# Competition and Incidence: Automotive Fuel Tax Pass-Through at State Borders

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**Abstract**

I estimate the pass-through of automotive fuel tax changes to final consumer prices, while accounting for how much of a retail market is covered by a tax change. In Spain, retail taxes on automotive fuel have a state-specific component. At state borders, then – where local competition straddles multiple states – a tax hike in one state only affects the marginal costs of *some* stations in a market. I show that incidence changes significantly when a cost shock is not uniform throughout a market: while average tax pass-through is nearly 100% (i.e., one-for-one) *away* from state borders, it is reduced to 57% within 5 km of a cross-border rival. At the same time, unaffected cross-border rivals actually *raise* retail prices, which causes some of the state tax's burden to fall on other, neighboring states. The magnitudes of responses on both sides of a border rise in the number and proximity of cross-border rivals. The results show a clear incentive for firms to raise their rivals' costs. More generally, accounting for firm-specific costs in pass-through estimation can inform both forecasting of (e.g., carbon) tax incidence and analysis of potential mergers.

*Keywords:* Pass-Through; Competition; Energy; Environment.

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# 1 Introduction

Regulation of energy usage has the potential to greatly improve social welfare through the pricing of pollution, but the distributional consequences of such regulation can vary widely and are not well understood. Under imperfect competition, the incidence of energy taxation depends on the marginal cost changes of each competing firm, as well as the competition and demand properties that govern the pass-through of those cost changes (Weyl and Fabinger 2013). Recent research documents a wide range of energy cost pass-through rates throughout industry (Ganapati, Shapiro, and Walker 2016). Empirical work also confirms the theoretical logic that incidence varies with local characteristics like supply constraints (Marion and Muehlegger 2011), market power (Miller, Osborne, and Sheu 2016), and the wealth of consumers (Stolper 2016). However, it is less appreciated that pass-through occurs in response to both one's own costs *and* those of one's rivals. Very few empirical studies of pass-through jointly consider own and rival costs, so nearly all of these studies measure something in between own-cost pass-through and industry-cost pass-through.[1] This, in turn, obscures the true local incidence of cost changes and makes counterfactual policy analysis difficult.

In this paper, I show how the incidence of automotive fuel taxes depends on the degree to which a local market is covered by a tax. In particular, I estimate pass-through of state-specific diesel taxes by retail fuel stations situated along state borders. I use data from Spain, whose government collects daily retail price data from all 10,000 of its gas stations, and whose diesel tax has a state-specific component that discretely rises fourteen times between 2010 and 2013. When one state raises its diesel tax, stations just inside the border experience a rise in their own marginal costs, while competing stations just outside the border experience a rise in the costs of their rivals. This specific setting provides clean variation in own vs. rival costs and is representative of a broad class of situations in which cost changes are firm-specific. For example, a uniform tax on carbon dioxide emissions will have heterogeneous effects on affected firms as long as there is variation in those firms' energy input choices. It may even be possible for certain firms to profit from regulation, if their rivals experience relatively larger cost increases.

I estimate own- and rival-cost pass-through using event study and fixed effects regression, leveraging the quasi-random pattern of state-specific tax hikes in Spain. I first focus on the spread between competing fuel stations on either side of a state border. I find strong evidence that this spread changes in the aftermath of a tax hike. I also find that the spread change is related to the toughness of competition, decreasing in the number of cross-border rivals. Next, I regress retail prices on taxes

[1] As explained by Miller, Osborne, and Sheu 2015, this statement is borne out of econometric intuition: rivals' costs, which are omitted variables in these studies, tend to be positively correlated with whatever cost measure is included (Ashenfelter et al. 1998 illustrate this empirically using cost data for Staples and its Office Depot competitors). Thus, failure to consider rival-cost pass-through leads to overestimates of own-cost rates and, unless the correlation between and own and rival costs is perfect, an underestimate of industry-cost pass-through.

(and fixed effects and controls) while varying the observation sample. The full national sample is characterized by a 93% point estimate on pass-through; that is, every additional cent per liter (c/L) of diesel taxation is associated with a 0.93 c/L rise in retail prices. Meanwhile, average pass-through in the sample of 31 gas stations with at least one cross-border rival is only 57%.

I then use the full sample to examine the relationship between pass-through and cross-border rivalry. I interact both own-state and rival-state tax levels with different measures of this rivalry: a dummy for at least one cross-border rival; an absolute count of such rivals; and a count that is inverse-weighted by driving distance from rivals. All of these parameterizations yield significant statistical relationships. Each additional cross-border rival is associated with a 19 percentage-point drop in own-cost pass-through and a 13 percentage-point rise in rival-cost pass-through, both of which are significant at the 2% level or below. The distance-weighted measures of cross-border rivalry are even stronger and suggest that the impact of an "unaffected" rival rises faster than linearly in its proximity to the affected station. In the extreme – i.e., at a station facing the maximum weighted count of cross-border rivals observed in my sample – the estimated coefficients imply that own-cost pass-through would rise 59 percentage-points higher with a one-unit reduction in that weighted count.

My estimates contribute to a limited existing literature on firm-specific cost transmission, which contains mixed evidence on own-cost pass-through (e.g., Doyle and Samphantharak 2008) and no direct evidence on rival-cost pass-through. Together, the results strongly suggest that automotive fuel retailers in Spain are very much restricted in their ability to pass through their own cost shocks when those shocks are not shared by competitors. At the same time, competitors actually raise their prices as well, which suggests that they profit from the regulation and therefore have incentive to raise their rivals' costs.

More generally, accurate local pass-through rates can greatly improve forecasting of a wide variety of policy impacts. In public finance, the incidence of carbon taxes and energy prices is often captured through general equilibrium models based on input-output matrices and detailed expenditure data (Bovenberg and Goulder 2001; Hasset, Mathur, and Metcalf 2009; Grainger and Kolstad 2010), but strong assumptions on the nature of competition and the shape of demand and supply curves preclude the pass-through patterns which I find here. In industrial organization, firm-specific cost pass-through is important for merger analysis, because merger-specific efficiencies typically lead to firm-specific cost savings (Ashenfelter et al 1998; Jaffe and Weyl 2012). However, pass-through estimates in the existing literature are not, in general, interpretable as firm-specific rates.[2]

The rest of this paper is laid out as follows: Section 2 describes the intuition for and existing research on firm-specific pass-through; Section 3 describes the empirical context and methods; Section

[2]Ashenfelter et al (1998) and Besanko, Dubé, and Gupta (2005) are exceptions.

4 presents results of cross-border spread analysis as well as own- and rival-cost pass-through estimation; Section 5 discusses the implications of these results and concludes.

# 2 Firm-Specific vs. Industry-Wide Cost Pass-Through

## 2.1 The pass-through matrix

Pass-through is usually discussed and measured as a response to industry-wide cost shocks. That is, firm $i$ changes price $p_i$ as a function of industry-wide cost $c$, defined as $\frac{dp_i}{dc}$. However, this industry-cost pass-through is really an aggregation of responses to firm-specific cost changes, $\frac{dp_i}{dc_j}$, where $j$ indexes all firms within a given market. To develop intuition for firm-specific cost pass-through, consider two firms – say, retail gasoline stations – engaging in Hotelling competition (Hotelling 1928), with constant marginal costs $c_1$ and $c_2$, respectively. Assume that consumers are uniformly distributed along a unit-length road between the two stations; location $t$ captures a consumer's distance from Firm 1, while $(1-t)$ is its distance from Firm 2. Each consumer buys one unit of fuel at a price of either $p_1$ or $p_2$, getting utility $v$ from this fuel and *dis*utility $\tau$ per unit travel time required to purchase it.

