Strategic Pricing and Positioning in Response to Tax Notches: Evidence From Gasoline Retail

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Motivation

- Consumers respond to tax kink and notches.

  Chetty et al. (2011), Kleven and Waseem (2013), Chiou and Muehlegger (2014)

- Firms react to state taxes on their location decisions.

  Bartik (1985), Coughlin et al. (1991), Holmes (1998), Chirinko and Wilson (2008)

- Administrative borders create tax notches for firms and consumers.
- Tax notches create differentiated competition.

  Stolper (2017), Coyne (2017), Muehlegger and Sweeney (2017)

- However, tax notches also create differentiated location incentives
- In this paper, the relation between:
  - Bunching due to spatial tax notches.
  - Differentiated tax pass-through at the border.

Question and Methodology

Question:

- Do retailers bunch near the border due to spatial tax notches?
- What is the effect of administrative borders on the local competition?
- What model explains both discontinuous price and location choices?

Methodology:

- I use a unique dataset of prices and locations of 140,000 gas retailers
  - web-scraping the network of GasBuddy.
- Model of firm location accounting for spatial tax notches.
  - Grid over America that uses tax differences across state boundaries.
- Tax pass-through for all retailers and those at the border.
  - Controls for gasoline regulations, regional market, and local demand.

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Preview of Findings

- Bunching of gasoline retailers due to state tax notches.
  - Tax notches lower the odds of seeing a gas station across the border.
  - Higher taxes reduce the expected number of retailer at the border.

- Differentiated pricing function at the border.
  - Average pass-through is 100%, but at the border is smaller.
  - The pass-through is higher for stations at the low tax side of the border.
  - Regular gas: the pass-through at the border can be higher than 100%.

A model of price discrimination: A tale of two elasticities

On the Agenda

1. Data
2. Methodology and Results
3. Conclusions

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Data

- Unique dataset that includes:
  - Excise gasoline tax: American Petroleum Institute
  - Location of gasoline retailers: Web-scraping a prominent website.
  - Spatial tax notches: $\Delta\tau$, using spatial location.
  - Regulation: Gasoline requirements and regional supply.
  - Population: Census block groups estimates from the ACS.
  - Roads: Primary and secondary roads from Census Bureau.
  - Gas Price: Daily reported price of retailers.

Data

- Large dataset on gasoline prices and stations locations
  - Web-scraping information from the network of GasBuddy[1].
- Other research on retail gasoline markets also uses the same data.
  - Price:

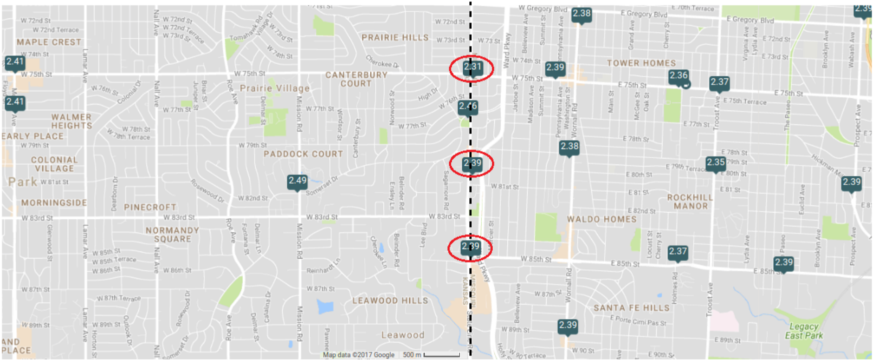
    Eckert and West (2004b,a, 2005), Noel (2015), Yilmazkuday and Yilmazkuday (2016), Byrne (2017), Coyne (2017), González and Hurtado (2018)
  - Consumer search:

    Lewis and Marvel (2011), Byrne et al. (2013)
  - Potential sample selection:

    Atkinson (2008)
- In this paper: location choice of retailers and pricing function.
- Example: Kansas, MO - Paris, PA

[1] The network operates under different advertiser-sponsored domain names: www.chicagogasprices.com, www.newyorkgasprices.com, www.losangelesgasprices.com, ect.

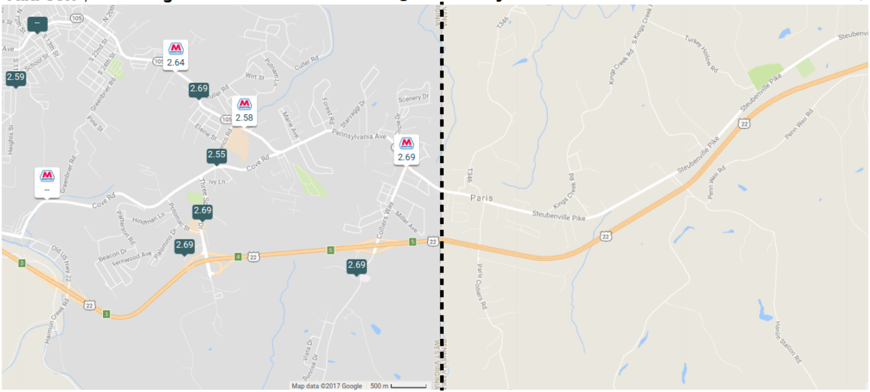
Tax: 24.04 ¢ **Average Price: 2.44** **Kansas** **Missouri** **Average Price: 2.38** **Tax: 17.35 ¢**



$$\Delta\tau = 6.68¢$$

Source: GasBuddy Webpage (retrieved on Nov-7-2017)

Tax: 35.7 ¢ **Average Price: 2.65** **West Virginia** **Pennsylvania** **Tax: 59.3 ¢**



$\Delta\tau = 23.6$¢

Source: GasBuddy Webpage (retrieved on Nov-7-2017)

