Local Pass-Through and the Regressivity of Taxes: Evidence from Automotive Fuel Markets

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Abstract

The distributional impact of commodity taxation depends on not just relative consumption but also relative price changes. I illustrate this by estimating the pass-through of energy taxes in Spain's retail automotive fuel market. The average pass-through rate of regional diesel tax changes from 2010-2013 is approximately 94 percent, but predicted station-specific rates range from 70 to 115 percent as a function of local characteristics. Pass-through rises monotonically in municipal-average house prices, a proxy for wealth. Accounting for this relationship in distributional analysis suggests that, contrary to conventional wisdom about fuel taxation, the consumer surplus impact of this tax is progressive.

Keywords: Incidence, Distributional Equity, Pass-Through, Energy

JEL Codes: H22, L13, Q41

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Introduction

The distributional welfare impacts of taxation are a fundamental consideration in policy design and analysis. For instance, distributional analysis of tax burdens is a principle task of the United States Treasury Department's Office of Tax Analysis, which provides policy makers "guidance on the 'fairness' of proposed changes in tax law" (Cronin 1999). Retail taxes on items as disparate as food, cigarettes, and energy are commonly thought to be regressive, which is generally seen as unattractive from a social welfare standpoint. Why are such taxes labeled regressive? The answer is that poorer households have frequently been found to devote a greater proportion of their budget to these goods than their richer counterparts. Yet it is not just relative quantities that dictate regressivity; it is also relative *price* impacts. The first-order approximation of a tax's effect on consumer surplus is a function of both consumption *and* price changes, but studies of tax regressivity in academia and government alike tend to exclusively focus on the former (e.g., Horowitz et al. 2017; Bento et al. 2009; Gruber and Koszegi 2004). Accounting for the empirical relationship between tax pass-through and wealth has the potential to change the answer to "who bears the burden?" questions about taxes.

In this paper, I estimate pass-through patterns in an imperfectly competitive market and assess their implications for distributional welfare. The empirical setting is the Spanish market for retail automotive fuel – a large, localized, and imperfectly competitive market. I collect daily prices of automotive fuel at nearly 10,000 retail stations in Spain, made available through an informational mandate unveiled in January 2007 by Spain's Ministry of Energy. I combine these data with panel-varying fuel taxes, station attributes, and socioeconomic indicators to estimate average pass-through as well as "local" pass-through conditional on firm and market characteristics. I then match pass-through rates to fuel consumption by wealth bracket, in order to estimate the effect of variation in local pass-through on the regressivity of Spain's fuel tax.

My analysis builds on a long, as well as broad, economics literature related pass-through (see, for instance, Jenkin 1872). In public finance, pass-through is used to assess the incidence of taxes on consumers versus producers (Poterba 1996; Ganapati, Shapiro, and Walker 2020). In industrial organization, it has been used to examine the impact of market structure and design on pricing (Bonnet et al. 2013; Fabra and Reguant 2014). In international economics, it has been the focus of studies of exchange-rate fluctuation (Berman, Martin, and Mayer 2012; Amiti, Itskhoki, and Konings 2014) and tariff incidence (Cavallo et al. 2020). Across fields within economics, there have been recent advances in understanding the determinants of pass-through in imperfectly competitive markets

(Weyl and Fabinger 2013) and using pass-through as a sort of sufficient statistic (Chetty 2009) to reveal underlying demand, supply, and policy parameters of interest (Jaffe and Weyl 2013; Atkin and Donaldson 2015; Pless and van Benthem 2019).

I extend this literature by studying the empirical relationship between "local" pass-through and wealth and linking it to distributional welfare among consumers. Multiple features of my empirical setting make it useful for this type of study. First, dozens of countries currently employ retail automotive fuel taxes, and hundreds of millions of drivers are more generally affected by the pass-through of cost shocks in the automotive fuel sector. Second, markets for automotive fuel are inherently local, due to spatial and brand differentiation. Third, there is existing evidence that the elasticity of demand for automotive fuel varies with wealth (West and Williams 2004; Houde 2012), which suggests that pass-through may do so as well. Fourth, the availability of daily, station-specific prices makes it possible to identify not just the timing of the pass-through response but also the predictive impact of high-resolution characteristics.

I begin my empirical analysis by conducting an event study of Spanish tax hikes, which provides a sense of how prices evolve in the run-up to and aftermath of these events. I find strong evidence of parallel trends: conditional on panel fixed effects, prices vary very little in the months leading up a tax hike. The pass-through response begins the week of the tax hike and stabilizes two weeks later. The difference-in-differences point estimate of average pass-through rate ranges from 92-95 percent, depending on the specification. These results follow a long literature on the price impacts of automotive fuel taxes, which generally points to full or very nearly full pass-through (Alm, Sennoga, and Skidmore 2009; Marion and Muehlegger 2011).

The average pass-through rate, however, masks significant heterogeneity at the local level. To illustrate this, I estimate a model of fuel prices in which pass-through depends on all observable characteristics of stations and their environs. I then use it to predict station-specific pass-through rates and find a range of rates from approximately 70 to 115 percent. Among all characteristics, local ownership concentration – an indicator of market power – and house prices – which indicate wealth – are the most significant predictors of local pass-through here.