Since consumers are only differentiated by location, the market is split by a location threshold $t^*$, at which a consumer is indifferent between Firm 1 and Firm 2:

$$v - \tau t - p_1 = v - \tau(1-t) - p_2 \tag{1}$$

Thus, $t^*$ is the "quantity" of consumers that purchase from Firm 1, and Firm 1's profit function becomes

$$\pi(p_1) = (p_1 - c_1)t^* = (p_1 - c_1)\Big(\frac{1}{2} - \frac{p_1 - p_2}{2\tau}\Big) \tag{2}$$

From here, total differentation of Firm 1's first-order condition with respect to $c_1$ yields

$$2\frac{dp_1^*}{dc_1} - \frac{dp_2}{dc_1} - 1 = 0 \tag{3}$$

The analogous expression for Firm 2 is

$$2\frac{dp_2^*}{dc_1} - \frac{dp_1}{dc_1} = 0 \tag{4}$$

Solving for the two unknowns in Equations (3) and (4) shows that Firm 1's own-cost pass-through rate ($\frac{dp_1^*}{dc_1}$) is 2/3, while Firm 2's rival-cost pass-through rate ($\frac{dp_2^*}{dc_1}$) is 1/3.

By symmetry, the full pass-through matrix in this example is

$$\frac{d\mathbf{p}}{d\mathbf{c}} = \begin{bmatrix} \frac{dp_1}{dc_1} & \frac{dp_1}{dc_2} \\ \frac{dp_2}{dc_1} & \frac{dp_2}{dc_2} \end{bmatrix} = \begin{bmatrix} \frac{2}{3} & \frac{1}{3} \\ \frac{1}{3} & \frac{2}{3} \end{bmatrix} \tag{5}$$

It is clear, then, that own-cost and rival-cost pass-through rates are not the same in this market. However, econometric challenges make it difficult to accurately estimate each rate. Researchers commonly observe correlated shocks to $c_1$ and $c_2$ – for example, a tax change that raises both firms' marginal costs equally. In that case, one cannot recover the individual elements of this matrix. What is instead estimated is the sum across rows of this matrix – the aggregate price response of firm $i$ to all firms' marginal cost shocks. In Equation (5), that aggregate response is 1, or 100%, full pass-through – but it is not particularly informative of incidence in the broad class of cases in which $c_1 \neq c_2$. If, for instance, only Firm 1 were taxed, then Firm 1 would be limited to passing through only 2/3 of the tax. Meanwhile, Firm 2 would *raise* its price by 1/3, which implies a welfare gain for Firm 2 (and a welfare loss for incumbent Firm-2 customers). The same pattern of incidence may happen more generally if both firms are taxed but one firm's marginal costs increase much more (twice more, in the Hotelling example) than the other's.

## 2.2 Evidence from industry-wide cost shocks

Industry-wide cost pass-through has been estimated for dozens of products. Besley and Rosen (1999), for example, identify pass-through of sales taxes for each of twelve different commodities and find wildly divergent rates across commodities – from nearly negligible in the case of McDonald's cheeseburgers to 242% in the case of bread.[3] Within energy markets, pass-through has been found to be well above 50% across a variety of different cost types, from prices of permits under the European Union Emissions Trading System (Fabra and Reguant 2014) and certificates under the U.S. Renewable Fuel Standard (Knittel, Meiselman, and Stock 2015), to crude and refined oil prices (Borenstein, Cameron, and Gilbert 1997), to sales and excise taxes on automotive fuel (Doyle and Samphantharak 2008; Marion and Muehlegger 2011). Automotive fuel tax pass-through, in particular, has been consistently estimated to be approximately 100% on average (Chouinard and Perloff 2004; Alm, Sennoga, and Skidmore 2009; Bello and ContÃn-Pilart 2012; Stolper 2016).

Most of the aforementioned studies utilize cost shocks that are either physically uniform across firms in a market (such as federal tax changes) or measured as an average across that market (such as benchmark crude oil prices). As such, estimates are interpretable as industry-cost pass-through rates.

[3] Besley and Rosen (1999), among others, estimate pass-through *elasticities*, which are percentage changes in price per percentage change in costs. In this paper as well as most of those that I cite here, pass-through is estimated as the absolute change in price per absolute change in cost.

Some studies interact an industry-cost variable with firm- or area-specific measures, which allows for estimation of local responses to industry-wide changes. For example, Doyle and Samphantharak (2008) and Scharfstein and Sunderam (2014) interact cost measures with indicators of spatial and ownership concentration, respectively; Marion and Muehlegger (2011) interact state-level taxes with proxies for supply elasticity; and Stolper (2016) interacts taxes with proxies for wealth.

### 2.3 Evidence from firm-specific cost shocks

The difficulty of obtaining comprehensive data on firm-specific costs makes estimates of own-cost pass-through rare in the literature. Ashenfelter et al. (1998) show empirically that, even when one has price and cost data for one specific firm (Staples, in their case), omission of other firms' costs (such as Office Depot's) can bias estimates of own-cost pass-through. This is because Staples' costs aggregate industry-wide costs and firm-specific ones, and the inclusion of rival Office Depot's costs controls for the common, industry-wide component. In their preferred regression, Ashenfelter et al. estimate Staples' own-cost pass-through rate to be approximately 15%.

Similarly, several studies of pass-through examine cost shocks that are neither industry-wide nor single-firm-specific. Miller, Osborne and Sheu (2015) estimate fuel cost pass-through by U.S. cement producers which rely variously on coal, petroleum coke, natural gas, and fuel oil for energy inputs. Ganapati, Shapiro, and Walker (2016) estimate the pass-through of energy input costs in six different U.S. manufacturing industries, using variation in coal and electricity prices that affect multiple (but not all) firms in a market simultaneously. Both of these studies provide aggregate pass-through measures which likely fall somewhere in between firm-specific and industry-wide. Relatedly, Atkin and Donaldson (2015) measure the pass-through of origin prices to destination prices among intranationally traded goods. While the price of a given good at its port of arrival is, naturally, firm-specific, it may be correlated with omitted prices of substitutes and thus is not interpretable as an own-cost shock in pass-through analysis.

Leveraging administrative borders can be a simple, yet powerful, way to identify the effects of own-cost shocks. For instance, researchers have identified cross-border shopping behavior in response to heightened in-state cigarette prices (Chiou and Muehlegger 2008), higher in-state lottery prices (Knight and Schiff 2013), and more stringent in-state gun laws (Knight 2013). With respect to price impacts (as opposed to the quantity impacts just described), there are at least four relevant cross-border studies, and they provide very mixed evidence on own-cost pass-through. In each of these studies, the identification strategy is to compare price changes at different locations relative to a state border, where one tax regime ends and another begins.

Hanson and Sullivan (2009) and Harding, Leibtag, and Lovenheim (2012) both study cigarette tax changes. The former finds that stores near one state border pass on significantly less of a tax hike while stores near a second state border pass on significantly more. The latter, meanwhile, finds a strong increasing trend in pass-through with distance from a neighboring state with a lower tax rate. Bergman and Hansen (2013) focus instead on Danish national beverage taxes but are unable to discern any relationship between pass-through and distance to neighboring Germany. Finally, and most relevantly, Doyle and Samphantharak (2008) study the response of gasoline prices to a repeal and subsequent reinstatements of sales taxes in Wisconsin and Indiana. The repeal is associated with a *larger* drop in prices at gas stations nearer to borders with control states, but the reinstatements are associated with *smaller* rises. There is thus some evidence that own-cost pass-through is smaller than industry-cost pass-through, due to the competition provided by nearby substitutes not subject to cost changes. However, the evidence is far from consistent. Furthermore, there are, to date, no existing estimates of *rival*-cost pass-through, which is no less important a component of the pass-through matrix.

