Behavioral Responses to Spatial Tax Notches in the Retail Gasoline Market

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Abstract

I employ a unique dataset on fueling station locations in the United States and their corresponding retail gasoline prices to estimate how state tax discontinuities affect business location decisions and tax incidence. The analysis shows that the expected number of fueling stations on the low-tax side of a state border is between 20 and 30 percent higher than on the high-tax side. Gasoline consumers bear 75 percent of the fuel tax on the high-tax side, as compared to 100 percent on the low-tax side. The effect of the border on station location and tax incidence disappears with 15 miles of distance. These results provide some of the first estimates of the effect of tax discontinuities at borders on the location choices of retailers, their competitors, and consequences for the pass-through of taxes to prices.

Keywords: Business Location Decisions, Spatial Differencing, Cross-border Tax
JEL Classification Numbers: R12, R32, H22, H32, L22

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1 Introduction

The effects of taxes on business location decisions and local competition are core issues in public finance. Taxation could discourage business entry or encourage firm reallocation if after-tax profits are more favorable in other jurisdictions. On the contrary, higher taxes might not have a negative effect on business location if, for example, tax revenues are spent on public goods that improve business activity.[1] A notable feature in the literature is the lack of consensus as to whether taxes deter business entrance. The retail gasoline industry faces significant fuel tax differences across state borders that make it possible to revisit this classical debate. For example, in 2017, the excise gasoline tax in California was 36 cents greater than in neighboring Arizona, and 31 cents greater in Pennsylvania than in Ohio. These differences represent 12 percent to 14 percent of the average price consumers paid for a gallon of gasoline that year. These sizeable state tax differences, or "spatial tax notches," might alter the location decisions of gasoline retailers. They may also affect local competition, particularly if businesses on the higher-tax side of the border face fewer rivals to split the local market.[2] Studying the retail gasoline market can inform the debate in two respects, offering insight into how taxes sway the location choices of firms, and whether taxes influence local competition in a market in which prices are salient to consumers.

This paper provides some of the first direct evidence of the effect of taxes on the entry and location choices of firms and their competitors, and the effect of these location choices on prices. It addresses two important questions. First, how do spatial tax notches affect the entry and location decisions of retailers? Second, what are the effects of these notches on the distribution of the tax burdens between buyers and sellers? The answer to the first question sheds light on how taxes affect firm entry into markets where consumers have heterogeneous sensitivities to prices. The answer to the second question informs us about how competitive is the retail market. In particular, are retailers willing to locate on the high-tax side of the border when they face such a clear disadvantage relative to retailers on the low-tax side? How do prices and, potentially, market shares compensate firms for these disadvantages?

To addresses these questions, I use a unique and comprehensive dataset on retail gasoline

[1] Several studies find weak or no evidence of the effect of taxes on business location choices. These include, among others: Carlton (1983); Bartik (1985); Coughlin et al. (1991); Bartik (1994); Hines Jr (1996); Holmes (1998); Rathelot and Sillard (2008); Chirinko and Wilson (2008); Duranton et al. (2011); Rohlin et al. (2014); Giroud and Rauh (2015); and Suárez-Serrato and Zidar (2016).

[2] Notice that these spatial tax notches could deter business entrance if consumers are highly sensitive to gasoline prices and cross jurisdictions to avoid taxation. On the contrary, gasoline retailers could pass-through the fuel taxes to consumer prices to keep the same profit. Recent studies, such as Hughes et al. (2008) and Coglianese et al. (2017), show that gasoline consumers have a small price elasticity in the United States, and meta-analyses, such as Brons et al. (2008), show that this is the case for several countries.

prices and fueling station locations collected by web-scraping a network of prominent websites between March 2017 and April 2018. My estimating framework also accounts for important local regulations and policies beyond taxation that change at state boundaries. I arrive at two main results that were previously overlooked by the literature. First, the expected number of fueling stations rises by 20 to 30 percent when crossing from the high- to the low-tax side of a state border. That is, controlling for local characteristics, the number of firms is significantly lower on the high-tax side. Second, gasoline consumers bear 75 percent of the fuel tax on the high-tax side within 15 miles of a state border, as compared to 100 percent on the low-tax side within the same distance. The incomplete pass-through of gasoline taxes to consumers suggests that competition on the high-tax side is indeed weaker than on the low-tax side, where the number of retailers is larger. These results suggest that retailers on the high-tax side may receive more of their business from relatively inelastic or less mobile shoppers.

Previous literature using the McFadden (1973) conditional logit analysis or the spatial differencing approach pioneered by Holmes (1998) finds weak or no evidence of the effect of taxes on business location decisions. Early literature such as Bartik (1985) and Coughlin et al. (1991) uses the conditional logit approach at fairly large spatial units (e.g., states). More recent research such as Duranton et al. (2011) and Rohlin et al. (2014) focuses on detailed microgeographic data to improve the modeling of the business location choice. However, as is well recognized, the estimation of the conditional logit model is difficult computationally when the number of spatial alternatives is large, as when considering counties, ZIP Codes, or census blocks. To overcome the computational burdens, numerous scholars who focus on detailed geographic data generally use either the spatial differencing approach or the equivalence between the likelihood function of the conditional logit and the Poisson regression as developed in Guimarães et al. (2003). Regardless of the estimation method, a notable feature of those studies is their lack of consensus as to whether taxes deter business entrance.

This paper contributes to the literature by showing the responsiveness of firms to spatial tax notches using both the spatial differencing and the conditional logit approaches. Using a choice model on a fine rectilinear grid over the 48 contiguous states and the District of Columbia, I show a significant increase in the expected number of gasoline retailers on the low-tax side of a state border. The grid consists of 3-by-3-mile squares (9 square miles, about 25 square kilometers) overlaid across the entire continental United States. This grid is on its own a methodological contribution, because it improves the representation of the geographic choice set of the gasoline retailers. It allows for the use of critical site-specific controls such as the number of roads, the distance to the road, and the distance to the border. Additionally, the grid facilitates the testing of the critical identification assumption of smooth variation of location-specific characteristics across space.

Spatial tax notches can alter the incidence of taxation on consumers and retailers due to the price sensitivity of consumers and the market competitiveness of retailers.[3] The previous literature shows that some consumers avoid local taxes and regulations by crossing jurisdictions to purchase products such as cigarettes (Merriman, 2010; Chiou and Muehlegger, 2014) and alcoholic beverages (Stehr, 2007; Asplund et al., 2007). Previous research also shows that the *average* pass-through of taxes to consumers near spatial tax notches is smaller than the state average for cigarettes (Harding et al., 2012) and gasoline (Doyle and Samphantharak, 2008; Stolper, 2017; Coyne, 2017). However, the previous literature studying these markets close to borders has overlooked the change in competition due to the strategic location choices of retailers that affects tax incidence only on the side with fewer competitors.

This research contributes to the public finance and environmental regulation literature by showing that the smaller pass-through of retail gasoline taxes to consumer prices happens only on the side of the border with higher taxes. This side also has fewer retailers. To the best of my knowledge, this result provides some of the first evidence on the change of the competitive nature of the retail market due to the behavioral responses of firms. To reach this conclusion, I use a two-way fixed-effect model to recover the retailer's idiosyncratic prices. Using the retailers' idiosyncratic prices, I identify the tax pass-through using ordinary least-squares regression. After controlling for additional regulations and local policies – other than taxes – that also change at state borders, I show a complete pass-through of taxes to consumer prices away from the border; by contrast the pass-through for retailers in a high-tax state located within 15 miles of a border is 75 percent.

The rest of the paper proceeds as follows: Section 2 reviews the theoretical and empirical literature for tax incidence under perfect and imperfect competition. Section 3 describes the data and background on the U.S. gasoline retail market. Section 4 illustrates the empirical strategy and the main findings. Finally, Section 5 presents conclusions.

2 Tax Incidence and Competition in the Literature

Understanding the economic tax incidence –the burdens from the tax policy– is important because policymakers may be more interested in distribution effects than efficiency effects. Moreover, understanding the pass-through from a theoretical perspective is crucial because it relates to fundamental economic parameters such as the elasticity of demand, the elasticity

[3] Weyl and Fabinger (2013) shows a smaller pass-through of taxes to prices under imperfect competition. Fullerton and Muehlegger (2018) explains how this phenomenon translates to environmental regulation.

of supply, and the shape of the demand curve. Using these relationships, economic theory makes a testable prediction: in markets where consumers can search, firms with some market power bear a larger share of the tax burden as compared to firms with no market power. In this section, I briefly review the theoretical results and the related empirical findings on gasoline tax incidence and competition.

2.1 Perfect Competition Benchmark

The fundamental principle of tax incidence under perfect competition associates the theoretical local pass-through of taxes with the ratio between the elasticity of demand and the elasticity of supply. In this context, the pass-through of taxes to prices is close to one-for-one (100 percent) for goods with significantly inelastic demand or highly elastic supply. Several empirical papers show that the demand for retail gasoline is relatively inelastic, and other related literature shows that the motor fuel tax incidence is on average close to 100 percent. Together, these findings are aligned with a competitive retail gasoline market under normal conditions.

Following the notation in Weyl and Fabinger (2013), denote by p the price paid by consumers and by τ an excise tax. Define $\rho = dp/d\tau$ as the local pass-through of taxes to consumer prices when taxes increase, and let Q denote the equilibrium quantity. In equilibrium, demand equates supply, or $D(p) = S(p - \tau)$. By the implicit function theorem, assuming that the tax begins at zero, defining the elasticity of demand as $\epsilon_D = -\left(D^{'}p/Q\right)$ and the elasticity of supply as $\epsilon_S = \left(S^{'}p/Q\right)$, with $D^{'}$ and $S^{'}$ denoting the derivatives with respect to price, it follows that

$$\rho = \frac{dp}{d\tau} = \frac{S'}{S' - D'} = \frac{\epsilon_S}{\epsilon_S + \epsilon_D} = \frac{1}{1 + (\epsilon_D/\epsilon_S)}.$$

Hence, the ratio between the elasticity of demand and supply determines the local pass-through rate. Notice that the rate is bounded between zero and one. Also, for very inelastic demand, $\epsilon_D \to 0$, the pass-through rate goes to one. Moreover, for a very elastic supply, $\epsilon_S \to \infty$, the pass-through rate also goes to one.

In practice, empirical research shows that the *average* demand for gasoline is not very price sensitive (Brons et al., 2008; Hughes et al., 2008; Dahl, 2012; Coglianese et al., 2017). Moreover, several papers show that, under standard conditions, the *average* incidence of fuel taxes is close to one-for-one in the United States.[4] Furthermore, the average retail gasoline supply seems to be very elastic due to the possibility of storage. These empirical findings are

[4]Chouinard and Perloff (2004), Chouinard and Perloff (2007), Doyle and Samphantharak (2008), Alm et al. (2009), Marion and Muehlegger (2011), Kopczuk et al. (2016)

in concordance with the idea of a competitive retail gasoline market under normal conditions.

2.2 Imperfect Competition

In general, under imperfect competition, the pass-through of taxes to consumer prices may be larger or smaller than one-for-one, depending on the shape of the demand curve and the responsiveness of other competitors to changes in input costs.[5] In particular, under monopoly power, the pass-through of taxes to consumer prices exhibits a relationship that depends on the curvature of the demand function. When consumers can avoid taxes by crossing jurisdictional borders, the applied literature finds smaller pass-through of taxes to consumer prices. These findings are evidence of the distortionary effects of spatial tax notches on the local incidence.

To understand the incidence of taxation under monopoly power, consider a firm that faces linear costs in quantity produced, q, with smooth inverse demand given by $p(q)$ and excise tax τ.[6] From solving the profit-maximization problem, the local pass-through of taxes to consumer prices is

$$\rho = \frac{dp}{d\tau} = \frac{dp}{dq}\frac{dq}{d\tau} = \frac{p'}{p''q + 2p'},$$

where p' and p'' denote the first and second derivatives of price with respect to quantity, respectively. Notice that the pass-through rate depends on the shape of the inverse demand. For example, if the inverse demand is linear, then $p^{''} = 0$, and the tax incidence is one-half. More generally, under monopoly and constant marginal cost, the pass-through rate is smaller than 100 percent if and only if the demand function is log-concave.[7]

The empirical literature shows behavioral responses among some consumers who cross inter-jurisdictional borders to avoid state and local taxes and regulations for cigarettes (Merriman, 2010; Chiou and Muehlegger, 2014; Harding et al., 2012) and alcoholic beverages (Stehr, 2007; Asplund et al., 2007). However, Agrawal (2015) shows that local sales tax rates in the United States increase on the low-tax side of a border, reducing the differential between cross-border state sales tax rates by over three-quarters. Given this reduction on the

[5] Weyl and Fabinger (2013) and Adachi and Fabinger (2017) develop a broad theoretical framework of tax incidence under oligopoly competition.

[6] This result, a simplified version of the monopolistic case in Weyl and Fabinger (2013), offers intuition on the effect of consumer demand on local pass-through of taxes to consumer prices. Refer to their paper for the full derivation and proofs.

[7] A function q is log-concave if and only if the second derivative of $\log q$ is negative, or $(\log q)'' < 0$. Define $\mu = -\frac{q}{q'}$, where q' is the derivative of q. Then, $(\log q)'' = \frac{\mu'}{\mu^2}$, where μ' is the derivative of μ. Also, notice that $\mu = \frac{p}{\epsilon_D}$, and the demand function is log-concave when $\frac{d \log \epsilon_D}{d \log p} > 1$. Intuitively, under monopoly and constant marginal cost, the pass-through rate is smaller than one-for-one if the elasticity of demand increases more than proportional to an increase in prices.

differential between sales tax rates across state borders, the behavioral responses in the empirical literature imply that consumers are mainly avoiding the state tax policy instead of the local tax policy. Fullerton and Muehlegger (2018) summarizes this and other considerations that can alter the incidence of environmental regulation. Finally, Doyle and Samphantharak (2008), Stolper (2017) and Coyne (2017) show that the average pass-through of taxes to consumer prices for retail gasoline is on average smaller than 100 percent in the proximity to state borders. Together, these empirical results show that consumer search and distortions to competition reduce the proportion of taxes paid by consumers.

3 Data and Context on the U.S. Fuel Retail Market

The new data for this paper contain the near-universe of fueling station locations in the United States, and their corresponding daily gasoline prices collected from web-scraping a prominent network of web pages from March 2017 to April 2018. These detailed data are complemented with population information from the American Community Survey (ACS) and data on the system of primary and secondary roads from the U.S. Census Bureau. Additionally, the dataset contains other characteristics such as state gasoline excise taxes, local minimum wage, and the context of gasoline regulation. This section describes the location data, the gasoline prices, and additional variables used to analyze the location choices and the tax incidence.

3.1 Fueling Stations Locations and Retail Gasoline Prices

Retail gasoline prices and fueling station locations were obtained by web-scraping roughly 140,000 gasoline retailers from the network GasBuddy. This network of web pages collects information to create price reports of the Oil Price Information Service (OPIS), the most comprehensive price survey in the retail gasoline industry, and a widely used source of information for research purposes. The network operates under different advertiser-sponsored domain names.[8] Members of each website input data to earn points by reporting and updating information on prices, locations, and features of the gasoline retailers. They also receive points for notifying the network about the presence of new stations. With the collected points, the users can choose to participate in daily raffles of monetary prizes. The users can find and announce fuel prices using the web platform or a mobile app for smartphones.

Table 1 shows the number of gasoline retailers ordered by Petroleum Administration for

[8] The names of the local domains are, for example, www.chicagogasprices.com, www.newyorkgasprices.com, and www.losangelesgasprices.com.

Defense District (PADD). The column for the year 2016 shows the total number of gasoline stations and convenience stores from the most recent available report by the U.S. Census Bureau of the County Business Patterns. The column for the year 2018 summarizes the total number of fueling stations and convenience stores obtained from the network GasBuddy. Both columns exclude Alaska and Hawaii, because the analysis exploits spatial tax notches at state borders, and these two states do not share boundaries with any other U.S. state. Table 1 shows that the data collected from GasBuddy seem to aggregate closely to the universe of gasoline retailers in the United States.

Another important aspect of these data is the daily price information. Table 2 presents summary statistics on the daily prices (in U.S. dollars) of regular gasoline by state, including the District of Columbia. Column (a) of the table presents the minimum price per gallon reported during the period of analysis, column (b) shows the median price, and column (c) reports the maximum price. Column (d) of the same table shows the standard deviation of the price distribution by state. It is worth noting the considerable variability of the retail gasoline prices both between and within states. The variability in regular gasoline prices across states arises from spatial tax notches, differences in labor costs, differences in blends of gasoline required at the local level, and from differences in other regulations explained in the following subsection. The variability in prices within states arises from differences in costs at the establishment level, differences in margins, or idiosyncratic differences.

As mentioned above, part of the variability in the gasoline prices across states arises as a result of spatial tax notches across jurisdictional boundaries. These spatial tax notches can occur at the state, county, or city levels, because local authorities can define local gasoline taxes. The ideal dataset would include all these local differences in taxes and fees; however, the information of these local differences is not centralized or readily available. Nevertheless, the American Petroleum Institute (API) computes a state average of the local excise gasoline taxes and fees that is published in its quarterly State Gasoline Tax Report. The API, that has information on the local taxes and fees, calculates the average rate weighting by the population of the areas subject to each particular tax.[9] Figure 1 shows the spatial variation of the API's gasoline taxes in November 2017.

Another source of variation in gasoline prices is the differences in minimum wages across states. To account for that variation, I review the regulation and collect data on the minimum wage at state, county and city levels during the period of analysis. Appendix A develops the details, shows the spatial variation of minimum wages, and shows the variability of daily

[9]The API's gasoline tax report also accounts for additional state and local fees, such as, for example, inspection fees, delivery fees, environmental assurance fees, and underground storage tank fees. Moreover, the API computes the equivalent excise gasoline tax for the eight states with some portion of an ad valorem gasoline tax: Alaska, California, Florida, Hawaii, Illinois, Michigan, New York, and Virginia.

retail gasoline prices by state.

Finally, the number of regular gasoline price reports within the sample is in column (e) of Table 2. The total number of daily price observations in the period of analysis is around 25 million. Although the dataset has a large sample size of prices and covers almost the entire population of gasoline retailers, a limitation of the dataset is the number of reports per station. Some of the fueling stations have price reports on every day during the observation period, whereas other gasoline retailers only have a few price reports. The empirical strategy in Section 4 explains the detail of how I address the unbalanced panel aspect of the price data.