Since property values are a proxy for wealth, the empirical relationship between pass-through and house prices has a first-order bearing on the regressivity of taxation. I find, in my context, that pass-through rises monotonically in house prices. How does this affect the ultimate distribution of lost consumer surplus due to the Spanish diesel tax? To answer this question, I examine fuel consumption by expenditure decile in the Spanish Household Budget Survey. The traditional method employed in distributional analyses of taxation – in both government and academic work – is to calculate, for each wealth bracket, the average expenditure on the taxed good as a proportion of household budget (Poterba 1991). This procedure provides an accurate first-order approxiation of *relative* changes in consumer surplus induced by the tax only if pass-through is uniform. To account for the systematically *non*-uniform pass-through in my context, I multiply proportional fuel expenditure in each wealth decile by the pass-through rate predicted for that decile of the house-price distribution. Ignoring pass-through heterogeneity leads to the conclusion that the tax has a roughly equal (proportional) impact on consumer surplus across the wealth distribution. In stark contrast, the augmented procedure that accounts for local pass-through suggests that the effect is strongly progressive.

1 Pass-through and distributional welfare

The term "pass-through" refers to what Alfred Marshall (1890) described as "the diffusion throughout the community of economic changes which primarily affect some particular branch of production or consumption." Most commonly, these economic changes are costs, physically imposed on one part of a supply chain and passed through to others. A positive cost shock elicits a direct change in consumer surplus through two channels: (a) the additional cost of consumption maintained in the face of rising prices; and (b) the utility lost from reduced consumption.[1] Pass-through physically measures the former (per unit consumption), which is the first-order approximation to the consumer surplus impact of a marginal tax change. It is thus an integral part of distributional welfare analysis, which generally focuses on estimating changes in surplus among different segments of society (for instance, consumers vs. producers, and richer consumers vs. poorer ones). If the price impacts of rising taxes vary across geographic regions, firms, or individuals, then welfare varies accordingly.

In perfect competition, pass-through is entirely a function of elasticities of supply and demand. Equation 1 provides the mathematical definition:

$$\frac{dp_c}{dc} = \frac{\epsilon_S}{\epsilon_S - \epsilon_D} = \frac{1}{1 - \frac{\epsilon_D}{\epsilon_S}} \tag{1}$$

[1]Individual welfare is also determined by (a) ownership of supply-side capital; (b) externalities; (c) other goods' prices and quantities that are affected in general equilibrium; and (d) the use of government revenues obtained through taxation. In this paper, however, I focus only on the utility derived directly from the purchase and consumption of energy. See Sterner (2012) for a fuller discussion of the various channels through which a tax affects welfare in the context of fuel markets.

Pass-through of cost c to retail price p_c rises in the supply elasticity (ϵ_S) and falls in the absolute demand elasticity (ϵ_D). In the polar cases of either perfectly elastic supply ($\epsilon_S \to +\infty$) or perfectly *in*elastic demand ($\epsilon_D \to 0$), pass-through rates are identically 100%.

In *im*perfect competition, pass-through varies with not just the first derivative (elasticity) but also the second (convexity). Consider the formula for pass-through in monopoly with constant marginal costs c:

$$\frac{dp_m}{dc} = \frac{\frac{\partial p(q_m)}{\partial q_m}}{2\frac{\partial p(q_m)}{\partial q_m} + q_m \frac{\partial^2 p(q_m)}{\partial q_m^2}} \tag{2}$$

Equation 2 shows that monopoly pass-through can, in principle, be higher or lower than perfectly competitive pass-through – it depends on the demand convexity parameter $\frac{\partial^2 p(q_m)}{\partial q_m^2}$ (Seade 1985).[2] Under perfect competition, constant marginal cost (i.e., perfectly elastic supply) guarantees fully 100 percent pass-through. Under monopoly with linear demand, $\frac{\partial^2 p(q_m)}{\partial q_m^2} = 0$ and pass-through simplifies to a constant 50 percent. If, however, $\frac{\partial^2 p(q_m)}{\partial q_m^2} > 0$, then market power increases pass-through relative to that of perfect competition. If $\frac{\partial^2 p(q_m)}{\partial q_m^2}$ is positive and sufficiently large,[3] then pass-through can exceed 100 percent.[4]

Empirically, pass-through has been shown to vary with market power (Doyle and Samphantharak 2008; Pless and van Benthem 2019; Preonas 2019), supply elasticity (Marion and Muehlegger 2011), and cost structure (Muehlegger and Sweeney 2020). However, there is a disconnect between the literatures on empirical pass-through estimation and distributional welfare analysis. Studies which focus on how progressive or regressive a cost change is uniformly rely only on inspection of relative consumption – i.e., quantities and not prices. The researcher does not allow for heterogeneous markup adjustment by firms, instead choosing a single pass-through rate to apply throughout the analysis. This practice is especially prevalent in the energy tax literature (Metcalf 1999; West 2004; Bento et al. 2009; Mathur and Morris 2012) but is also employed in studies of the U.S. sales tax (Caspersen and Metcalf 1994) and cigarette taxes (Gruber and Koszegi 2004).

[2] Ritz (2020) shows that *cost* convexity can also produce a positive relationship between market power and pass-through, all else equal.

