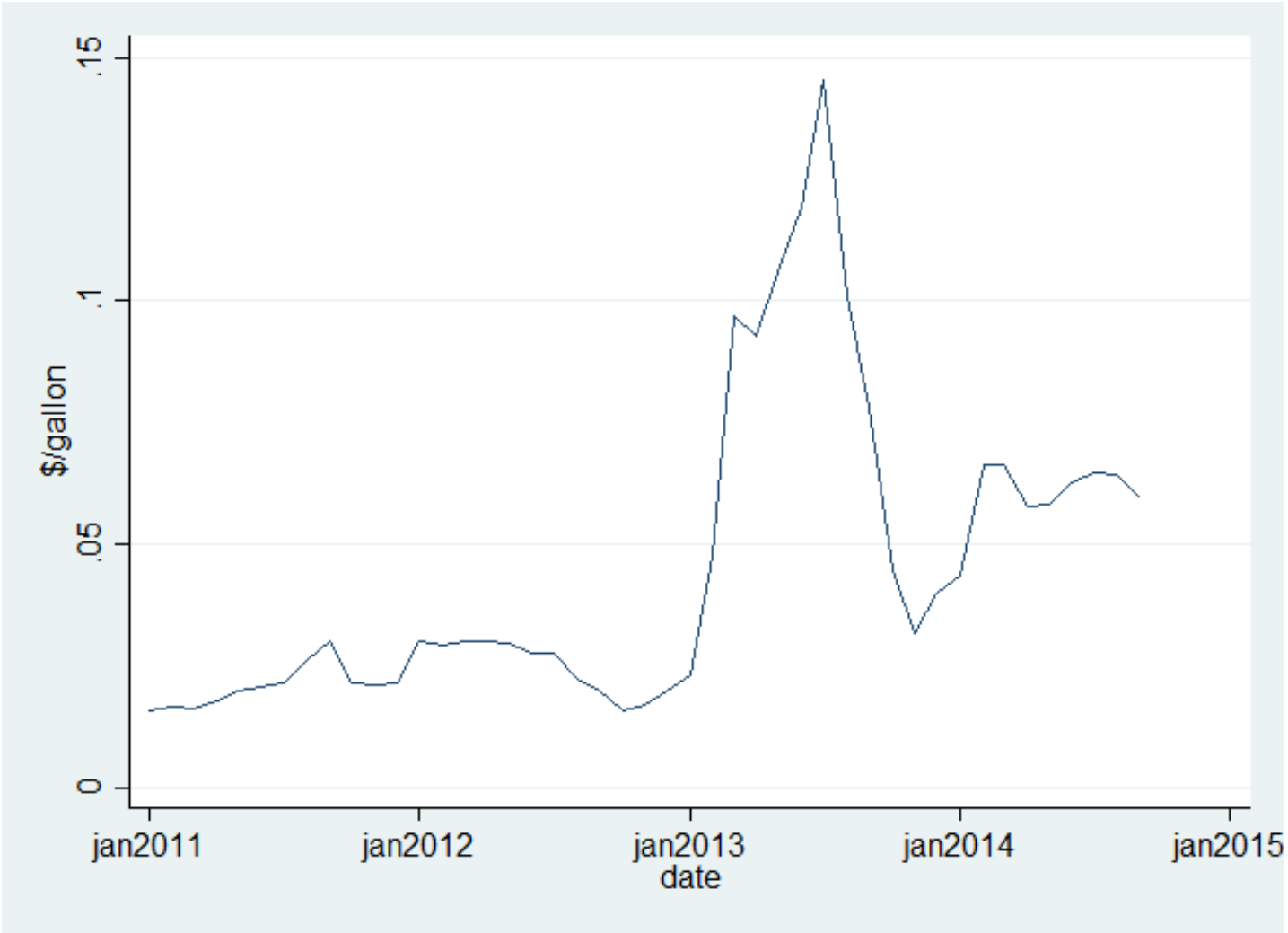
RIN Price or The Tax on Gasoline and Diesel Production



Prices, Marginal Costs, Markups, Quantities and RFS Credit Prices (RIN)

$$\Delta P_{fjst} = \beta_0 + \beta_1 \Delta RIN_t + \beta_2 \Delta P_{fst}^{crude} + \beta_3 \boldsymbol{X}_{fjst} + m_t + \varepsilon_{fjst}$$