To visualize the geographic location of the gasoline retailers, panel (a) of Figure 2 uses U.S. Census Bureau data to create a map of the United States indicating the location of the most populated areas, and the routes of the primary and secondary roads.[10] Panel (b) of the same Figure 2 exhibits the map of the location of the gasoline retailers. Every point on the map represents a fueling station. It is evident that the location choice of the retailers closely aligns with the distribution of the population and the U.S. road network. Appendix B has additional statistics on the number of retailers per state, and the services and characteristics of those retailers.

3.2 Background on the U.S. Gasoline Retail Market

The gasoline supply chain starts with distillation at the refinery and transportation of the product to the wholesale supplier (a.k.a. terminal). From the supplier, the gasoline goes to the retailer through distributors. Although about half of the gasoline retailers sell branded gasoline from specific refiners, the major oil companies are not in the retail business of selling gasoline. According to figures from the National Association of Convenience Stores, less than 1 percent of the fueling stations were owned by one of the five major oil companies as of July 2017. Overall, about 60 percent of the convenience stores selling fuel are single-store operators, and 85 percent of the retailers' gasoline sales consist of regular fuel. Gasoline stations in the United States earn just 21 percent of their total revenues from non-fuel sales, and most of these non-fuel revenues come from food, cigarettes, and alcohol.

The retail gasoline industry in the United States faces different regional wholesale prices that are related to the movements of crude oil and the local regulation of gasoline standards to control air pollution. The U.S. Energy Information Administration aggregates the main crude oil markets in the United States by the PADD. The U.S. Environmental Protection Agency regulates the gasoline standards to control air pollution through five gasoline stan-

[10]The Census Bureau classifies as primary roads the highways within the Interstate Highway System, including Toll Highways. Secondary ways include main arteries in the State and County Highway System.

dard programs: Gasoline Sulfur, Mobile Source Air Toxics (MSAT), both regulated at the federal level; and Reformulated Gasoline (RFG), Reid Vapor Pressure (RVP), and Winter Oxygenates (WO), which are regulated at state and local levels with federal oversight by the EPA. The objective of these regulations is to reduce ground-level ozone (commonly known as smog), particulate matter, and the emissions of carbon monoxide and other hazardous air pollutants. Appendix A presents a detailed description of the programs and the geographic determination of the PADD.

4 Empirical Strategy and Results

As emphasized earlier, the primary goal in the empirical work is to estimate the effect of spatial tax notches on the location decisions of the gasoline retailers, and the effect of these tax notches on the distribution of the tax burdens between buyers and sellers. The first part of this section develops a location choice model over a rectilinear grid to estimate the effects of these tax notches on the probability of finding a fueling station across jurisdictional borders. The estimation uses spatial differencing and conditional logit approaches. The second part of the analysis develops a two-way fixed-effects model to recover the retailers' idiosyncratic prices that then serve for the analysis of pass-through of taxes to consumer prices near state borders.

To preview the results, the location choice model shows an increase of around 0.7 percent on the probability of finding a gasoline retailer on the low-tax side of a state border. That represents an increment of nearly a 22 percent in the expected number of establishments on the low-tax side of a border. In other words, after controlling for local characteristics, the number of retailers falls significantly on the high-tax side. Moreover, using the retailers' idiosyncratic prices, the analysis shows that gasoline consumers bear 75 percent of the fuel tax on the high-tax side within 15 miles of a state border, as compared to 100 percent on the low-tax side within the same distance.

4.1 Spatial Tax Notches and Business Location Decisions

State borders create measurable distortions to the location choices of firms. The empirical strategy to show the distortions is to develop a discrete choice model on a rectilinear grid over the United States. The estimation of the location choice model uses the spatial differencing and the conditional logit approaches. Both methods show the effect of spatial tax notches on the location decisions of the gasoline retailers, but the two approaches have a different interpretations.

4.1.1 Rectilinear Grid over the United States

Gasoline retailers choose to establish their businesses in a geographic location with specific characteristics (e.g., the intersection of two avenues or a site close to the exit of a highway). Many factors within a given geographic location may affect their entry decisions. The empirical method represents accurately the choice set of gasoline retailers by using a fine rectilinear grid that consists of 3-by-3-mile squares (9 square miles, about 25 square kilometers), overlaid across the 3 million square miles of the continental United States. Thus, the grid includes around 330,000 units of observation. For squares that lay over state borders, the square is split into two parts to account for state differences. For reasons such as infeasible location or legal restrictions to cross the border, I remove from the grid the area of the Great Lakes, the parts of the squares that overlaid in the sea, and the locations in Canada and Mexico near the U.S. border.

The fine rectilinear grid provides structure for modeling the specific local characteristics that retailers may use to choose their sites. Examples of local characteristics are population and the network of roads. In particular, major metropolitan areas have more retailers, and most retailers choose to locate close to main avenues. As shown in Figure 2 (b), the location configuration of the gasoline retailers mirrors the most significant metropolitan areas of the United States, and the network of highways.

Data on the current population estimates of the Census Blocks Groups (CBG) were obtained from the American Community Survey to account for the distribution of people across space. Geographic Information System (GIS) software was used to determine which centroids of the CBG locate over every square of the grid. Then, each element of the grid was assigned with the sum of the population estimates of the CBGs that lay over each square.[11] Finally, GIS software was again used to determine the number of primary and secondary roads passing over each square of the grid, and the shortest linear distance between the centroids of the squares and the roads.

The population patterns and the network of roads are not the sole determinants of the location of retailers over the rectilinear grid. Proximity to a border also relates to the location decision. Each of the 107 line segments that define a pair of bordering states determines a "proximity region" with specific tax differences. The definition of proximity depends on the

[11] This approximation has two limitations: First, the shape of the census block groups does not necessarily fit inside the boundaries of a square in the grid. Hence, part of the population that the procedure assigns to one unit of observation may be located in an adjacent square of analysis. Second, if one block group covers several squares of the grid (as may be the case for low-population-density areas), the assignment methodology locates all the population to one place, and designates no people to adjacent squares. Given the mobility of consumers, however, this methodology works as a first-order approximation of the distribution of people across space.

meaning of distance. Possible metrics consist of at least three types of distances: Euclidean (linear) distance, driving distance, and driving time. The Euclidean distance between two points is the length of a straight line that connects those points. Driving distance is the physical length of the road path that connects two points. Driving time is a transformation that uses average speed to recover the minutes required to travel a driving distance.

GIS software was used to determine the closest state border and its corresponding Euclidean linear distance for each centroid of the grid squares.[12] Figure 3 shows proximity regions for each of the 107 internal borderlines in the United States. Darker grey represents a higher gasoline tax compared to the neighboring state. All borders of some states, such as Pennsylvania, Washington, and North Carolina, lie on the high-tax side, whereas all borders of some other states, such as North Dakota, Oklahoma, and Virginia, lie on the low-tax side. Every spatial tax notch defines one of these proximity regions.

4.1.2 Location Choice Model

This subsection develops a discrete choice model to explain the observed location patterns of the gasoline retailers using the rectilinear grid described in the previous subsection. Figure 4 depicts the average location pattern around borderlines. The figure is the result of a two-step procedure where I first compute the number of gasoline retailers per 10,000 residents, for each borderline and various ranges of distance to the border, and then I take the average of each range of distance using the 107 border pairs. The vertical dashed line in Figure 4 marks the state boundary. The horizontal axis shows the linear distance to the border. By convention, the negative numbers on the horizontal axis are the distances to the border from the state with lower excise tax on gasoline.

A striking pattern emerges from the histogram in Figure 4: Crossing the border from the low-tax to the high-tax side abruptly reduces the average number of establishments from 4.5 to 3.3 retailers per 10,000 residents. This decrease represents a raw reduction of about 25 percent in the number of retailers on the high-tax side just by crossing the border. The figure suggests responses to gasoline taxes on the location choices of the fueling stations, but the chart does not control for other relevant factors described in Section 3, such as other gasoline regulation or differences in minimum wages. To give some structure to the analysis, I develop a substantially simplified, but not entirely unrealistic reduced-form model to rationalize the

[12] Notice that every definition of distance needs two points as input. Finding the closest state line using driving distance or driving time is difficult because some segments of the border are unreachable by car. However, using those metrics, I determine the closest state line using the intersections of primary and secondary roads with the state borders. I use Bing Maps to determine the driving distance and driving time. The figures look similar because the Euclidean distance is correlated with the driving distance. The information is available upon request.

location decision of the gasoline retailers. The estimation uses the spatial differencing and the conditional logit approaches.

The spatial differencing method proposes that the location choice of the retailers between similar sites across administrative borders depends on each side's potential profit, which in turn depends on the distance to the border and other characteristics. This spatial differencing approach gives estimates on the probability of choosing between two sides, instead of choosing between any possible locations. The use of the spatial differencing method over the rectilinear grid is feasible computationally because it reduces the problem to a binary choice. On the other hand, the conditional logit method estimates the effect of these tax notches on the probability of choosing any possible location, with the advantage of direct interpretation of the coefficients as the percentage changes in the expected number of establishments. However, as is well recognized, the estimation of the conditional logit model is difficult computationally when the number of alternatives is as large as in the rectilinear grid. To overcome the computational burdens, I use the equivalence between the likelihood function of the conditional logit and the Poisson regression developed in Guimarães et al. (2003).[13]

Entry of Gasoline Retailers

Define Π_{rs} as the potential profit of retailer r on a square s of the grid. It is specified as

$$\Pi_{rs} = \Omega\left(\xi_r, \zeta_s\right) + \varepsilon_{rs},$$

where Ω is a function that transforms to dollar values the vectors of retailer-specific characteristics ξ_r, and location-specific characteristics ζ_s, with a retailer location-specific shock ε_{rs}. Further, assume that the transformation Ω is linear, such that the retailer's profit takes the form of

$$\Pi_{rs} = w_r^{'}\eta + v_r\beta_0 + x_s^{'}\theta + h_s\beta_1 + g(\Delta\tau_s)\lambda + k_{j(s)}\beta_2 + \varepsilon_{rs} \tag{1}$$

where w_r is a vector of observable retailer characteristics, v_r is an unobserved idiosyncratic effect of the retailer, x_s is a vector of observed location characteristics, h_s is an unobserved location-specific effect, g is a function of the tax differential, $\Delta\tau_s$, that captures the price differential of location s with respect to neighboring locations, and $k_{j(s)}$ is a jurisdiction-fixed effect that depends on the location s. In equation (1), the coefficients η, λ, θ, β_0, β_1, and β_2 represent the vectors (or scalars) to be estimated.

The standard approach to estimating the coefficients in equation (1) is to assume that shocks ε_{rs} follow the appropriate i.i.d. type I extreme value distribution as in the McFadden

[13] An important caveat, however, is that the equivalence between the likelihoods only holds in the absence of retailer-specific characteristics and no spatial correlation.

(1973) conditional logit analysis. Then, the probability of retailer r choosing location s as the maximizer of profits is

$$P_{rs} = \frac{\exp\left(\Omega\left(\xi_r, \zeta_s\right)\right)}{\sum\limits_{f \in S} \exp\left(\Omega\left(\xi_r, \zeta_f\right)\right)}, \tag{2}$$

where the summation is across all possible locations s. The estimates of the coefficients in equation (1) maximize the log likelihood function based on equation (2). One advantage of using this estimation approach is the natural interpretation of the coefficient estimates.

In particular, the expected number of retailers in location s is

$$E\left(n_s\right) = nP_{rs} = n\frac{\exp\left(\Omega\left(\xi_r, \zeta_s\right)\right)}{\sum\limits_{f \in S} \exp\left(\Omega\left(\xi_r, \zeta_f\right)\right)},$$

where n is the total number of retailers and n_s is the number of retailers in location s. Hence, the percentage change in the expected number of retailers in region s, with respect to a unit change in the k-th observed location characteristic of region s, is proportional to the estimated coefficient because

$$\frac{\partial \log E(n_s)}{\partial x_{sk}} = E(n_s)\left(1 - P_{rs}\right)\theta_{sk}. \tag{3}$$

However, as is well recognized, the estimation of the conditional logit model is difficult when controlling for retailer-specific characteristics, and when the set of possible locations is as large as it is in the rectilinear grid over the continental United States. A possible solution is to use the equivalence between the log likelihood functions for the conditional logit and the Poisson model, proposed by Guimarães et al. (2003), and extended by Schmidheiny and Brülhart (2011). The estimation of the Poisson regression is more manageable computationally, but the equivalence between the likelihoods only holds in the absence of retailer-specific characteristics ξ_f.

Spatial Differencing

A way around the computational burdens induced by the retailer-specific characteristics is spatial differencing. As pointed out in Duranton et al. (2011), spatial differencing provides an alternative that controls for both observed and unobserved location-specific factors and retailer-specific unobserved characteristics. The approach considers two neighboring locations s_1 and s_2 located across the border of two jurisdictions j_{s_1} and j_{s_2}. Because the two locations are close, the critical identification assumption is that unobserved location-specific effects and observed location characteristics vary smoothly across space. If the shocks ε_{rs} follow the appropriate i.i.d. type I extreme value distribution, the probability of choosing the site s_1 becomes the logistic probability

$$Pr\left(s=s_1|s\in\{s_1,s_2\}\right)=\frac{1}{1+\exp\left(-\lambda\left(g(\Delta\tau_{s_1})-g(\Delta\tau_{s_2})\right)-\beta_2\left(k_{j(s_1)}-k_{j(s_2)}\right)\right)}. \tag{4}$$

This approach considers a gasoline retailer who chooses between neighboring sites across borders. This method only involves jurisdictional variables (a fixed effect for each border pair) and the difference $g(\Delta\tau_{s_1})-g(\Delta\tau_{s_2})$ that captures potential profit differences of location s_1 with respect to neighboring locations s_2 due to tax differences. For the rest of the analysis, assume further that this difference depends linearly on the distance of s_1 to the border, the magnitude of the spatial tax notch, and their interactions.[14]

Identification Assumption and Results with This Method:

The critical identification assumption holds if observed location-specific characteristics and unobserved location-specific effects vary smoothly across space. Table 3 presents the results of a balance test to validate this assumption on observed location-specific characteristics. The balance test was performed by estimating an OLS regression of the location-specific characteristic on an indicator for being on the high-tax side of the administrative boundary and including border pair fixed effects.[15] The coefficient estimate of the indicator variable for being on the high-tax side of the border measures the average difference of the observed characteristics with respect to the low-tax side of the administrative boundary.

Table 3 shows the coefficient estimates, standard errors, t-statistics, and p-values for the indicator variable in the balance test regression. As expected, the table shows that fuel taxes change by an average of about 7 cents when crossing an administrative boundary. The p-value of the gasoline tax indicator shows that this change is statistically significant. Further, by inspecting the p-values it is clear that most of the other characteristics do not significantly change at the border. Exceptions are the requirements of winter oxygenates and the price gouging laws; therefore, the preferred specifications control for these two regulations that significantly change at the border.

The implementation of the spatial differencing approach in equation (4) reduces to a logistic regression estimation with border pair fixed effects, where the dependent variable is

[14] Further improvements to this assumption require a model for gasoline demand similar to Manuszak and Moul (2009) or Houde (2012) that are beyond the scope of the current analysis.

[15] The observed location-specific characteristic of each square of the grid include the excise gasoline taxes from the API, indicators for having requirements of winter oxygenates as described in Figure A.3 of Appendix A, indicators for having price gouging laws as described in footnote 23 of Appendix A, population estimates from the CBGs, the number of roads and distance to the road computed using GIS software, indicators for having requirements of reformulated gasoline as described in Appendix A, indicators for states where the point of taxation of gasoline is at the distributor level as explained on footnote 24 of Appendix A, and the local minimum wage computed as described in Appendix A.

a binary indicator that takes the value of one if the square has at least one gasoline retailer and zero otherwise. As mentioned before, I assume further that the probability of choosing one side vs. the other depends linearly on the distance to the border, the magnitude of the spatial tax notch, and their interactions. Table 4 presents the estimates for the logit model and also includes the probit and linear probability models to show the robustness of the results. The results in Table 4 show the marginal effects at the mean of the logit and probit models for selected coefficients and interactions of interest. Table C.2 of Appendix C presents the complete list of estimates and alternative nonlinear specifications.

Models 1 and 2 under the logit column in Table 4 show the marginal effects at the mean without and with regulatory controls that change across borders. As explained before, those regulatory controls are the price gouging laws and requirements of winter oxygenates. Notably, the signs and magnitudes of the probit and linear estimates, models 3 to 6, are similar to those of the logit model estimates. The similarity shows robustness of the results under different estimation methods. The preferred specification is model 2, because it estimates the logit model with controls for regulation that changes at state borders. The preferred specification shows that gasoline retailers choose the low-tax side of the border with 0.7 percent higher probability than on the high-tax side. This higher probability falls by 0.45 percent when moving away from the border by 50 miles to the interior of the low-tax state. Also, the reduction effect of distance-to-the-border intensifies by 0.40 percent on the low-tax side for every 10 cent tax difference.

Conditional Logit

The standard method to estimate the coefficients in equation (1) is to use the McFadden (1973) conditional logit approach. As mentioned before, one advantage of using this method is the natural interpretation of the coefficient estimates as the percentage change in the expected number of retailers due to changes in observed characteristics. To overcome the computational burdens of the estimation, I use the equivalence between the likelihood function of the conditional logit and the Poisson regression developed in Guimarães et al. (2003). However, the equivalence between the likelihoods only holds in the absence of retailer-specific characteristics. For that reason, the results of the regressions presented below only include location-specific characteristics.[16]

[16]The location-specific characteristics include regulation controls, such as indicators for having requirements of winter oxygenates, indicators for having price gouging laws, indicators for having requirements of reformulated gasoline, indicators for states where the point of taxation of gasoline is at the distributor level, and the local minimum wage. Other location-specific characteristics are the distance to the border, the magnitude of the spatial tax notch and the interactions between the former and the later, population estimates, the number of roads, distance to the road, and the area of the square, because the element is split

Results with This Method:
The estimation of the conditional logit coefficients offers insights into the expected number of retailers. Table 4 shows the estimates of the conditional logit model for selected coefficients and interactions of interest. Table C.2 of Appendix C presents the complete list of coefficient estimates and alternative nonlinear specifications. Models 7 and 8 under the conditional logit column in Table 4 show the coefficient estimates with and without regulation controls. Both specifications include additional location characteristics such as population, distance to the closest road, and area of the square on the grid. The signs and magnitudes of models 7 and 8 in the table are similar, and this similarity indicates robustness of the results. The estimates in model 8, the preferred specification, show a significant increase of 28.9 percent in the expected number of retailers on the low-tax side than on the high-tax side. This higher expected number of retailers falls by 9.9 percent as distance to the border grows by 50 miles towards the interior of the low-tax state. Also, distance-to-the-border exacerbates the reduction effect by 14.8 percent on the low-tax side for every 10 cent tax difference.