# 3 Empirical Context

The Spanish retail market for automotive fuel is a convenient place to study firm-specific cost shocks for two main reasons: first, a government informational mandate has produced high-resolution data on pricing and market structure over time; and second, applicable taxes vary both across states and over time. Since the start of 2007, every gas station in the country has had to submit its retail fuel prices to the Ministry of Energy whenever they change, and weekly at a minimum[4]. Over the length of my sample – January 2007 to June 2013 – 9,277 mainland-Spanish gas stations appear in the data. I observe prices of retail diesel, brand, wholesale contract type, amenities, and geographic coordinates of every one of these stations[5]. Into these data, I merge information on excise taxes, applicable to retail diesel and with statutory incidence on the gas stations.

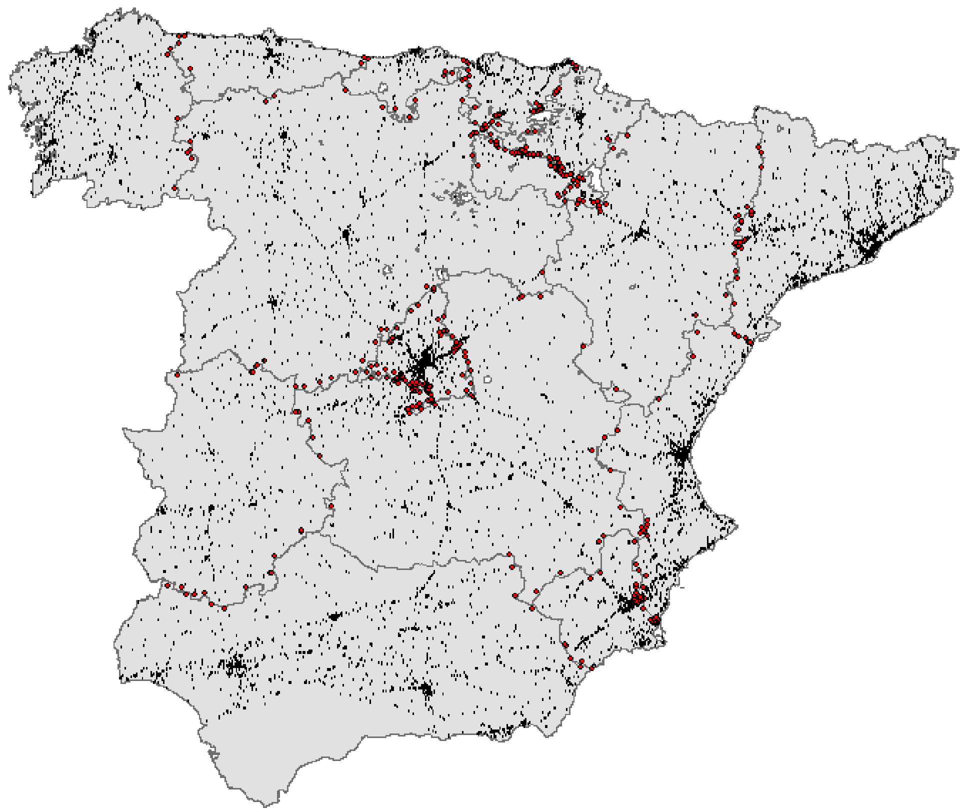
## 3.1 Cross-border markets in Spain

Figure 1 maps the full sample of mainland Spanish gas stations, while highlighting those stations that are within five kilometers of a state border. 459 stations satisfy the latter criterion; I highlight them (in red) because they represent one of the sub-samples that I use in my analysis. Table 1 lists summary statistics for both the full and 5-km samples, in addition to two others.

[4]This policy is motivated by consumer welfare interests. Spain's oil market is highly concentrated and subject to frequent allegations of collusion. See El PaÃs (2015) for an example of government investigation on this subject, or ContÃn-Pilart, CorreljÃ©, and Palacios (2009) and Perdiguero and Borrell (2007) for further background on the Spanish oil market. Stolper (2016) describes the data, especially with respect to brands and contracts, in greater detail.

[5]The non-price characteristics, however, are only available cross-sectionally, from the time of entry into the sample.

Figure 1: Gas Stations on the Spanish Mainland



Notes: All dots are Spanish retail gasoline stations. Large red dots indicate the 459 stations that lay within five kilometers of a state border; small black dots denote the remaining 8,809 stations that comprise the full sample.
Source: Author's calculation, using data from the Ministries of Industry, Energy and Tourism

Table 1: Summary of Selected Station Samples

| | Full | Rivals | Border | CB Rivals |
|---|---|---|---|---|
| # stations | 9,277 | 6,753 | 459 | 31 |
| Avg. retail price (c/L) | 98.37 | 98.44 | 97.79 | 98.27 |
| P(Refiner branded) | 0.60 | 0.61 | 0.61 | 0.52 |
| P(Unbranded) | 0.26 | 0.25 | 0.26 | 0.26 |
| Avg. # of rival stations | 2.13 | 2.99 | 1.13 | 3.13 |
| Avg. # of cross-border rival stations | 0.00 | 0.01 | 0.09 | 1.29 |
| Distance to nearest state border (km) | 63.03 | 66.36 | 2.57 | 1.14 |

Notes: "Rivals" are other stations within 5 minutes' drive of the reference station. The 'Full' sample includes all mainland stations with non-missing price and tax data. 'Rivals' restricts to all stations with >0 stations within 5 minutes' drive. 'Border' restricts to all stations within 5 km of a state border. 'CB Rivals' restricts to all stations with >0 stations within 5 minutes' drive and situated in a different state.

Column 1 of Table 1 shows the average station has a mean after-tax retail price of 98.37 Euro-cents/liter (c/L) over the seven-year sample time period.[6] 60% of stations bear the brand of one of the three oligopolistic oil refiners in Spain, 26% of stations are unbranded independents, and the remaining 14% bear the brand of a retail chain with no refining capacity. The average station has a bit more than two other stations within five minutes' drive and is 63 km from a state border.

I am primarily interested in estimating tax pass-through at stations "treated" by competition from out of state. In much of my analysis, I compare such stations to the remainder of the full sample. However, restrictions to the full sample may be useful if one is concerned about the adequacy of the control group in the full sample. Columns 2 and 3 of Table 1 thus display the analogous summary stats after two such restrictions are made. In column 2, the sample is all stations with at least one rival within five minutes' drive[7], while in column 3, it is the 459 stations within five kilometers of a state border.

All three of these samples are to be compared to the sample summarized in column 4: stations with at least one cross-border rival. Here, again, I define a rival to be any other station within five minutes' drive. This subset of 31 stations can be thought of as the treatment group. Notably, a few things are different about this treatment group, relative to other samples. First, there are fewer refiner-branded stations – 52% in the treatment group as compared to 60-61% in the broader samples. Second, there are *more* nearby rivals – 3.13 in column 4 as compared to 2.13, 2.99, and 1.13 in columns 1-3, respectively. Thus, branding and spatial competition appear to differ among stations with cross-border rivals, relative to the stations included in the broader samples.[8] One of the primary challenges to estimating the effect of cross-border competition on pass-through is controlling for these characteristics and other potentially omitted variables correlated with proximity to a state border.

