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**Incidence and Avoidance Effects of Spatial Fuel Tax Differentials:
Evidence using Regional Tax Variation in Spain**

**Ander Iraizoz
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JEL Codes: D12, H22, H71, Q35, Q41.

Keywords: Automotive Fuel, Tax Incidence, Spatial Avoidance.



Incidence and Avoidance Effects of Spatial Fuel Tax Differentials: Evidence using Regional Tax Variation in Spain*

Ander Iraizoz José M. Labeaga

September 27, 2022

Abstract

In this paper, we study the effect of spatial tax differentials on fuel tax pass-through and sales responses. We use two-way fixed effects methods to exploit regional variation in diesel excise taxes in Spain. Using a dataset containing daily diesel prices for the universe of petrol stations in Spain, we find that diesel tax pass-through is asymmetric depending on the sign of tax differentials with bordering regions. Petrol stations bordering with lower tax regions pass-through only 56% of fuel taxes, petrol stations bordering with higher tax regions pass-through 120% of fuel taxes. We provide evidence to attribute the asymmetric spatial incidence of fuel taxes to the market power given by the competitive tax advantage relative to competitors. Furthermore, we use diesel sales data aggregated at the province level and we find significant spatial tax avoidance responses to regional fuel tax differentials.

JEL classification: D12, H22, H71, Q35, Q41.

Keywords: Automotive Fuel, Tax Incidence, Spatial Avoidance.

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1 Introduction

Fuel taxes are widely used by governments to influence the car usage decision and reduce the amount of CO₂ emissions. However, the level of fuel taxes is highly heterogeneous across US states and European countries. Automotive fuels are homogeneous, and their consumption is mobile, making them subject to spatial tax avoidance. The possibility to circumvent local regulation by filling the tank at lower taxed jurisdictions has critical economic and policy implications. First, the possibility of spatial substitution of fuel consumption affects the geographical incidence of fuel taxes. Second, fuel tax avoidance could have large effects on revenues for different tax jurisdictions. Third, the possibility of fuel tax avoidance reduces the ability of fuel taxation to reduce CO₂ emissions.

This paper aims to shed light on two research questions on the implications of spatial fuel taxation. First, we aim to study the spatial incidence of fuel taxes in the presence of cross-border tax differentials. Second, we aim to study the fuel tax avoidance response to cross-border tax differentials.

We exploit a unique case study provided by the Spanish fuel excise taxation system. In 2002, the Spanish government introduced a regional excise tax band for fuel sales, allowing the Autonomous Communities in Spain to set a regional excise tax of up to 4.8 cents/litre, in excess of the central fuel excise tax band. We use two-way fixed effects methods in order to study the spatial incidence and tax avoidance effects of regional excise tax changes applied by Spanish Autonomous Communities.

First, we study the spatial incidence of diesel taxes around regional borders. For this, we use daily petrol price data for the universe of retail petrol stations in Spain between July 2014 and December 2019, which was provided by the Spanish Ministry of Ecological Transition and Demographic Challenge. We find a large asymmetry in diesel tax pass-through depending on whether petrol stations face a tax advantage or disadvantage relative to cross-border competitors. For petrol stations facing a cross-border tax disadvantage, we estimate a pass-through of 56% of diesel taxes within 10km from cross-border competitor. For petrol stations benefiting from a cross-border tax advantage, we estimate over-shifting with a pass-

through around 120%, which extends up to 50km from a cross-border competitor. Therefore, the asymmetric incidence of fuel taxes concerns both the dimension and the length of the effect of tax differentials at borders.

We attribute the asymmetric pass-through of diesel taxes around borders to the market power provided by competitive tax advantages. This explanation is consistent with Pless and Van Benthem (2019), who show that over-shifting can be used as evidence for market power. We further provide evidence the asymmetry of spatial incidence is heterogeneous depending on the market power of petrol stations. For top petrol station brands, a large share of them vertically integrated with Spanish oil refineries, we find strong over-shifting of diesel taxes when having a tax advantage, while we do not find under-shifting when facing a tax disadvantage. In contrast, we estimate that smaller petrol station brands, most in hands of independent owners, drive the under-shifting result when facing a tax disadvantage, passing only 24% of diesel taxes through to consumers.

Second, we study spatial diesel sales responses to regional taxes using province level monthly data on petrol prices and sales available at the Spanish National Markets and Competition Commission (CNMC). We find that regional tax differentials induce significant tax avoidance across regions, estimating an elasticity between -1.72 and -2.50 of tax avoidance incentives¹. However, we find no evidence of an asymmetry in the elasticity of tax avoidance. In addition to this, we show that price elasticities estimated using spatial diesel tax variation are highly sensitive to controlling for diesel tax avoidance incentives. Indeed, we show that controlling for tax avoidance incentives reduces the estimated tax elasticities from -2.51 to -0.66. In addition to this, we provide evidence on the sensitivity of price elasticities to diesel tax avoidance by focusing on subsets of provinces that differ in the possibility for diesel tax avoidance. While the fuel price elasticities in integrated areas vary between -4 and -5, the estimate in the subset of provinces not sharing a border with other Autonomous Communities is -0.64.

Our paper contributes to four main strands of literature. First, we relate to the literature on spatial pass-through. Prior studies have studied the incidence at borders depending on

¹These results are in line with the findings by Banfi et al. (2005) for Switzerland. Leal et al. (2009) also find that higher tax in neighbouring regions with Aragon (Spain) raise its long term fuel demand.

distance to lower taxed jurisdictions for cigarettes (DeCicca et al., 2013; Harding et al., 2012) or fuels (Romero-Jordán et al., 2013; Stolper, 2016). To the best of our knowledge, this is the first paper to show the asymmetry of pass-through at borders depending on the sign of tax differentials. We show that petrol stations facing a tax disadvantage under-shift diesel taxes, while those benefiting from a tax advantage over-shift diesel taxes.

Second, our paper relates to the determinants of the incidence of fuel taxes and costs. The literature has shown the impact of supply conditions (Marion and Muehlegger, 2011), cost structure (Muehlegger and Sweeney, 2021), competition (Alm et al., 2009), tax remittance regime (Kopczuk et al., 2016), vertical relationships (Bajo-Buenestado and Borrella-Mas, 2022), local wealth (Stolper, 2021), or rivals costs (Stolper, 2016). We provide direct evidence that the effect of the sign of relative costs to competitors induce asymmetric pass-through rates. We further show that the effects of tax advantages persist for a longer distance than the effects of tax disadvantages.

Third, our paper is closely related to the literature on the interaction of cost pass-through with competition (Stolper, 2016; Correa-Giraldo et al., 2021; Muehlegger and Sweeney, 2021; Bajo-Buenestado and Borrella-Mas, 2022). We contribute to this literature providing direct evidence that the sign of own costs relative to competitors' costs is a key parameter of cost pass-through. While those with a cost advantage can afford to over-shift own costs, those facing a cost disadvantage under-shift their costs.

Fourth, we also contribute to the literature on the estimation of consumption responses to fuel prices (Davis and Kilian, 2011; Coglianese et al., 2017; Levin et al., 2017; Knittel and Tanaka, 2021). To the best of our knowledge, this is the first paper to show the sensitivity of fuel price elasticities to spatial avoidance when using spatial tax variation. We show that fuel price elasticities could be overestimated if not controlling for fuel tax avoidance incentives of spatial tax variation². Our results also suggest that spatial fuel tax avoidance could be contributing to the estimation of an overreaction to price variation from excise taxes compared to fuel supply costs (Li et al., 2014; Rivers and Schaufele, 2015; Tiezzi and Verde, 2016).

The rest of this paper is structured as follows. Section 2 describes the Spanish oil market

²The sensitivity of price elasticities to avoidance was previously studied for tobacco by Lovenheim (2008).

and the taxation of fuels in Spain and Section 3 presents the fuel price and consumption data used for this study. The empirical methods are introduced in Section 4. Section 5 presents and comments on the spatial fuel tax incidence results. Section 6 presents and comments on the results on spatial diesel tax avoidance. Finally, Section 7 provides some conclusions.

2 Institutional design

This section briefly describes the main characteristics of the fuel market and fuel taxation in Spain. In particular, we provide details on the variation in regional fuel excise taxes that provides the quasi-experimental variation for this study.

2.1 Fuel markets in Spain

The liberalization and privatization of the Spanish petrol market started in the mid-1980s, following a public monopoly run by Campsa (now Repsol) (Perdiguero and Borrell, 2007; Perdiguero, 2010, 2012), and continued in the 1990s up to full liberalization (Bajo-Buenestado and Borrella-Mas, 2022). All the segments of the Spanish oil industry (refining, transportation, distribution and retailing) are currently fully liberalized and privatized. However, the Spanish petrol market has remained highly concentrated, with three firms (Repsol, BP and Cepsa) owning all nine oil refineries producing automotive fuel in Spain. Furthermore, the fuel market is forward-integrated since a large fraction of retail petrol stations are either owned or managed by producer brands³. In the period 2014-2019, up to 49.31% of petrol stations in peninsular Spain sell under the brands of the three forward integrated firms. For further details on the Spanish market for fuels, see Contín-Pilart et al. (2009) and Perdiguero and Borrell (2007).