4.2 Spatial Tax Notches and Tax Incidence

For the analysis of the pass-through of taxes to gasoline prices at state borders, I use the idiosyncratic prices of the retailers in the sample. As the next subsection emphasizes, the use of these prices is necessary due to the absence of enough state tax changes during the 13-month period of analysis.[17] These idiosyncratic prices allow for the implementation of two separate analyses of the retail gasoline prices. The first investigation uses OLS to estimate the average pass-through of taxes to prices, and it shows that consumers bear nearly 100 percent of the gasoline tax on average. The second analysis uses an OLS estimation of the pass-through of taxes to prices close to state borders, and it shows that the pass-through of taxes to prices falls to 75 percent on the high-tax side within 15 miles of a state border.

4.2.1 Idiosyncratic Prices

Gasoline retailers set prices based on observed and unobserved characteristics. For example, retailers determine prices in proportion to their observed taxes and other costs but target unobserved idiosyncratic margins. Also, the retail gasoline industry exhibits specific time

into two parts when it lays over a state border creating some differences in areas.

[17]The only sizable tax change happened in California. In April 2017 California Governor Jerry Brown signed into law a plan to fund road and bridge repairs. It raised the base excise tax on gasoline by 12 cents per gallon starting November 1, 2017, and it cut the price-based excise tax to 17.3 cents per gallon starting in July 2019.

trends and asymmetric pricing behavior.[18] Therefore, analysing the effects of tax differences on consumer prices must account for retailer fixed effects and time trends. However, the impacts of taxes on daily gasoline prices are undetermined because of the time variation mismatch. During the period of analysis, only one tax change occurred in California, a state that only has 3 out of the 107 borderlines. To address this issue, I first determine the retailers' idiosyncratic prices from a two-way fixed effects model that also controls for time trends. Then, the subsequent analysis uses these time-invariant idiosyncratic prices.

To obtain the idiosyncratic prices, I estimate a simple two-way fixed effects model defined as

$$p_{rt} = \rho_r + \gamma_t + \epsilon_{rt}, \tag{5}$$

where p_{rt} is the price of retailer r on day t. The model includes retailer fixed effects, ρ_r, daily time trends, γ_t, and classical measurement error, ϵ_{rt}. This model is identified for the set of retailers with more than one price observation and with different prices on the observed days.[19] I use the retailer fixed effects, ρ_r, as the idiosyncratic prices. Notice that the variance of these estimates depends on the number of daily observations. In particular, more price observations increase precision. The subsequent analysis uses the inverse of the idiosyncratic price variance as weights in the regressions.[20]

4.2.2 Pass-Through of Fuel Taxes to Consumer Prices

The idiosyncratic prices allow for the use of an OLS estimation of the pass-through of fuel taxes to gasoline prices controlling for local demand, regulation, and distance to the border. Results show that the gasoline tax incidence on consumers is close to 100 percent on average. However, the pass-through of taxes to consumer prices is 75 percent for gasoline stations in the high-tax state located within 15 miles of a border. These results arise from a model of the idiosyncratic prices as

$$\rho_r = tax_r\beta_0 + x_r^{'}\theta + \mathbb{1}(Regulation_r)\,\gamma + \mathbb{1}(PADD_r)\,\eta + \epsilon_r, \tag{6}$$

where ρ_r is the idiosyncratic price of retailer r, the corresponding state tax is tax_r, and x_r, $\mathbb{1}(Regulation_r)$, and $\mathbb{1}(PADD_r)$ are a vector of controls with local characteristics, indicators

[18] Noel (2016) presents a recent review of the literature. Doyle et al. (2010) and González and Hurtado (2018) develop on the idiosyncratic effect of asymmetric pricing.

[19] The identification is similar to the models of worker and firm fixed effects (Abowd et al., 1999), or schools and students fixed effects (Laliberté, 2018).

[20] This correction is related to the sequential two-step estimation of parameters of interest based on initial estimation of unknown parameters. See Cameron and Trivedi (2005).

of regulation, and indicators for regional petroleum markets, respectively.[21] I begin using the full sample to recover the standard result of complete pass-through of taxes. Then, I investigate with a subsample close to the border, and use interactions with indicators of low- vs. high-tax side of the border.

Average Pass-Through

Table 5 presents some of the estimates of the coefficients in equation (6) using OLS. The table presents results for the full sample and subsamples of retailers chosen to be 15 or more miles away from the border or within 15 miles of the border. I call these subsamples *inner land* and *border*, respectively. Table 5 presents coefficients of interest, but Table D.4 of Appendix D.1 presents all the coefficients estimates. The unit of analysis is the gasoline retailer, except for model 1 of the table in which the analysis is at the state level.[22] Models 2 and 3 of Table 5 use the idiosyncratic prices of all the gasoline retailers, model 4 uses the subsample of inner land, and models 5 and 6 use the border subsample.

Notable, across all specifications in Table 5, is that the distance to the border has no statistical impact on the gasoline prices when it is not interacted with the tax notch. The effects of the population, the number of retailers per square mile, and the number of roads per square mile in models 3, 4, and 6 have the expected signs. The estimate of interest across the columns of Table 5 is the tax coefficient on the first row. Model 1 shows an average 100 percent tax pass-through, with the idiosyncratic state price and no controls. The same result is valid for models 2 and 3 that use all the retailers, and account for distance to the borders and other local controls, respectively. Model 4 of the same Table 5, for the inner land subsample, shows a slightly higher point estimate of 105 percent, but this is statistically indistinguishable from 100 percent. Finally, the average pass-through of taxes to consumer prices is close to 90 percent on the border subsample in models 5 and 6 of Table 5. These coefficients are statistically different from 100 percent. These results for the border subsample are consistent with the findings in Doyle and Samphantharak (2008) and Stolper (2017), and these findings motivate further investigation.

[21] The controls include population per 10,000 residents on that square of the grid where the retailer locates, density of gasoline retailers per square mile on that square of the grid, number of roads per square mile on the grid element, and retailers' distance to the border. Regulation controls are explained in footnote 16.

[22] The analysis at the state level estimates equation (5) using state fixed effects instead of retailer fixed effects. Then, I use the idiosyncratic state price to estimate equation (6) and report the coefficients in model 1 of Table 5.

Pass-Through Close to State Borders

Table 6 exhibits the OLS coefficient estimates of models that use equation (6), and models with an equation that is the same but also includes interactions with an indicator for being on the low- or high-tax side of the border. The table presents results for the full sample and the border subsample. The square brackets bellow the coefficients on Table 6 show the 95% confidence interval. For brevity of exposition, I only present the coefficient of interest here, but Appendix D.1 has a table with other important estimates. Models 3 and 6 of Table 5 and Table 6 use the same specification, but the later table shows that the average 89 percent estimate of pass-through of taxes to consumer prices in model 6 is statistically different from 100 percent, because the 95% confidence interval excludes the number one. Also, model 3 on Table 6 shows that the average 99 percent pass-through of gasoline taxes is statistically indistinguishable from 100 percent. Finally, the coefficient estimates of the equation that includes the interactions with an indicator for being on the low- or high-tax side of the border, models 3i and 6i, are statistically indistinguishable from one another, and from 100 percent. To better understand the result for model 6 in Table 6, I continue the investigation by rethinking the relationship of prices to own costs vs. inter-jurisdictional costs near state borders.

In the proximity of a state border, the inter-jurisdictional difference between own cost and costs of other retailers across the border has a relevant effect in the definition of prices. This effect should depend on the distance to the border, because of the traveling cost for consumers. Taking that cost into account, I model gasoline prices close to state borders as follows:

$$\begin{aligned} \rho_r &= tax_r \beta_0 + \Delta\tau_r d_r \beta_1 + \cdots \\ &= tax_r \beta_0 + (tax_r - tax_o)\, d_r \beta_1 + \cdots \\ &= tax_r \beta_0 + tax_r d_r \beta_1 - tax_o d_r \beta_1 + \cdots , \end{aligned} \tag{7}$$

where, as before, ρ_r is the idiosyncratic price of retailer r, the gasoline tax is tax_r, the closest outside state tax is tax_o, the spatial tax notch with the closest outside state tax is $\Delta\tau_r$, and d_r is the distance of retailer r to the border.

If gasoline prices close to borders follow equation (7), retailer r has a pass-through of taxes to prices defined by

$$\rho'_r = \frac{d\,\rho_r}{d\,tax_r} = \beta_0 + d_r \beta_1, \tag{8}$$

where ρ'_r is the derivative with respect to own gasoline tax. This pass-through depends on the distance of the retailer to the state border. Notice that specifying a relationship for distance is complicated by the fact that the effect of distance to the border on the pass-through of taxes to consumer prices could be nonlinear. Farther away from the border, a one-mile increase in distance has little effect on the incidence of taxes, while near to the border such a change may have a significant impact. For that reason, I perform the following analysis only with retailers that locate within 30 miles of distance to the border.

To estimate the pass-through of taxes to prices from equation (8), I model the idiosyncratic prices as

$$\rho_r = tax_r \beta_0 + tax_r d_r \beta_1 + x_r^{'} \theta + \mathbb{1}(Regulation_r)\,\gamma + \mathbb{1}(PADD_r)\,\eta + \epsilon_r, \tag{9}$$

where the controls are as in equation (6), but also include the interaction of distance to the border and the closest outside state tax. Notice that the pass-through from equation (8) is a linear combination of the estimates β_0 and β_1, and this pass-through estimate has a variance. For brevity of exposition, I present the estimates of the pass-through of taxes to gasoline prices close to state borders in Figure 5. Appendix D.2 presents a table with the list of coefficients and additional specifications.

Each dot of Figure 5 represents the point estimate of the pass-through using the coefficients of equation (9). The vertical dashed line in the figure marks the state border. The horizontal axis shows the distance to the border. By convention, the negative values of distance represent locations on the low-tax side of the border, whereas the positive values of distance are locations on the high-tax side. The lines in Figure 5 show the tax pass-through estimates from a local linear regression that uses the point estimates, a triangular kernel, and weighs by the inverse of the variance of the point estimate; the colored areas represent the 95 percent confidence intervals. A noteworthy aspect of the figure is that the pass-through of taxes to consumer prices is statistically smaller than 100 percent on the high-tax side of the border within 15 miles. Also, the low-tax side shows suggestive evidence of an average higher incidence of taxation close to spatial notches. The retailers on the high-tax side bear the burdens of some part of their gasoline tax. This result shows that, under the assumption of perfect competition, consumers have a non-zero price elasticity of demand. That is, consumers respond to gasoline prices and have a downward sloping demand curve close to borders.

4.3 What do we learn from the analysis?

The subsections above show the long-term effects of spatial tax notches on the entry and location choices of gasoline retailers and their competitors, and the impact of these location choices on the pass-through of taxes to consumer prices. The expected number of retailers on the low-tax side increases significantly; in other words, the number of fueling establishments is substantially lower on the high-tax side. This sharp reduction of competitors goes along with an incomplete pass-through of taxes to prices only on the high-tax side of the border. Why should any retailers being willing to locate on the high-tax side of the border when they face such a clear disadvantage relative to retailers on the low-tax side? If some retailers are eager to locate on the high-tax side of a jurisdictional border, and they bear part of the tax burden, in equilibrium they have to compensate revenue with higher shares of the local market. Unfortunately, I do not have information on the quantities sold by each retailer on each day to address this question directly.

How do gasoline retailers use prices to compensate for the side of the border that they choose? I hypothesize that the gasoline retailers choose to locate on different sides of the border because they target different type of consumers. The dynamics of the pricing strategy may be different for retailers on the low- than on the high-tax side of the border. In fact, in González and Hurtado (2018) we address the pricing strategy heterogeneity using the same dataset that I use here. In the paper, we show that gasoline retailers on the low-tax side change prices more frequently, and this is related with a strategy that aims to target more price-sensitive consumers.

5 Conclusion

This study uses a rich data environment to examine the location decisions of gasoline retailers and the pass-through of taxes to prices near state borders. The analysis of the business location decisions develops a choice model over a rectilinear grid that covers the 48 contiguous states and the District of Columbia. The investigation of the pass-through of taxes near state borders uses the retailers' idiosyncratic prices in various OLS specifications. The results of this paper provide some of the first evidence of the effect of spatial tax notches on the location choices of retailers, their competitors, and the consequences of those choices for pass-through of taxes to prices. The estimates show a significant increase in the expected number of fueling stations when crossing the border from the high- to the low-tax side. This result is robust under various estimations and shows how taxes affect establishment location decisions. The results also demonstrate an incomplete pass-through of taxes only on the high-tax side of the border, where the number of retailers is smaller.

Previous studies have found mixed or no evidence that taxes influence business location decisions. For example, Duranton et al. (2011) found no effects of taxes on the location of England manufacturing establishments, and Rohlin et al. (2014) found weak evidence of the entrance of new establishments operating close to a state border in the United States. This study contributes to the literature by showing how spatial tax notches deter the entrance of gasoline retailers near state borders. I do not address the impact of state tax policies on the overall level of business activity. Instead, I show the tendency of retailers operating near state borders to choose their locations strategically. These findings relate to the sensitivity of gasoline consumers to prices, the pass-through of taxes to prices, and the market shares that retailers face when choosing sides of borders.

The previous literature shows that the average pass-through of taxes to prices near spatial tax notches is smaller than the state average for alcoholic beverages, cigarettes, and gasoline. This paper shows that the smaller tax pass-through happens on the side of the border with fewer competitors. This result suggests that retailers on the high-tax side may receive more of their business from relatively inelastic shoppers who face fewer retail options. This observation provides some of the first evidence on the change of competition of the retail market due to the strategic responses of establishments.

This paper shows the strategic responses of gasoline retailers to spatial tax notches. The empirical evidence is robust to various specifications and relates to consumer search and market structures. The costs of inter-jurisdictional shopping, tax avoidance, and lower competition are part of the deadweight loss that alters the welfare cost of gasoline taxation near borders. The empirical findings shed light on how spatial tax notches alter the distribution of the burdens between buyers and sellers. Calculating the social welfare cost of these taxes, including search costs, is beyond the scope of this analysis; the results of this paper, however, suggest that this would be a prosperous area for further research.

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Tables

Table 1: Gasoline Retailers by Petroleum Administration for Defense District (PADD)

PADD Region	Year 2016	Year 2018
East Coast	55,544	49,631
Midwest	38,481	40,902
Gult Coast	24,605	25,416
Rocky Mountain	4,260	5,033
West Coast	17,487	16,232
Total	140,377	137,214

Note: The table counts the number of gasoline retailers arranged by Petroleum Administration for Defense District (PADD). The column for the year 2016 shows the total number of gasoline stations and convenience stores using data from the County Business Patterns that the U.S. Census Bureau releases yearly. The column for the year 2018 adds the total number of fueling stations and convenience stores obtained from the network GasBuddy. Both columns exclude Alaska and Hawaii.

Table 2: Summary Statistics of Prices and Number of Gasoline Retailers by State

State	(a) Price min.	(b) Price med.	(c) Price max.	(d) Price sd.	(e) Price observations	(f) Gasoline Stations	(g) Stations per Capita
AL	1.69	2.19	3.12	0.16	551,420	3,667	7.5
AR	1.29	2.21	3.29	0.14	275,501	1,897	6.3
AZ	1.84	2.29	4.39	0.19	475,192	2,029	2.9
CA	2.15	3.09	5.29	0.29	2,158,215	9,493	2.4
CO	1.88	2.38	4.11	0.17	383,690	2,037	3.7
CT	1.99	2.61	3.83	0.20	215,836	1,438	4.0
DC	2.09	2.63	3.98	0.28	18,747	114	1.7
DE	1.93	2.39	2.99	0.15	78,674	307	3.2
FL	1.74	2.44	5.99	0.18	1,604,191	7,501	3.6
GA	1.15	2.35	3.79	0.19	978,478	6,378	6.2
IA	1.81	2.43	3.34	0.20	155,558	2,083	6.6
ID	2.08	2.59	3.54	0.17	119,384	834	5.0
IL	1.48	2.49	3.99	0.23	1,056,842	4,429	3.5
IN	1.73	2.45	3.90	0.18	792,829	3,194	4.8
KS	1.76	2.29	2.99	0.13	228,274	1,663	5.7
KY	1.77	2.37	3.46	0.18	458,624	2,459	5.5
LA	1.50	2.23	3.19	0.16	403,584	2,853	6.1
MA	1.89	2.49	3.99	0.19	390,988	2,443	3.6
MD	1.99	2.44	3.69	0.17	424,662	1,913	3.2
ME	1.96	2.47	3.07	0.16	122,729	953	7.2
MI	1.87	2.53	3.95	0.17	991,518	4,446	4.5
MN	1.79	2.39	3.04	0.12	496,725	2,614	4.7
MO	1.69	2.24	3.37	0.14	608,397	3,229	5.3
MS	1.69	2.19	3.09	0.15	294,996	2,247	7.5
MT	2.08	2.54	3.16	0.13	74,600	642	6.2
NC	1.55	2.35	3.65	0.16	962,103	5,672	5.6
ND	1.79	2.39	3.39	0.17	57,845	560	7.4
NE	1.54	2.45	3.18	0.19	111,544	1,212	6.4
NH	1.99	2.44	3.35	0.17	133,364	741	5.6
NJ	1.99	2.49	3.79	0.20	527,982	2,997	3.4
NM	1.34	2.34	3.98	0.17	167,355	1,025	4.9
NV	2.15	2.69	4.25	0.22	196,503	941	3.2
NY	1.61	2.61	4.29	0.19	775,311	5,496	2.8
OH	1.78	2.37	4.00	0.16	1,176,577	4,735	4.1
OK	1.49	2.19	3.35	0.18	381,594	2,522	6.4
OR	2.02	2.79	4.09	0.20	240,562	1,185	2.9
PA	1.98	2.69	3.99	0.16	893,342	4,627	3.6
RI	1.89	2.51	3.15	0.18	53,414	396	3.7
SC	1.49	2.19	3.29	0.17	470,041	3,089	6.2
SD	1.89	2.41	3.09	0.16	61,926	702	8.1
TN	1.61	2.25	3.49	0.19	657,981	4,026	6.1
TX	1.21	2.23	3.99	0.16	2,460,181	13,727	4.9
UT	2.01	2.47	3.79	0.17	217,067	1,095	3.6
VA	1.61	2.28	3.39	0.18	815,062	3,938	4.7
VT	2.08	2.53	3.50	0.16	55,208	557	8.9
WA	2.09	2.93	4.04	0.21	477,890	2,584	3.5
WI	1.89	2.39	3.39	0.13	560,657	3,029	5.2
WV	1.99	2.49	3.19	0.16	154,410	1,070	5.8
WY	1.85	2.37	3.49	0.18	50,483	425	7.3
USA	1.15	2.40	5.99	0.31	25,018,056	137,214	4.3

Note: The table presents summary statistics on the daily price reports by state, including the District of Columbia. Columns (a) to (d) are in USD. Column (a) presents the minimum price per gallon reported during the period of analysis, column (b) shows the median price, and column (c) reports the maximum price. Column (d) shows the standard error of the price distribution by state. The number of regular gasoline price reports of the sample is in column (e). Column (f) shows the total number of gasoline retailers by state and column (g) reports the number of fueling stations per 10,000 residents using the state population estimates for 2016.