Table 2 gives exclusive focus to the treatment group, by examining each of the local areas in which cross-border rivals are within five minutes' drive of each other. There are twelve such areas; they exhibit variation in the number of tax changes experienced, the number of stations on each side of the border[9], and their brand and spatial concentrations. For instance, market #1 straddles the states of MurcÃa and Valencia. There are six stations total in this border market – four in the former and two in the latter. On average, these stations are 3.35 minutes away from their nearest rivals. Finally, these six stations are owned by six different firms; there is no brand concentration in market #1. Figure 2

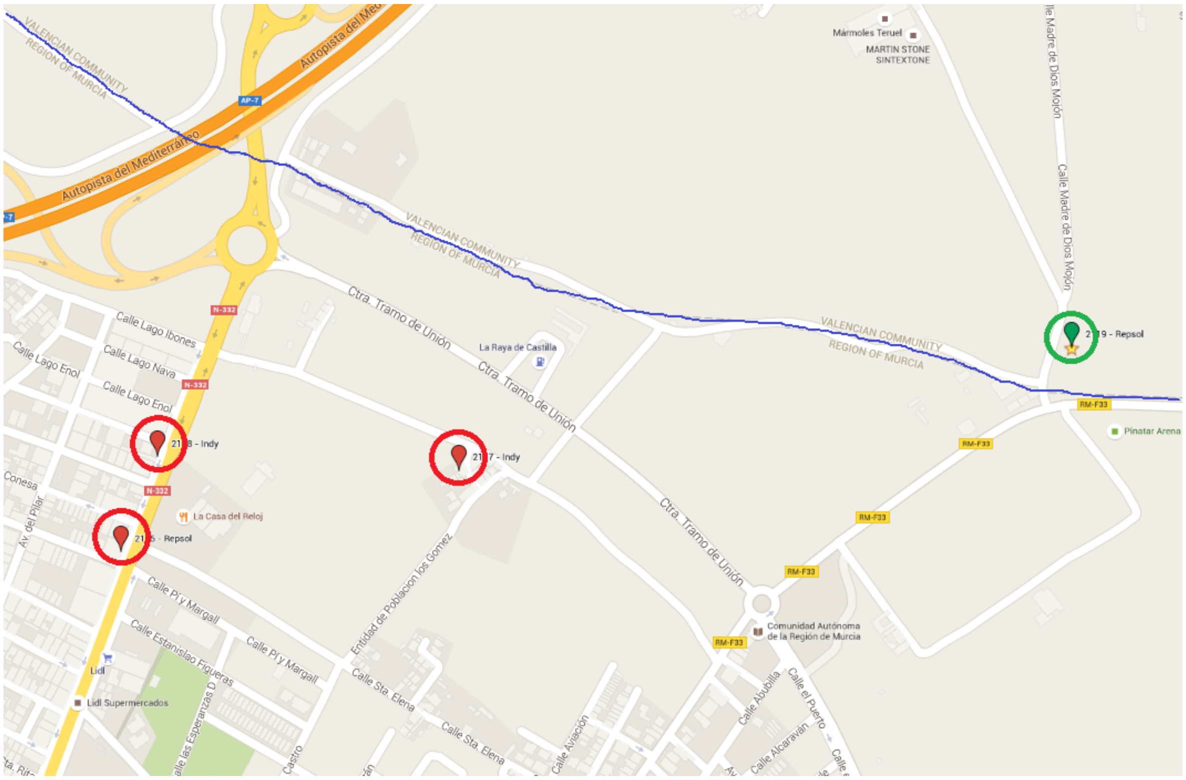
[6]Sales tax, however, is removed from these prices, to avoid the multiplicative effect sales taxes have on other taxes.

[7]I choose five minutes largely because Perdiguero and Borrell (2012) estimate 5-6 minutes as the relevant extent of spatial competition in Spanish retail automotive fuel markets. However, I test the robustness of my results to smaller "market sizes" in Table 6.

[8]One might theorize that the 5-km sample in column 3 is the best control group, because it holds distance to the border roughly constant while comparing stations *with* cross-border rivals to stations without them. However, column 3 shows that the former set tends to have almost three times more nearby rivals.

[9]Note that in Table 2, a station is counted as being within a border market if it is five minutes away from a rival in either direction (to *or* from); 41 stations satisfy this criteria. In contrast, a station is counted in column 4 of Table 1 only if it is five minutes' drive *to* a cross-border rival; 31 stations satisfy that criteria.

Figure 2: A Representative Border Market




Notes: The map depicts stations situated along the Valencia/MurcÃa state border, in the municipalities of San Pedro del Pinatar and Pilar de la Horada, respectively. Three stations in Murcia (red color) are within five minutes' drive of a station just over the border in Valencia (green color).
Source: Author's calculation, using data from the Ministries of Industry, Energy and Tourism.

depicts this market geographically, showing the four stations closest to the border.

The most obvious source of variation within the twelve border markets, according to Table 2, is the number of rivals on either side of the border. In contrast, there is very little variation in brand concentration or average drive time across markets. Only one market – #4, with four Repsol-owned stations – has any brand concentration whatsoever. The average drive time ranges from 3.35 to 4.92 minutes – though individual stations can be as close as 44 seconds to a nearby cross-border rival. In analysis, I explore the impact of each additional cross-border rival and corresponding driving distance on tax pass-through.

## 3.2 Diesel tax variation in Spain

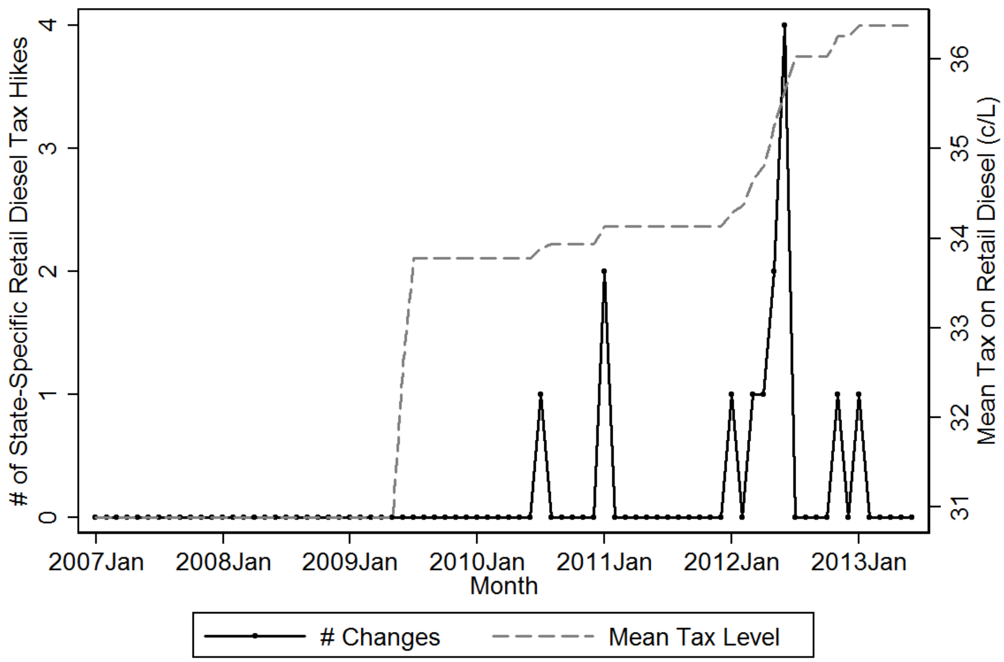
There are three taxes applicable to retail diesel in Spain: the national sales tax; the national excise tax on diesel; and the 'centimo sanitario' ("public health" tax), another per-unit tax which has a national and a state-specific component and has a stated purpose of generating revenues to be used for public health improvements. The state-specific component, which is what I use in all analyses, varies from 0 to 4.8 Eurocents/liter (or about 0-5% of average retail prices, net of sales tax) across states and

Table 2: Characteristics of Border Markets

| Market | State 1 | State 2 | # Tax Changes | # Stations, S1 | # Stations, S2 | Avg. Drive Time (Min) | % Independent |
|---|---|---|---|---|---|---|---|
| 1 | Murcia | Valencia | 3 | 4 | 2 | 3.35 | 100 |
| 2 | Valencia | Castilla La Mancha | 2 | 2 | 4 | 3.75 | 100 |
| 3 | Castilla La Mancha | Madrid | 1 | 1 | 1 | 3.68 | 100 |
| 4 | Castilla La Mancha | Madrid | 1 | 1 | 1 | 4.78 | 100 |
| 5 | Castilla La Mancha | Madrid | 1 | 5 | 2 | 3.5 | 38 |
| 6 | Castilla La Mancha | Madrid | 1 | 2 | 1 | 4.39 | 100 |
| 7 | Castilla La Mancha | Madrid | 1 | 2 | 2 | 4.58 | 100 |
| 8 | Catalunya | Aragon | 1 | 1 | 1 | 4.88 | 100 |
| 9 | Navarra | La Rioja | 1 | 1 | 1 | 3.92 | 100 |
| 10 | Castilla y Leon | Pais Vasco | 1 | 2 | 1 | 4.47 | 100 |
| 11 | Navarra | Pais Vasco | 1 | 1 | 1 | 4.82 | 100 |
| 12 | Navarra | Pais Vasco | 1 | 1 | 1 | 4.92 | 100 |

Notes: A station is included in a market if there is at least one other station that is less then 5 minutes away in one direction. "Avg. Drive Time" is the drive time between each station and its nearest cross-border rival, averaged across stations in a market. "% Independent" divides the number of *unique* firms in the market by the total number of firms in the market.