Data

Number of Retailers by Petroleum Administration for Defense Districts

PADD Region♣	Year 2015[A]	Year 2018[B]
East Coast	55,170	49,798
Midwest	38,713	41,006
Gulf Coast	24,442	25,495
Rocky Mountain	4,292	5,049
West Coast	17,480	16,266
Total	140,097	137,614

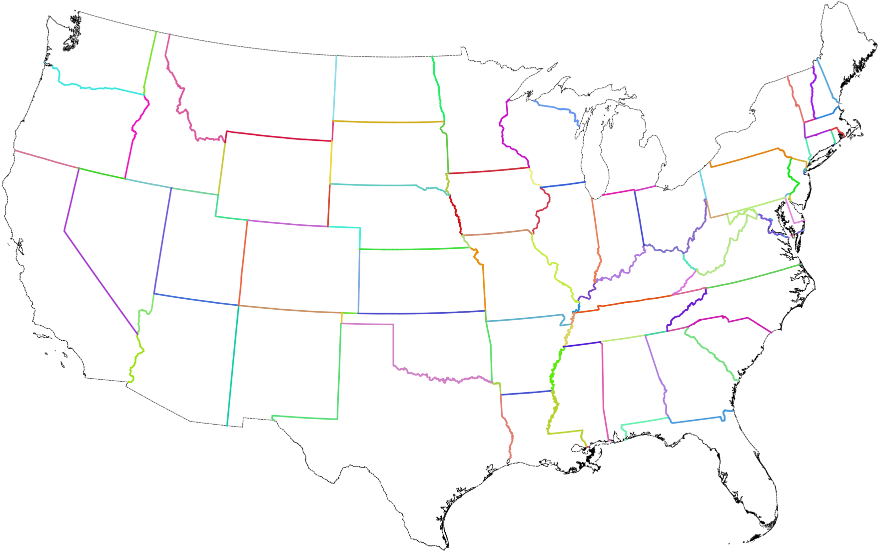
♣ Excluding Alaska and Hawaii

[A] Gasoline Stations and Convenience Stores from CBP

[B] Information from GasBusy.com

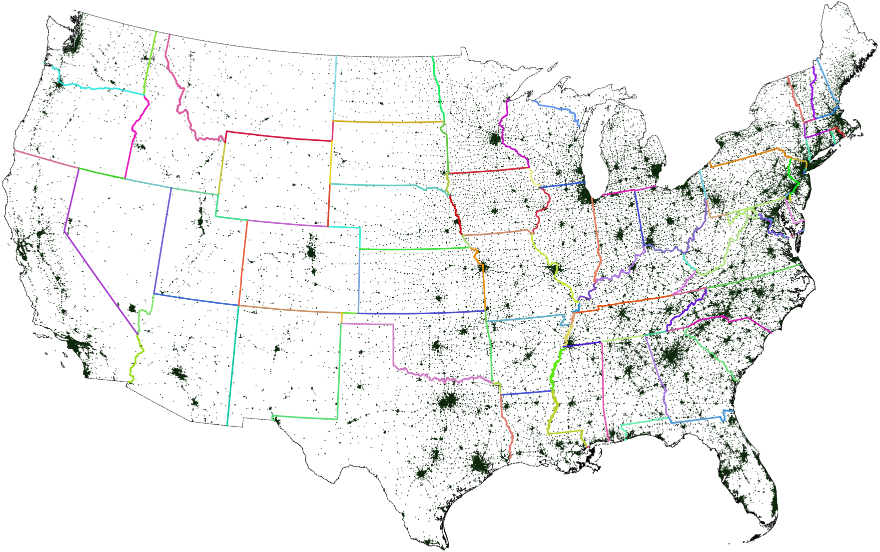
Source: County Business Patterns (CBP) and Author's calculation