[3] The mathematical condition is $\frac{\partial^2 p(q_m)}{\partial q_m^2} > -\frac{\partial p(q_m)}{\partial q_m}\frac{1}{q_m}$.

[4] See the Appendix for a graphical depiction of "overfull" monopoly pass-through using an isoelastic demand curve (Figure A1), as well as derivations and further discussion of pass-through under perfect competition, monopoly, and oligopoly.

To date, there is a lack of evidence on the relationship between pass-through and wealth.[5] However, evidence on the link between demand elasticity and income implies that pass-through may vary with wealth. In industrial organization, demand estimation commonly includes a parameter capturing how disutility of price varies with income; the parameter estimate is almost always negative (as in Houde 2012, in Quebec City's retail gasoline market), which implies that wealthier individuals have lower demand elasticity. Moreover, several studies have directly estimated demand elasticities as a function of wealth (West 2004; West and Williams 2004; Gruber and Koszegi 2004; Hughes, Knittel, and Sperling 2008). Gruber and Koszegi (2004) and West and Williams (2004) both note that a negative relationship between (absolute) demand elasticity and wealth makes taxes more progressive, but the channel that they focus on is reduced consumption. They do not extend their logic to the first-order welfare effect – pass-through.

2 Background on Spain's oil markets

The Spanish retail automotive fuel market is ologipolistic and vertically integrated.[6] Three companies (Repsol, Cepsa, and BP) own the nine oil refineries operating in Spain (imports account for only 10% of refined diesel), and together they own a majority stake in the national pipeline distribution network. Most importantly, they are heavily forward-integrated into the retail market: 61% of retail gas stations in Spain bear the brand of a refiner. Not surprisingly, these companies face significant scrutiny from government and popular media alike, on the grounds of alleged collusion and some of the highest estimated retail margins in all of Europe (see, for example, El País 2015).

One result of such scrutiny has been very close monitoring of pricing by gas stations. A government mandate which went into effect in January 2007 requires all stations across the country (more than 10,000 today) to send in their fuel prices to the Ministry of Energy whenever they change, and weekly regardless of any changes. These prices are then posted by the Ministry to a web page - called the *Geoportal* - that is streamlined for consumer use.[7] I obtain daily price data for retail diesel (which has a 67% share of the retail automotive fuel market), as well as the location, amenities, brand, and wholesale contract type at all Spanish gas stations from January 2007 to June 2013.[8]

[5]Harding, Leibtag, and Lovenheim (2012) find different point estimates of cigarette tax pass-through by income tercile, but the difference does not appear to be significant.

[6]For background on the evolution of Spain's oil markets, see Contín-Pilart, Correljé, and Palacios (2009) and Perdiguero and Borrell (2007).

[7]Appendix Figure A1 displays a screenshot of the *Geoportal*, while Appendix Figure A2 provides a map of all stations.

[8]Corresponding quantity (consumption) data are unavailable: the Ministry of Energy collects station-year total sale volume,

In addition to using station brand, contract type, and amenities, I calculate two station-specific proxies for market power. The first is a count of open stations within a 10-minute distance radius, weighted by $\frac{1}{1+d}$, where d is the travel distance (in minutes) between a pair of stations.[9] This proxy thus captures the degree of spatial isolation, or differentiation, from competitors. The second is the proportion of stations within a 10-minute radius that share one's brand; this measure captures the degree of brand concentration in local markets. Both of these competition proxies vary cross-sectionally and over time due to entry and exit of stations. The final characteristics I add to the station-level dataset are municipality-year population density and municipality-quarter average house prices per unit area. The latter variable is only available for municipalities with greater than 25,000 residents, to which I refer as the "urban" sample.

There are four taxes applicable to retail diesel in Spain, but only one of them exhibits panel variation. This tax, colloquially known as the "centimo sanitario" (" health cent"), was originally levied to generate revenues to be used for public health improvements.[10] In my sample time period, it varies from 0 to 4.8 Eurocents/liter (c/l) across Spain's Autonomous Communities and discretely rises 14 times over my seven-year time period. The first tax change occurs in early 2010, and each month thereafter has 0-4 Community-specific tax changes – all increases. The tax *changes* are marginal; their average size is 2.8 c/L, which is about 2.3 percent of retail prices.[11] However, two national excise taxes on retail diesel push the total excise tax burden to an average of 32 c/l, or 32.5 percent of retail price.

The raw *Geoportal* data contain 9,911 stations as of June 2013 (the end of my sample period). The total drops to 9,457 when I remove stations from the three areas with unknown tax levels: the Community of the Canary Islands and the island territories Ceuta and Melilla. The urban sample contain 3,605 stations; the non-urban sample contains the remaining 5,852. Table 1 presents summary statistics for the main analysis variables nationally as well as in the urban and non-urban samples separately. The national average retail price is 98.49 c/l, and urban and non-urban averages are within 0.25 c/l of this number.[12] However, other characteristics differ substantially between urban

but these data cannot be reliably matched to the *Geoportal* price data.