Figure 3: Tax Variation




Note: The solid line plots state-specific tax hikes. The dashed line plots the national mean tax level; it rises discretely in June 2009 because the *national* component of the diesel tax rises in that month.
Source: Author's calculation using data from the Spanish Ministry of Industry, Energy, and Tourism

discretely rises 14 times over my seven-year sample time period. This variation is plotted in Figure 3. While my data begin in January 2007, no state increases its diesel tax until early 2010. From that month forward, anywhere between 0 and 4 states raise their own tax levels in a given month. Meanwhile, the national excise tax jumps once, from 30.2 c/L to 33.1 c/L, in June 2009. In total, the mean per-unit tax on diesel rises from just under 31 c/L at the start of my sample time period to to above 37 c/L at the end.

## 4 Estimating Pass-Through at State Borders

My empirical analysis has two primary components. The first is an analysis of cross-border spreads – i.e., the difference between prices on one side of a border versus the other, and how that difference changes when one side experiences a tax hike. The primary advantage of this methodology is that it controls for all period-specific determinants of prices that affect both sides of the market equally. Thus, graphical inspection of cross-border spreads can be used to test whether a tax imposed on only part of a market is passed through heterogeneously by the two sides of a market. However, the magnitudes of own- and rival-cost pass-through cannot be disentangled using spreads – only their aggregate effect. For this reason, I conduct a second analysis of tax pass-through at borders using a difference-in-differences framework, which allows me to separately identify, in the same single regression, the response of firms on the tax-hike side of the border as well as the response of firms on the non-tax-hike side.

### 4.1 Spread analysis

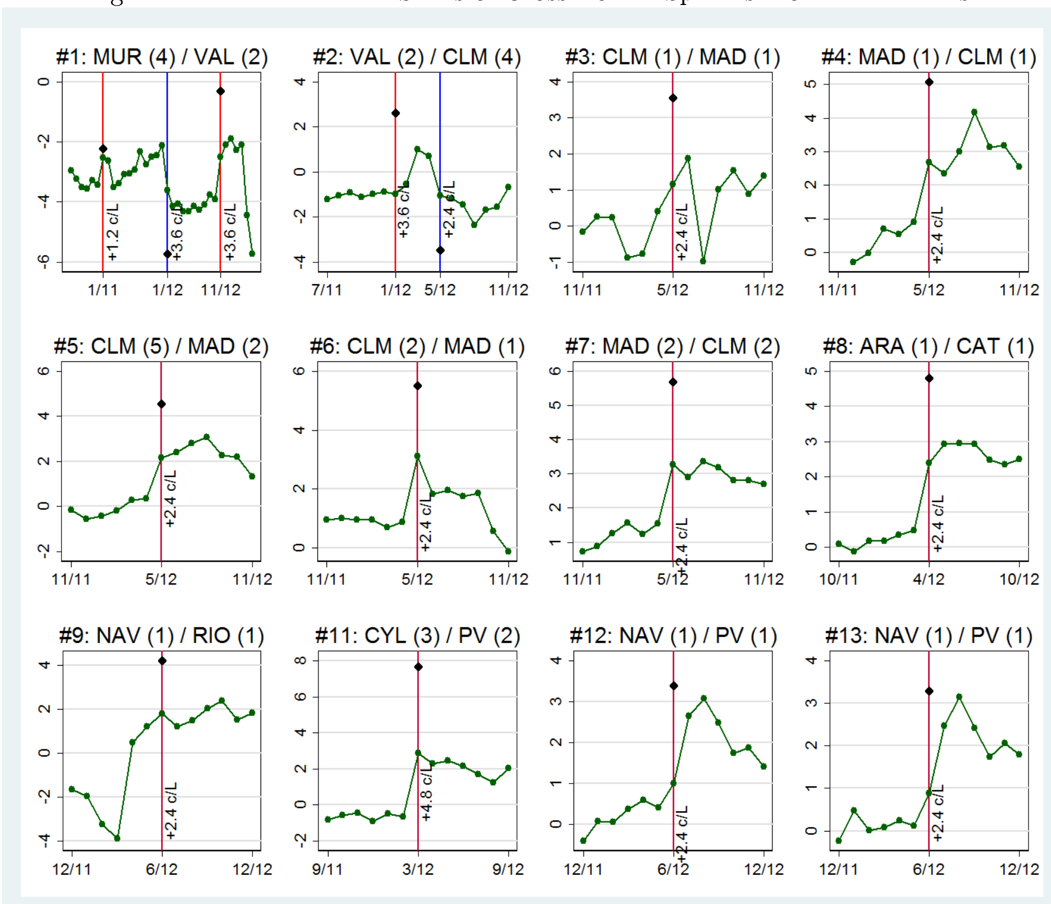
Consider a State 1 that faces a tax hike, and a neighboring State 2 that does not. A station situated in State 1 but close enough to be competing with a station in State 2 experiences an own-cost shock, and passes it through to retail price $p_1$ at some rate $x$. The station in State 2 experiences a rival-cost shock, and passes it through to price $p_2$ at some rate $y$. If we measure their cross-border spread $p_1 - p_2$ before and after State 1's tax hike, and the spread does not change, this suggests that $x = y$, i.e., own-cost pass-through is equal to rival-cost pass-through. If, on the other hand, the cross-border spread changes as much as would be expected away from the border – where the tax hike would be an industry-wide cost shock – that would suggest that own-cost pass-through is no different from industry-cost pass-through, and that rival-cost pass-through is zero.

To examine the empirical analog of the above scenario, I first trim the full sample to include only the twelve border markets listed in Table 2. In that table, "State 1" always refers to the state that first sees a tax hike; I define State 1 similarly for spread analysis. I then calculate, for each market and month, the mean price on each side of the market, and subtract the State-2 mean from the State-1 mean. These are my cross-border spreads, and I graph them in the vicinity of tax hikes for each market in Figure 4.

The results provide striking evidence of a change in spreads in direct response to tax hikes. Every market can be described as having a noticeable jump (or drop) in the spread right around the month of a tax hike. Of course, there is underlying movement in every one of these spreads, and the jump in the spread does not always occur in precisely the same month as the tax hike. Nonetheless, this raw evidence strongly suggests that the two sides of a border market do not respond equally. Figure 5 provides a cleaner picture by graphing the *average* spread across the twelve border markets and within relative month. One month before a tax hike, the cross-border spread averages very nearly zero. But as soon as the tax rises (i.e., in month 0), the spread jumps to nearly 1.5 c/L. There is some movement in the average spread after month 0, but the spread remains above 1 throughout the ensuing six-month period.