Spatial Tax Notches: $\Delta\tau$



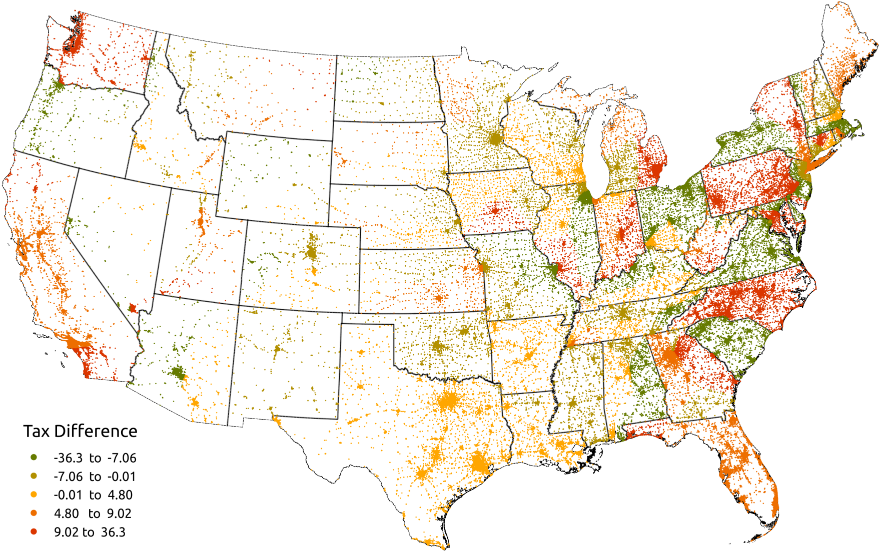
Source: Author's calculation

Spatial Tax Notches: $\Delta\tau$



Source: Author's calculation

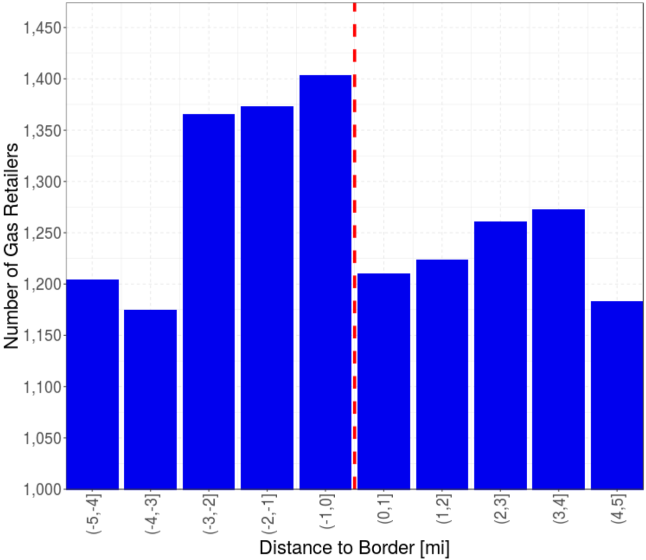
Spatial Tax Notches: $\Delta\tau$



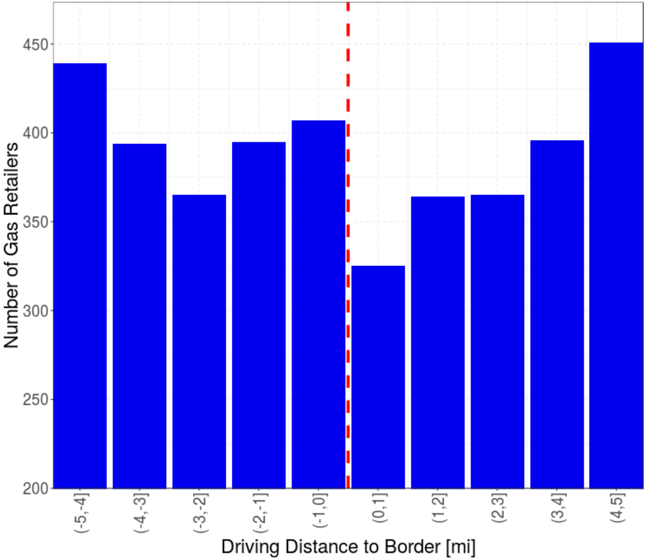
Source: Author's calculation

Bunching at the Border:

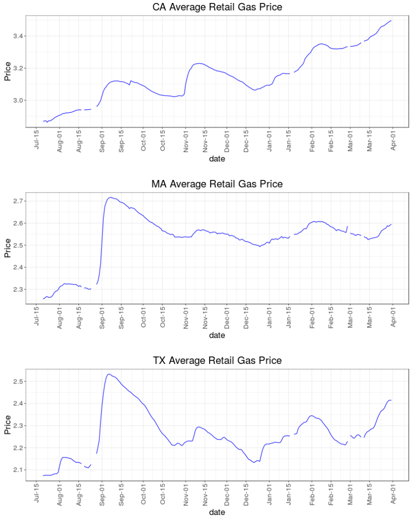
All Retailers



Bunching at the Border:
Close to Primary Roads and Low Population



Spatial Price Variation



(a) Gas Prices for Selected States

(b) Gas Prices Cycle in Some States of the Midwest

On the Agenda

1. Data
2. Methodology and Results
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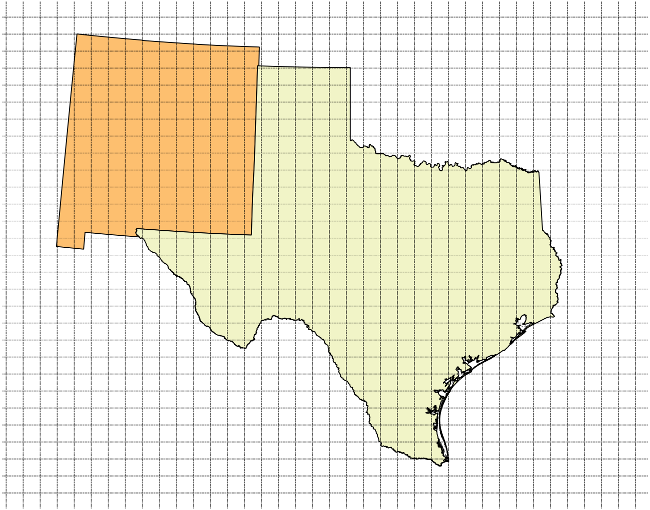
Methodology: Grid America

- Rectilinear grid of 5 km (3.1 mi) by 5 km to cover the continental US.
- Squares divided using administrative borders and coastlines.
  - Around 330 thousand grid points.
- Conditional logit model is computationally unfeasible to estimate.
  - 330,000 location choices and 140,000 retailers.
  - Identical coefficient estimates to Poisson.

    Guimarães et al. (2003), Schmidheiny and Brülhart (2011)
- Probability models that account for the spatial tax differences.

Methodology: Grid America



Methodology: Grid America

- Unobserved preferences of the retailers for a particular grid location:

$$y_g^* = \alpha_s + \Delta\tau_g \beta_0 + x_g' \beta + \varepsilon_g, \qquad (1)$$

  where
  - α_s: State specific constant term.
  - $\Delta\tau_g$: Tax notch for each element of the grid.
  - x_g: population, number of roads, distance to roads, area of grid point
- Observed choice defined as:

$$y_g = \begin{cases} 1 & y_g^* > 0 \\ 0 & y_g^* \leq 0 \end{cases}$$

- Poisson regression: logarithm of the expected number of stations:

$$\log(\lambda_g) = \alpha_s + \Delta\tau_g \beta_1 + x_g' \beta + u_g \qquad (2)$$

Results: Bunching at the Border

Probability Model Considering Administrative Boundaries

	LPM	Logit	Probit
Δ Tax [Cents] $\equiv \beta_0$			
Population [Thous.]			
Number of Roads			
Distance to Road [Km.]			
Area [Sq. Km.]			
State Fixed Effects			
Prob. Estimate $\equiv P$			
β_0/P [%]			
Num. obs.			