Table 3: Balance on Location-Specific Characteristics

Characteristics	**Estimate**	**Std. Error**	**t-value**	**p-value**
Unbalanced				
Gasoline Tax	6.76	0.75	8.95	0.00
Oxig. Fuels	-0.10	0.04	-2.24	0.03
Price-Gouging Law	0.17	0.09	1.90	0.06
Balanced				
Population	281.27	396.80	0.71	0.48
Number of Roads	0.03	0.12	0.25	0.80
Distance to Road	0.14	0.28	0.49	0.62
Reformulated Gasoline	0.01	0.09	0.17	0.87
Point of Taxation	-0.11	0.10	-1.11	0.27
Minimum Wage	0.33	0.26	1.26	0.21

Note: The table reports the coefficient estimates, standard errors, t-statistics, and p-values for a regression of the listed location-specific characteristics on an indicator variable for being on the high-tax side of the border. The regressions include border pair fixed effects. The observed characteristic of each square of the grid include the excise gasoline taxes from the API, indicators for having requirements of winter oxygenates as described in Figure A.3 of Appendix A, indicators for having price gouging laws as described in footnote 23 of Appendix A, population estimates from the CBGs, the number of roads and distance to the road computed using GIS software, indicators for having requirements of reformulated gasoline as described in Appendix A, indicators for states where the point of taxation of gasoline is at the distributor level as explained on footnote 24 of Appendix A, and the local minimum wage computed as described in Appendix A. Gasoline taxes increase on average 6.8 cents when crossing an administrative boundary. Most of the other characteristics do not change abruptly at the border. The exceptions are the oxygenated fuels regulation and the price-gouging laws.

Table 4: Location Decision of Gasoline Retailers

	Dependent Variable: Indicator of a Retailer on a Square of the Grid							
	Logit		Probit		Linear		Conditional Logit	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Low-Tax	.0059**	.0069***	.0073***	.0091***	.0093***	.0110***	.2178***	.2889***
	(.0019)	(.0019)	(.0021)	(.0022)	(.0023)	(.0024)	(.0124)	(.0128)
Low-Tax × Dist. to Border/50mi	−.0048***	−.0045***	−.0061***	−.0057***	−.0067***	−.0062***	−.1027***	−.0990***
	(.0012)	(.0012)	(.0013)	(.0013)	(.0014)	(.0014)	(.0073)	(.0073)
Low-Tax × Dist. to Border/50mi × ΔTax/10¢	−.0039*	−.0040**	−.0039*	−.0039*	−.0042*	−.0044*	−.1912***	−.1479***
	(.0015)	(.0015)	(.0017)	(.0017)	(.0020)	(.0020)	(.0093)	(.0094)
Regulation controls?	no	yes	no	yes	no	yes	no	yes
Other controls?	no	no	no	no	no	no	yes	yes
Adj. R^2					.0977	.0978		
Pseudo R^2	.1710	.1712	.1712	.1714			.6474	.6492
Num. obs.	331,076	331,076	331,076	331,076	331,076	331,076	331,076	331,076

Note: The table reports the marginal effects at the mean for the logit and probit estimations, models 1 to 4. The coefficients of the linear model come from an OLS estimation. The coefficients of the logit, probit, and linear models are for the spatial differencing approach of equation (4). The estimates of the conditional logit models are for equation (1) without retailer specific characteristics. All the regressions include border pair fixed effects. The squares of the grid are the unit of analysis. In models 1 to 6, the regulation controls include oxygenated fuels and price-gouging laws. In Model 8, the regulation controls include the complete list in Appendix C. In models 7 and 8, the other controls are the population, the number of highways, and the area of the square of analysis. The standard errors are presented in parentheses. The distance to the border is measured in 50-mile units. The tax difference, $\Delta\tau$, is in 10 cent units. The symbols *,**,*** denote significance at the 90%, 95%, and 99% levels, respectively. The full set of interactions is included in the regression but not presented in the table.

Table 5: Average Pass-Through of Fuel Taxes to Consumer Prices

	Dependent Variable: Retailers' Idiosyncratic Prices in cents					
	States	All Retailers		Inner Land	Border	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Tax in cents: β_0	1.00***	1.00***	.99***	1.05***	.91***	.89***
	(.09)	(.04)	(.04)	(.05)	(.04)	(.04)
Distance to Border in mi.		.00	.00	.01	−.07	−.07
		(.01)	(.01)	(.01)	(.08)	(.08)
Population per 10,000 res.			.54**	.88**		.30
			(.18)	(.34)		(.17)
Retailers per mi.^{2}			−1.93***	−2.82***		−.77
			(.53)	(.50)		(.64)
Roads per mi.^{2}			.72*	1.11**		.10
			(.31)	(.39)		(.20)
Regulation Controls	no	no	yes	yes	no	yes
PADD	yes	yes	yes	yes	yes	yes
Adj. R^2	.89	.74	.75	.78	.54	.55
Num. obs.	49	126,981	126,934	96,727	30,218	30,207
RMSE	29.56	14.17	14.06	14.14	13.12	13.03

Note: The dependent variable is the idiosyncratic price in cents per gallon. The unit of analysis is the gasoline retailer, except for Model 1, in which the analysis is conducted at the state level. All estimations use the OLS method. Standard errors clustered at the state level are in parentheses. The symbols *, **, *** denote significance at the 90%, 95%, and 99% levels, respectively. Regulation Controls indicates that the regression includes explanatory variables for gasoline regulation. All regressions include indicator variables for the five Petroleum Administration for Defense Districts (PADD). For the column States, the analysis uses the price fixed effects of the 49 contiguous states. For the column All Stations, the analysis uses the information from all gasoline retailers. The column Inner Land uses the information of retailers more than 15 miles away from the border. The column Border presents the results for the subsample of retailers within 15 miles of the border. The RMSE row presents the Root Mean Square Error. In models 5 and 6, with a significance smaller than 5%, the tax coefficient is different from 100 percent.

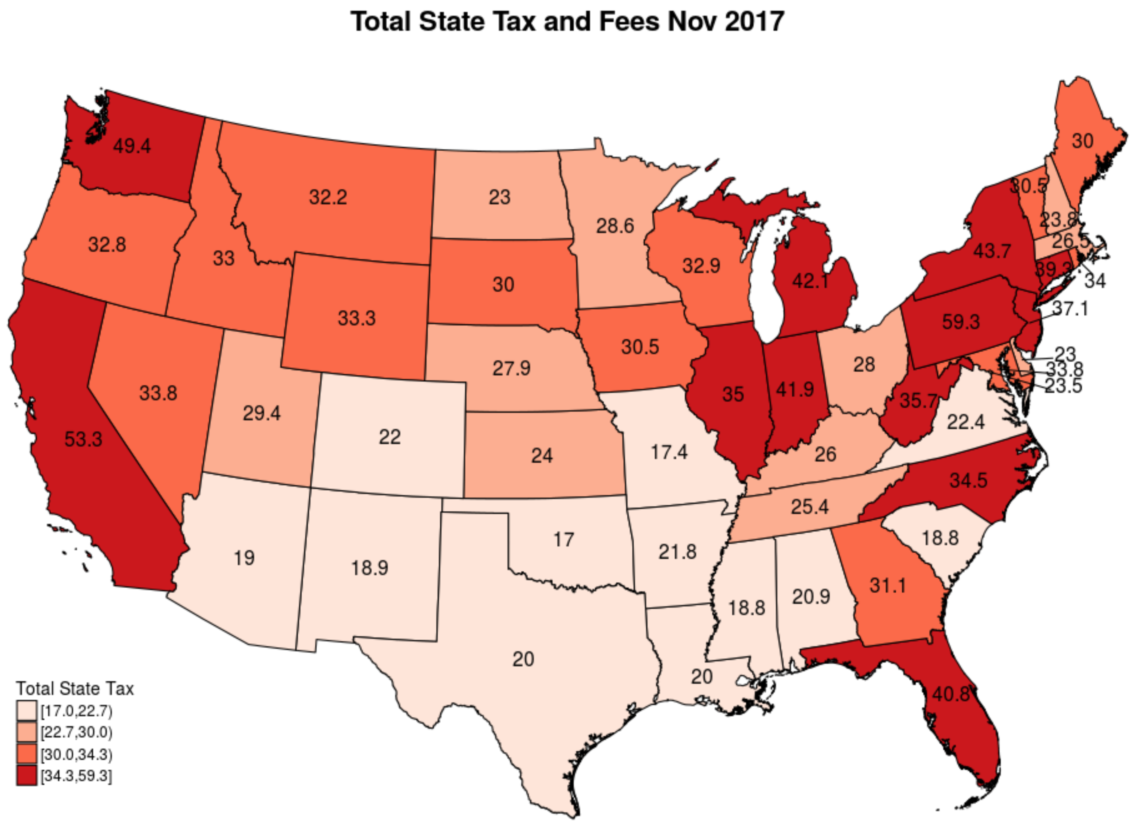
Table 6: Average Pass-Through of Fuel Taxes to Consumer Prices at the Border

	Dependent Variable: Retailers' Idiosyncratic Prices in cents			
	All Stations		Border	
	Model 3	Model 3i	Model 6	Model 6i
Tax in cents: β_0	.99		.89†	
	[.90; 1.07]		[.80; .98]	
Tax × Low		1.01		.82
		[.79; 1.23]		[.59; 1.06]
Tax × High		.95		.98
		[.82; 1.08]		[.84; 1.11]
All Other Controls	yes	yes	yes	yes
Share of Low [%]	-	44	-	53
Share of High [%]	-	56	-	47
Sample	All	All	Border	Border
Adj. R^2	.75	.76	.55	.58
Num. obs.	126,934	126,934	30,207	30,207
RMSE	14.06	13.84	13.03	12.60

Note: The dependent variable is the idiosyncratic prices in cents per gallon. The unit of analysis is the gasoline retailer. All estimations use the OLS method. The 95% confidence interval is indicated within the square brackets. The symbol † denotes that the number one is outside the confidence interval. The regressions include all other controls such as explanatory variables for gasoline regulation, PADD, and other characteristics. In the Sample row, those models labeled All use information from all gasoline retailers, and those labeled Border use the subsample of retailers within 15 miles of the border. The RMSE row presents the Root Mean Square Error.

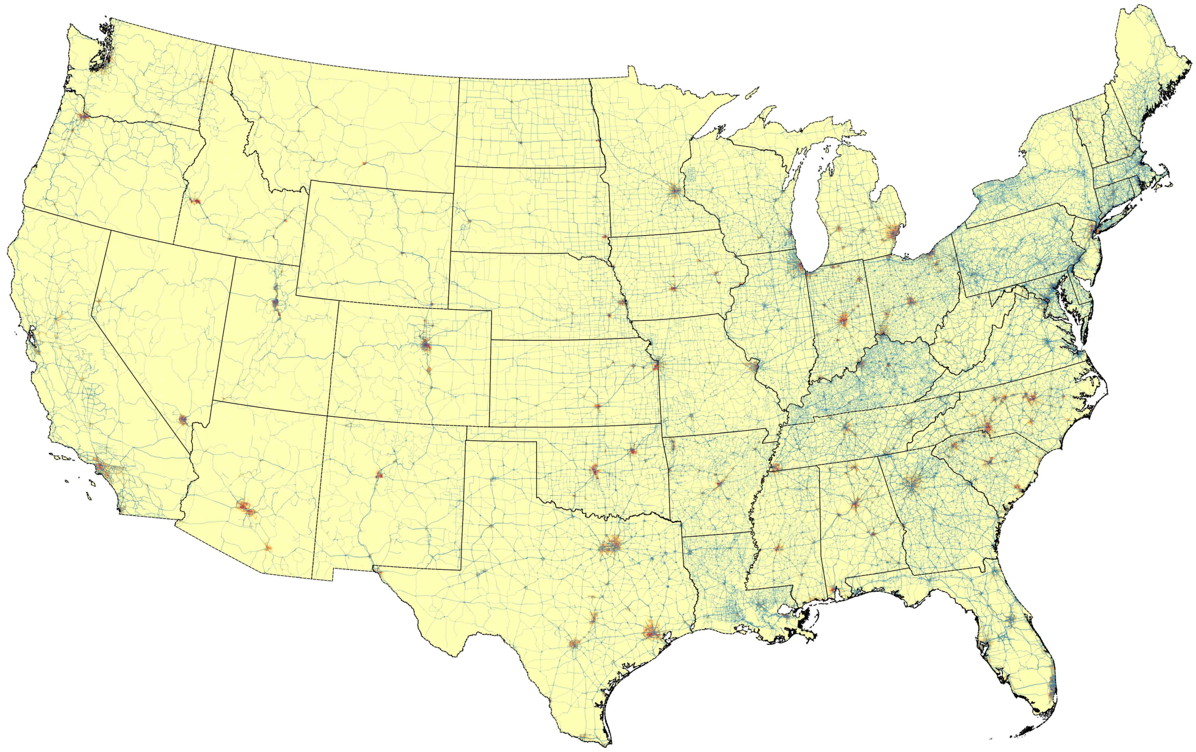
Figures

Figure 1: Spatial Variation of State Gasoline Taxes in the US

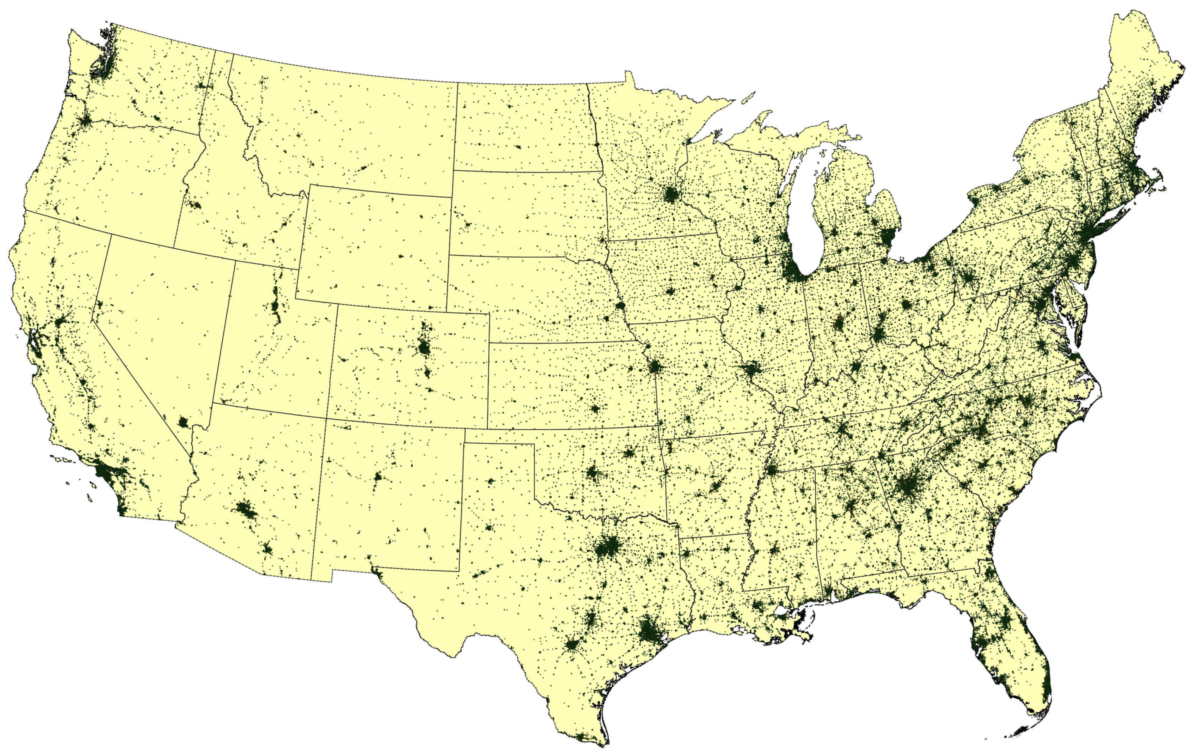


Note: The figure shows the spatial variation of state gasoline excise taxes using the quarterly State Gasoline Tax Report from the American Petroleum Institute (API). The API has information on the local taxes and fees and computes the average rate weighting by the population of the areas subject to each particular tax. The API's gasoline tax report also accounts for the average within each state of additional state and local fees, such as, for example, inspection fees, delivery fees, environmental assurance fees, and underground storage tank fees per gallon. Also, the API computes the equivalent excise gasoline tax for the eight states with some portion of an ad valorem gasoline tax: Alaska, California, Florida, Hawaii, Illinois, Michigan, New York, and Virginia.