[9] A station's relevant competitors are defined in part by typical travel patterns, including commuting (Houde 2012). Lacking commuting data for the whole of Spain, I use a much simpler, distance-based measure of competition. Genakos and Pagliero (2020) show, using fuel tax and price data from Greek Islands, that distance-restrictions on local retail fuel market definitions can lead to overestimation of pass-through when the number of nearby stations is small. In my context, however, the predictive effect of an additional rival drops quickly in driving distance and is not significant beyond ten minutes.

[10] In 2013, the tax was integrated into an excise duty on mineral oils to comply with European Union Law. In 2014, the European Court of Justice ruled that, from 2002 through 2011, the tax was unconstitutional and its revenues must be returned.

[11] There is a national sales tax of 21% that applies to retail diesel sales. I remove the contribution of this tax from retail prices in all analyses.

[12] 98.49 c/l corresponds to 4.70 US$/gallon at the end-of-sample exchange rate.

and non-urban areas. Urban stations are more likely to be branded but have lower own-brand shares of markets. This lower share is, in part, a function of spatial competition: the average urban station has 1.72 distance-weighted rivals, compared to only 0.91 at the average non-urban one. Nationally, the maximum weighted number of rivals observed is 11.27.

Table 1: *Summary Statistics*

	Non-urban	Urban	National
	(1)	(2)	(3)
After-tax retail price (c/l)	98.34	98.74	98.49
	(5.647)	(5.022)	(5.420)
Mean tax level (c/l)	1.733	1.796	1.757
	(1.116)	(0.971)	(1.063)
Brand			
Refiner (0/1)	0.587	0.642	0.608
	(0.492)	(0.479)	(0.488)
Wholesaler (0/1)	0.126	0.155	0.137
	(0.332)	(0.362)	(0.344)
Unbranded (0/1)	0.287	0.203	0.255
	(0.452)	(0.402)	(0.436)
# of rivals (distance-weighted)	0.910	1.720	1.219
	(1.038)	(1.380)	(1.244)
Brand market share ([0,1])	0.308	0.248	0.286
	(0.365)	(0.276)	(0.335)
Municipal population density (1000s/km^2)	0.258	2.363	1.060
	(0.737)	(3.472)	(2.445)
Municipal average house price (1000s of Euros/m^2)	.	1.872	1.872
	(.)	(0.630)	(0.630)
N	5,852	3,605	9,457

Notes: All statistics are calculated from station-level observations. Brand dummies are cross-sectional from the time of entry into Geoportal. All other variables vary over time and are collapsed to station-specific means prior to calculation of sample-wide means. “Urban” refers to stations in municipalities with greater than 25,000 residents; house price data are only available for urban stations. “Wholesaler” denotes a station with a brand that does not have refining capacity in Spain. “# of rivals” is weighted by inverse distance (in driving minutes). Source: Author’s calculation using data from the Spanish Ministry of Industry, Energy, and Tourism.

3 Pass-through estimation

I estimate average and local diesel tax pass-through using event study and difference-in-differences regression. I start with event study, in order to investigate price trends in the temporal vicinity of tax changes. Tax changes are not random; according to correspondence with the Ministry of Industry, Energy, and Tourism, the state-level taxes in question were raised in order to collect more revenue. States and times in which the need for revenue is relatively greater may be different along other relevant dimensions. Event study thus serves to assess endogeneity concerns.

I estimate the following model:

$$P_{it} = \alpha + \sum_{j=a}^{b} \pi^j D_{it}^j + \delta \mathbf{X}_{it} + \lambda_i + \sigma_t + \varepsilon_{it} \tag{3}$$

An observation is a station i in week t, which allows inclusion of station-specific characteristics to the analysis and balances high temporal resolution with computation tractability. P_{it} is the station-weekly, after-tax (but gross of sales tax) average price of retail diesel. The superscript j denotes a time period *relative* to the tax hike; D_{it}^j is thus a binary variable equalling one if an observation is both (a) in a state experiencing a tax hike and (b) j periods after (or before) that tax hike, where $j \in [a, b]$. X_{it} is a vector of observable demand and supply shifters. λ_i and σ_t are station and week fixed effects, respectively, and ε_{it} is a pricing residual that captures unobservable determinants of price. Equation 3 is a conventional event study model, allowing prices to respond to an event flexibly over time. If prices respond either prematurely or with a lag relative to a tax hike, that pattern will be captured by the coefficients π^j.