Asterisks denote statistical significance at the ***1%, **5%, and *10% level.
Robust standard errors in parentheses clustered by county.
LPM: Linear Probability Model.
Coefficients of Logit and Probit models show marginal effect at the mean.
Probability estimates report the mean of the estimated probabilities.

Results: Bunching at the Border

Probability Model Considering Administrative Boundaries

	LPM	Logit	Probit
Δ Tax [Cents] $\equiv \beta_0$	$-.0009^{**}$	$-.0003^{**}$	$-.0005^{**}$
	(.0003)	(.0001)	(.0002)
Population [Thous.]	$.0100^{***}$	$.0112^{***}$	$.0187^{***}$
	(.0016)	(.0006)	(.0011)
Number of Roads	$.0588^{***}$	$.0095^{***}$	$.0181^{***}$
	(.0013)	(.0006)	(.0011)
Distance to Road [Km.]	$-.0008^{***}$	$-.0059^{***}$	$-.0064^{***}$
	(.0001)	(.0001)	(.0002)
Area [Sq. Km.]	$.0010^{***}$	$.0004^{***}$	$.0006^{***}$
	(.0002)	(.0001)	(.0001)
State Fixed Effects	yes	yes	yes
Prob. Estimate $\equiv P$	0.1152	0.1152	0.1134
β_0/P [%]	-0.82	-0.24	-0.41
Num. obs.	331,076	331,065	331,065

Asterisks denote statistical significance at the ***1%, **5%, and *10% level.
Robust standard errors in parentheses clustered by county.
LPM: Linear Probability Model.
Coefficients of Logit and Probit models show marginal effect at the mean.
Probability estimates report the mean of the estimated probabilities.

Results: Bunching at the Border

Count Regression Considering Administrative Boundaries [2]

	Full	Pr>5%	Pr>10%
Δ Tax [Cents] $\equiv \beta_1$			
Population [Thous.]			
Number of Roads			
Distance to Road [Km.]			
Area [Sq. Km.]			
State Fixed Effects			
Count Estimates $\equiv \lambda$			
β_1/λ [%]			
Num. obs.			

Asterisks denote statistical significance at the ***1%, **5%, and *10% level.
Robust standard errors in parentheses clustered by county.
Full: Estimates for the full sample, Pr>5%: Estimates for the subsample with probability of a retailer bigger than 5%, Pr>10%: Estimates for the subsample with probability of a retailer bigger than 10%. All coefficients show marginal effect at the mean.
Count estimates report the mean of the estimated counts.

[2] I reestimate the probit model excluding ΔTax as explanatory variable for these ▸ Subsamples

Results: Bunching at the Border

Count Regression Considering Administrative Boundaries [2]

	Full	Pr>5%	Pr>10%
Δ Tax [Cents] $\equiv \beta_1$	$-.0004^{**}$	$-.0145^{*}$	$-.0185^{*}$
	(.0001)	(.0056)	(.0085)
Population [Thous.]	$.0002^{***}$	$.0073^{***}$	$.0116^{***}$
	(.0000)	(.0011)	(.0016)
Number of Roads	$.0019^{***}$	$.0759^{***}$	$.1138^{***}$
	(.0002)	(.0042)	(.0060)
Distance to Road [Km.]	$-.0101^{***}$	$-.2806^{***}$	$-.3036^{***}$
	(.0007)	(.0145)	(.0262)
Area [Sq. Km.]	$.0009^{***}$	$.0251^{***}$	$.0286^{***}$
	(.0001)	(.0026)	(.0040)
State Fixed Effects	yes	yes	yes
Count Estimates $\equiv \lambda$	0.414	1.0757	1.5949
β_1/λ [%]	-0.09	-1.34	-1.16
Num. obs.	331,065	125,330	82,262

Asterisks denote statistical significance at the ***1%, **5%, and *10% level.
Robust standard errors in parentheses clustered by county.
Full: Estimates for the full sample, Pr>5%: Estimates for the subsample with probability of a retailer bigger than 5%, Pr>10%: Estimates for the subsample with probability of a retailer bigger than 10%. All coefficients show marginal effect at the mean.
Count estimates report the mean of the estimated counts.

[2] I reestimate the probit model excluding ΔTax as explanatory variable for these ▸ Subsamples

Methodology: No time

- Ideal setup:

$$p_{i,t} = \beta\tau_{i,t} + W_{i,t}\delta + \rho_i + \gamma_t + \epsilon_{i,t} \tag{3}$$

  for retailer i on date t.
  - ρ_i: Retailer fixed effects to model individual heterogeneity.
  - γ_t: Date fixed effects to model price cycles and trends. Example.
- But, there is not enough variation of taxes on a daily frequency.
  - $\tau_{i,t}$ is in fact τ_i.
  - No identification of tax pass-through under retailer fixed effects.
- How can we remove the time effects from the price of each retailer?
  - For example, for each retailer, compute average price over time
  - Using the individual average price has some complications.

Methodology: No time

- First step, remove time effects from price:

$$p_{i,t} = \rho_i + \gamma_t + \epsilon_{i,t} \tag{4}$$

for retailer i on date t.

  - ρ_i: Retailer fixed effects (average prices for station i over time)
  - γ_t: Date fixed effects

- Second step, model the price using the fixed effects estimates:

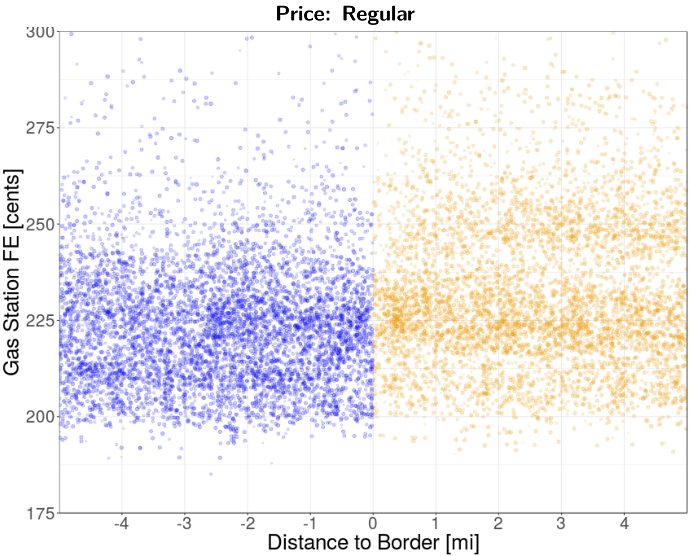
$$\hat{\rho}_i = \beta\tau_i + \mathbb{1}(\text{Regulation}_i)\gamma + \mathbb{1}(\text{PADD}_i)\eta + X_i\theta + \varepsilon_i \tag{5}$$

where

  - τ_i: State tax of retailer i
  - $\mathbb{1}(\text{Regulation}_i)$: RFG, RVP, OF, POT
  - $\mathbb{1}(\text{PADD}_i)$: Regional petroleum markets
  - X_i: Local demand characteristics for retailer i

- Third step, estimate $\hat{\beta}$ using weighted OLS

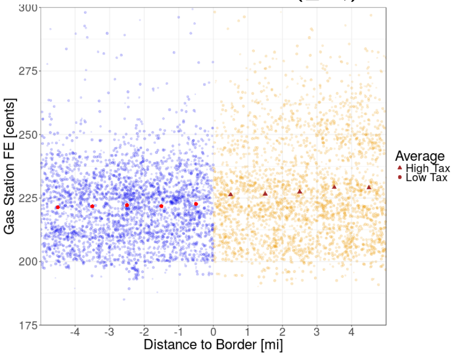
Results: Pricing



Results: Pricing

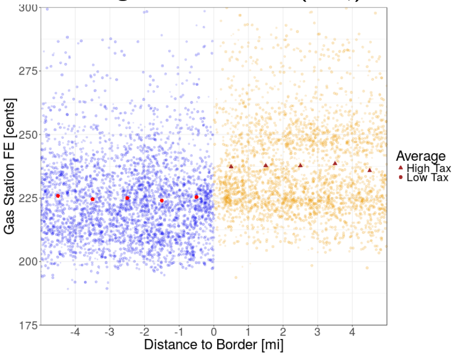
Price: Regular

Low Tax Difference ($\leq 7¢$)



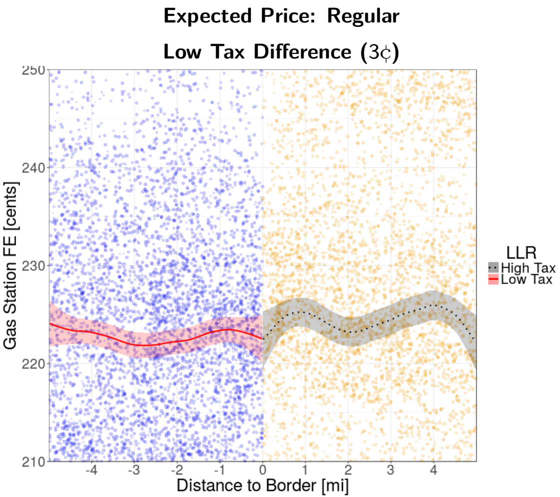
Price: Regular

High Tax Difference ($> 7¢$)



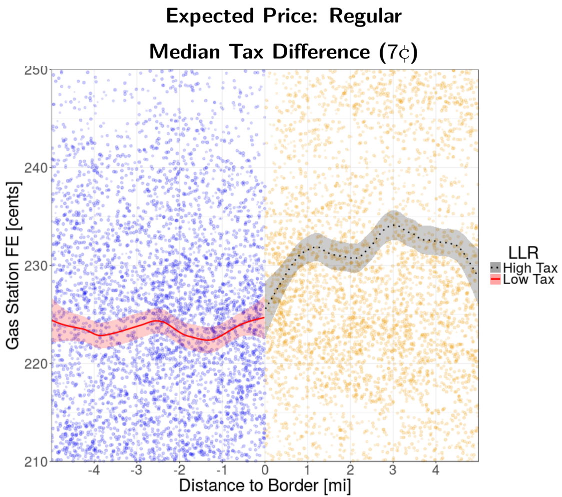
The dots and triangles of each figure show the average price using the data within 1 mile.

Results: Pricing



LLR:Local Linear Regression.

Results: Pricing



LLR:Local Linear Regression.

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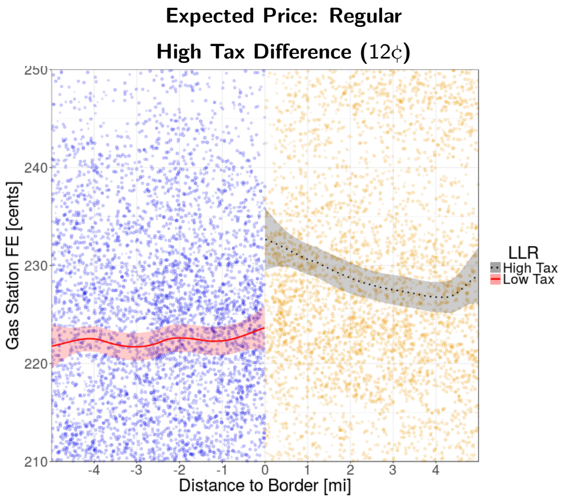

LLR:Local Linear Regression.