The concentration of the fuel market in Spain has motivated regular collection of fuel market data from public institutions. The Ministry for the Ecological Transition and the Demographic Challenge collects daily petrol prices for all petrol stations operating in Spain since 2007. The Ministry also collects average monthly province level fuel sales and prices for all retail petrol station brands since 2007.

³Contín-Pilart et al., (2004) and Bello and Contín-Pilart (2012) provide evidence on the concentration in the fuel retail market.

2.2 Fuel taxation in Spain

Fuel taxation in Spain is comprised of excise taxes on fuels and the Value Added Taxes (VAT), which together account for 49% of diesel price and 53% of gasoline price in 2021, down from the Eurozone average of 56% and 61%, respectively⁴. The VAT rate applying to fuels in Spain amounts to 21% since 2012, while fuel excise taxes amount to 0.38 €/litre of diesel and 0.47 €/litre of gasoline. Excise taxes for diesel have been historically lower than for gasoline, which has prompted 75% of cars in Spain being powered by diesel.

The “health cent”: Regional excise tax band for fuel sales

The Spanish government introduced the Tax on Retail Sales of Certain Mineral Oils⁵ (*Impuesto sobre las Ventas Minoristas de determinados Hidrocarburos*, IVMDH) in 2002. This regional excise tax band allowed the Autonomous Communities⁶ in Spain to set an fuel excise tax of up to 4.8 cents/litre⁷ in excess of the central government fuel excise tax. The effective impact of regional excise taxes was amplified by the VAT rate, which ranged between 16% and 21% for the period of study between 2007 and 2020. Therefore, Autonomous Communities could influence fuel taxes up to 5.808 cents/litre. This regional excise tax band is informally known as the “health cent” (*céntimo sanitario*), since the revenues raised through this tax were meant to be dedicated fund regional health expenditures. In 2013, the IVMDH was integrated into the general Excise Duty on Mineral Oils (*Impuesto Especial sobre Hidrocarburos*, IEH) to comply with European Union Law⁸.

Between 2002 and 2018, up to 32 regional excise tax changes were passed. In 2019, the central government mandated the regional fuel excise tax band to the maximum of 4.8 cents/litre following an European Directive, which implied an fuel excise tax increase for eight Au-

⁴[Excise duties \(europa.eu\)](http://europa.eu)

⁵Ley 24/2001, de 27 de diciembre, de Medidas Fiscales, Administrativas y del Orden Social.

⁶16 Autonomous Communities had competence to modify this tax, while the Canary Islands, Ceuta and Melilla did not since they have a separate indirect tax regime.

⁷The ceiling for this was 1.7 cents/litre in 2002-2003, 2.4 cents/litre in 2004-2007 and 4.8 cents/litre since 2008.

⁸IVMDH was rule unconstitutional because the Spanish government justified this based on budgetary purposes, while EU Law rules that fuel excise taxes should aim to influence fuel consumption based, for instance, on environmental objectives. In 2014, the European Court of Justice ruled the IVMDH unconstitutional and asked the revenues from IVMDH between 2002 and 2013 to be returned.

onomous Communities, while the rest already set their tax bands at the maximum. This implies that there were a total of 40 fuel excise tax changes during the 17 years the regional tax band was in place. Table 1 describes the characteristics of these excise tax changes applied by Spanish Autonomous Communities during the periods of study covered by our different datasets.

Figure 1 displays the spatial variation of automotive excise taxes for diesel in Spain over the period between 2002 and 2019. By the beginning of 2012, nine Autonomous Communities, most located on the south of Spain, set positive regional excise taxes, with only the Valencian Community setting their excise tax at the maximum of 4.8 cents/litre. By the beginning of 2013, up to eight Autonomous Communities set their regional excise tax band at the maximum, only three regions not applying any regional excise tax. Between 2013 and 2018, several Autonomous Communities decreased their regional excise taxes, with an increase in Galicia and Aragon. Finally, the regional tax band was mandated to the maximum of by 2019, which affected eight Autonomous Communities, five of which were applying a zero regional excise tax.

3 Data

This paper uses two main sources of data. First, our spatial fuel tax incidence analysis is based on the daily petrol station *Geoportal data*. Second, we study fuel price elasticities driven by regional taxes using monthly province level *CNMC data*.

Geoportal data. We use daily petrol price data for 10,686 retail petrol stations provided by the Spanish Ministry of Ecological Transition and Demographic Challenge for this study between July 2014 and December 2019. This data is collected by the Ministry, which mandates all petrol stations in Spain to send their price data since January 2007⁹. For each petrol station, this dataset provides daily prices on different retail diesel and gasoline products, as well as the geographic location, including municipality, postcode, address and coordinates, the brand

⁹Instantaneous daily fuel price data for each petrol station are posted by the Ministry to the Geoportal webpage for consumer use. We use daily data, but some petrol station change prices more frequently during a day and they also report these changes. In this case, we use the average daily price

name, opening hours and the agent sending the information to the Ministry. This dataset constitutes our main source of data to study the spatial incidence of diesel excise taxes.

We use the detailed geographic coordinates of petrol stations in order to calculate the distance between each petrol station and their nearest competitor in a different Autonomous Community. For this, we first identify the closest cross-border competitor of each petrol station following Picard (2010). We then follow Huber and Rust¹⁰ (2016) to calculate the distance and travel time by car between cross-border petrol station pairs using OpenStreetMap data. We calculate the distance to the closest cross-border competitor every week, which accounts for openings and closures of petrol stations. Table 2 provides the summary statistics of the main variables of study with the *Geoportal data*.

CNMC data. We use monthly province level data on petrol prices and consumption, which are available at the Spanish National Markets and Competition Commission (*Comisión Nacional de Mercados y Competencia*, CNMC). This data, which we will refer as the CNMC dataset, are based on province level price and fuel sales sent by petrol station brands operating in Spain to the Spanish Ministry of Ecological Transition and Demographic Challenge. The CNMC dataset provides average monthly petrol prices by type of diesel and gasoline, as well as total consumption litres by type of diesel and gasoline in each of the 52 Spanish provinces since 2007. The availability of fuel price and sales with such a time and geographic disaggregation is unique, Spain being one of the only European countries collecting and providing such data¹¹. This data constitutes our main source of data to study fuel sales responses to fuel price variation driven by regional excise taxes. Table 3 present the summary statistics for the variables for the *CNMC data*.

Sample selection. We exclude Ceuta, Melilla and the Canary Islands from our analysis since they have different indirect tax regimes and the comparability to the rest of Spain may be limited. We also exclude the petrol stations in the Balearic Islands and those within 50km

¹⁰They use the Open Source Routing Machine (OSRM) using OpenStreetMap data to calculate distances by mode of transport between given geographical coordinates.

¹¹Italy is only other European country providing fuel data at a similar disaggregation, but this is only available from 2015.

from borders with France and Portugal the spatial incidence analysis with the Geoportal data¹². This results in a sample of 9,504 different petrol stations.

4 Empirical strategy

We use various two-way fixed effects specifications for the empirical analysis of this study. First, we use linear panel event study methods to illustrate the dynamic effects of regional excise taxes. Second, we present the two-way fixed effects specification to estimate the geographic incidence of regional diesel taxes across borders. Third, we present the 2SLS specification to estimate the price elasticity of diesel sales using variation in regional excise taxes.

4.1 Event study methods

We use linear panel event study methods in order to provide graphical evidence on the dynamic effects of regional diesel excise tax changes in Spain. This allows to evaluate the plausibility of the exogeneity of regional excise taxes with respect to diesel prices and sales. We follow the event study implementation by Freyaldenhoven et al. (2021)¹³:

$$y_{it} = \alpha_i + \gamma_t + \sum_{m=-G}^M \beta_m \tau_{i,t-m} + \mathbf{x}_{it}\theta + \varepsilon_{it} \quad (1)$$

where y_{it} represents the outcomes of interest, which are diesel and gasoline prices $y_{it} = p_{it}$ and the log of diesel and gasoline consumption $y_{it} = \ln(c_{it})$ for unit i and time t ¹⁴. α_i refers to unit fixed effects and γ_t refer to time fixed effects. $\tau_{i,t-m}$ refer to the effective regional excise taxation of m periods before time t for unit i . \mathbf{x}_{it} refer to control variables that are specified in the summary statistics Table 2. In addition to this, we use endpoint variables ($t_{i,t+M+1} = 1$ for $m > M$ and $t_{i,t-G-1} = 1$ for $m > G$) to normalize the dynamic effects relative to a given pre-reform period. We normalize with respect to $m = 1$ when estimating fuel price responses, while we normalize with respect to $m = 2$ when estimating fuel sales responses,

¹²We only focus on peninsular Spain for our incidence analysis using Geoportal data because we focus on local effects at regional borders.