Figure 2: Location of Population and Gasoline Retailers



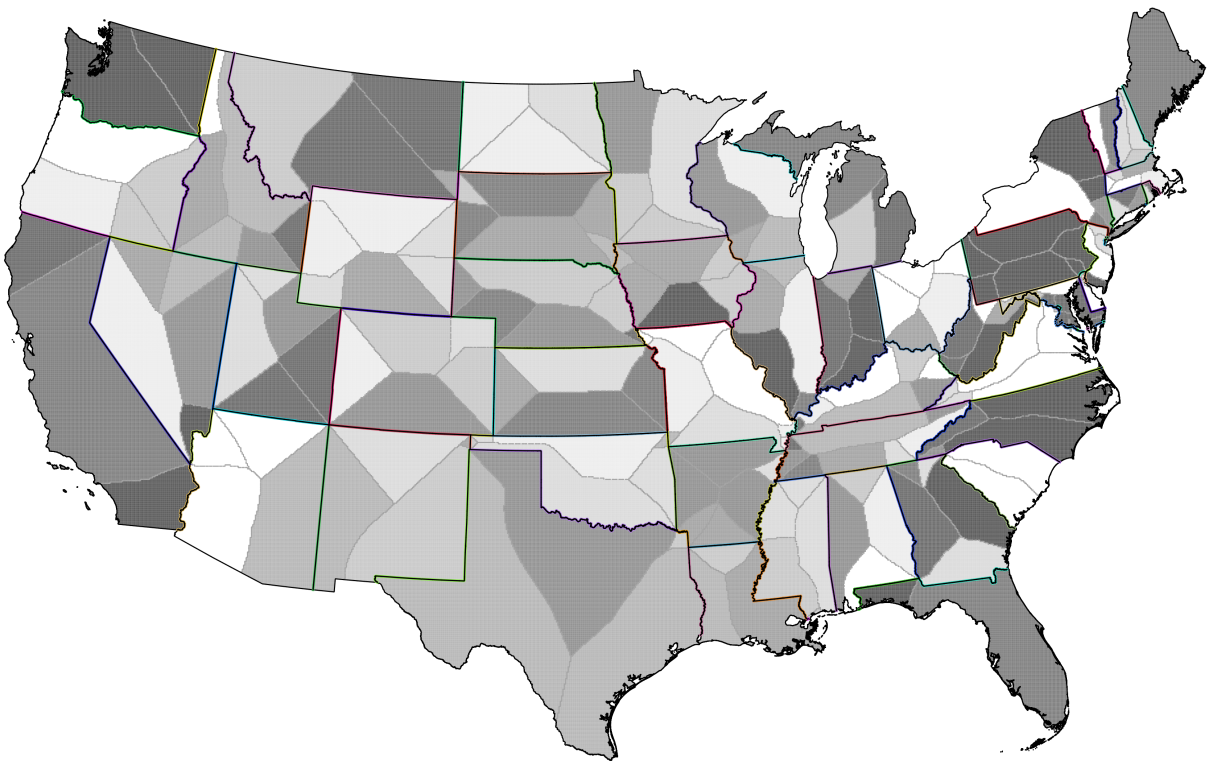
(a) Principal Cities and Primary and Secondary Roads



(b) Location of the Gasoline Retailers

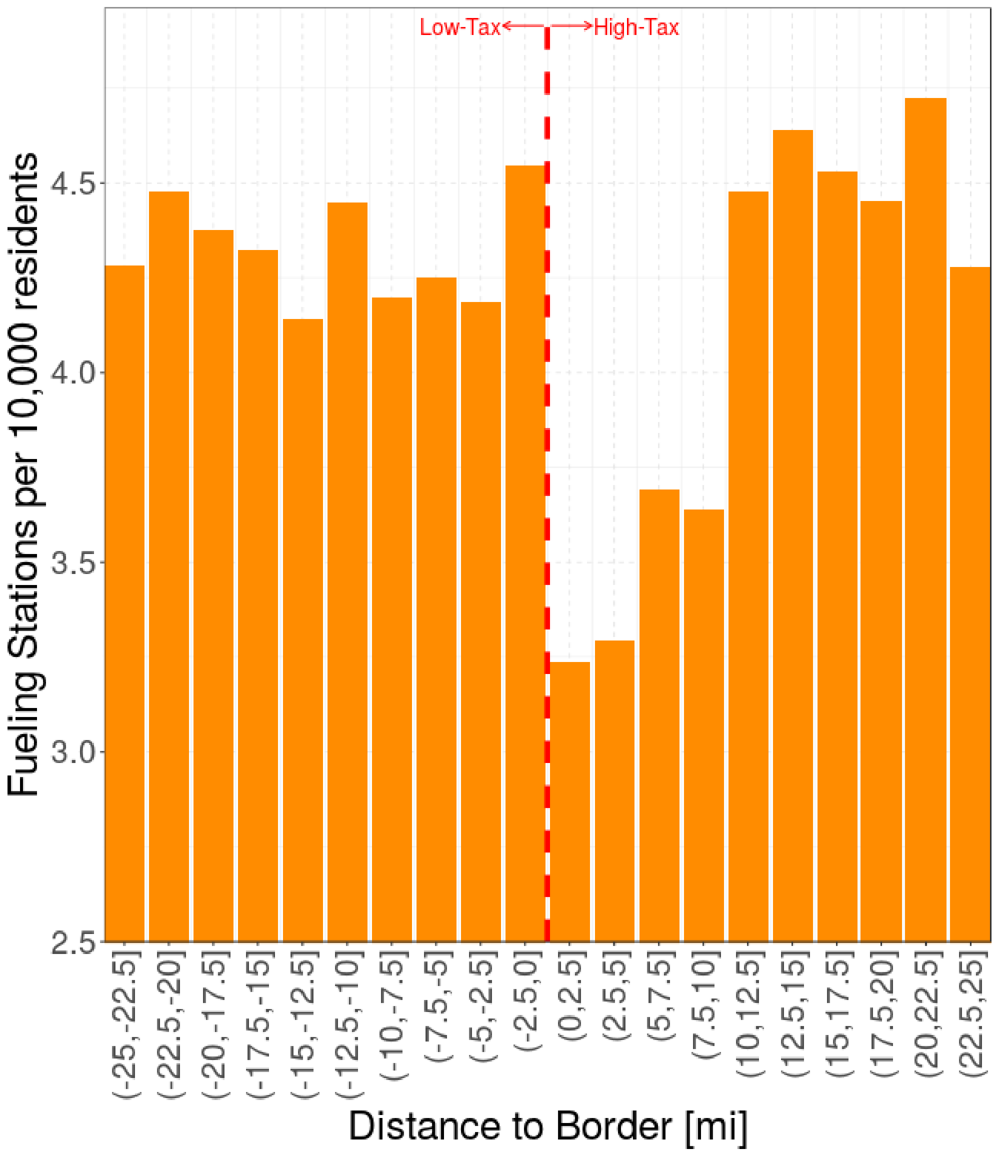
Note: Panel (a) of the figure uses U.S. Census Bureau data to create a map of the United States that highlights (in a darker color) the location of the most populated areas of each state, and the routes of the primary and secondary roads. Panel (b) of the figure exhibits the map of the location of the fueling stations. Every point on the map represents a gasoline retailer. It is evident that the location choice of the retailers closely aligns with the distribution of the population and the U.S. road network.

Figure 3: Proximity Regions for State Borders



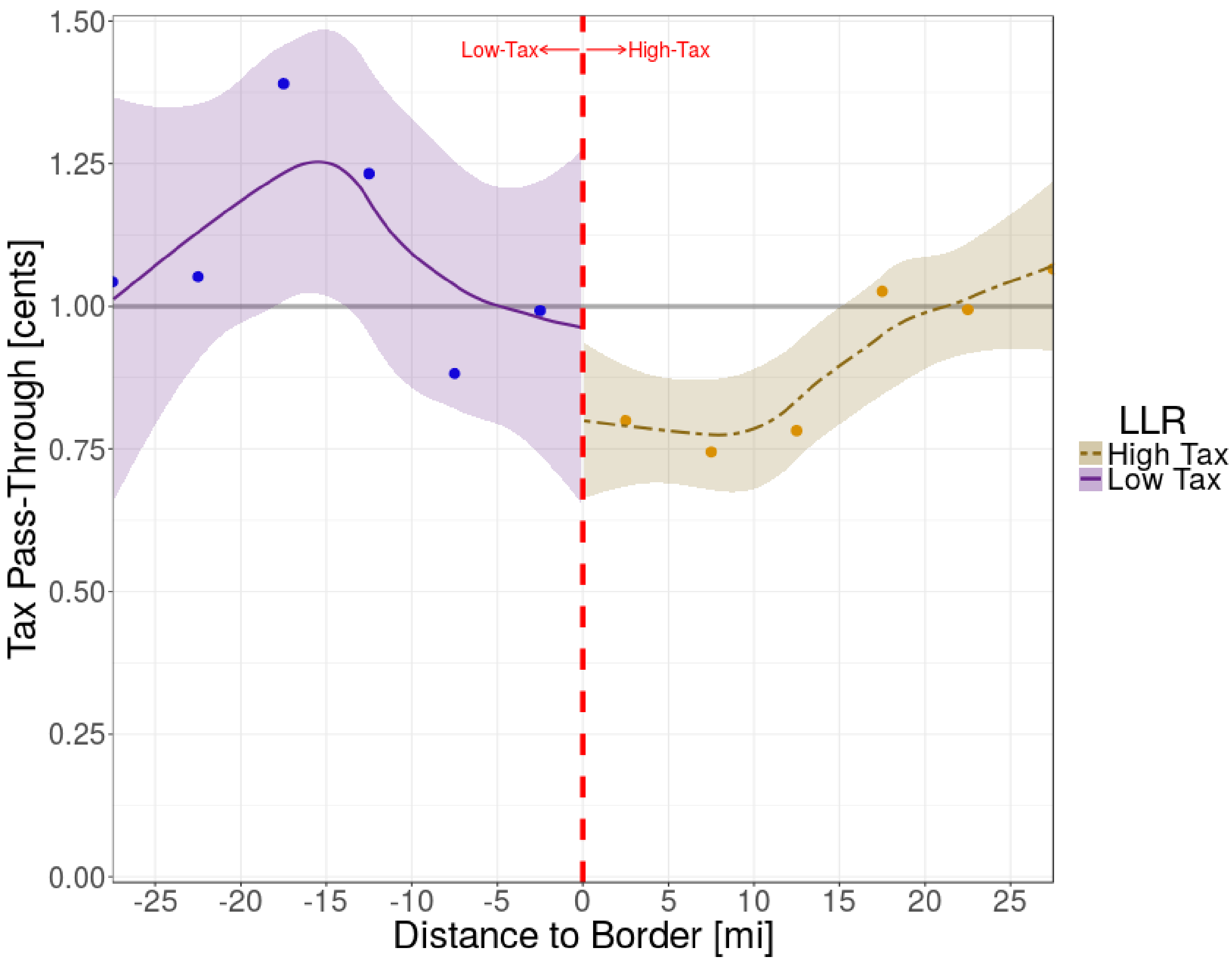
Note: Each of the 107 line segments that define a pair of bordering states determines a proximity region with a specific spatial tax notch. For each centroid of the squares of the grid, using Euclidean distance, I determine the closest state border and its corresponding linear distance. The map shows proximity regions of each state border. Darker grey represents a higher gasoline tax compared to the matching neighboring state. All borders of some states, such as Pennsylvania, Washington, and North Carolina, lie on the high-tax side, whereas all borders of some other states, such as North Dakota, Oklahoma, and Virginia, lie on the low-tax side. Every spatial tax notch defines one of these proximity regions. The map shows all the variations.

Figure 4: Average Number of Gasoline Retailers per Capita Close to Spatial Tax Notches



Note: The figure shows the average location patterns of gasoline retailers around state borders. The figure is the result of a two-step procedure where I first compute the number of gasoline retailers per 10,000 residents, for each borderline and various ranges of distance to the border, and then I take the average of each range of distance using the 107 border pairs. The vertical dashed line in marks the state boundary. The horizontal axis shows the linear distance to the border. By convention, the negative numbers on the horizontal axis are the distances to the border from the low-tax side of the border.

Figure 5: Pass-Through near State Borders



Note: The figure shows the pass-through of taxes to consumer prices from equation (8). Each point of the figure represents the estimate from the OLS regression that includes interactions for distance to the border and high- or low-tax side of the border. The lines in the figure show the tax pass-through estimates from a local linear regression that uses a triangular kernel. The estimates are statistically smaller than 100 percent on the high-tax side of the border within 15 miles.

Appendices

A Other Sources of Variation in Gasoline Prices

As previously indicated, part of the variability in gasoline prices across states arises as a result of spatial tax notches across jurisdictional boundaries. However, other sources of variation in gasoline prices include differences in local minimum wages, price gouging laws, the point on the supply change where states collect gasoline taxes, local wholesale prices, and additional gasoline regulations. To account for the variation in wages, the values of state and local minimum wages were collected for every month of the sample period. I obtained information on state and local regulations from the Minimum Wage Tracker of the Economic Policy Institute. Then, I determined monthly values by reviewing these regulations using Lexis Nexis Uni. Figure A.1 shows a map of the United States with the state and local minimum wages as of April 2018. Also from Lexis Nexis Uni, I found the list of state with price gouging laws.[23] Finally, I reviewed the regulation to determine the point of taxation of gasoline in the supply change.[24]

Another source of variation in the gasoline prices is the differences in local wholesale prices. The local wholesale gasoline prices depend on several factors related to the gasoline supply chain. The supply chain has four central nodes: extraction or importation of crude oil, production of gasoline at the refinery, blend of gasoline with ethanol at the bulk facilities or terminals, and distribution to retailers. The price of crude oil and other costs for the refineries depend on the infrastructure to transport the product. The U.S. Energy Information Administration uses the Petroleum Administration for Defense Districts (PADD) to assess regional petroleum product supplies.[25] Figure A.2 shows a map of the PADDs using the 48 contiguous states and the District of Columbia.

[23]The states with price gouging laws are Alabama, Arkansas, California, Connecticut, District of Columbia, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Massachusetts, Michigan, Mississippi, Missouri, New Jersey, New York, North Carolina, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Utah, Vermont, Virginia, West Virginia, and Wisconsin.

[24]The states that collect the gasoline taxes at the distributor level are Alabama, Colorado, Connecticut, Delaware, Georgia, Illinois, Kansas, Kentucky, Massachusetts, Maine, Montana, North Dakota, Nebraska, New Hampshire, Nevada, Ohio, Pennsylvania, Rhode, Island, Utah, Vermont, Oregon.

[25]The regions are as follows: PADD I (the East Coast) includes: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, Delaware, District of Columbia, Maryland, New Jersey, New York, Pennsylvania, Florida, Georgia, North Carolina, South Carolina, Virginia, and West Virginia. PADD II (the Midwest) includes: Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Ohio, Oklahoma, Tennessee, and Wisconsin. The PADD III (the Gulf Coast) includes: Alabama, Arkansas, Louisiana, Mississippi, New Mexico, and Texas. PADD IV (the Rocky Mountain region) includes: Colorado, Idaho, Montana, Utah, and Wyoming. Finally, PADD V (the West) includes: Alaska, Arizona, California, Hawaii, Nevada, Oregon, and Washington.

The U.S. gasoline requirements are the final source of variability in the gasoline prices. The Environmental Protection Agency (EPA) operates five gasoline standards programs to control ground-level ozone commonly known as smog. The gasoline standards regulated are: Gasoline Sulfur, Mobile Source Air Toxics (MSAT), which are both regulated at the federal level; and Reformulated Gasoline (RFG), Reid Vapor Pressure (RVP), and Winter Oxygenates (WO), which are regulated at state and local levels with federal oversight by the EPA. The objective of these regulations is to reduce smog, particulate matter, and the emissions of carbon monoxide and other hazardous air pollutants.

The EPA sets standards for the sulfur content in gasoline. Sulfur reduces the effectiveness of emission control technologies in cars. Sulfur also contributes to smog. The EPA gasoline standards on sulfur (Tier 2) decreased sulfur content by 90 percent from levels that existed before the regulation. On January 1, 2006, the sulfur content on gasoline produced at most refineries in the United States was as low as 80 parts per million (ppm) on a per-gallon basis, according to statistics of the American Fuel and Petrochemical Manufacturers. The current criteria (Tier 3) reduced the content of sulfur on gasoline to a maximum of 10ppm and mandated new vehicle emissions standards. Implementation of the current rule began in 2017.

The MSAT program aims to reduce dangerous air pollutants emitted by motor vehicles. The regulation started in 2001 (Phase 1) with rules from the EPA. Beginning on January 1, 2011, (Phase 2) refiners were required to meet annual average gasoline content limits on benzene, set at 0.62 percent (of volume) for all of gasoline produced at the refinery. Additionally, since July 1, 2012, refiners were also required a maximum benzene level of 1.3 percent (of volume). Phase 2 of the regulation has applied to all refineries since 2016. The program achieves less geographic variability in gasoline benzene levels around the country.

The 1990 amendments to the Clean Air Act introduced the RFG program. Under this program, some counties and cities require a gasoline blend to burn more cleanly than the conventional fuel. The RFG program is mandatory in towns with high smog levels, and it is optional elsewhere. On January 1, 2018, the RFG program operated in 17 states and the District of Columbia. According to the EPA statistics, 30 percent of the gasoline sold in the United States is reformulated. The RFG regulation operates on a year-round basis and requires cleaner standards than the conventional gas (see Code of Federal Regulations, Title 40, Chapter I, Subchapter C, Part 80, numeral 80.41). Phoenix, Arizona has a waiver from the RFG program because the state implemented the Cleaner Burning Gasoline (CBG) regulation, which is more stringent than the federal program's requirements. Similarly, California has more rigorous regulations than those set by the federal government.

Figure A.3 shows a map of the gasoline requirements for the RFG, the RVP, and the WO where the implementation occurs at the state and local levels. The gasoline blends of RFG vary for each location, but the colors in the figure indicate the location of the variability in regulation. For example, the RFG in California is different than the RFG in New Jersey.

Finally, Figure A.4 shows the average retail gasoline prices on a daily frequency for selected states. The missing dates are due to technical difficulties collecting the price data.[26] Regardless of the missing information, a noticeable variation of gasoline prices across space and time emerges. It is worth noting the saw-tooth pattern in the gasoline prices in the Midwest. The analysis of the pricing strategies at the station level is developed in González and Hurtado (2018). Also notice the variation in the price range, with California showing the highest prices, and Texas showing the lowest prices.