	(1)	(2)	(3)	(4)	(5)
	Panel A: Regular				
Tax [Cents]					
Num. obs.					
RMSE					
	Panel B: Midgrade				
Tax [Cents]					
Num. obs.					
RMSE					
	Panel C: Premium				
Tax [Cents]					
Num. obs.					
RMSE					
Demand Controls					
Regulation					
PADD	yes	yes	yes	yes	yes
Sample	States	All	All	Border	Border

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Robust standard errors in parentheses clustered by state

	(1)	(2)	(3)	(4)	(5)
Panel A: Regular					
Tax [Cents]	1.05***	1.09***	1.07***	.90***	.85***
	(.11)	(.12)	(.11)	(.15)	(.14)
Num. obs.	49	126,740	126,694	11,632	11,625
RMSE	35.97	14.61	14.40	14.64	14.40
Panel B: Midgrade					
Tax [Cents]	.99***	1.03***	1.01***	.76***	.72***
	(.13)	(.14)	(.13)	(.13)	(.13)
Num. obs.	49	109,697	109,658	10,132	10,126
RMSE	36.17	15.01	14.82	15.45	15.37
Panel C: Premium					
Tax [Cents]	1.08***	1.06***	1.04***	.76***	.74***
	(.15)	(.16)	(.15)	(.11)	(.12)
Num. obs.	49	110,264	110,223	10,161	10,155
RMSE	38.63	17.08	16.97	17.38	17.32
Demand Controls	no	no	yes	no	yes
Regulation	yes	yes	yes	yes	yes
PADD	yes	yes	yes	yes	yes
Sample	States	All	All	Border	Border

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Robust standard errors in parentheses clustered by state

	(1)	(2)	(3)
Low : Tax	1.11***	.88**	.78*
	(.22)	(.28)	(.38)
High: Tax	.74***	.61***	.65***
	(.12)	(.12)	(.11)
Type of Gasoline	Regular	Midgrade	Premium
All Other Controls	yes	yes	yes
Share of Low [%]	52	51	52
Share of High [%]	48	49	48
Num. obs.	11,625	10,126	10,155
RMSE	13.91	14.92	16.89

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Results: Pricing

- Price may also depend on $\Delta\tau$ and the distance to the border, d_i:

$$
\begin{aligned}
p_{i,t} &= \beta\tau_i + \gamma\Delta\tau_i + \eta d_i \Delta\tau_i + \theta d_i^2 \Delta\tau_i + \cdots \\
&= \beta\tau_i + \gamma\left(\tau_i - \tau_{-i}\right) + \cdots \\
&\quad \cdots + \eta d_i\left(\tau_i - \tau_{-i}\right) + \theta d_i^2\left(\tau_i - \tau_{-i}\right) + \cdots \\
&= \left(\beta + \gamma + \eta d_i + \theta d_i^2\right)\tau_i - \left(\gamma + \eta d_i + \theta d_i^2\right)\tau_{-i} + \cdots
\end{aligned}
$$

- where
  - τ_i: State tax for retailer i.
  - τ_{-i}: Out of state tax across the border for retailer i

Results: Pricing

- Price may also depend on $\Delta\tau$ and the distance to the border, d_i:

$$
\begin{aligned}
p_{i,t} &= \beta\tau_i + \gamma\Delta\tau_i + \eta d_i\Delta\tau_i + \theta d_i^2\Delta\tau_i + \cdots \\
&= \beta\tau_i + \gamma\left(\tau_i - \tau_{-i}\right) + \cdots \\
&\quad \cdots + \eta d_i\left(\tau_i - \tau_{-i}\right) + \theta d_i^2\left(\tau_i - \tau_{-i}\right) + \cdots \\
&= \left(\beta + \gamma + \eta d_i + \theta d_i^2\right)\tau_i - \left(\gamma + \eta d_i + \theta d_i^2\right)\tau_{-i} + \cdots
\end{aligned}
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- where
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Results: Pricing

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$$
\begin{aligned}
p_{i,t} &= \beta\tau_i + \gamma\Delta\tau_i + \eta d_i \Delta\tau_i + \theta d_i^2 \Delta\tau_i + \cdots \\
&= \beta\tau_i + \gamma\left(\tau_i - \tau_{-i}\right) + \cdots \\
&\quad \cdots + \eta d_i \left(\tau_i - \tau_{-i}\right) + \theta d_i^2 \left(\tau_i - \tau_{-i}\right) + \cdots \\
&= \left(\beta + \gamma + \eta d_i + \theta d_i^2\right)\tau_i - \left(\gamma + \eta d_i + \theta d_i^2\right)\tau_{-i} + \cdots
\end{aligned}
$$

- where
  - τ_i: State tax for retailer i.
  - τ_{-i}: Out of state tax across the border for retailer i

	(1)	(2)	(3)
Low : Tax	1.09***	.89***	.79*
	(.19)	(.26)	(.35)
High: Tax	.89***	.70***	.77***
	(.12)	(.13)	(.13)
Low : Tax × Dist.	.08**	.03	.05
	(.03)	(.06)	(.06)
High: Tax × Dist	−.16**	−.12*	−.14**
	(.06)	(.05)	(.05)
Low : Tax out × Dist.	−.07***	−.03	−.05
	(.02)	(.03)	(.04)
High: Tax out × Dist.	.21**	.17**	.20**
	(.08)	(.06)	(.06)
Type of Gasoline	Regular	Midgrade	Premium
All Other Controls	yes	yes	yes
Share of Low [%]	52	51	52
Share of High [%]	48	49	48
Num. obs.	11,625	10,126	10,155
RMSE	13.69	14.84	16.78

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

	(1)	(2)	(3)
Low : Tax	1.19***	.99***	.88*
	(.19)	(.26)	(.35)
High: Tax	.94***	.72***	.81***
	(.12)	(.13)	(.13)
Low : Tax × Dist.	.04	−.08	.04
	(.11)	(.22)	(.22)
High: Tax × Dist	−.47**	−.36*	−.50**
	(.18)	(.17)	(.16)
Low : Tax out × Dist.	−.13	−.02	−.11
	(.07)	(.15)	(.16)
High: Tax out × Dist.	.62*	.52*	.71***
	(.25)	(.24)	(.20)
Low : Tax × Dist.^{2}	.00	.02	−.00
	(.03)	(.05)	(.05)
High: Tax × Dist.^{2}	.08*	.06	.09**
	(.03)	(.03)	(.03)
Low : Tax out × Dist.^{2}	.02	−.00	.02
	(.02)	(.03)	(.03)
High: Tax out × Dist.^{2}	−.11*	−.09	−.13**
	(.04)	(.05)	(.04)
Type of Gasoline	Regular	Midgrade	Premium
All Other Controls	yes	yes	yes
Share of Low [%]	52	51	52
Share of High [%]	48	49	48
Num. obs.	11625	10126	10155
RMSE	13.60	14.80	16.72