¹³Regional diesel excise tax changes represent the treatment, which is continuous and multiple per unit.

¹⁴The unit of observation i refers to retail petrol stations and t refers to days when using Geoportal petrol station data, while i refers to Spanish provinces and t to months when using CNMC data.

which addresses the possibility of anticipation to the reform (Coglianese et al., 2017).

4.2 Geographic diesel tax incidence

We study the spatial diesel tax incidence across regional borders, allowing for differential effects of positive or negative tax differentials with respect to neighbouring regions. We further interact the effect of tax differentials with dummies indicating distance from the closest cross-border competitors, which represents the cost of geographic tax avoidance. This drives to the following regression specification¹⁵:

$$P_{it} = \alpha_i + \gamma_t + d_{ij} + \beta_1 \tau_{it} + \beta_2 (\tau_{it} - \tau_{jt}) + \beta_3 \mathbf{1}\{\tau_{it} > \tau_{jt}\} + \beta_4 \mathbf{1}\{\tau_{it} > \tau_{jt}\} \times (\tau_{it} - \tau_{jt}) + \sum_{d=1}^{10} \lambda_d (\tau_{it} - \tau_{jt}) \times d_{ij} + \sum_{d=1}^{10} \eta_d \mathbf{1}\{\tau_{it} > \tau_{jt}\} \times (\tau_{it} - \tau_{jt}) \times d_{ij} + \mathbf{x}_{it} \theta + \varepsilon_{it} \quad (2)$$

where τ_{it} represents the regional diesel excise tax applying to petrol station i , τ_{jt} represents the regional diesel excise tax applying to the closest cross-regional competitor petrol station j , $(\tau_{it} - \tau_{jt})$ represents the tax differential between petrol station the regional diesel tax applying to i to that applying to closest cross-regional competitor j , $\mathbf{1}\{\tau_{it} > \tau_{jt}\}$ represents an indicator taking value 1 if own taxes are larger than the closest cross-border competitor's and 0 otherwise, d_{ij} represent indicator variables taking value 1 if distance between petrol station i and its closest cross-border competitor station j is in 10km bin d , α_i represents petrol station fixed effects and γ_t represents weekly time effects. Standard errors are clustered at the petrol station level.

Based on the coefficient estimates in Equation 2, we derive the pass-through of own regional excise taxes as follows:

$$\frac{\partial P_{it}}{\partial \tau_{it}} = \beta_1 + \beta_2 + \beta_4 \mathbf{1}\{\tau_{it} > \tau_{jt}\} + \sum_{d=1}^{10} \lambda_d \delta_d + \sum_{d=1}^{10} \eta_d \mathbf{1}\{\tau_{it} > \tau_{jt}\} \times \delta_d \quad (3)$$

This implies that the pass-through of petrol stations bordering with a lower tax state in distance range d is $\frac{\partial P_{it}}{\partial \tau_{it}} = \beta_1 + \beta_2 + \lambda_d$, while for those bordering with a lower tax state the

¹⁵Harding et al. (2012) use a similar specification to study the geographic incidence of state tobacco taxes exploiting tax differentials across US states. However, they only consider the distance to the closest tobacco store with in a lower tax state, so they do not consider the asymmetric incidence effect of tax differentials.

pass-through is $\frac{\partial P_{it}}{\partial \tau_{it}} = \beta_1 + \beta_2 + \beta_4 + \lambda_d + \eta_d$.

4.3 Price and tax avoidance elasticity of diesel sales

We use a 2SLS approach to estimate the effect of diesel prices and regional price differentials on spatial diesel sales. Given that diesel prices are endogenous to diesel sales, we use regional variation in excise taxes as an instrument for diesel prices and regional price differentials using the implementation proposed by Baum et al. (2007). We estimate the following regression:

$$\begin{aligned} \ln(S_{it}) = & \alpha_p + \gamma_t + \beta_1 \ln(P_{it}) + \beta_2(\ln(P_{it}) - \ln(P_{jt})) + \beta_3 \mathbf{1}\{\ln(P_{it}) > \ln(P_{jt})\} + \\ & + \beta_4 \mathbf{1}\{\ln(P_{it}) > \ln(P_{jt})\}(\ln(P_{it}) - \ln(P_{jt})) + \mathbf{x}_{it}\theta + \varepsilon_{it} \end{aligned} \quad (4)$$

where $\ln(S_{it})$ represents the log of diesel sales in province i and at time t , $\ln(P_{it})$ represents log of diesel prices in province i and at time t , $\ln(P_{jt})$ represents log of diesel prices of the weighted competitor province j for province i and at time t . In particular, we define $P_{jt} = \sum_{k \neq i} w_{ik} P_{kt}$, where the weights w_{ik} represent the share of petrol stations in province i with closest border is with region k . The same applies for regional excise taxes $\tau_{jt} = \sum_{k \neq i} w_{ik} \tau_{kt}$. In order to calculate these province weights, we find the nearest cross-border competitor petrol stations using Geoportal data.

Since prices are endogenous in Equation 4, we instrument for $\ln(P_{it})$, $(\ln(P_{it}) - \ln(P_{jt}))$, $\mathbf{1}\{\ln(P_{it}) > \ln(P_{jt})\}$ and $\mathbf{1}\{\ln(P_{it}) > \ln(P_{jt})\}(\ln(P_{it}) - \ln(P_{jt}))$ using their respective regional excise tax counterparts. We use clustered standard errors at the province level, and we weight province level observations using their respective number of petrol stations, which represents the sampling unit from which the CNMC collects petrol price and sales data.

5 Results on spatial incidence of diesel taxes

We present our results on the spatial incidence of diesel excise taxes using petrol station *Geoportal data*. First, we provide graphical evidence on the dynamic pass-through of diesel taxes using an event study regression. Second, we describe our baseline diesel tax incidence results across regional borders. Third, we further evaluate the heterogeneity of the baseline

results for the three largest petrol station brands (Repsol, BP and Cepsa) and for smaller petrol station brands. Fourth, we perform several robustness checks.

5.1 Event study evidence

A critical assumption behind the use of regional excise taxes as exogenous variation is that the timing of regional tax changes are uncorrelated with regional trends in diesel prices. We provide graphical evidence on this using the linear panel event study regression presented in Equation 1.

Figure 2 displays the dynamic pass-through of diesel excise taxes. First, we do not observe differential regional price trends leading to excise tax changes, which point to the exogeneity assumption for using regional excise taxes. Second, we estimate roughly full pass-through of diesel excise taxes into prices within two weeks of a tax change. These results are consistent with prior studies (Chouinard and Perloff, 2004; Alm et al., 2009; Marion and Muehlegger, 2011; Stolper, 2021).

5.2 Baseline results

Figure 3 displays our baseline results on the spatial incidence of diesel taxes depending on the distance to the closest cross-border competitor¹⁶. We find that the spatial incidence of diesel taxes is asymmetric depending on the sign of tax differentials to cross-border competitors. When bordering with lower tax jurisdictions, petrol stations within 10km from a cross-border competitor only pass 56% of diesel taxes on to consumers. We do not reject full pass-through at distances above 10km. In contrast, petrol stations bordering with larger tax jurisdictions over-shift diesel taxes, passing 115% to 125% of diesel taxes on to consumers. The length of the effect of tax differentials is also highly asymmetric. While tax disadvantages only drive reduced pass-through at less than 10km from a cross-border competitor, over-shifting of diesel tax advantages extends up to 50km from a cross-border competitor.

While several studies documented a reduced pass-through when bordering with lower tax regions (Harding et al., 2012), this is the first study to document the asymmetry of pass-

¹⁶Table 4 provides the regression results underlying the spatial incidence results.

through depending on whether bordering regions set smaller or larger taxes. We attribute the asymmetric pass-through of diesel taxes around borders to the market power provided by competitive tax advantages. This explanation is consistent with several studies that attribute over-shifting of costs and taxes to market power (Pless and Van Benthem, 2019; Correa-Giraldo et al., 2021). Indeed, Pless and Van Benthem (2019) show that over-shifting of taxes can be used as evidence for market power. This is also consistent with Bajo-Buenestado and Borrella-Mas (2022), who find a larger pass-through for petrol stations with vertical relationships in Spain, which could be expected to have lower marginal costs.

5.3 Heterogeneity in petrol station market power

In this subsection, we study the heterogeneity of the asymmetry in pass-through of diesel taxes depending on the size and market power of petrol stations. For this, we split the sample between top petrol station brands (Repsol, BP and Cepsa) and the rest of petrol stations in Spain, which differ in market power. Top petrol station brands represent around 49.31% of petrol stations in Spain during the time span of our study and a large share of them are vertically integrated with oil refineries in Spain (Bajo-Buenestado and Borrella-Mas, 2022). They could therefore be considered to have market power and smaller supply costs compared to smaller (and generally independent) petrol stations.