The clear jump in spreads illustrated by Figures 4 and 5 strongly suggests that $x \neq y$, i.e., that own-cost pass-through differs from rival-cost pass-through. Furthermore, it is clear from the latter figure that if own-cost pass-through is not 0, it is also not fully 100%. Depending on how one measures average pre-tax-hike and post-tax-hike prices from Figure 5, the difference ranges from about 1-2.2

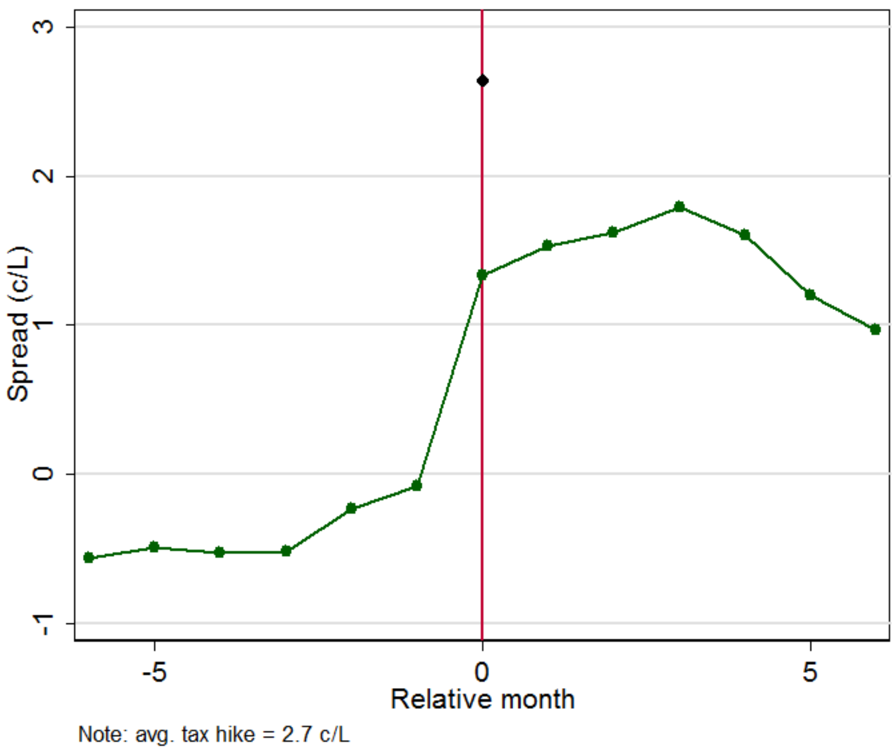
Figure 4: Individual Time Series of Cross-Border Spreads around Tax Hikes




Notes: The figure displays cross-border spreads over time in each of the twelve border markets which experience at least one tax change. The cross-border spread is defined as the average price on 'Side 1' of the border minus the average price on 'Side 2'. In all cases, I set 'Side 1' to be the side that experiences the first tax hike. Red lines denote a tax hike on 'Side 1'; blue lines denote a tax hike on 'Side 2'.

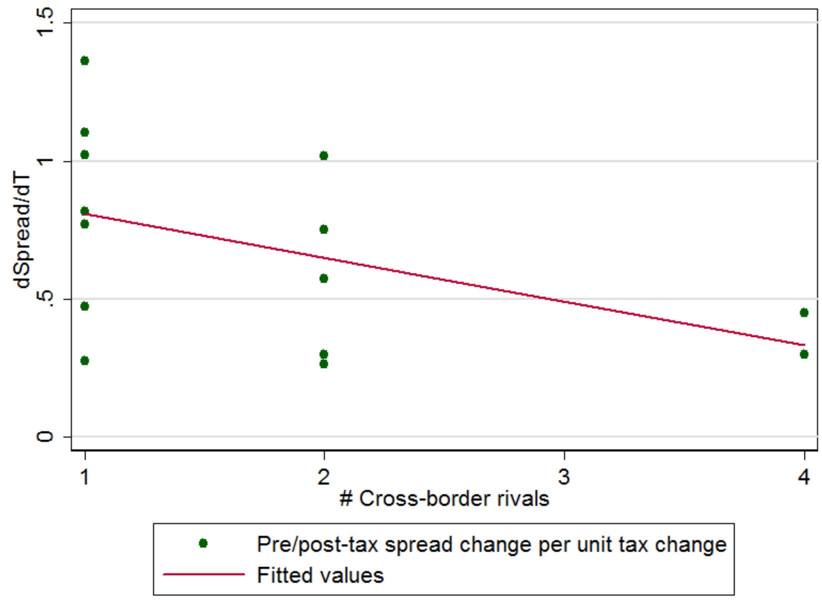
Source: Author's calculation using data from the Spanish Ministry of Industry, Energy, and Tourism.

Figure 5: Average Cross-Border Spread around a Tax Hike




Notes: The figure displays the average cross-border spread as it changes over time in the vicinity of a tax hike. Mathematically, the figure plots averages across the 12 markets (and 15 tax changes) depicted in Figure 4, within each month relative to a tax hike. The red line at x=0 denotes the month in which a tax changes.
Source: Author's calculation using data from the Spanish Ministry of Industry, Energy, and Tourism.

Figure 6: Change in Cross-Border Spread vs. # of Cross-Border Rivals




Notes: The figure plots the change in cross-border spread in a market versus the number of cross-border rivals in that market. Mathematically, each point is the average cross-border spread over the time period [0,6] (where the number denotes the month relative to a tax hike) minus the average cross-border spread over the time period [-6,-1].
Source: Author's calculation using data from the Spanish Ministry of Industry, Energy, and Tourism.

c/L. Even at the upper bound of that range, the spread does not change as much as the average tax hike, which is 2.7 c/L in the border-market sample.

If the average trend depicted in Figure 5 smooths over the noise inherent in the individual trends, it also obscures the fact that border markets with varying degrees of competition may not respond uniformly to a tax hike. Since the single most variable characteristic of these border markets is the number of stations present (see Table 2), I explore the relationship between changes in spread and number of cross-border rivals. This relationship is displayed in Figure 6. The x-axis indexes the number of cross-border rivals faced by the average station on the tax-hike side of a given market. The y-axis measures the change between the average pre-tax-hike spread and the average post-hike spread ("dSpread"), divided by the size of the tax hike (dT). A linear fit of these $(x, y)$ pairs is overlaid to emphaise the main point: the spread changes less as cross-border competition intensifies.

## 4.2 Difference in differences

While the structural equation for pass-through in asymmetric oligopoly is not linear, one can imagine firm $i$ responding to firm-specific costs in linear fashion (Miller, Osborne, and Sheu 2015):

$$P_{it} = \rho_{ii}C_{it} + \sum_{j \neq i} \rho_{ij}C_{jt} + X_{it}^{'}\gamma + \lambda_i + \sigma_t + \varepsilon_{it} \tag{6}$$

In the above equation, there is a unique pass-through coefficient ($\rho_{ij}$) corresponding to the cost of each firm competing with firm $i$. I do not observe the costs of every firm in every market; indeed, such data are extremely rare. Rather, I observe tax levels in each state, which are own or rival costs depending on the location of a station with respect to state borders. I thus begin my regression analysis by estimating the following equation:

$$P_{it} = \alpha + \beta OwnTax_{it} + \gamma RivalTax_{it} + \delta \mathbf{X}_{it} + \lambda_i + \sigma_t + \varepsilon_{it} \tag{7}$$

Here, $OwnTax_{it}$ measures the tax in station $i$'s state and in month $t$, while $RivalTax_{it}$ measures the tax in the nearest neighboring state to station $i$, as measured by drive-time. $\mathbf{X}_{it}$ is a vector of station and area characteristics; in regressions this will usually contain a count of all rivals (defined as stations under different ownership and within five minutes' drive), but a number of other controls are included in robustness checks. $\lambda_i$ and $\sigma_t$ are station and month fixed effects, respectively, which capture the impact of cross-sectional characteristics (like brand and contract) and national time-specific shocks (like the price of crude oil).