B Other Summary Statistics

Table B.1 presents the number of stations per state as well as the number of retailers per 10,000 residents. Columns (a) to (f) display the percentage of retailers offering additional services, such as convenience store, pay at the pump, or cash discounts. The last row of the table shows the corresponding value for the United States.

Table B.1 shows considerable variability in the number of gasoline retailers per state. Notably, Texas has the most retailers of any state. Its retailers represent almost 10 percent of the total number of stations nationwide. California, Florida, and Georgia follow Texas in terms of the ranking of states with the most retailers. The locations with the fewest retailers are: the District of Columbia, Delaware, Hawaii, and Alaska. However, the case looks strikingly different for the number of retailers per 10,000 residents. Vermont, South Dakota, Mississippi, and Alabama are the states with the most stations per capita. The fewest retailers per capita are in the District of Columbia, Hawaii, California, and New York.

Column (a) of Table B.1 presents the percentage of fueling stations offering also a convenience store or service station. The numbers show that the gasoline retailers in the United States sell a variety of other everyday products in their convenience stores. Column (b) of the same table presents the proportion of gas stations offering the service of pay-at-the-pump. Wyoming, Georgia, California, and New Jersey are the states with the highest percentage of retailers providing the service. On the opposite side of the ranking, in the states of Mississippi, Oregon, Alaska, and Vermont, fewer than 50 percent of the listed retailers offer the pay-at-the-pump service.

[26] An example of a technical difficulty is the change of the design of the web page, or changes in the policy of allowed requests per second.

Column (c) of Table B.1 shows that more than 70 percent of the reported gasoline retailers also sell diesel in the states of Wyoming, Utah, and Idaho. By contrast, fewer than 50 percent of the retailers sell diesel in the District of Columbia, Vermont, and Rhode Island. Table B.1 column (d) exhibits that Arkansas, Oregon, and Louisiana are the states with the smallest proportion of retailers holding an ATM, whereas, in Georgia, Nevada, Pennsylvania, and Delaware more than 50 percent of stations offer the service.

Column (e) of Table B.1 shows great variability in the number of retailers that offer a car wash. More than 15 percent of the fueling stations in Minnesota, Utah and Nevada offer this service. On the contrary, fewer than 6 percent of the gasoline retailers offer the service in Connecticut, New Jersey and Vermont. Finally, Table B.1 in column (f) shows that some states have a considerable proportion of gasoline retailers offering cash discounts. In particular, more than 50 percent of New Jersey's stations provide this benefit. Connecticut, California, New York, and Nevada follow the ranking. By contrast, fewer than 2 percent of gasoline retailers offer such a discount in West Virginia, Montana, Minnesota, and Iowa.

Panel (a) of Figure B.5 shows the ranking of states by the number of gasoline retailers. The horizontal axis exhibits, from left to right, the states with the highest number of stations. Similarly, panel (b) of the same Figure B.5 presents the ranking of states using the number of retailers per 10,000 residents. Finally, Figure B.6 shows the same ranking but using the proportion of retailers offering the additional services listed in columns (a) to (f) of Table B.1.

C Additional Estimates on Location Decision

The most economic-relevant estimates of the coefficients in the choice model were presented in Table 4 of the main document. However, the magnitudes and significance of the other estimates shed light on the effects of regulation and other controls on the probability that a gasoline retailer is located in a given area. The regulation controls include indicators for the Winter Oxygenates Fuels and Reformulated Gasoline programs described in Appendix A. Other regulation controls include indicators for price-gouging laws and the point of taxation as described below. The price-gouging laws regulate prices to prevent retailers from charging exorbitant prices for necessities. These laws enter into effect in some states during a declared state of emergency. To define the indicator variables on the regressions, I used the list of states that have price-gouging laws from findlaw.com. The point of taxation refers to the tax collection location in the supply chain of gasoline. Kopczuk et al (2016) has a detailed explanation of the importance of the point of taxation to reduce tax avoidance. To define the indicator variables, I used the point of taxation of gasoline from the Motor Fuel Tax

Information report from the Federation of Tax Administrators. Finally, the minimum wage variable corresponds to the value of the local regulation in April of 2018.

Table C.2 presents all the coefficients of the spatial differencing approach in equation (4) and the conditional logit from equation (1). The table also presents additional specifications exploring nonlinearities on distance to the border. Table C.2 presents the estimates for the logit model, and also includes the probit and linear probability models to show the robustness of the results. The results in Table C.2 show the marginal effects at the mean of the logit and probit models. All the estimations include border pair fixed effects. Models 1 and 2 under the logit column in the table show the marginal effects at the mean without and with regulatory controls that change across borders. Notably, the signs and magnitudes of the probit and linear estimates, models 3 to 6, are similar to those of the logit model estimates. Also, higher taxes reduce the probability that a gasoline retailer is located in a given area near a state border. Moreover, the distance to the border and the interaction between being on the low-tax side, the distance to the border and the tax differential are statistically indistinguishable from zero.

Table C.2 also presents models exploring nonlinearities of distance to the border on the probability that a gasoline retailer is located in a given area, models 9 to 12. It is worth noting that the introduction of nonlinearities on distance to the border reduces the estimates of the effect of crossing to the low-tax side of the border, although the effect remains statistically significant. Moreover, the maximum probability of finding a gasoline retailer on the high-tax side can be computed as $d^* = \alpha/2\eta$, where α is the coefficient for distance to the border and η is the coefficient of square distance to the border. Replacing the coefficients in models 9 to 11, the maximum probability on the high-tax side happens 15 to 20 miles away from the border. However, the quadratic specifications seem to misrepresent the probabilities for locations that are far away from the border. Further research is needed to better understand the location decisions of the retailers away from the border.

D Other Estimates of Pass-Through

D.1 Pass-Through of Regulation to Prices

The pass-through of regulation to prices has gain a renewed interest in the environmental literature due to the recent work of Fullerton and Muehlegger (2018). The literature on public economics has developed the analysis of the tax incidence, but other non-tax regulations are also of importance. Table D.3 presents the estimates of the coefficients in equation (6) using OLS. The coefficients of tax, distance to the border, population, retailers and roads are those presented in the main text. The first pattern to notice is the variability of the gasoline prices by PADD. The Gulf Coast tends to have the smallest average price per gallon whereas the West Coast has the highest gasoline prices. It is also very interesting to note that one dollar increase in the minimum wage passes-through gasoline prices in about 3 cents, but this relationship is only 2.3 cents in inland stations whereas it goes to almost 4 cents on the border. Finally, the point of taxation and the Reformulated Gasoline program increase the gasoline prices.

This paper contributes to the literature by analyzing the pass-through of many regulations to prices from the high- and low-tax sides of the border. The differentiated pass-through of regulation and other characteristics depending on the side of the border can inform of the distortionary effects of administrative jurisdictions. Table D.4 presents the average pass-through of regulation and other controls near state borders. The dependent variable is the retailers' idiosyncratic prices in cents per gallon. The regressions include explanatory variables for gasoline regulation, PADD, and other characteristics. Model 3i in Table D.4 presents selected interaction coefficients using the full sample. The coefficients show that the Reformulated Gasoline program increases the price of gasoline in about 4 cents regardless of the size of the gasoline taxes. Also, from Model 3i in Table D.4, the point of taxation does not have a significant average effect on the price of gasoline. The pass-through of the minimum wage seems to be balanced, but more population seems to have a substantial impact on the price of gasoline only for the part of the state with low gasoline tax compared to the neighboring jurisdiction. Importantly, from Model 3i in Table D.4, more competitors reduce the average price of gasoline.

The results show some substantial differences when looking at the same regression but using the subsample of retailers within 15 miles of the border. Model 6i in Table D.4 shows selected interaction coefficients using the restricted subsample. The coefficients show that the Reformulated Gasoline program increases in almost 7 cents the price of gasoline only on the low-tax side of the border whereas the high-tax side increases the price by an average of 4 cents. Also, from Model 6i in Table D.4, the point of taxation generates a significant increase in the price of gasoline only on the low-tax side of the border. Again, the pass-through of the minimum wage seems to be balanced, but more population increases the price of gasoline only on the low-tax side of the border. Perhaps the most interesting result in the appendix, more competition reduces the average price of gasoline only on the low-tax side. This result seems to be relevant for future research.

D.2 Pass-Through near Borders

Table D.5 presents the estimates of equation (6) for the interaction of tax, distance to the border, and high- or low-tax side. The first column of the table, Model 1, presents the OLS estimates of the selected distances. The second column of the table presents the estimates of pass-through of taxes to prices using equation (8). The negative intervals represent distance to the border form a location on the low-tax side whereas positive intervals cover locations on the high-tax side of the border. I use the absolute value of the midpoint of the interval to compute the estimates of in column 2 of Table D.5. For example, the pass-through for the interval (-20,-15] corresponds to $1.39 = 0.92 + 0.027 * 17.25$. The standard errors come from the appropriate linear combination of the variance-covariance matrix. The point estimates of the pass-through on the low-tax side are statistically indistinguishable from one except in the (-20,-15] interval. On the high-tax side, the pass-through of taxes to prices is smaller than one within 15 miles of border.

Tables of Appendices

Table B.1: Additional Descriptive Statistics

State	Gasoline Stations	Stations per Capita	(a) Conv. Store	(b) Pay at Pump	(c) Has Diesel	(d) ATM	(e) Car Wash	(f) Cash Disc.
AL	3,667	7.5	78.7	57.2	51.7	34.4	10.5	2.7
AR	1,897	6.3	77.2	60.8	62.4	22.4	12.4	4.3
AZ	2,029	2.9	86.8	75.5	64.6	40.4	13.7	10.9
CA	9,493	2.4	91.8	84.3	58.4	43.9	18.5	36.7
CO	2,037	3.7	79.8	67.6	72.8	34.1	21.9	2.3
CT	1,438	4.0	77.5	65.4	49.5	30.5	6.1	42.6
DC	114	1.7	81.6	72.8	37.7	37.7	7.9	26.3
DE	307	3.2	91.2	81.4	63.8	50.5	11.7	5.5
FL	7,501	3.6	88.5	73.5	60.9	42.6	15.0	14.4
GA	6,378	6.2	92.8	84.9	60.4	77.3	8.0	13.8
IA	2,083	6.6	79.3	68.7	54.7	34.6	8.6	1.3
ID	834	5.0	77.9	69.7	77.3	32.6	11.4	5.4
IL	4,429	3.5	87.9	82.0	58.5	49.6	17.2	6.2
IN	3,194	4.8	83.2	71.3	60.9	40.7	10.5	4.4
KS	1,663	5.7	73.7	64.3	63.1	29.4	11.3	3.6
KY	2,459	5.5	73.5	57.3	63.3	28.0	7.4	2.4
LA	2,853	6.1	71.2	53.5	58.3	22.7	7.6	3.8
MA	2,443	3.6	82.6	67.9	45.9	32.3	7.1	18.7
MD	1,913	3.2	82.5	76.4	62.5	44.1	14.7	18.9
ME	953	7.2	91.6	54.9	56.5	35.7	6.2	5.4
MI	4,446	4.5	83.7	68.9	64.1	37.4	9.0	27.7
MN	2,614	4.7	85.5	68.8	67.2	45.1	26.7	1.2
MO	3,229	5.3	82.3	72.7	63.1	28.3	12.9	3.6
MS	2,247	7.5	76.9	46.6	53.6	27.1	11.3	2.1
MT	642	6.2	72.0	61.5	72.4	36.3	7.8	0.9
NC	5,672	5.6	91.1	60.8	61.8	46.6	12.8	3.6
ND	560	7.4	76.2	59.8	72.9	27.1	17.9	1.4
NE	1,212	6.4	73.8	53.3	58.2	33.1	15.0	2.2
NH	741	5.6	86.6	64.4	56.1	36.2	10.0	5.5
NJ	2,997	3.4	72.7	84.0	55.0	27.9	4.9	55.0
NM	1,025	4.9	79.9	70.9	68.0	24.6	10.3	2.8
NV	941	3.2	90.0	80.3	65.6	58.7	22.6	31.0
NY	5,496	2.8	84.6	73.8	50.3	38.1	6.6	33.4
OH	4,735	4.1	84.2	76.7	59.3	47.0	10.0	5.3
OK	2,522	6.4	74.0	52.4	60.1	29.6	7.7	2.1
OR	1,185	2.9	71.1	49.2	68.1	23.2	9.3	25.9
PA	4,627	3.6	86.4	77.1	52.6	56.1	8.0	6.7
RI	396	3.7	88.9	67.2	44.2	33.3	8.1	15.9
SC	3,089	6.2	86.8	68.9	57.3	42.1	8.7	21.7
SD	702	8.1	81.8	59.5	63.8	26.1	12.3	9.3
TN	4,026	6.1	76.7	62.1	54.3	27.7	9.2	2.6
TX	13,727	4.9	77.9	67.4	69.3	36.9	11.0	9.4
UT	1,095	3.6	86.2	78.4	79.5	29.8	23.7	3.6
VA	3,938	4.7	90.2	79.0	65.7	45.5	11.2	6.6
VT	557	8.9	87.8	51.2	42.5	39.0	3.2	1.8
WA	2,584	3.5	82.1	64.4	68.3	49.2	12.5	28.7
WI	3,029	5.2	86.2	72.2	62.3	47.0	20.5	3.6
WV	1,070	5.8	79.7	61.0	61.8	40.6	7.2	0.6
WY	425	7.3	86.4	86.1	85.2	45.4	8.0	9.6
USA	137,214	4.3	83.3	70.2	60.7	40.5	11.8	13.1

Note: The table reports the number of gasoline stations per state. The column of stations per capita exhibits the number of gasoline retailers per 10,000 residents. Columns (a) to (f) show the percentage of petrol retailers offering the particular service on the header of the table. Column (a) refers to convenience store or service stations. Column (f) refers to cash discounts. The last row of the table presents the number of gasoline retailers and the percentage offering corresponding services for the US

Table C.2: Location Decision of Gasoline Retailers Including All Coefficients

	Dependent Variable: Indicator of a Retailer on a Square of the Grid											
	Logit		Probit		Linear		Conditional Logit		Nonlinearities on Distance			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Low-Tax	.0059**	.0069***	.0073***	.0091***	.0093***	.0110***	.2178***	.2889***	.0037*	.0028	.0041*	.2125***
	(.0019)	(.0019)	(.0021)	(.0022)	(.0023)	(.0024)	(.0124)	(.0128)	(.0018)	(.0016)	(.0018)	(.0107)
ΔTax/10¢	−.2173*	−.2189*	−.2636*	−.2644*	−.4496**	−.4512**	.5718	3.6794***	−.2540*	−.2100*	−.4391**	3.9622***
	(.0968)	(.0968)	(.1172)	(.1172)	(.1566)	(.1566)	(.7382)	(.7514)	(.1168)	(.0964)	(.1565)	(.7517)
Dist. to Border/50mi	−.0014	−.0017	−.0007	−.0011	−.0018	−.0022*	.0653***	.0531***	3.0553***	1.8595*	2.5122**	66.5055***
	(.0009)	(.0009)	(.0010)	(.0010)	(.0010)	(.0010)	(.0056)	(.0057)	(.8875)	(.8599)	(.8078)	(4.9419)
Low-Tax × ΔTax/10¢	−.0010	−.0008	−.0020	−.0022	−.0032	−.0036	.0450***	−.0367**	.0001	−.0009	−.0009	−.0307**
	(.0019)	(.0019)	(.0023)	(.0023)	(.0028)	(.0028)	(.0123)	(.0126)	(.0020)	(.0018)	(.0023)	(.0104)
Low-Tax × Dist. to Border/50mi	−.0048***	−.0045***	−.0061***	−.0057***	−.0067***	−.0062***	−.1027***	−.0990***	−4.6335***	−3.4566***	−5.9135***	−58.9928***
	(.0012)	(.0012)	(.0013)	(.0013)	(.0014)	(.0014)	(.0073)	(.0073)	(1.1062)	(1.0424)	(1.0789)	(6.1699)
ΔTax/10¢ × Dist. to Border/50mi	.0094***	.0096***	.0106***	.0110***	.0129***	.0133***	.2168***	.1973***	.8818	2.1306	−.1114	100.5802***
	(.0011)	(.0011)	(.0013)	(.0013)	(.0014)	(.0014)	(.0068)	(.0069)	(1.3705)	(1.3056)	(1.3048)	(7.2095)
Low-Tax × Dist. to Border/50mi × ΔTax/10¢	−.0039*	−.0040**	−.0039*	−.0039*	−.0042*	−.0044*	−.1912***	−.1479***	16.2882***	10.1294***	17.5260***	357.2722***
	(.0015)	(.0015)	(.0017)	(.0017)	(.0020)	(.0020)	(.0093)	(.0094)	(2.8249)	(2.5452)	(3.1514)	(13.4846)
Square of Dist. to Border/(50mi)^2									−4.7340***	−5.6786***	−3.2805***	−30.7190***
									(.8646)	(.8190)	(.8041)	(4.9111)
Low-Tax × Square of Dist. to Border/(50mi)^2									−1.7481	−.0775	−3.8927***	−29.7247***
									(1.0251)	(.9606)	(.9870)	(5.8082)
ΔTax/10¢ × Square of Dist. to Border/(50mi)^2									−3.7468**	−.8417	−8.4838***	−29.2118***
									(1.3440)	(1.2370)	(1.3376)	(7.2457)
Low-Tax × Square of Dist. to Border/(50mi)^2 × ΔTax/10¢									20.8573***	13.3939***	25.7229***	451.7644***
									(2.4908)	(2.2016)	(2.8032)	(12.7468)
Oxygenated Fuels		−.0005		−.0010		−.0025		−.0971***	−.0015	−.0012	−.0029	−.0847***
		(.0026)		(.0029)		(.0030)		(.0212)	(.0028)	(.0026)	(.0030)	(.0212)
Price-Gouging Laws		.0082***		.0111***		.0085***		.0824***	.0111***	.0080***	.0090***	.1003***
		(.0017)		(.0019)		(.0019)		(.0129)	(.0019)	(.0017)	(.0019)	(.0130)
Reformulated Gasoline								.0713***				.0725***
								(.0100)				(.0101)
Minimum Wage / USD								.0732***				.0732***
								(.0040)				(.0040)
Point of Taxation								−.2313***				−.2223***
								(.0093)				(.0093)
Area of Square on Grid / mi^2							.1506***	.1510***				.1456***
							(.0023)	(.0023)				(.0024)
Population / 100,000 residents							.8615***	.8462***				.8684***
							(.0068)	(.0069)				(.0070)
Number of Highways							.1279***	.1286***				.1289***
							(.0003)	(.0003)				(.0003)
Nonlinearities model estimation?									Logit	Probit	Linear	Cond. Logit
Adj. R^2					.0977	.0978					.0991	
Pseudo R^2	.1710	.1712	.1712	.1714			.6474	.6492	.1737	.1735		.6518
Num. obs.	331,076	331,076	331,076	331,076	331,076	331,076	331,076	331,076	331,076	331,076	331,076	331,076

Note: The table presents all the coefficients of the spatial differencing approach in equation (4) and the conditional logit from equation (1). The table reports the marginal effects at the mean for the logit and probit estimations, models 1 to 4. The coefficients of the linear model come from an OLS estimation. The coefficients of the logit, probit, and linear models are for the spatial differencing approach of equation (4). The estimates of the conditional logit models are for equation (1) without retailer specific characteristics. All the regressions include border pair fixed effects. The squares of the grid are the unit of analysis. The table also presents models exploring nonlinearities of distance to the border on the probability of finding a gasoline retailer, models 9 to 12. The standard errors are presented in parentheses. The distance to the border is measured in 50-mile units. The tax difference, $\Delta\tau$, is in 10 cent units. The symbols *,**,*** denote significance at the 90%, 95%, and 99% levels, respectively.