Figure 4 displays the spatial incidence of diesel taxes for top petrol station brands and for the rest of the petrol stations. This shows that top petrol station brands drive the more than full pass-through when having a tax advantage, with a pass-through of 125% up to 50km from a border competitor. However, they do not significantly reduce their pass-through when facing a tax disadvantage. On the contrary, smaller petrol station brands drive the reduced pass-through when facing a tax disadvantage, passing only 24% of taxes to consumers within 10km from a cross-border competitor. Small petrol station brands also seem to benefit less from a tax advantage compared to top petrol station brands, especially when facing a relatively close competitor.

The results suggest that petrol stations with lower marginal costs, which is comparable to having lower taxes, are less sensitive to a tax disadvantage. This supports the interpretation of

the asymmetric effect of tax differentials representing the market power given by a competitive cost advantage.

5.4 Robustness checks

We assess the robustness of our results for a number of alternative specifications. The results on spatial incidence of diesel excise taxes for alternative specifications are presented in Table 5, and Figure 5 depicts the spatial incidence depending on travel time from the closest cross-border competitor. Furthermore, Appendix A further provides the robustness checks on the heterogeneity of spatial incidence for top petrol station brands (Table A.1) and the rest of petrol stations (Table A.2).

Control for the closest cross-border station in the second closest region. Spatial pass-through estimates depending on the closest cross-border competitor could be affected by tax differentials relative to the second closest Autonomous Community. We check the robustness of our results to controlling for the closest cross-border competitor from the second closest Autonomous Community. Table 5 shows that controlling for the closest cross-border competitor from the second closest Autonomous Community has little effect on spatial pass-through estimates.

Control for competition on the effect of excise taxes. We check whether spatial pass-through results are reflecting spatial heterogeneity in competition levels. For this, we generate quintiles on the level of competition, which we generate by weighting the number of competitors j by their distance to i below 10km: $Comp_i = \sum_j \frac{1}{1+dist_{ij}}$. We then control quintiles of $Comp_i$ and their interaction with τ_i for each petrol station. Our results are very similar controlling for the effect of competition on diesel pass-through.

Control for province income on the effect of excise taxes. We check whether spatial pass-through results are reflecting spatial heterogeneity in province level incomes. For this, we generate quintiles of province level income and their interaction with τ_i for each petrol station. Our results are very similar controlling for the effect of province income on diesel pass-through.

Travel time instead of distance. The cost of diesel tax avoidance by filling the tank at the neighbouring Autonomous Community can be measured in terms either distance, which measures the monetary cost, or travel time, which measures the time use cost. Figure 5 shows that estimating spatial incidence at different bins of travel times from the closest cross-border competitor provides a similar interpretation as for distances.

6 Results on spatial avoidance of diesel taxes

In this section, we describe the results on spatial sales responses to diesel prices using variation from regional excise tax changes in Spain. We use province level monthly data on diesel prices and sales provided by CNMC, which covers the period since 2007. First, we describe the event study results on the dynamic effect of diesel excise taxes on diesel prices and sales. Second, we estimate diesel sales responses to prices and diesel tax avoidance incentives. Third, we estimate the heterogeneity of diesel price elasticities for subsets of provinces that differ in the possibilities of spatial diesel tax avoidance.

6.1 Event study results

Figure 6 displays the event study results on the dynamic effect of regional excise taxes on diesel prices and diesel sales.

Pass-through estimates. Figure 6a displays the event study plot on the dynamic effect of fuel excise taxes on fuel prices. First, we find no differential regional diesel price trends before diesel excise tax changes, which gives confidence on the exogeneity of the variation of diesel tax changes. Second, we estimate a translation between 90% and 95% of diesel excise taxes into diesel prices within 12 months after an excise tax change. This is in line with prior studies on fuel tax pass-through (Chouinard and Perloff, 2004; Alm et al., 2009; Marion and Muehlegger, 2011).

Sales responses. Figure 6b displays the event study plot on the dynamic effect of fuel excise taxes on fuel sales. First, we find that consumers anticipate the reform and increase their diesel purchases the month prior to the excise tax change, a result consistent with Coglianese et al.

(2017). Our two-way fixed effects regressions drop the observations the month before and after an excise tax change to control for the effect of anticipation of tax changes. Otherwise, we find no evidence of differential regional trends in diesel sales, which is critical for the exogeneity of regional diesel tax instruments. Second, we estimate that diesel sales decrease by 2.24% per cent/litre of diesel 12 months for an increase in one cent/litre of diesel tax.

6.2 Sales responses to prices and cross-border price differentials

Table 6 describes the results on sales responses to prices and cross-border price differentials, which represents the incentive for diesel spatial tax avoidance. Sales responses are estimated using 2SLS regressions where we instrument for diesel prices using variation from their regional excise tax counterparts.

Instrument relevance. Table 6 shows the Kleibergen-Paap Wald F-statistics (Kleibergen and Paap, 2007). We confidently reject the null hypothesis of weak instruments in the first three regression specifications as they are substantially larger than Stock and Yogo (2005) critical values. We cannot be confident about the rejection of the null of weak instruments in our fourth specification ¹⁷. Indeed, standard errors are very large in our fourth specification.

Diesel price elasticities. We show the sensitivity of diesel price elasticities to the effect of tax avoidance using spatial variation in diesel taxes. Without controlling for cross-border price differentials, we estimate a diesel price elasticity of -2.51 using regional tax variation in Spain. This estimate is substantially larger compared to the literature, which estimates elasticities ranging between 0.3 and 0.8 (Sterner, 2006; Brons et al., 2008; Dahl, 2012; Labandeira et al., 2017). However, when controlling for the price differential relative to the closest Autonomous Community, the own price elasticity decrease below -1 and it is not statistically insignificant at standard levels.

Tax avoidance elasticities. We find that the tax avoidance elasticity ranging between -1.72 and -2.50 across our specifications, significant at the 5% significance level. We estimate that the tax avoidance elasticity is stronger when we account for differential effects for provinces

¹⁷Stock and Yogo (2005) critical values are only available up to instrumenting for two endogenous variables.

not sharing a border with other Autonomous Communities, for whom tax avoidance is more costly. Our results on the elasticities of tax avoidance are in line with Banfi et al. (2005) on Swiss international borders and much larger than Jansen and Jonker (2016) for Dutch international borders. We also estimate whether there is an asymmetry depending on the sign of price differentials, and we do not find significant asymmetry. Nevertheless, standard errors are very large in the specification estimating the asymmetric effect of tax avoidance incentives.

Robustness checks. We provide robustness checks of our results in Appendix B. First, Table B.1 provides the robustness of our results to not using province level petrol station weights. Second, Table B.3 estimates the results without dropping the observations immediately before and after an excise tax change, which are dropped in our baseline specification to account for anticipation (Coglianese et al., 2017). The results and the interpretation of the results remain very similar.

6.3 Sensitivity of diesel price elasticities by avoidance possibility

In this subsection, we provide further evidence on the sensitivity of diesel price elasticities to the possibility of spatial avoidance. For this, we estimate 2SLS price elasticities, instrumenting for diesel prices with diesel taxes, for different subsets of provinces that differ in the possibility of spatial avoidance. Table 7 displays the price elasticities of diesel sales for different subsets of provinces in Spain depending on the possibility of regional diesel tax avoidance. We reject the null hypothesis of weak instruments as the Kleibergen-Paap Wald F-statistic (Kleibergen and Paap, 2007) is larger than the Stock and Yogo (2005) critical values, as well as the rule of thumb value of 10 suggested by Staiger and Stock (1997).

Integrated areas. We estimate diesel price elasticities for subsets of provinces represent relatively nearby and integrated areas, obtaining substantially larger elasticities. First, we restrict our estimation to the central part of Spain (Madrid, Avila (Castile-Leon), Segovia (Castile-Leon), Soria (Castile-Leon), Cuenca (Castile-Mancha), Guadalajara (Castile-Mancha) and Toledo (Castile-Mancha)), which are integrated around Madrid, estimating a diesel price elasticity of -4.98. Second, we restrict to the northern area (Cantabria, Basque Country,

Navarre, Rioja, Burgos (Castile-Leon) and Huesca (Aragon)), which is comprised of several small Autonomous Communities and giving access to the Atlantic coast, estimating a diesel price elasticity of -4.50. Third, we restrict to the eastern area (Aragon, Catalonia and Valencian Community), which gives access to the Mediterranean coast, finding a diesel price elasticity of -4.51. These large values of the own price elasticity reveal a large possibility of tax avoidance in the three areas.

No bordering provinces. We estimate diesel price elasticities for the subset of provinces in Spain that do not border with other Autonomous Communities and therefore have limited possibilities of regional fuel tax avoidance. This subset of provinces comprise either islands, are located at the center or at the coast of large Autonomous Communities in Spain. Our estimated price elasticities are reduced to -0.64, which is in the range of responses estimated in the literature (Sterner, 2006; Brons et al., 2008; Dahl, 2012; Labandeira et al., 2017).