$OwnTax_{it}$ should have a strong correlation with price $P_{it}$ because it is a very real cost to station $i$. $RivalTax_{it}$, however, should only predict price if (a) station $i$ competes with another station situated in the state corresponding to $RivalTax_{it}$, and (b) rival-cost pass-through is truly non-zero. Thus, in the national sample, I do not expect this latter variable to be a significant predictor of prices; the average station in Spain is nowhere near a state border, and retail automotive fuel markets are, for the most part, highly localized. In the border sample, where every station is less than five minutes' drive from a cross-border rival, I expect the coefficient $\gamma$ to be significant.

Identification of both $\beta$ and $\gamma$ may be confounded if the tax variables are correlated with omitted costs or demand properties. This may occur if, for example taxes are systematically lower in states with higher-cost supply of diesel, or if tax hikes are precipitated by downward trends in prices and/or demand. However, Stolper (2016) uses event study of Spain's state-level diesel tax hikes to show that price trends are, on average, very flat throughout the six months prior to (as well as after) a tax hike; the pass-through response appears to be about three weeks long, centered on the week of the hike itself.

Table 3 displays the results of estimation of Equation 7 using four different samples. Column 1's point estimates imply that pass-through of state-wide taxes is, on average, 93.1% in the full national sample. This estimate can be interpreted as a measure of industry-cost pass-through, since very nearly

Table 3: Average Pass-Through of State Taxes Among Different Samples

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Own-State Tax Level (c/L) | 0.931*** | 0.937*** | 0.729*** | 0.572*** |
| | (0.039) | (0.041) | (0.049) | (0.096) |
| Rival-State Tax Level (c/L) | 0.081 | 0.092 | 0.065 | 0.211 |
| | (0.051) | (0.055) | (0.061) | (0.223) |
| Sample | Full | Rivals | Border | CB Rivals |
| N | 581,452 | 416,774 | 30,393 | 2,200 |

Notes: Dependent variable is retail price (c/L). An observation is a station-month. The 'Full' sample includes all stations with non-missing price and tax data. 'Rivals' restricts to all stations with >0 stations within 5 minutes' drive. 'Border' restricts to all stations within 5 km of a state border. 'CB Rivals' restricts to all stations with >0 stations within 5 minutes' drive and situated in a different state. All specifications are estimated via OLS with station and month fixed effects. Standard errors, clustered at the state level, are in parentheses.
Source: Author's calculation using data from the Spanish Ministry of Industry, Energy, and Tourism.

all 9,277 stations in this sample are not within five minutes of a border and therefore compete (roughly) exclusively with other stations facing the same tax levels. Column 1 also confirms that neighbor-state tax levels are not a significant predictor of one's own price among stations far from a border. The results in column 2, which restricts the sample to those stations with at least one rival within five minutes' drive, are very similar.

Column 3 shows results from the sample of stations within 5 km of a border. Here we see average pass-through drop significantly, to 72.9% as a point estimate. This could be be driven by cross-border competition, or it could be driven by any other difference in the makeup of stations near state borders as compared to stations further away from them. Notably, stations near borders tend to be much more rural than the average station, and this could be associated with, for example, a different type of consumer (or supplier). Column 4 thus zeros in on the stations of primary interest: those within five minutes' drive of a cross-border rival. In this sample, pass-through is at its lowest yet: 57.2% on average. Since the 31 stations in this sample are very likely competing with out-of-state rivals, $OwnTax_{it}$ is no longer an industry cost, and $RivalTax_{it}$ is a real rival cost. The coefficient on this latter variable is still not significant at conventional levels, but it is interesting to note that its magnitude is more than double the corresponding point estimates in columns 1-3.

Another way to estimate the degree to which pass-through of diesel taxes differs at borders is to compare stations "treated" with border competition with untreated control stations, conditional on tax levels, local characteristics, and fixed effects. Equation 9 captures this type of framework:

$$P_{it} = \alpha + \beta_1 OwnTax_{it} + \beta_2 OwnTax_{it} * CBR_{it} + \gamma_1 RivalTax_{it} \tag{8}$$

$$+\gamma_2 RivalTax_{it} * CBR_{it} + \theta CBR_{it} + \delta \mathbf{X}_{it} + \lambda_i + \sigma_t + \varepsilon_{it} \tag{9}$$

Here, $CBR_{it}$ is a variable measuring cross-border rivalry at station $i$ in month $t$. I experiment with three different parameterizations of this variable: (1) a dummy for having at least one cross-border rival (where 'rival' again indicates a station less than five minutes' drive away); (2) a raw count of the number of cross-border rivals; and (3) a count of cross-border rivals weighted by inverse distance (1/minutes). These three options together provide a broad picture of the relationship between pass-through and cross-border competition. I include the level of $CBR_{it}$ as well as its interaction with each of the two tax variables. $\mathbf{X}_{it}$ contains a count of all rivals again, as well as its interaction with $OwnTax_{it}$.[10]

In this formulation, $\beta_1$ and $\gamma_1$ represent average pass-through rates of one's own and one's neighboring-state taxes in the non-border sample at large. The former should be nearly 100% and the latter should be indistinguishable from zero, matching column 1 of Table 3. $\beta_2$ and $\gamma_2$ are the key explanatory variables, measuring the average difference in pass-through associated with cross-border rivalry. I expect $\beta_2$ to be negative, to confirm that own-cost pass-through is less than industry-cost pass-through. I expect $\gamma_2$ to be positive, if rival-cost pass-through is greater than zero.

Columns 1-3 of Table 4 provide the results of using the full national sample and the each of the three parameterizations of $CBR_{it}$. Uniformly, pass-through of one's own state tax is about 94% and pass-through of one's neighbor's is not distringuishable from zero, for stations without cross-border rivals (CBRs). The first two coefficients match the results of Table 3, column 1 and again imply 94% industry-cost pass-through. Meanwhile, the bottom three coefficients speak to firm-specific pass-through, via CBRs. Column 1 implies that stations with at least one CBR pass through 27.7 fewer percentage points of their own cost shock, and 15.9 more percentage points of a rival's cost shock, relative to those with a CBR. These coefficients are significant at the 4% and 12% levels, respectively. Column 2 says that each additional CBR (controlling for the number of in-state rivals) is associated with 19.2 percentage points lower own-tax pass-through and 12.9 percentage points higher rival-tax pass-through, significant at the 1% and 2% levels, respectively.

Column 3's own- and rival-cost pass-through coefficients are interpreted differently because of their weighting; the impact of an additional cross-border rival is being modeled as non-linear in distance. The raw coefficients on own-tax and rival-tax are -0.754 and 0.554, respectively and are both significant at the 1% level. One way to interpret these numbers is to consider a station facing a single CBR, as Table 5 does. The impact of *moving* that CBR closer depends on how close it is to begin with. The change in pass-through of both own and rival taxes is in the low single-digit percentage points for a station five minutes away, but it rises faster than linearly as that drive time falls. Moving a station from two minutes away to one is associated with a 37.3 percentage-point drop in own-tax pass-through

[10] When parameterizing $CBR_{it}$ as a count, I define the rival count control as "the number of rival stations in the *same* state"; this makes $\beta_2$ and $\gamma_2$ interpretable as pass-through changes associated with an additional cross-border rival.