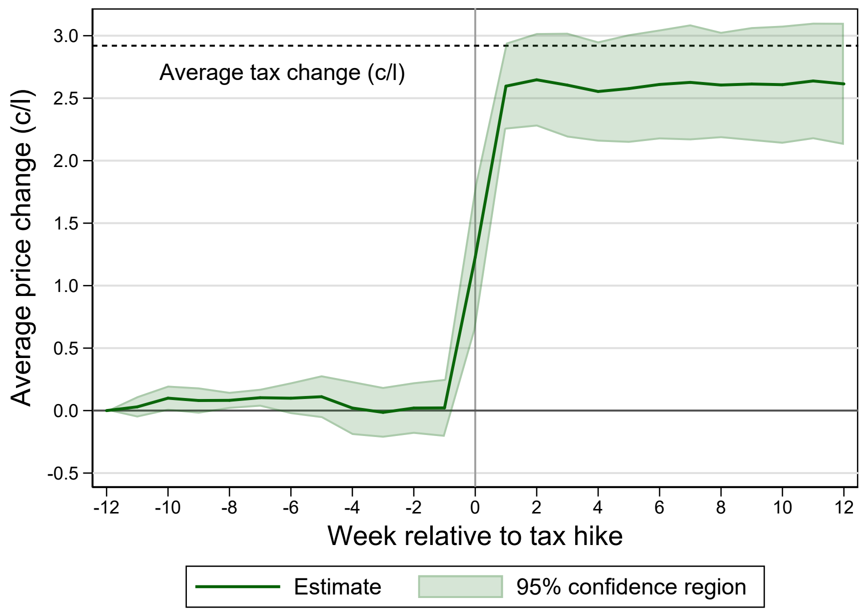
Several implementation details should be noted. First, I choose $[a, b]$ to be equal to $[-12, 12]$, which is an observation window of 6 months, and omit the term $\pi^{-12} D_{it}^{-12}$ so that the price impact twelve weeks before the tax hike is normalized to zero. Second, I use all weeks from January 2007 through June 2013, regardless of their temporal proximity to tax hikes; this helps pin down the time fixed effects but necessitates the creation and inclusion of two additional dummy variables: one for an observation being from a period $j < -12$, and one for an observation being from a period $j > 12$. Third, I use all states, regardless of whether they are "treated" (with a tax hike) or "untreated".[13]

[13] Estimation is also possible using *only* treated states, but this requires an additional parametric assumption (see McCrary 2007).

Fourth, and finally, I cluster standard errors at the province level.[14]

Figure 1 plots the estimated event study coefficients. On average, prices remain flat throughout the three months preceding a tax hike. They begin rising in the week of the tax hike itself and restabilize two weeks later, after which they remain flat out to the three-month mark. There is no evidence of differential pre-trends in "treated" and "control" stations. The average tax hike is 2.9 c/l, and the post-restabilization price level is about 2.6 c/l higher than the baseline level estimated twelve weeks prior to an event.

Figure 1: *Event Study of Tax Hikes: Overall Pass-Through*



Notes: Data points are week-specific coefficients estimated via event study (Equation 3). Average price twelve weeks prior to a tax hike is normalized to zero and omitted from the estimating equation. Plotted coefficients are thus interpretable as price changes at stations experiencing a tax change, relative to 12 weeks before the tax change. The regression includes indicator variables capturing observations from outside the six-month event window, station and week fixed effects, and clustering of standard errors at the province level.

To obtain a point estimate of diesel tax pass-through, I estimate the following difference-in-differences (DD) model:

$$P_{it} = \alpha + \beta Tax_{it} + \delta \mathbf{X}_{it} + \lambda_i + \sigma_t + \varepsilon_{it} \quad (4)$$

[14]There are 48 Spanish provinces in the main analysis sample; these may be viewed as analogous to U.S. counties.

The only difference between this DD model and its event study analog is that the set of event study dummies is replaced by the tax level. The coefficient on that tax level, β, captures the average pass-through rate of diesel taxes in Spain. While stations set prices in response to both own costs and rival costs, state diesel taxes affect all stations' costs in exactly the same way (except in areas with cross-border competition, which are quite rare in this context); thus, β is a measure of "industry-cost" pass-through, not own- or rival-cost analogs.

The point estimate of β is very consistent across a broad set of specifications of Equation 4: the average pass-through rate of Spanish diesel taxes is approximately 94 percent (see Appendix Table A1). The estimated rate never deviates beyond the range of [92,95], whether I include observable controls or community-year fixed effects, weight observations by municipality population, use only observations from the four-year period (2010-2013) in which tax hikes were occurring, or restrict the sample to urban stations,. All of these estimates are significantly different from 100 percent (or full, or complete, or one-for-one) pass-through.

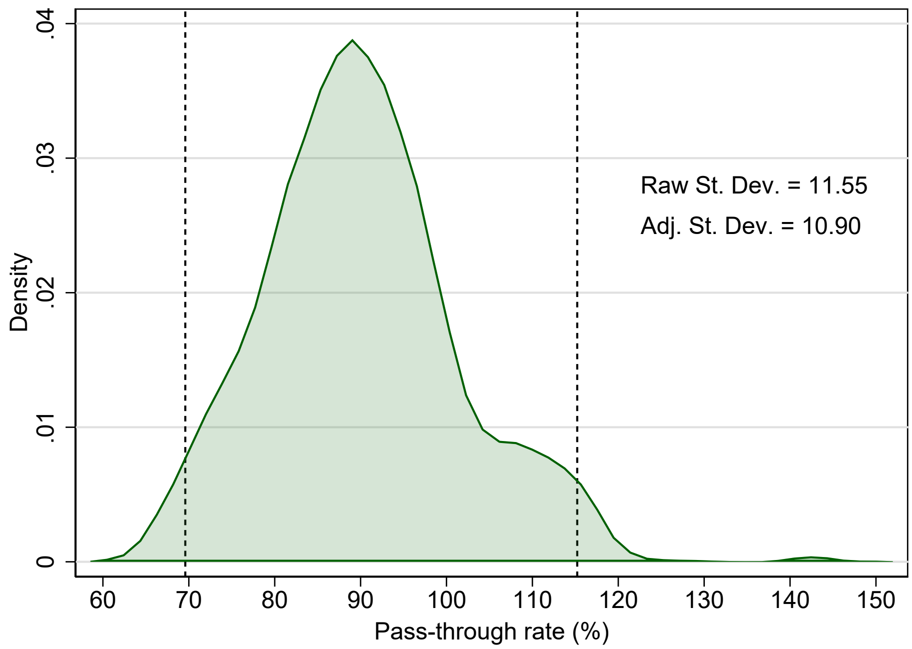
A pass-through rate exceeding 90 percent is quite common in the automotive fuel tax literature; in fact, Chouinard and Perloff (2004), Alm, Sennoga, and Skidmore (2009), and Marion and Muehlegger (2011) all fail to reject the null hypothesis that state-level automotive fuel tax pass-through is fully 100 percent. The point estimates corresponding to control variables, when included, are also sensible. Additional spatial isolation and brand concentration, both of which imply weaker competition, is associated with higher prices. On the demand side, greater population density (which is likely correlated with public transit availability) is associated with lower prices, while average house prices – a proxy for wealth – are associated with higher ones.