Table D.3: Average Pass-Through of Regulation to Consumer Prices

	Dependent Variable: Retailers' Idiosyncratic Prices in cents					
	States	All Stations		Inner Land	Border	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Tax in cents: β_0	1.00***	1.00***	.99***	1.05***	.91***	.89***
	(.09)	(.04)	(.04)	(.05)	(.04)	(.04)
Distance to Border in mi.		.00	.00	.01	−.07	−.07
		(.01)	(.01)	(.01)	(.08)	(.08)
Population per 10,000 res.			.54**	.88**		.30
			(.18)	(.34)		(.17)
Retailers per mi.^{2}			−1.93***	−2.82***		−.77
			(.53)	(.50)		(.64)
Roads per mi.^{2}			.72*	1.11**		.10
			(.31)	(.39)		(.20)
Oxygenated Fuels	−1.68	−1.73	−1.55	.05	−5.04**	−4.88**
	(3.11)	(1.68)	(1.65)	(2.10)	(1.76)	(1.69)
California	27.06***	25.37***	24.91***	26.30***	59.65***	60.49***
	(5.38)	(2.25)	(2.24)	(2.61)	(3.33)	(3.13)
Arizona	−30.06***	−27.42***	−27.63***	−25.44***	−25.94***	−25.79***
	(6.32)	(2.23)	(2.20)	(2.80)	(3.73)	(3.48)
Reformulated Gasoline	4.22*	3.56***	3.29**	2.17	6.07***	5.76***
	(1.59)	(1.00)	(1.00)	(1.19)	(.96)	(.96)
Point of Taxation	3.36*	3.94**	3.70**	3.07	4.84***	4.99***
	(1.52)	(1.29)	(1.31)	(1.57)	(1.15)	(1.12)
Price-Gouging Laws	−.56	1.32	1.23	1.18	1.66	1.44
	(1.85)	(1.72)	(1.71)	(1.99)	(1.97)	(1.83)
Minimum Wage in USD	2.70***	3.03***	2.82***	2.31***	3.96***	3.75***
	(.58)	(.55)	(.50)	(.57)	(.59)	(.55)
East Coast	−39.69***	164.24***	166.46***	168.33***	158.53***	161.13***
	(5.84)	(5.40)	(5.09)	(5.65)	(5.79)	(5.71)
Midwest	−39.09***	164.71***	167.09***	169.40***	159.54***	162.16***
	(5.41)	(4.84)	(4.52)	(5.19)	(5.39)	(5.35)
Gulf Coast	−42.84***	161.24***	163.90***	167.14***	154.92***	157.54***
	(5.38)	(4.93)	(4.59)	(5.00)	(5.55)	(5.53)
Rocky Mountain	−30.91***	172.92***	175.38***	177.39***	178.69***	181.22***
	(5.81)	(6.11)	(5.74)	(6.08)	(4.92)	(4.91)
West Coast	−9.03	193.81***	196.57***	197.25***	192.66***	195.51***
	(7.29)	(5.82)	(5.49)	(6.41)	(7.38)	(7.23)
Adj. R^2	.89	.74	.75	.78	.54	.55
Num. obs.	49	126,981	126,934	96,727	30,218	30,207
RMSE	29.56	14.17	14.06	14.14	13.12	13.03

Note: The dependent variable is the idiosyncratic price in cents per gallon. The unit of analysis is the gasoline retailer, except for Model 1, where the analysis is at the state level. All estimations use the OLS method. Standard errors clustered at the state level are in parentheses. The symbols *, **, *** denote significance at the 90%, 95%, and 99% levels, respectively. East Coast, Midwest, Gulf Coast, Rocky Mountain and West Coast are indicator variables for the five PADDs. For the column States, the analysis uses the price fixed effects of the 49 contiguous states. For the column All Stations, the analysis uses the information from all gasoline retailers. The column Inner Land uses the information of retailers more than 15 miles away from the border. The column Border presents the results for the subsample of retailers within 15 miles of the border. The RMSE row presents the Root Mean Square Error. In models 5 and 6, with a significance smaller than 5%, the tax coefficient is different from 100 percent.

Table D.4: Average Pass-Through of Regulation and Other Controls at the Border

	Dependent Variable: Retailers' Idiosyncratic Prices in cents	
	All Stations	Border
	Model 3i	Model 6i
Low × Tax	1.01***	.82***
	(.11)	(.12)
High × Tax	.95***	.98***
	(.07)	(.07)
Low × Reformulated Gasoline	4.27**	6.79***
	(1.32)	(1.40)
High × Reformulated Gasoline	3.75**	3.55*
	(1.30)	(1.72)
Low × Point of Taxation	3.03	5.25**
	(1.73)	(1.62)
High × Point of Taxation	2.55	2.77
	(1.60)	(1.44)
Low × Minimum Wage in USD	3.02***	3.65***
	(.81)	(.79)
High × Minimum Wage in USD	2.42***	3.93***
	(.53)	(.68)
Low × Population per 10,000 res.	1.38*	1.87**
	(.59)	(.68)
High × Population per 10,000 res.	.43***	.18
	(.08)	(.11)
Low × Retailers per mi.^{2}	−2.71***	−3.56***
	(.73)	(.95)
High × Retailers per mi.^{2}	−2.32***	−1.11
	(.63)	(.60)
Low × Roads per mi.^{2}	.33	.48
	(.22)	(.41)
High × Roads per mi.^{2}	.96*	.22
	(.39)	(.17)
All Other Controls	yes	yes
Share of Low [%]	44	53
Share of High [%]	56	47
Sample	All	Border
Adj. R^2	.76	.58
Num. obs.	126,934	30,207
RMSE	13.84	12.60

Note: The dependent variable is the idiosyncratic prices in cents per gallon. The unit of analysis is the gasoline retailer. All estimations use the OLS method. Standard errors clustered at the state level are in parentheses. The symbols *, **, *** denote significance at the 90%, 95%, and 99% levels, respectively. All other controls indicates that the regression includes explanatory variables for gasoline regulation, PADD, and other characteristics. If Sample reports All, the method uses the information from all gasoline retailers. If Sample shows Border, the regression uses the subsample of retailers within fifteen miles of the border. The RMSE row presents the Root Mean Square Error.

Table D.5: Pass-Through Near State Borders

	Dependent Variable: Retailers' Idiosyncratic Prices in cents	
	Model 1	Tax Pass-Through
(-30,-25]		1.04***
		(.20)
(-30,-25] x Tax	1.04***	
	(.23)	
(-30,-25] x Tax x dist	.01	
	(.01)	
(-25,-20]		1.05***
		(.15)
(-25,-20] x Tax	1.05***	
	(.21)	
(-25,-20] x Tax x dist	.01	
	(.01)	
(-20,-15]		1.39***
		(.18)
(-20,-15] x Tax	.92***	
	(.16)	
(-20,-15] x Tax x dist	.03*	
	(.01)	
(-15,-10]		1.23***
		(.14)
(-15,-10] x Tax	.83***	
	(.16)	
(-15,-10] x Tax x dist	.03**	
	(.01)	
(-10,-5]		.88***
		(.19)
(-10,-5] x Tax	.61***	
	(.14)	
(-10,-5] x Tax x dist	.04*	
	(.02)	
(-5,0]		.99***
		(.17)
(-5,0] x Tax	.79***	
	(.16)	
(-5,0] x Tax x dist	.08***	
	(.03)	
Adj. R^2	.78	
Num. obs.	126,934	
RMSE	13.33	

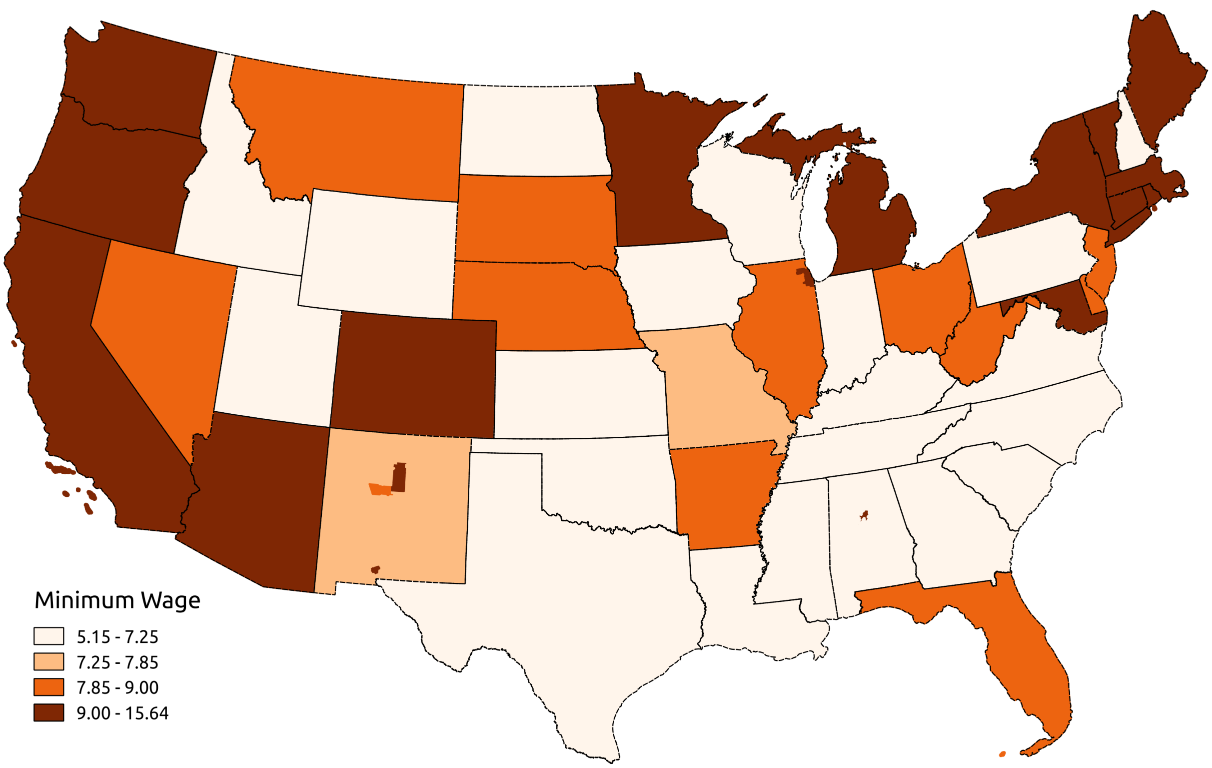
The table continues on next page

	Dependent Variable: Retailers' Idiosyncratic Prices in cents	
	Model 1	Tax Pass-Through
(0,5]		.80***
		(.08)
(0,5] x Tax	1.02***	
	(.09)	
(0,5] x Tax x dist	−.09**	
	(.03)	
(5,10]		.74***
		(.10)
(5,10] x Tax	1.09***	
	(.11)	
(5,10] x Tax x dist	−.05*	
	(.02)	
(10,15]		.78***
		(.07)
(10,15] x Tax	1.11***	
	(.06)	
(10,15] x Tax x dist	−.03***	
	(.01)	
(15,20]		1.03***
		(.08)
(15,20] x Tax	1.03***	
	(.08)	
(15,20] x Tax x dist	−.01	
	(.01)	
(20,25]		.99***
		(.11)
(20,25] x Tax	.99***	
	(.12)	
(20,25] x Tax x dist	−.01	
	(.01)	
(25,30]		1.07***
		(.08)
(25,30] x Tax	1.07***	
	(.20)	
(25,30] x Tax x dist	−.00	
	(.01)	
Adj. R^2	.78	
Num. obs.	126,934	
RMSE	13.33	

Note: The dependent variable is the idiosyncratic prices in cents per gallon. The unit of analysis is the gasoline retailer. The estimation of Model 1 uses the OLS method. Standard errors clustered at the state level are in parentheses. The symbols *, **, *** denote significance at the 90%, 95%, and 99% levels, respectively. All other controls such as explanatory variables for gasoline regulation, PADD, and other characteristics included but not reported. The RMSE row presents the Root Mean Square Error

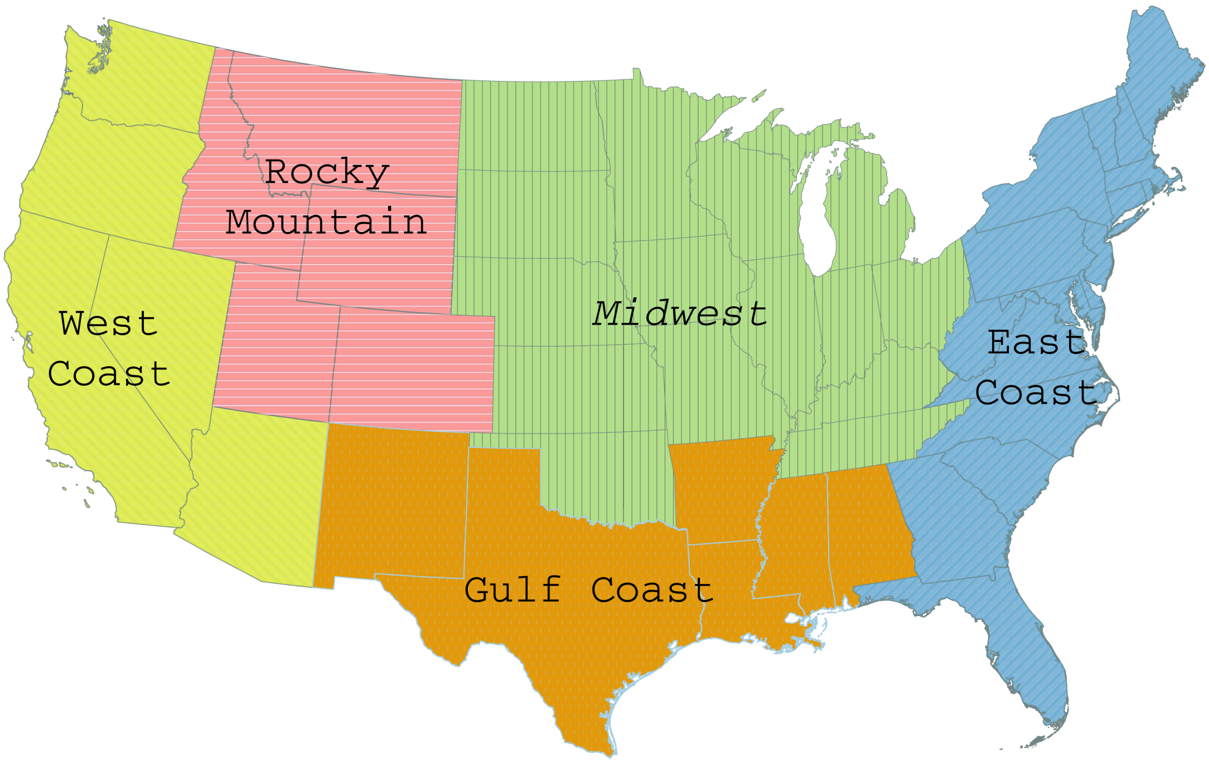
Figures of Appendices

Figure A.1: Minimum Wage in April 2018



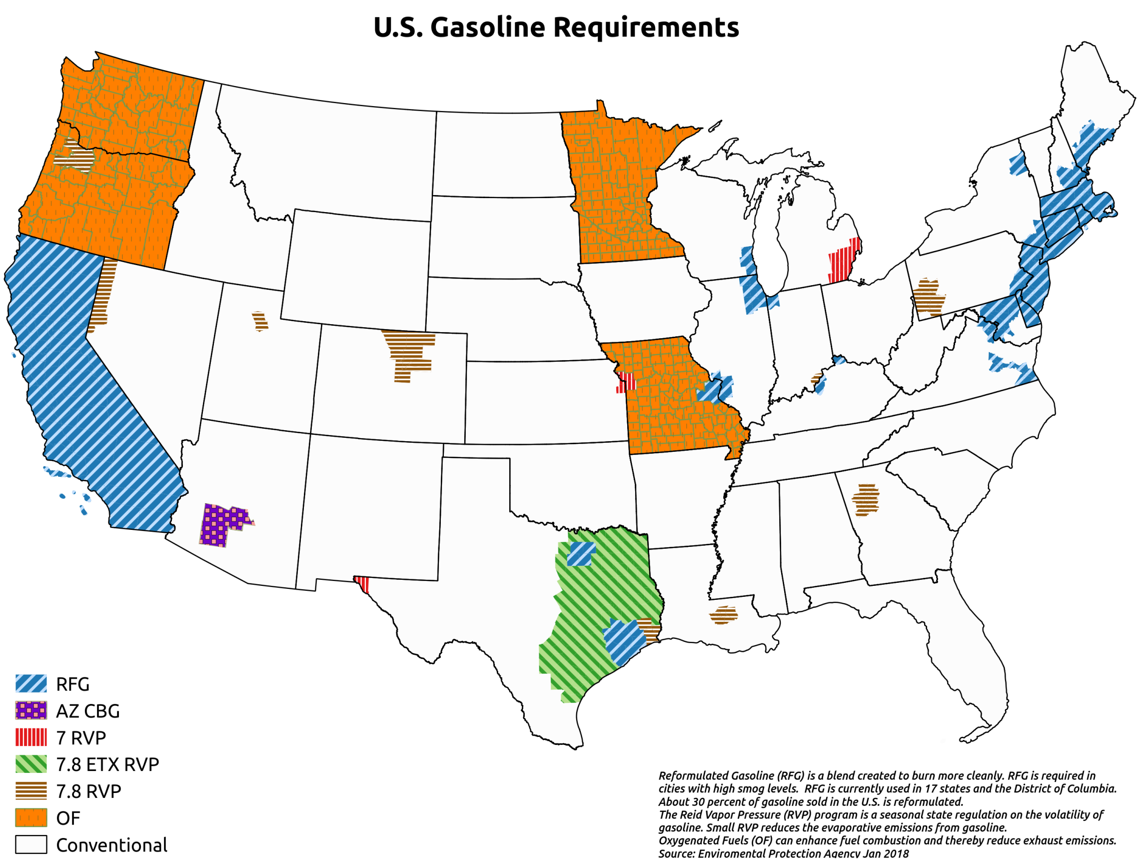
Note: The figure shows a map of the United States with the state and local minimum wages as of April 2018. The values of the state and local minimum wages were collected for every month of the sample period. Data were collected on state and local regulations from the Minimum Wage Tracker of the Economic Policy Institute. Then, a further determination was performed by reviewing these regulations using Lexis Nexis Uni.