Overall, our results suggest that the estimates for diesel price elasticities are very sensitive to the possibilities of spatial avoidance. This calls for careful selection of treatment and control regions when estimating fuel price responses that exploit spatial variation in fuel taxes. We show that fuel price elasticities estimated using spatial tax variation could be overestimated if tax avoidance incentives are not controlled for. The sensitivity of price elasticities to avoidance was previously studied for tobacco by Lovenheim (2008). Furthermore, spatial fuel tax avoidance could be contributing to the estimation of an overreaction to fuel price variation coming from taxes than supply costs (Li et al., 2014; Rivers and Schaufele, 2015; Tiezzi and Verde, 2016).

7 Conclusion

This paper has studied the spatial incidence and tax avoidance responses to diesel taxes in Spain. We use two-way fixed effects methods to study the effect of regional excise tax changes applied by Spanish Autonomous Communities, which were allowed to set diesel excise taxes of up to 4.8 cents/litre between 2002 and 2019.

We find that the pass-through of diesel taxes around borders is asymmetric depending

on the sign of spatial tax differentials. Petrol stations facing larger diesel taxes than their cross-border competitors only pass-through 56% of diesel taxes, while those with lower taxes pass-through around 120% of diesel taxes. Furthermore, the effect of tax disadvantages is restricted to 10km from cross-border competitors, while the effect of tax advantages extends up to 50km from the border.

We find a large spatial pass-through heterogeneity depending on the market power of petrol stations, for which we split the sample depending on top petrol station brands and other smaller brands. We further find that the reduced pass-through for a tax disadvantage is fully driven by small petrol station brands, who can be thought to have larger costs and reduced market power. We attribute the asymmetric effect of tax differentials around borders to the market power provided by the competitive advantage of lower costs relative to competitors.

We also study spatial diesel sales responses to regional taxes using monthly data aggregated at the province level, for which we estimate an elasticity of tax avoidance incentives ranging between -1.72 and -2.50. We find that spatial avoidance is the main margin of responses to spatial variation in diesel taxes. We also show that diesel price elasticities are highly sensitive to controlling for diesel tax avoidance incentives. We show that the estimated price elasticities of diesel sales decrease from -2.51 to -0.66 when controlling for diesel tax avoidance incentives.

Future work should aim, if data availability allows for this, to jointly study the effect of spatial taxes on individual petrol station sales and petrol station pass-through in a structural model. This would allow to make simulations of new fuel tax policies and estimate the welfare effects of fuel taxation. In addition to this, further studies should aim to explore the spatial incidence of fuel taxes across international borders.

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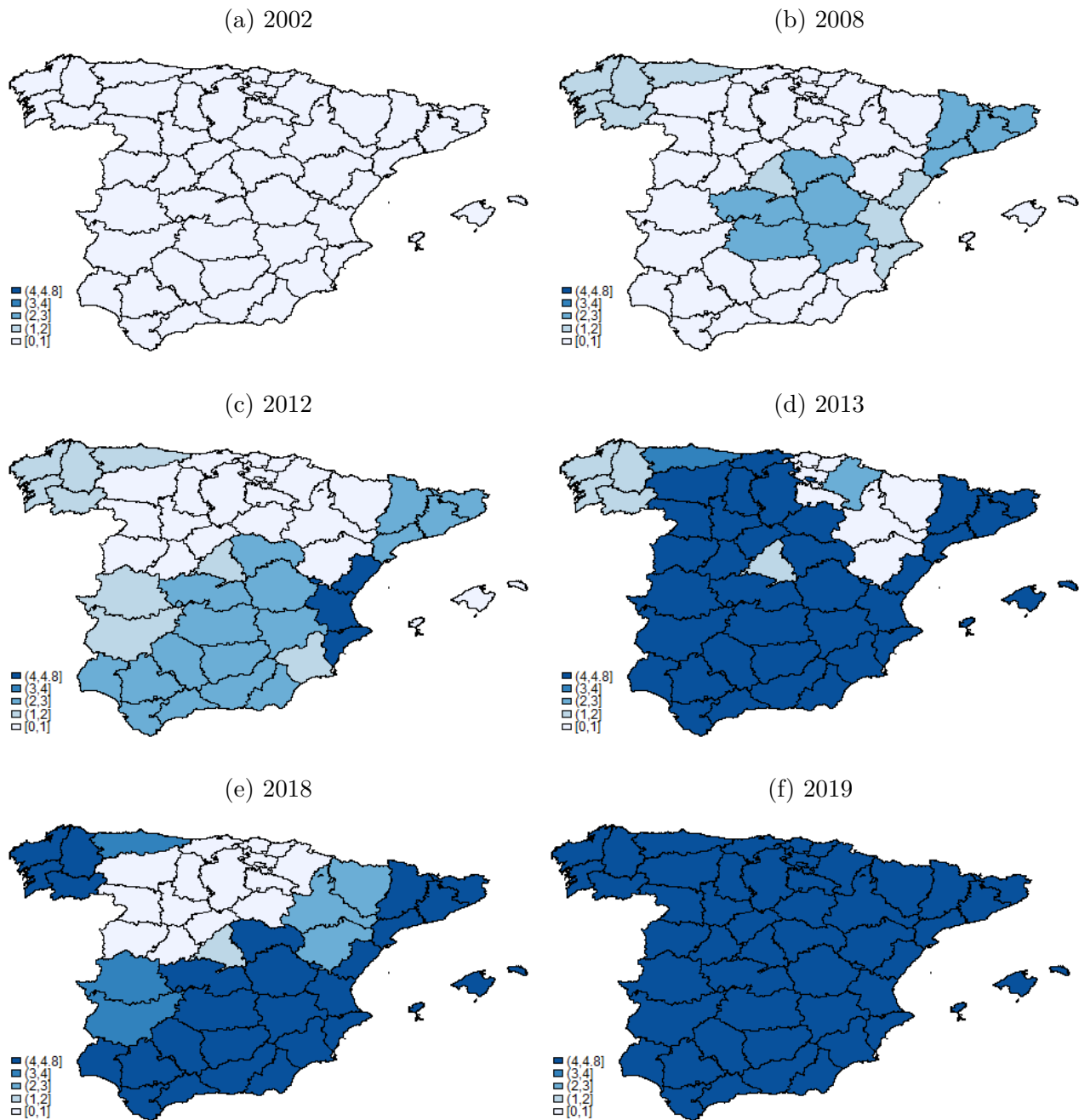
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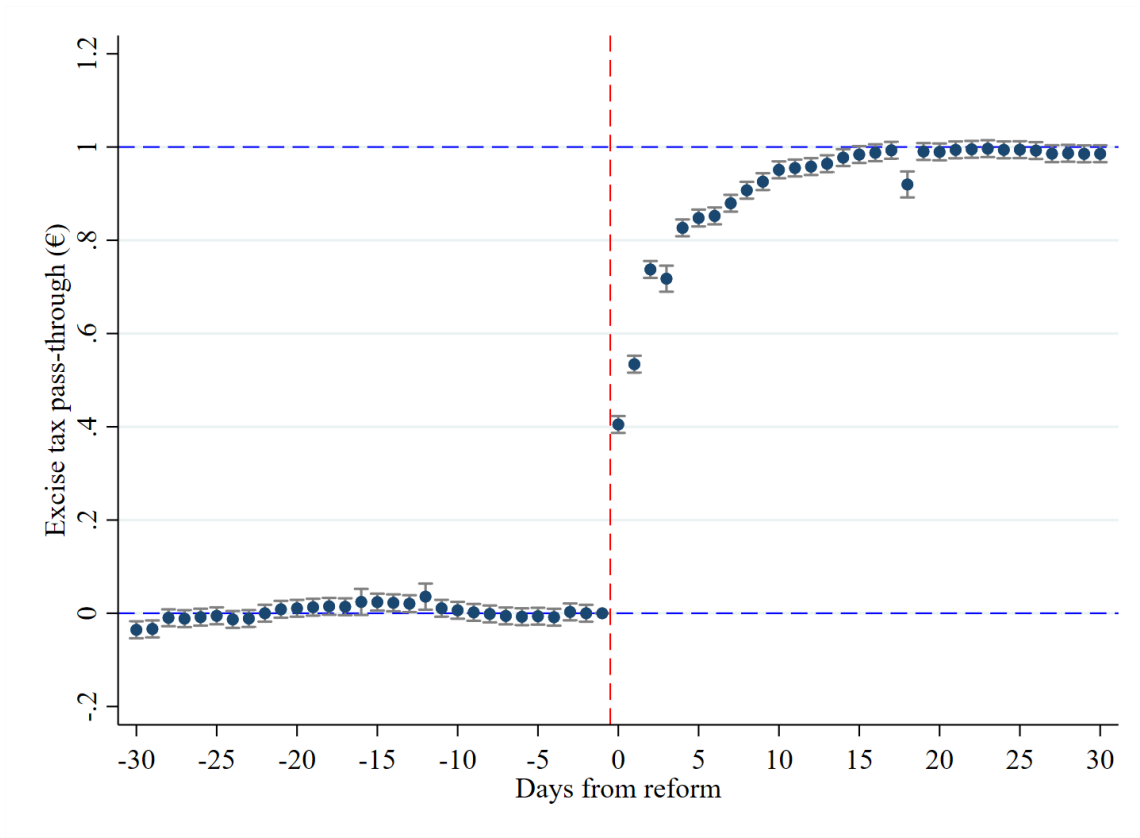
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Figure 1: Regional excise tax for automotive diesel between 2002-2019.