Next, I estimate pass-through as a function of all observable characteristics of stations and their environs, to quantify the heterogeneity in local pass-through rates. The estimating equation is identical to Equation 4, except for the addition of interaction terms between tax level and each of fourteen different characteristics:

$$P_{it} = \alpha + \beta Tax_{it} + \sum_{k=1}^{K} \left(\gamma_k Tax_{it} * X_{it}^k \right) + \delta \mathbf{X}_{it} + \lambda_i + \sigma_t + \varepsilon_{it} \tag{5}$$

γ_k captures the predictive effect on pass-through of a one-unit increase in X_{it}^k. I estimate Equation 5 in the urban subsample of stations, in order to include municipality-average house prices as an

Figure 2: *Empirical Distribution of Pass-Through*



Notes: The plotted curve is a kernel density of pass-through rates at urban stations. Each input data point is a pass-through rate calculated from Equation 5. There is one data point for each station, corresponding to the last day of its observation in the data. Vertical dashed lines denote percentiles 2.5 and 97.5 of the empirical distribution. "Raw" standard deviation pertains to the empirical distribution as predicted by the calibrated regression model. "Adjusted" standard deviation pertains to the 'shrunk' distribution. I calculate the latter as the square root of the sample variance of pass-through rates minus noise, where I estimate noise as the average of the variances of each station-specific pass-through estimate.

interaction term.

I then calculate station-specific price impacts of taxation as the linear combination of the predictive effects of all tax terms – $\beta Tax_{it} + \sum_{k=1}^{K}\left(\gamma_k Tax_{it} * X_{it}^{k}\right)$ in Equation 5 above. I divide this value by Tax_{it} to yield an estimate of pass-through $\frac{dp_{it}}{dt_{st}}$ for each station i in week t. In Figure 2, I plot these rates on the last day of observation for each station, using a kernel density estimator. Not surprisingly, probability density peaks around 90 percent pass-through. However, the full range of observed pass-through rates ranges from under 60% to over 150%. 95% of these rates fall between 70% and 115%.

It is natural to ask how much of the pass-through distribution's spread is due simply to noise. To answer this question, I calculate the empirical variance of the pass-through rates used in Figure 2 and subtract off an estimate of noise. To obtain this estimate of noise, I compute the standard error of each station's pass-through estimate, square it, and take the average across all stations. As is indicated on the right side of Figure 2, removing noise drops the standard deviation of the station pass-through rate from a raw value of 11.55 to an adjusted value of 10.9. That change corresponds to a contraction in the 95% confidence range of about 4 percentage points.[15]

Two attributes in particular stand out as statistically significant predictors of local pass-through: house prices, and the local concentration of a station's own brand (see Appendix Table A2). Both of these are positively correlated with pass-through, which suggests that pass-through is higher in wealthier municipalities and among stations with greater market power. The former relationship is especially relevant to distributional considerations, because non-uniform pass-through with respect to wealth has direct consequences for the regressivity (or progressivity) of taxation. I thus zoom in on house prices and estimate versions of Equation 5 that exclusively interact the tax level with different parameterizations of this variable. I use municipality-quarter observations, because that is the level of observation of average house prices.

Table 2 displays the results. Column 1 features results from a linear interaction between tax level and average house price; the coefficient is statistically significant at the 1 percent level, and its magnitude implies a 22.5 percentage-point rise in pass-through for every 1,000 Euros/meter-squared increase in average house price. In columns 2 and 3, I interact tax level with house price quartiles. Column 2 shows that pass-through rises monotonically and significantly in quartile. Column 3, meanwhile, shows where non-urban stations rank; to use these stations in house-price regressions, I include a dummy for having missing house price and then recode missing house prices to zero. Pass-through at non-urban stations is not significantly different from pass-through in the lowest quartile of observed house prices. This is consistent with the notion that, were house prices available in non-urban areas, they would fall at the bottom end of the property value distribution.