On the Agenda

Conclusions

- Bunching of gasoline retailers due to state tax notches.
  - Negative effect of tax notches on the probability of seeing a fueling station across the border.
  - Expected number of stations is smaller on the border of the state with higher tax.
- Differentiated pricing function at the border.
  - Average pass-through is 100%, but at the border is smaller.
  - The pass-through is higher for stations at the low tax side of the border.
  - Regular gas: the pass-through at the border can be higher than 100%.
- More research is needed: How to model location choice and differentiated pass-through?
- More data: City and county level for taxes

Thank you!

questions, comments, suggestion:
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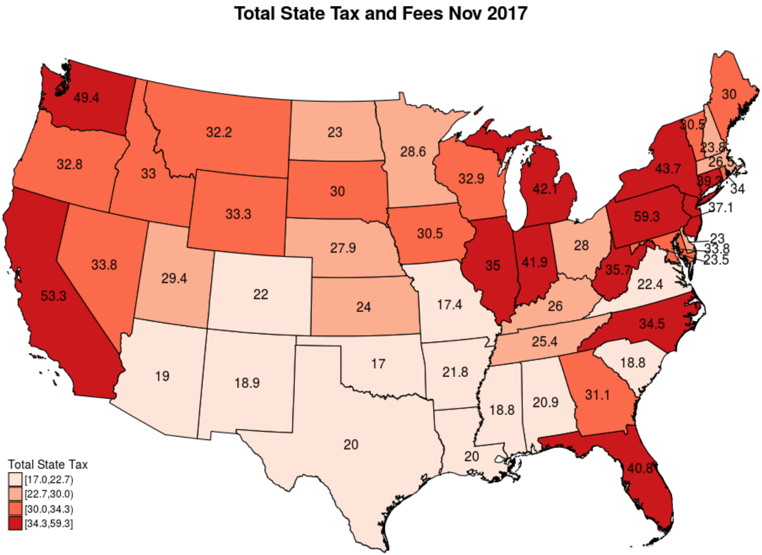
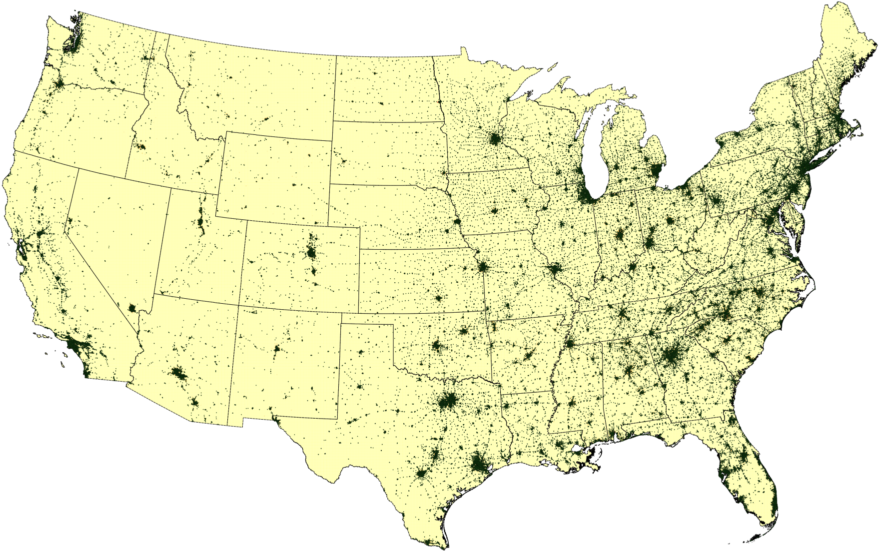


Back Source: American Petroleum Institute

Location of Gasoline Retailers



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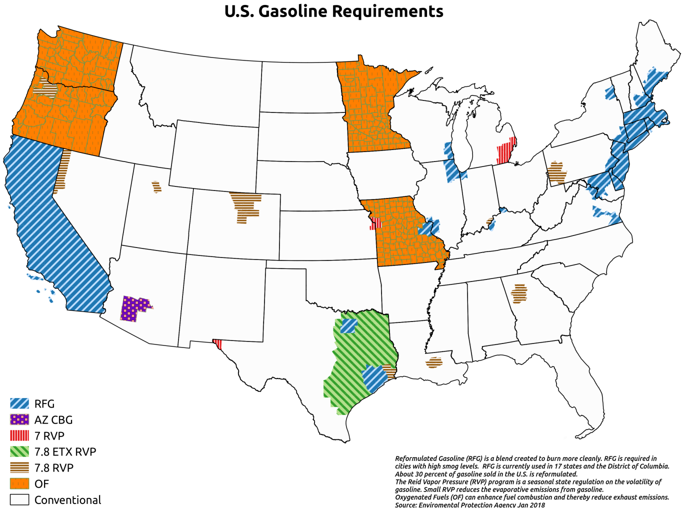
Source: Author's calculation