Notes: The figure displays the regional band of automotive diesel excise taxes for Spanish provinces on the 1st January in years 2002 (panel a), 2008 (panel b), 2012 (panel c), 2013 (panel d), 2018 (panel e) and 2019 (panel f). The automotive taxes for gasoline correspond almost identically.
Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

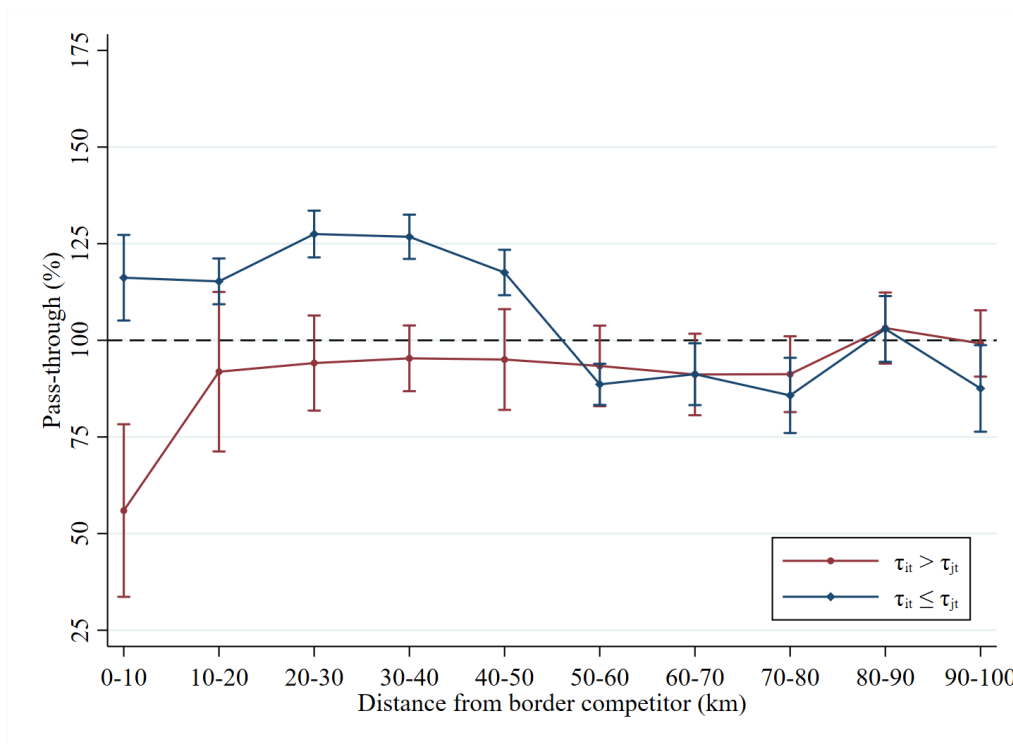
Figure 2: Event study results on diesel excise tax pass-through.



Notes: The figure shows the pass-through estimate of fuel excise taxes on diesel prices in Spain. The vertical dashed red line refers to the day prior to the reform. The pass-through estimate on the top left-hand side refers to the pass-through estimate 30 days after the reform.

Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

Figure 3: Spatial incidence depending on distance to cross-border competitors

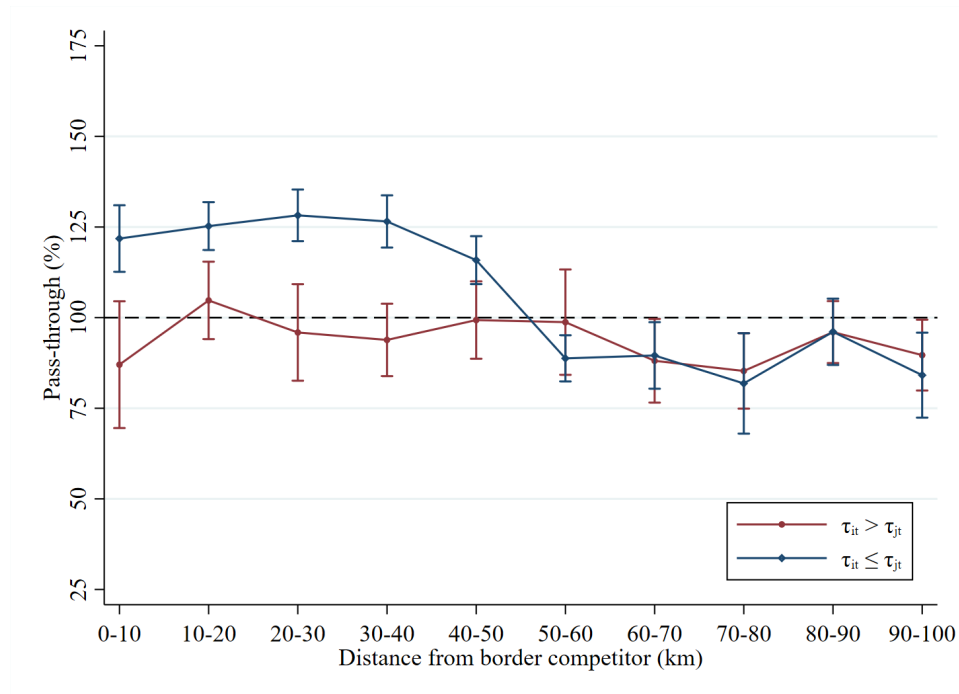


Notes: The figure shows the spatial incidence of diesel taxes depending on the distance to the closest cross-border competitor, provided in 10 km bins. The red line represents the spatial incidence for petrol stations whose excise tax is larger than cross-border competitors. The blue line indicates that own diesel taxes are smaller than cross-border competitors.

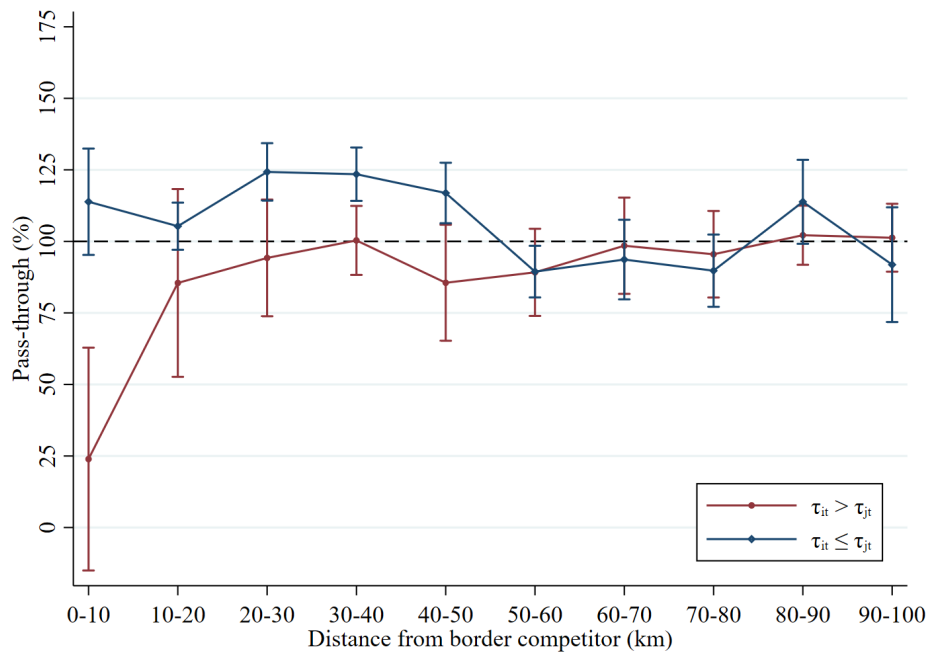
Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