4 The welfare impact of progressive pass-through

The fact that tax pass-through rises with a proxy for wealth has significant implications for the distributional welfare impacts of the tax. Mathematically, the first-order approximation of the consumer surplus loss induced by a marginal tax hike is the additional cost paid to continue

[15]While there is additional noise coming from the explanatory variables themselves, it is more than counteracted by attenuation of the estimates due to measurement error.

Table 2: *Pass-Through and Local House Prices*

	Urban		National
	(1)	(2)	(3)
Mean tax level (c/l)	0.578	0.886	0.906
	(0.076)	(0.033)	(0.032)
Tax X Avg. house price	0.225		
	(0.038)		
Tax X 1[Avg. house price in 2nd quartile]		0.085	0.083
		(0.028)	(0.027)
Tax X 1[Avg. house price in 3rd quartile]		0.264	0.259
		(0.038)	(0.039)
Tax X 1[Avg. house price in 4th quartile]		0.467	0.457
		(0.053)	(0.057)
Tax X 1[Avg. house price missing]			-0.005
			(0.023)
R-Squared	0.999	0.999	0.998
N	6,766	6,766	77,371

Notes: The dependent variable is after-tax retail diesel price in c/l. An observation is a municipality-quarter. Average house price is recorded in thousands of Euros per meter squared. All specifications are estimated via OLS with municipality and quarter fixed effects. Standard errors, clustered at the province level, are in parentheses.

consuming the taxed good – a rectangle with width equal to quantity consumed (Q) and height equal to the pass-through rate ($\frac{dp}{dt}$). Equivalently, and perhaps more intuitively, it is likely that the primary burden on a car owner's mind when a tax is raised is the extra cost of all the gasoline that they will continue to purchase. The welfare loss from this extra cost is likely to be significantly larger than the welfare loss due to reduced consumption, because demand for retail automotive fuel tends to be relatively inelastic.

The progressivity of a marginal tax increase can be approximated by estimating, at different points of the wealth (W) spectrum,

$$\frac{Q\frac{dp}{dt}}{W} \tag{6}$$

This is equivalent to the extra cost of consuming fuel after the tax, as a proportion of wealth. If the above expression rises with wealth, then the tax change is progressive; if it falls, then the tax change is regressive. This kind of calculation is quite common in distributional analysis of tax burdens in academia (Poterba 1991; Fullerton and West 2003) and government – for example, the US Treasury Department's Office of Tax Analysis (Fullerton and Metcalf 2002) – alike. However, it is standard practice to omit pass-through from the calculation, in which case the relative burden measure simplifies to $\frac{Q}{W}$. This expression accurately captures tax *revenues* per unit consumption but is only proportional to relative burden if pass-through is uniform.[16]

To show the effect of progressive pass-through on distributional welfare, I carry out the incidence calculation both with and without the assumption of uniform pass-through, using data from the 2013 Spanish Household Budget Survey. I divide households' fuel consumption Q (in liters) by their overall expenditure E – a smoother proxy for wealth than income (Poterba 1991) – and collapse these values into averages within each decile of overall expenditure. As is, these average values of $\frac{Q}{E}$ can be interpreted as estimates of the government revenues generated by households per unit tax hike, as a proportion of their overall wealth.

I then replicate the calculation while relaxing the assumption of uniform pass-through. I match pass-through rates with consumption at different levels of wealth, implicitly equating house price decile with expenditure decile. To the extent that this is not true, it induces bias in both directions: bias

[16]Moreover, data limitations mean that implementation usually relies on energy expenditure rather than energy consumption. fuel expenditure is only proportional to fuel *consumption* if prices are the same for all households, so the calculation relies on an assumption of uniform pricing that is often unrealistic.

towards progressivity to the extent that some poorer people actually live in richer neighborhoods (and vice versa),[17] and bias away from it due to measurement error (see the Appendix for a mathematical formulation of this challenge).

To obtain wealth decile-specific pass-through rates, I estimate the regression model below:

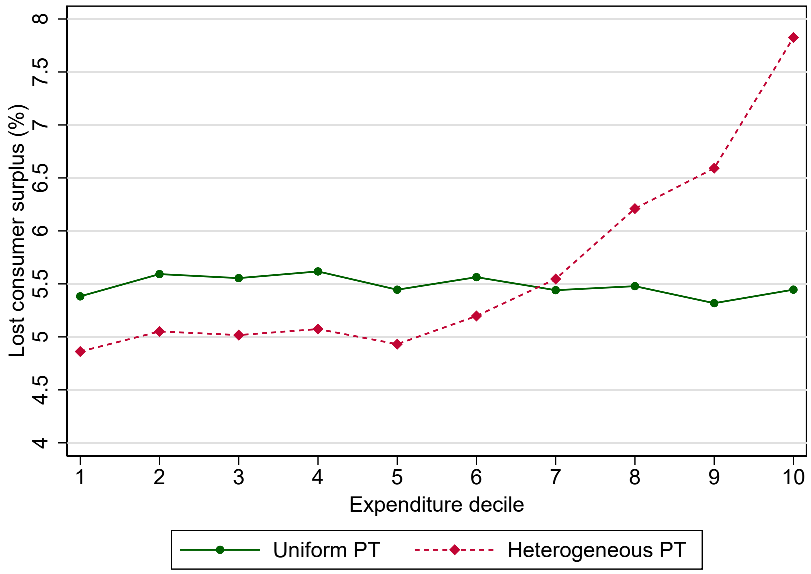
$$P_{it} = \alpha + \beta_0 Tax_{it} * 1[Non-urban]_i + \sum_{Q=1}^{6} \left(\beta_Q Tax_{it} * 1[HPQuantile = Q]_{it}\right) + \delta \mathbf{X}_{it} + \lambda_i + \sigma_t + \varepsilon_{it} \quad (7)$$