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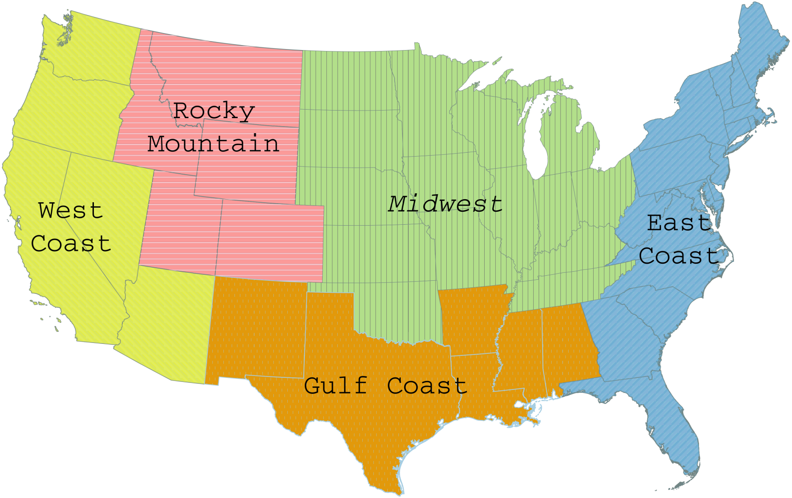
Petroleum Administration for Defense Districts



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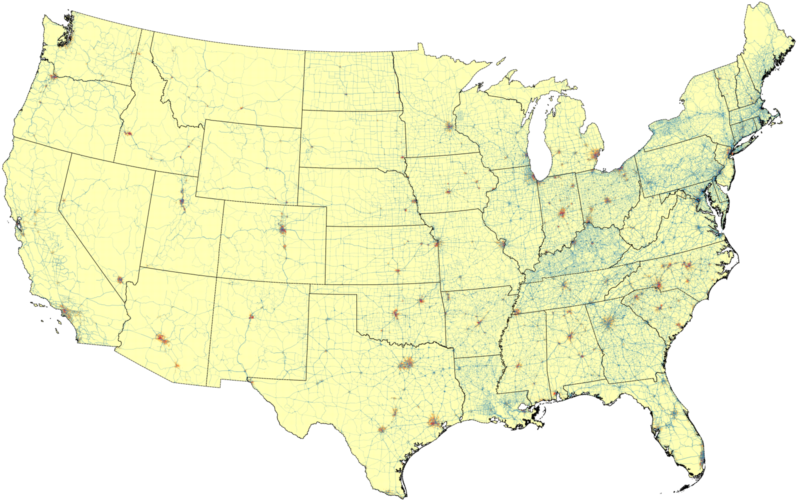
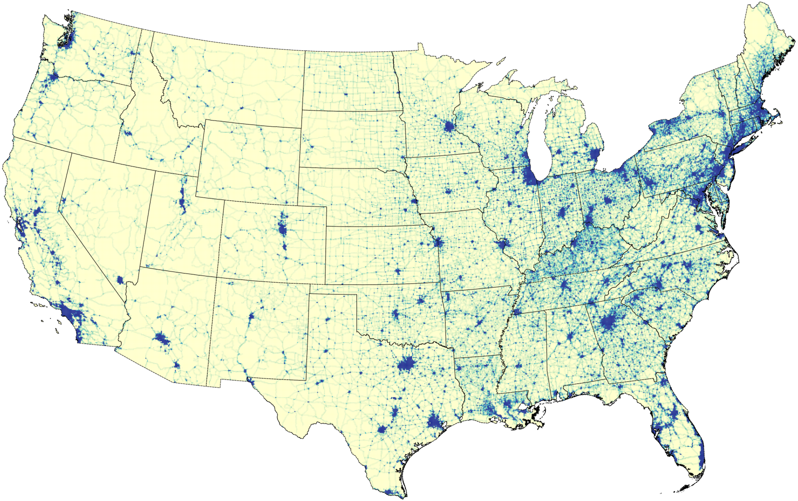
Population and Roads



Back Source: Census Bureau

Full Sample



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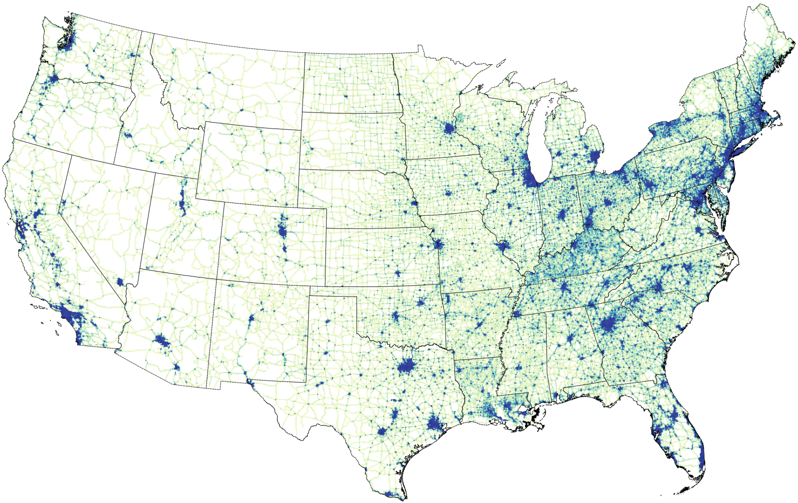
Pr>10%



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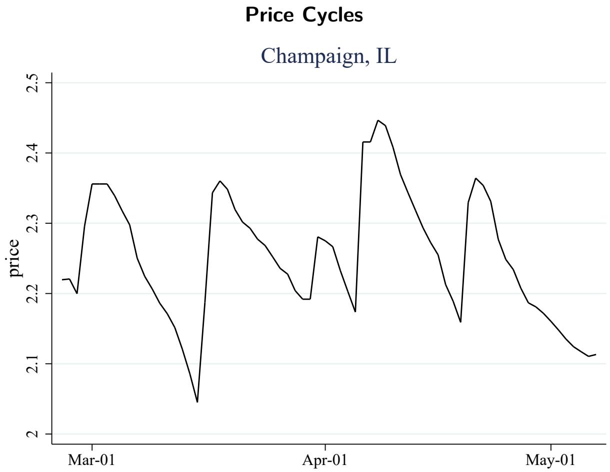

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