Table 4: Pass-Through and Cross-Border Rivalry

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Dummy | Count | Weighted | Dummy | Count | Weighted |
| Own-State Tax Level (c/L) | 0.938*** | 0.941*** | 0.934*** | 0.754*** | 0.760*** | 0.767*** |
| | (0.039) | (0.040) | (0.039) | (0.051) | (0.051) | (0.048) |
| Rival-State Tax Level (c/L) | 0.078 | 0.078 | 0.080 | 0.053 | 0.053 | 0.053 |
| | (0.050) | (0.050) | (0.051) | (0.058) | (0.060) | (0.059) |
| Own-State Tax X CBR | -0.277** | -0.192*** | -0.745*** | -0.116 | -0.106 | -0.399** |
| | (0.123) | (0.062) | (0.208) | (0.174) | (0.067) | (0.186) |
| Rival-State Tax X CBR | 0.159 | 0.129** | 0.554*** | 0.139 | 0.101* | 0.446** |
| | (0.096) | (0.049) | (0.187) | (0.083) | (0.050) | (0.199) |
| Own-State Tax X Rival count | -0.004 | -0.007 | -0.003* | -0.005 | 0.024 | -0.094*** |
| | (0.005) | (0.006) | (0.002) | (0.016) | (0.018) | (0.028) |
| Sample | Full | Full | Full | Border | Border | Border |
| N | 581,452 | 581,452 | 581,452 | 26,264 | 26,264 | 26,264 |

Notes: Dependent variable is retail price (c/L). An observation is a station-month. "Rival-State Tax Level" is defined as the tax level in the nearest neighboring state. "CBR" refers to the cross-border rivalry variable; it is parameterized as a dummy (columns 1 and 4), an unweighted count (2 and 5), or a count weighted by inverse travel time (3 and 6). The 'Full' sample includes all stations with non-missing price and tax data. 'Border' restricts to all stations within 5 km of a state border. All specifications are estimated via OLS with station and month fixed effects. Standard errors, clustered at the state level, are in parentheses.
Source: Author's calculation using data from the Spanish Ministry of Industry, Energy, and Tourism.

Table 5: Non-Linear Impacts of Cross-Border Proximity

| Change in proximity of CBR | (1) ΔOwn-Tax PT | (2) ΔRival-Tax PT |
|---|---|---|
| 5 minutes → 4 minutes | -3.7 | +2.7 |
| 4 minutes → 3 minutes | -6.2 | +4.6 |
| 3 minutes → 2 minutes | -12.4 | +9.2 |
| 2 minutes → 1 minute | -37.3 | +27.7 |

Notes: Numbers in columns 1 and 2 are the percentage-point changes in own- and rival-tax pass-through, respectively, associated with a single cross-border rival moving closer, as described under the column heading 'Change in proximity of CBR'. Changes are calculated from coefficients in column 3 of Table 4, as the predictive effect of changing the value of the CBR variable.
Source: Author's calculation using data from the Spanish Ministry of Industry, Energy, and Tourism.

and a 27.7 percentage-point rise in rival-tax pass-through.

It is helpful to compare the impact of a cross-border rival with the impact of an in-state rival; this is why I tabulate the estimated coefficient on 'Own-state tax X Rival count'. In all columns, that coefficient differs from 'Own-state tax X CBR' by two orders of magnitude. In column 3, the coefficient is significant at the 8% level, suggesting that rivalry in general may matter. But it does not matter in any way relative to the degree that *cross-border* rivalry matters.

Columns 4-6 of Table 4 act as a first robustness check on the full-sample results, by restricting to the 5-km sample. The statistical significance of the firm-specific pass-through coefficients is not quite as consistent in these columns, but the qualitative result remains. Cross-border rivalry, especially when modeled on an intensive margin (as measured in columns 5 and 6), continues to predict significant changes in pass-through rates, and the magnitude of all estimated cross-border impacts dwarf the corresponding in-state impacts. Table 6 delves further into robustness checks by displaying the results of several other adjustments to the specification of Equation 9. I experiment with the inclusion of a more detailed set of control tax-interactions and state-year fixed effects in columns 1 and 2, and I use a stricter definition of spatial rivalry in columns 3 and 4. In all columns, cross-border rivals continue to significantly predict changes in own- and rival-tax pass-through rates.

## 5 Conclusion

Across a variety of graphical and regression analyses, cross-border rivalry consistently predicts deviations in a gas station's rates of pass-through from both zero and the >90% rate of industry-cost pass-through. The first evidence of this is that cross-border price spreads change significantly – but not one-for-one – with a tax hike on one side of the market; this is a clear sign that responses are different on each side of the border. The second piece of evidence is that average pass-through of in-state

Table 6: Robustness Checks on Own- and Rival-Cost Pass-Through

| | 5-km<br>(1) | 5-km<br>(2) | 4-km<br>(3) | 3-km<br>(4) |
|---|---|---|---|---|
| Own-State Tax Level (c/L) | 0.855*** | 0.924*** | 0.939*** | 0.938*** |
| | (0.037) | (0.042) | (0.040) | (0.039) |
| Rival-State Tax Level (c/L) | 0.081 | 0.032 | 0.078 | 0.078 |
| | (0.050) | (0.031) | (0.050) | (0.050) |
| Own-State Tax X CBR | -0.183** | -0.190*** | -0.260*** | -0.362*** |
| | (0.057) | (0.058) | (0.068) | (0.074) |
| Rival-State Tax X CBR | 0.125** | 0.140** | 0.256*** | 0.275*** |
| | (0.047) | (0.051) | (0.095) | (0.030) |
| Controls | X | | | |
| State-year FE | | X | | |
| N | 581,396 | 581,452 | 581,452 | 581,452 |

Notes: Dependent variable is retail price (c/L). An observation is a station-month. All regressions use the full (mainland) national sample and parameterize the CBR variable as an absolute count. Column 1 includes interactions between the own-tax variable and: rival count; dummies for refiner and retailer brands; dummies for station amenities; and municipal population density. Column 2 includes state-year fixed effects. Columns 3 and 4 define rival stations (both in-state and cross-border) according to 4- and 3-minute driving radii, respectively. All specifications are estimated via OLS with station and month fixed effects. Standard errors, clustered at the state level, are in parentheses.
Source: Author's calculation using data from the Spanish Ministry of Industry, Energy, and Tourism.

taxes is vastly reduced among stations within five minutes' drive of a cross-border rival: such stations pass-through only a bit more than half (57%) of a tax hike, as compared to nearly all (93%) at the average Spanish station. And the third piece of evidence is that interacting in-state and rival-state tax variables with measures of cross-border rivalry indicate robustly significant relationships. Own-cost pass-through rates are lower than industry-cost rates, and rival-cost pass-through rates are greater than zero.

Competition in this market, then, has a very real effect on incidence. While a tax affecting all competing firms equally is, on average, passed through nearly fully to retail consumers, a tax affecting only part of the market is borne in relatively greater proportion by the suppliers in that part of the market. Moreover, competing firms whose costs are not affected by that tax actually *raise* their prices, so that patrons of those unaffected stations nonetheless share some of the tax burden.

In principle, the coefficients which I estimate here could be used to calibrate the full pass-through matrix, as a function of the number and distance of local rivals. This, in turn, could enhance the forecasting accuracy for a variety of policies – such as merger decisions and energy tax changes – on a variety of outcomes – including prices, quantities, and economic welfare. Furthermore, the pass-through patterns which I identify here have application beyond excise taxes. Consider one policy example that is quite relevant today and almost assuredly characterized by non-uniform cost shocks: the U.S. Environmental Protection Agency's Clean Power Plan (CPP). This regulation would impose limits on greenhouse gas emissions by electric power plants. It is expected that power plants would, to some degree, pass through the costs of compliance to consumers; indeed, existing research suggests that the pass-through rate would be, on average, quite high (Fabra and Reguant 2014). However, power plants use a variety of different energy sources to produce power, and each energy source has a different emissions profile. In addition, many types of power plants are likely to be exempt from the regulation. Thus, the cost shocks engendered by CPP emissions limits would be highly non-uniform. In order to forecast the price, quantity, and welfare impacts of the CPP – especially with distributional impacts in mind – one requires an understanding of competition and firm-specific behavior. This is precisely what I have sought to capture in Spain's retail automotive fuel markets.

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