Here, an observation is municipality-quarter, and the regression weights observations by municipal population. The dummy variable $1[Non-urban]_i$ equals one for all municipalities with no house price data; β_0 thus provides an average pass-through rate in non-urban areas, which comprise roughly 40 percent of Spain's total population. That leaves 60 percent of the population in urban areas, and consequently I estimate a pass-through rate β_Q for each of six quantiles Q of the house price distribution. These rates are then used to compute $\frac{Q\frac{dp}{dt}}{E}$ at different expenditure deciles. I match the non-urban pass-through rate to the bottom four expenditure deciles, given the likelihood that non-urban areas feature the lowest house prices. I then match the six quantile-specific pass-through rates to the top six expenditure deciles.

Figure 3 plots the proportional tax burdens with and without the pass-through adjustment. Interestingly, when pass-through is assumed full and uniform (solid line), households appear to have roughly equal fuel tax burdens as a proportion of their full budget. Incidence is neither regressive nor progressive in this formulation of the exercise. This pattern runs counter to the belief that poorer households spend more of their budget on fuel than richer ones, which would, on its own, yield a downward-sloping line in Figure 3. Understanding the flat trend with respect to Spanish automotive fuel consumption is thus a subject for further research; however, the main point of Figure 3 is to show the effect of heterogeneous pass-through relative to this flat baseline. When pass-through heterogeneity is explicitly accounted for in analysis (dashed line), higher-expenditure households appear to have much higher effective fuel-tax rates. Incidence now looks strongly progressive over the top half of the wealth distribution while remaining flat over the bottom half.

[17] This upward bias may be counteracted by the propensity for the relative poor to engage in more price shopping.

Figure 3: *The distributional impact of fuel taxes*



Notes: The green line ("Uniform PT") depicts the average household consumption of auto fuel as a percentage of total household expenditure, for each total expenditure decile. The red line ("Heterogeneous PT") does the same, except that consumption is multiplied by the pass-through rate corresponding to a household's expenditure decile. Pass-through rates come from Equation 7. See Section 4 for details.

5 Discussion

The previous exercise suggests that the consumer surplus effect of the Spanish diesel tax is progressive. Importantly, the aggregate progressivity of this tax depends on how the other effects of the tax – including those on supplier prices and quantities, pollution, traffic, and vehicular safety, government revenue use, and general equilibrium outcomes – are distributed across the wealth spectrum. The consumer surplus effect, however, is often at the forefront of policy discussion as well as media coverage of taxation, perhaps because of the immediate salience of price in the consumption decision. The main point of this paper is to suggest that, to the extent that pass-through rises with wealth in other contexts, traditional calculations of distributional impacts on consumer surplus are biased towards finding more regressive impacts.

Understanding the mechanism(s) by which pass-through rises in wealth in my context would inform predictions of external validity. Pass-through is inherently related to demand elasticity, and one candidate explanation of the identified pass-through/wealth relationship is that people living in wealthier areas have a lower elasticity of demand, as has been shown for gasoline by West and Williams (2004) and Hughes, Knittel, and Sperling (2008). I cannot test for this mechanism directly because reliable quantity data are unavailable at a suitable level of temporal and geographic resolution. I *can* test whether the pass-through/wealth correlation is being driven by variation in other observable characteristics. In fact, adding all possible interaction terms (between the tax and station/area attributes) to the pass-through regression (as in Equation 5) only reduces the magnitude of the key house-price interaction coefficient by 7 percent. This suggests that observable patterns of local competition and product differentiation are not what drives "progressive" pass-through.

Another important question related to external validity is whether wealth is correlated with pass-through of fuel *input* costs, which account for the majority of the consumer price of fuel in most countries. I investigate this by estimating how pass-through responds to crude oil price shocks. Following a long literature on the "rockets and feathers" of oil price pass-through (e.g., Borenstein, Cameron, and Gilbert 1997), I include lagged values of crude price and interact these variables with the same station and area characteristics as in the rest of my analysis. The results are shown in Appendix Table A3. They suggest that input cost pass-through does rise with house prices, but at a much more modest rate than tax pass-through. This fact may be explained, for instance, by the greater persistence or salience of tax changes relative to oil price changes (Li, Linn, and Muehlegger 2014).

There thus remain open questions of economic and policy relevance about the relationship between pass-through and wealth. The evidence here from Spanish diesel taxes suggests that these two can be systematically related, and that a positive relationship can flip conventional wisdom about the regressivity of tax-induced consumer surplus impacts. The distribution of welfare impacts is a fundamental consideration for both political viability and economic justice. Future research on the existence of "progressive" pass-through in other contexts, as well as the mechanisms behind it, will inform the pursuit of equitable policy.

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