- ΔP_{fjst} - firm $f's$ price of product j sold in state s at time t
- ΔRIN_t - average RIN obligation in time period t
- ΔP_{fst}^{crude} - price of crude for firm f in state s
- $\boldsymbol{X}_{fjst}$ includes the number of firms in a market
- m_t - seasonal dummies

Output Prices and RIN Credit Prices

	ΔPrice 2013 All Fuels	ΔPrice 2013 Gasoline	ΔPrice 2013 Diesel	ΔPrice 2013 Other
ΔRIN Price	0.855***	1.824***	-0.021	1.116***
	(0.103)	(0.105)	(0.101)	(0.340)
ΔCrude Price	0.138***	0.152***	0.134***	0.093
	(0.022)	(0.033)	(0.024)	(0.074)
Seasonal FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
R-squared	0.219	0.381	0.247	0.154
N	7532	2941	3083	1508

* p<0.1, ** p<0.05,*** p<0.01

Standard errors clustered at the firm-product-state level

Marginal Costs, Markups, and Credit (RIN) Prices

$$\ln \Pi_{fjst} = \gamma_0 + \gamma_1 \ln RIN_t + \gamma_2 \boldsymbol{X}_{fjt} + \lambda_{ft} + J_j + m_t + G_f + \nu_{fjst}$$

- $\ln \Pi_{fjst}$ - log of firm $f's$ *markup or marginal cost* for product j in state s at time t
- $\ln RIN_t$ - log RIN obligation
- $\boldsymbol{X}_{fjst}$ - market share, productivity, the number of firms in a market, log crude prices
- λ_{ft} - firm-year fixed effects
- J_j - product fixed effects
- m_t - seasonal fixed effects
- G_f - PADD fixed effects

	Log MC Gas+Diesel >=2012	Log μ Gas+Diesel >=2012	Log μ Gas 2013	Log μ Reg Diesel 2013	Log μ ULSD 2013	Log μ Other >=2012
Log RIN price	0.056***	-0.016***	0.084***	-0.029*	0.012**	-0.012*
	(0.003)	(0.003)	(0.005)	(0.017)	(0.005)	(0.006)
Firm-Year FE	Y	Y	Y	Y	Y	Y
Fuel FE	Y	Y	Y	Y	Y	Y
PADD FE	Y	Y	Y	Y	Y	Y
Seasonal FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
R-squared	0.763	0.568	0.615	0.582	0.625	0.579
N	16904	16904	2971	497	2614	4123

* p<0.1, ** p<0.05,*** p<0.01

Standard errors clustered at the firm-product-state level

Production Decisions and Credit (RIN) Prices

$$PS^j_{rt} = \delta_0 + \delta_1 RIN_t + \lambda_{rt} + m_t + \nu_{rt}$$

- PS^j_{rt} - product share for fuel j including
  - Regulated Fuels
    - Conventional gasoline
    - Reformulated gasoline
    - Regular diesel
    - Ultra low sulfur diesel
  - Unregulated Fuels
    - Aviation fuel
- RIN_t - RIN prices
- λ_{rt} - refinery-year fixed effects
- m_t seasonal dummies

Production Decisions and Credit Prices

	CONV	RFG	Diesel	ULSD	Aviation
RIN Prices	0.020	0.074	-0.082*	0.011	0.026*
	(0.059)	(0.106)	(0.046)	(0.062)	(0.014)
Seasonal Dummy	-0.011***	0.005	-0.003	0.010***	0.001
	(0.004)	(0.006)	(0.002)	(0.003)	(0.001)
Refinery-Year FE	Y	Y	Y	Y	Y
R-squared	0.932	0.942	0.955	0.921	0.790
N	3694	1415	3977	3709	283

* p<0.1, ** p<0.05,*** p<0.01

Standard errors clustered at the refinery-product level

Final Remarks

1. Jointly estimate firm-product level markups and marginal costs for petroleum products
2. I find that the Renewable Fuel Standard
    1. *Increased* markups for gasoline and ultra low-sulfur diesel in 2013
    2. Caused firms to reallocate production to non-regulated fuels
3. Next Step: to develop welfare estimates of the results.

Thank You

Comments?