Figure A.2: Petroleum Administration for Defense District (PADD)



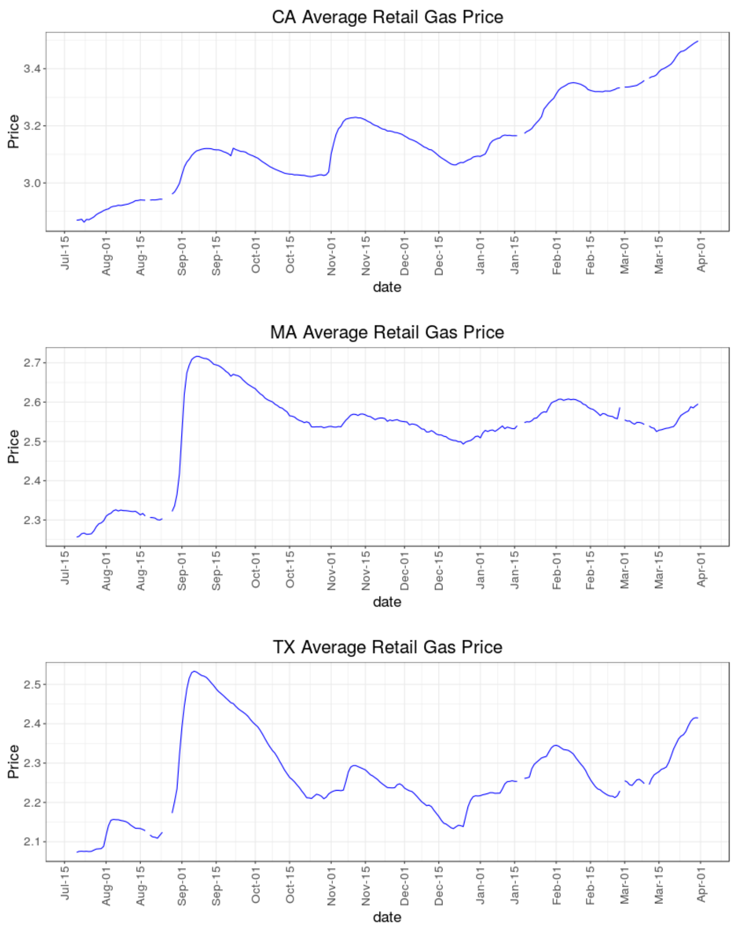
Note: The figure shows a map of the PADDs using the 48 contiguous states and the District of Columbia. The U.S. Energy Information Administration uses the PADDs to assess regional petroleum product supplies. These regions were defined during World War II to ration gasoline, although the regulation was abolished in 1946. The PADD I, — East Coast— is composed by Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, Delaware, District of Columbia, Maryland, New Jersey, New York, Pennsylvania, Florida, Georgia, North Carolina, South Carolina, Virginia, and West Virginia. The PADD II — Midwest — is composed by Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Ohio, Oklahoma, Tennessee, and Wisconsin. The PADD III — Gulf Coast — includes Alabama, Arkansas, Louisiana, Mississippi, New Mexico, and Texas. The PADD IV — Rocky Mountain — has Colorado, Idaho, Montana, Utah, and Wyoming. Finally, the PADD V — West Coast — includes Alaska, Arizona, California, Hawaii, Nevada, Oregon, and Washington.

Figure A.3: The Environmental Protection Agency Gasoline Standards

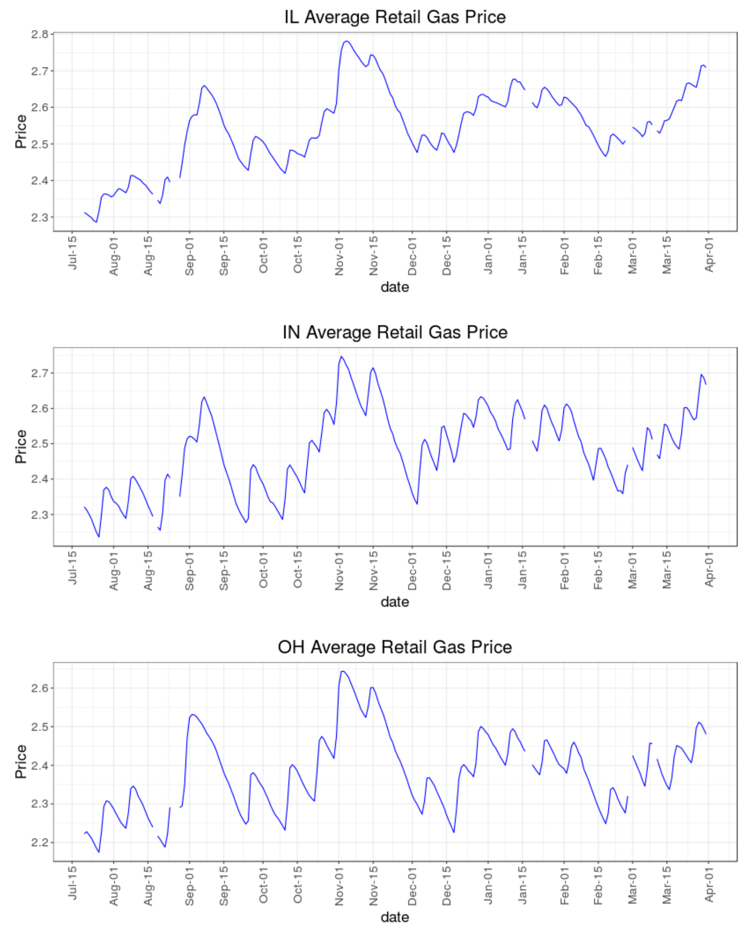


Note: The figure shows a map of the gasoline requirements for the RFG, the RVP, and the WO where the implementation occurs at the state and local levels. The gasoline blends of RFG vary for each location, but the colors in the figure indicate the location of the variability in regulation. For example, the RFG in California is different than the RFG in New Jersey.

Figure A.4: Gasoline Prices for Selected States



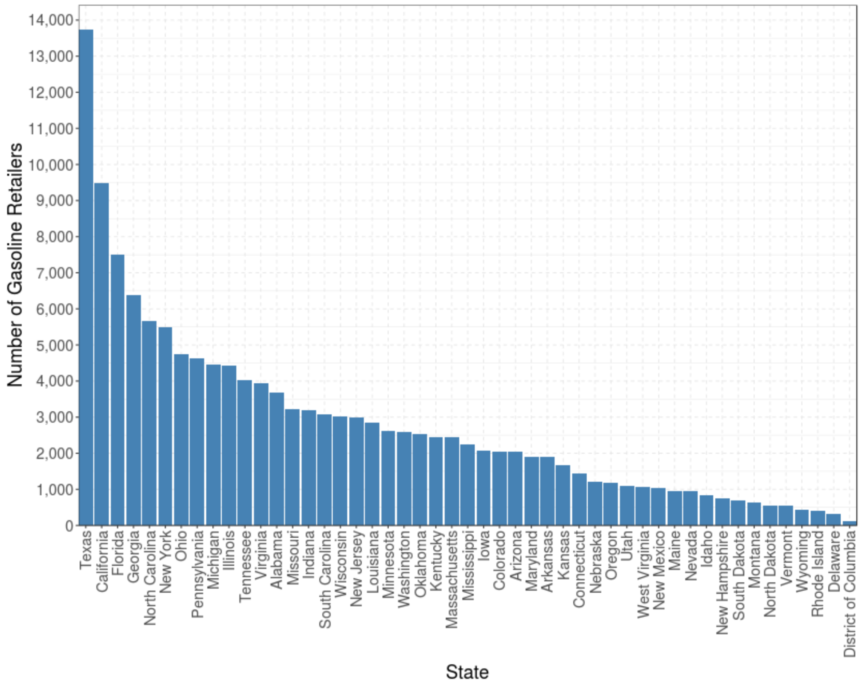
(a) Gas Prices for Selected States



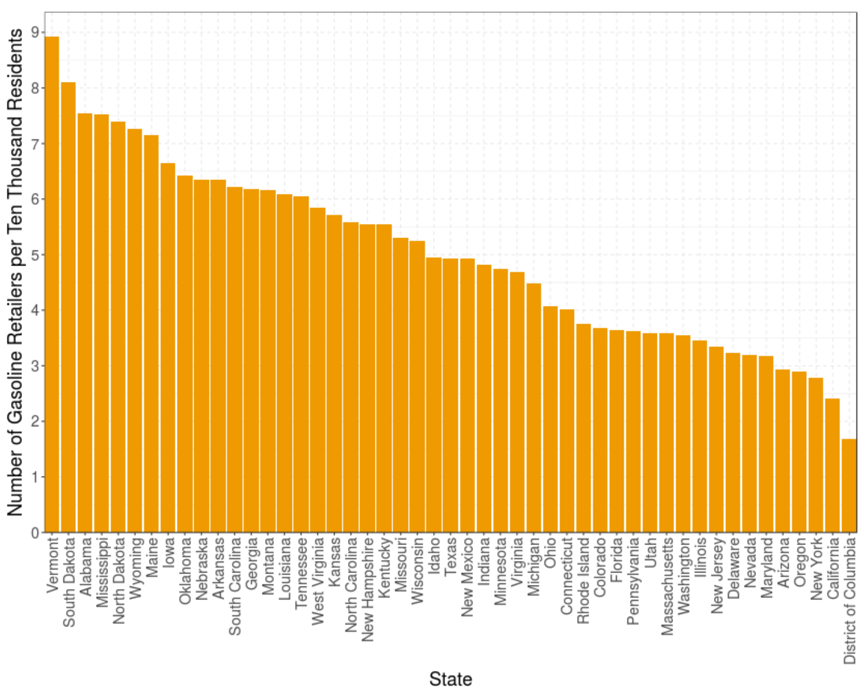
(b) Gas Prices Cycle in Some States of the Midwest

*Note:*The figure shows the average retail gasoline prices on a daily frequency for selected states. The missing dates are due to technical difficulties collecting the price data. Examples of the technical difficulties include changes of the design of the web pages, or changes in the policy of allowed request per second. The analysis of the pricing strategies at the station level is developed in Gonzalez and Hurtado (2018). Also notice the variation in the price range, with California showing the highest prices and Texas showing the lowest prices.

Figure B.5: Number of Gasoline Retailers



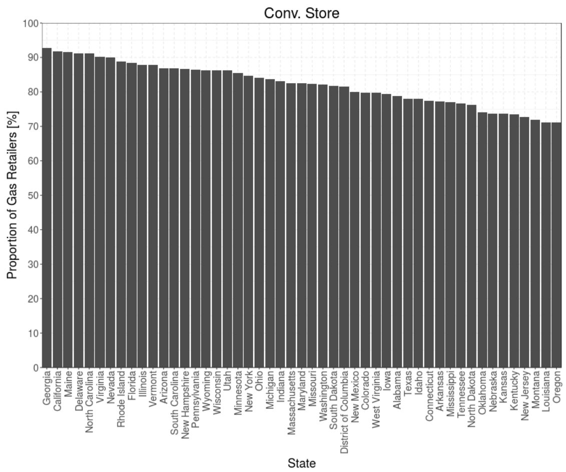
(a) Total Number of Gasoline Retailers



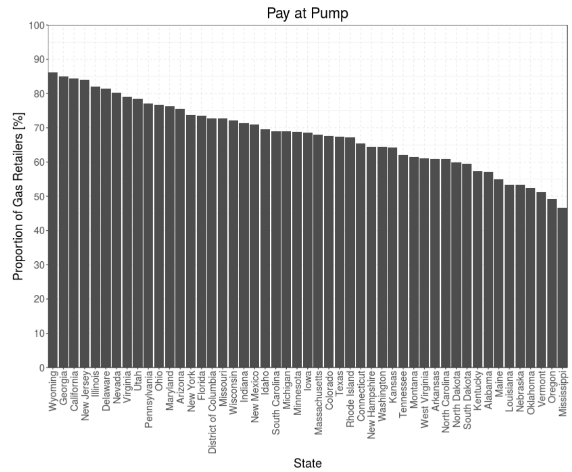
(b) Gasoline Retailers Per Capita

Note: The figure shows the ranking of states by the number of gasoline retailers. The horizontal axis exhibits, from left to right, the states with the highest number of stations. Panel (a) shows the total number of gasoline retailers. Panel (b) presents the ranking of states using the number of retailers per ten thousand residents.

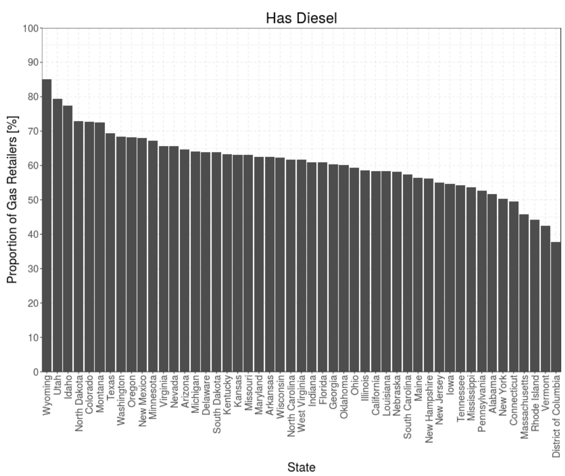
Figure B.6: Proportion of Gasoline Retailers by Additional Services



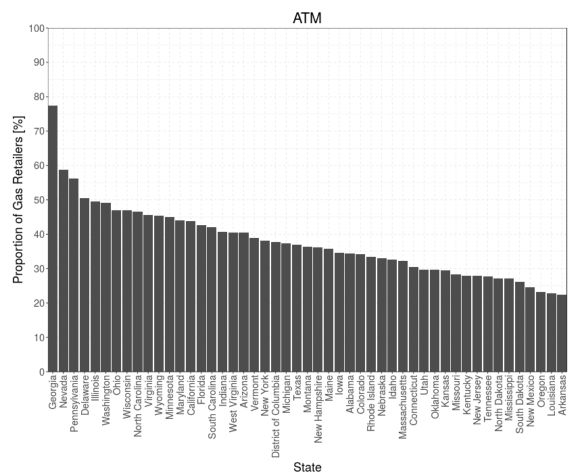
(a) Retailers Offering Convenience Store



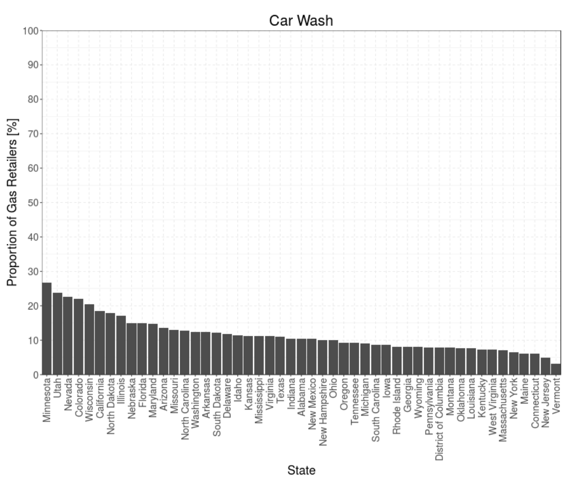
(b) Retailer Offering the Service of Pay-at-the-Pump



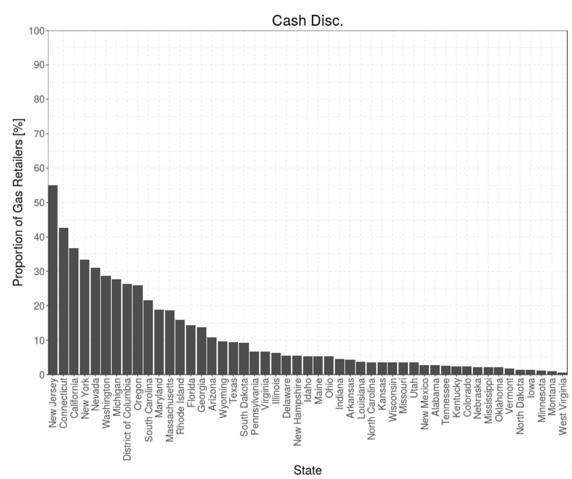
(c) Retailers Also Selling Diesel



(d) Retailers Holding an ATM



(e) Retailers Offering Cash Discounts



(f) Retailers Offering Cash Discounts

Note: The figure shows the ranking of states by the proportion of gasoline retailers offering additional services. The horizontal axis exhibits, from left to right, the states with the highest proportion of retailers offering the additional services listed in columns (a) to (f) of Table B.1. This is just a graphical visualization that shows the variability of additional services provided by the gasoline retailers.