Figure 4: Spatial incidence by type of petrol station

(a) Top petrol station brands



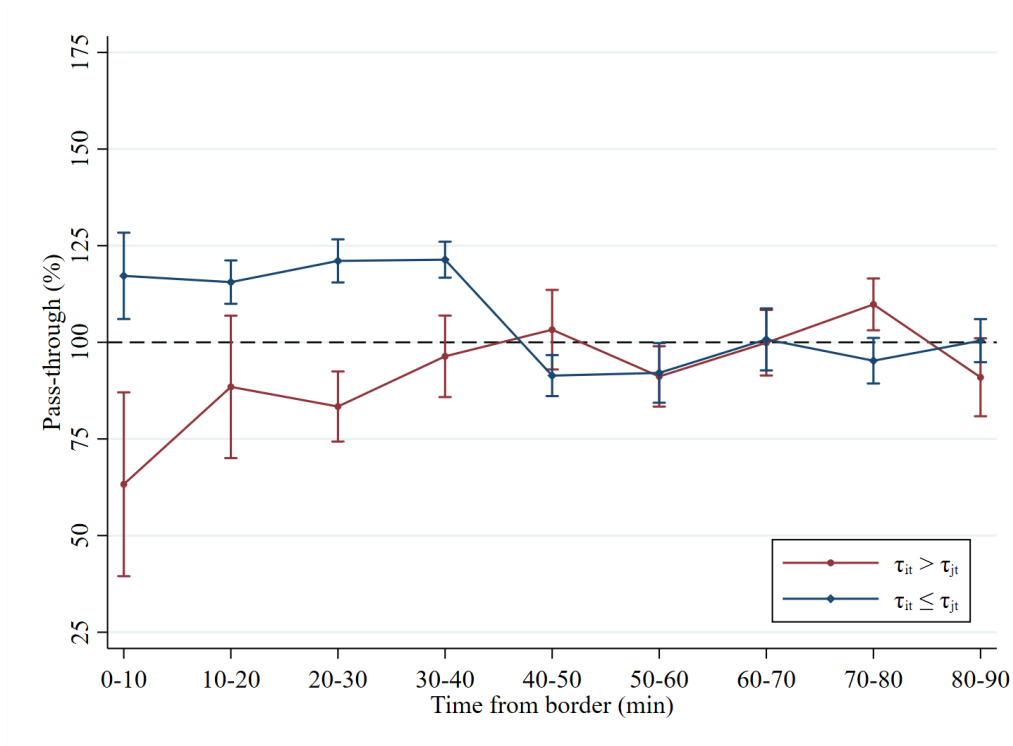
(b) Other brands



Notes: The figure shows the spatial incidence of diesel taxes depending on the distance to the closest cross-border competitor provided for the top petrol station brands (panel a) and the rest of the petrol stations (panel b). The red line represents the spatial incidence for petrol stations whose excise tax is larger than cross-border competitors. The blue line indicates that own diesel taxes are smaller than cross-border competitors.

Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

Figure 5: Spatial incidence depending on travel time to cross-border competitors

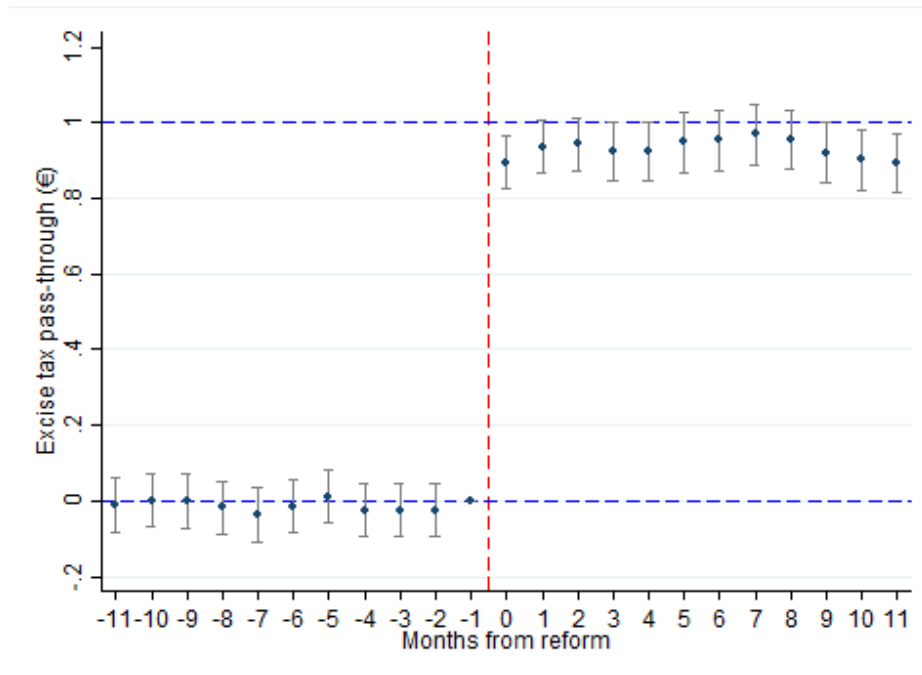


Notes: The figure shows the spatial incidence of diesel taxes depending on the travel time to the closest cross-border competitor, measured in 10 minutes bins. The red line represents the spatial incidence for petrol stations whose excise tax is larger than cross-border competitors. The blue line indicates that own diesel taxes are smaller than cross-border competitors.

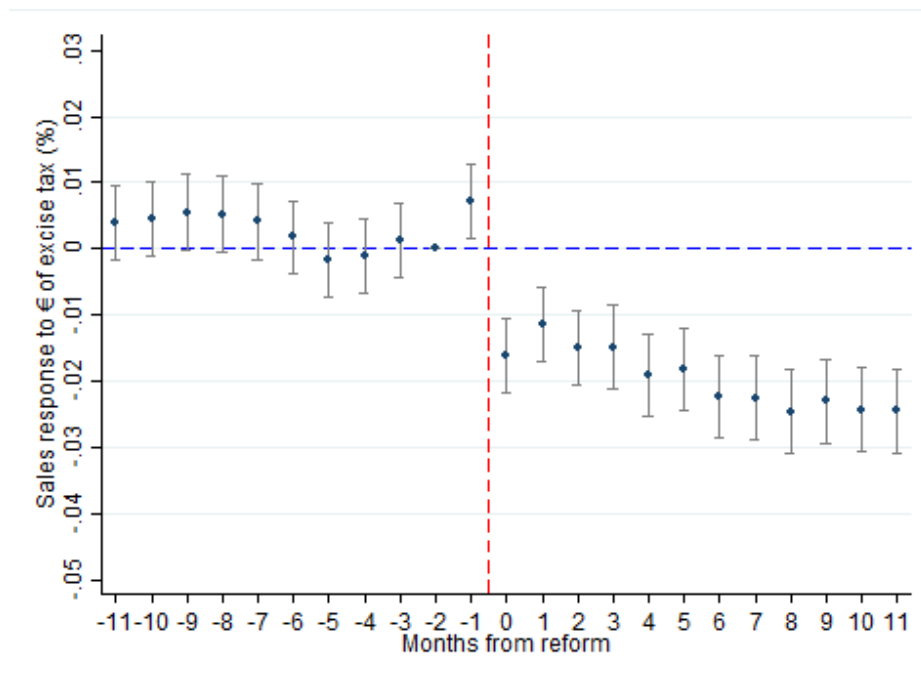
Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

Figure 6: Event study results on price and sales responses to regional diesel excise taxes

(a) Pass-through



(b) Diesel sales responses



Notes: The figure shows the event study graph on the dynamic effect of the diesel excise taxes on diesel prices (panel a) and on sales responses (panel b) up to 11 months before and after a diesel excise tax change. The vertical dashed red line refers to the month prior to the reform.

Source: Spanish National Markets and Competition Commission (CNMC).

Table 1: Characteristics of regional diesel excise tax changes

	All (2002-2019)	Monthly data (2007-2019)	Petrol station data (2014-2019)
	(1)	(2)	(3)
N. of changes	40	33	16
Increases	33	26	11
Decreases	7	7	5
Average dimension (cent/l)	2.69	2.93	2.91
$ \Delta t \leq 2$	12	7	4
$2 < \Delta t \leq 3$	15	13	5
$ \Delta t > 3$	13	13	7

Notes: The table describes the characteristics of regional excise tax changes in Spain. This describes all changes between 2002 and 2019 (column 1), the period for which monthly data is available between 2007 and 2019 (column 2) and the period for which we have petrol station level data (column 3).

Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

Table 2: Summary statistics on the Geoportal dataset

	Mean (1)	S.D. (2)	Min (3)	Max (4)	N(obs) (5)
Diesel prices and taxes (cents/litre)					
Retail price	115.026	10.509	75.914	146.900	2,429,387
Pre-tax price	58.044	8.499	24.839	83.505	2,429,387
Tax component	56.982	2.701	46.330	63.395	2,429,387
Regional excise tax (inc. VAT)	4.742	1.996	0.000	5.808	2,429,387
Tax differential	0.398	2.305	-5.808	5.808	2,429,387
Additional variables					
Brent (cents/litre)	33.29	6.625	16.461	51.633	2,429,387
Type of station (%)					
Top station	55.111	49.738	0.000	100.000	2,429,387
Others	44.889	49.738	0.000	100.000	2,429,387
Distance to closest cross-border comp. (%)					
0-10km	2.497	15.605	0.000	100.000	2,429,387
10-20km	6.563	24.763	0.000	100.000	2,429,387
20-30km	7.707	26.67	0.000	100.000	2,429,387
30-40km	8.695	28.176	0.000	100.000	2,429,387
40-50km	6.176	24.072	0.000	100.000	2,429,387
50-60km	5.494	22.787	0.000	100.000	2,429,387
60-70km	5.628	23.046	0.000	100.000	2,429,387
70-80km	4.893	21.572	0.000	100.000	2,429,387
80-90km	5.958	23.67	0.000	100.000	2,429,387
90-100km	5.954	23.664	0.000	100.000	2,429,387

Notes: The table describes the summary statistics for the main variables of the petrol station price dataset, which covers the period between July 2014 and December 2019. The sample excludes the Canary Islands, Ceuta, Melilla and the Balearic Islands. Observations within 50 km to the borders with Portugal and France are dropped. Diesel regional excise tax represents the tax variation induced by regional excise taxes, including the 21% VAT. Top stations are comprised of top petrol station brands (Repsol, Campsa, BP, Cepsa and Galp).

Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

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Table 3: Summary statistics on main variables using CNMC data

	Mean (1)	S.D. (2)	Min (3)	Max (4)	N(obs) (5)
Diesel products					
Retail price (cents/litre)	116.187	15.228	82.181	146.570	7,488
Pre-tax price (cents/litre)	62.427	11.125	38.119	83.466	7,488
Tax component (cents/litre)	53.760	5.914	41.535	63.338	7,488
Regional excise tax (inc. VAT) (cents/litre)	2.944	2.543	0.000	5.808	7,488
Tax differential (cents/litre)	0.476	2.348	-5.808	5.808	7,488
Price differential (cents/litre)	0.284	2.380	-8.018	9.221	7,488
Total sales (litres)	38280.797	34288.638	3955.610	218952.810	7,488
Additional variables					
Number petrol stations	183.563	135.435	37.000	704.000	7,488
Population	919985.118	1167365.812	89415	6686513	7,488
Real GDP	22696.339	4928.279	14525.440	40748.402	7,488
Employment rate (%)	47.150	5.542	32.78	63.12	7,488

Notes: The table describes the summary statistics for the main variables of the CNMC dataset, which covers the period between 2007 and February 2020. This considers monthly data for all Spanish provinces excluding the Canary Islands, Ceuta and Melilla.
Source: Spanish National Markets and Competition Commission (CNMC).

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Table 4: Regression results on spatial incidence of diesel excise taxes

	Baseline (1)	Control 2 nd (2)	Control compet. (3)	Control inc. (4)
τ_{it}	1.05*** (0.01)	1.06*** (0.01)	1.04*** (0.02)	1.05*** (0.02)
$\tau_{it} - \tau_{jt}$	-0.08*** (0.02)	-0.06** (0.02)	-0.08*** (0.02)	-0.04 (0.02)
$\tau_{it} - \tau_{jt} \times 1\{\tau_{it} > \tau_{jt}\}$	-0.06* (0.03)	-0.11*** (0.03)	-0.06* (0.03)	-0.10** (0.03)
$1\{dist_{ij} \in [0 - 10]\} \times (\tau_{it} - \tau_{jt})$	0.19*** (0.06)	0.16** (0.06)	0.19*** (0.06)	0.10 (0.06)
$1\{dist_{ij} \in [0 - 10]\} \times (\tau_{it} - \tau_{jt}) \times 1\{\tau_{it} > \tau_{jt}\}$	-0.54*** (0.13)	-0.48*** (0.13)	-0.54*** (0.13)	-0.42*** (0.13)
$1\{dist_{ij} \in [10 - 20]\} \times (\tau_{it} - \tau_{jt})$	0.18*** (0.03)	0.13*** (0.03)	0.16*** (0.03)	0.09** (0.04)
$1\{dist_{ij} \in [10 - 20]\} \times (\tau_{it} - \tau_{jt}) \times 1\{\tau_{it} > \tau_{jt}\}$	-0.18 (0.11)	-0.07 (0.11)	-0.14 (0.11)	-0.10 (0.11)
$1\{dist_{ij} \in [20 - 30]\} \times (\tau_{it} - \tau_{jt})$	0.31*** (0.03)	0.23*** (0.03)	0.26*** (0.03)	0.21*** (0.04)
$1\{dist_{ij} \in [20 - 30]\} \times (\tau_{it} - \tau_{jt}) \times 1\{\tau_{it} > \tau_{jt}\}$	-0.28*** (0.07)	-0.18* (0.07)	-0.24*** (0.07)	-0.20** (0.07)
$1\{dist_{ij} \in [30 - 40]\} \times (\tau_{it} - \tau_{jt})$	0.30*** (0.03)	0.20*** (0.03)	0.24*** (0.03)	0.19*** (0.04)
$1\{dist_{ij} \in [30 - 40]\} \times (\tau_{it} - \tau_{jt}) \times 1\{\tau_{it} > \tau_{jt}\}$	-0.26*** (0.06)	-0.12* (0.06)	-0.20*** (0.06)	-0.16** (0.06)
$1\{dist_{ij} \in [40 - 50]\} \times (\tau_{it} - \tau_{jt})$	0.21*** (0.03)	0.13*** (0.03)	0.17*** (0.03)	0.12*** (0.03)
$1\{dist_{ij} \in [40 - 50]\} \times (\tau_{it} - \tau_{jt}) \times 1\{\tau_{it} > \tau_{jt}\}$	-0.17* (0.08)	-0.07 (0.08)	-0.13 (0.07)	-0.09 (0.07)
$1\{dist_{ij} \in [50 - 60]\} \times (\tau_{it} - \tau_{jt})$	-0.08** (0.03)	-0.12*** (0.03)	-0.08** (0.03)	-0.12*** (0.03)
$1\{dist_{ij} \in [50 - 60]\} \times (\tau_{it} - \tau_{jt}) \times 1\{\tau_{it} > \tau_{jt}\}$	0.11 (0.06)	0.17** (0.06)	0.10 (0.06)	0.15* (0.06)
$1\{dist_{ij} \in [60 - 70]\} \times (\tau_{it} - \tau_{jt})$	-0.06 (0.04)	-0.08 (0.05)	-0.04 (0.04)	-0.07 (0.04)
$1\{dist_{ij} \in [60 - 70]\} \times (\tau_{it} - \tau_{jt}) \times 1\{\tau_{it} > \tau_{jt}\}$	0.06 (0.07)	0.11 (0.07)	0.05 (0.07)	0.07 (0.07)
$1\{dist_{ij} \in [70 - 80]\} \times (\tau_{it} - \tau_{jt})$	-0.11* (0.05)	-0.13* (0.05)	-0.07 (0.05)	-0.11* (0.05)
$1\{dist_{ij} \in [70 - 80]\} \times (\tau_{it} - \tau_{jt}) \times 1\{\tau_{it} > \tau_{jt}\}$	0.11 (0.07)	0.16* (0.07)	0.07 (0.07)	0.12 (0.07)
$1\{dist_{ij} \in [80 - 90]\} \times (\tau_{it} - \tau_{jt})$	0.06 (0.05)	0.06 (0.05)	0.04 (0.04)	0.05 (0.04)
$1\{dist_{ij} \in [80 - 90]\} \times (\tau_{it} - \tau_{jt}) \times 1\{\tau_{it} > \tau_{jt}\}$	0.06 (0.07)	0.09 (0.07)	0.08 (0.07)	0.07 (0.07)
$1\{dist_{ij} \in [90 - 100]\} \times (\tau_{it} - \tau_{jt})$	-0.10 (0.06)	-0.10 (0.06)	-0.10 (0.06)	-0.09 (0.05)
$1\{dist_{ij} \in [90 - 100]\} \times (\tau_{it} - \tau_{jt}) \times 1\{\tau_{it} > \tau_{jt}\}$	0.16* (0.07)	0.20** (0.08)	0.17* (0.07)	0.16* (0.07)
N (obs)	2,428,919	2,428,919	2,428,919	2,428,919

Notes: This table provides regression results to estimate spatial incidence using alternative specifications, including baseline results for a tax disadvantage (column 1) and a tax advantage (column 2) relative to the closest competitor; controlling for the second closest competitor from a different Autonomous Community for a tax disadvantage (column 3) and a tax advantage (column 4); controlling for quintiles of the level of competition on the effect of pass-through for a tax disadvantage (column 5) and a tax advantage (column 6); quintiles of province level income on the effect of pass-through for a tax disadvantage (column 7) and a tax advantage (column 8). The table only reports the results from parameters used to calculate the pass-through. Standard errors clustered at the province level in parenthesis. * p<0.05, ** p<0.01, *** p<0.001.

Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

Table 5: Spatial incidence of diesel excise taxes

	Baseline results		Control 2 nd closest		Control competition		Control prov income	
	$\tau_{it} \leq \tau_{jt}$ (1)	$\tau_{it} > \tau_{jt}$ (2)	$\tau_{it} \leq \tau_{jt}$ (3)	$\tau_{it} > \tau_{jt}$ (4)	$\tau_{it} \leq \tau_{jt}$ (5)	$\tau_{it} > \tau_{jt}$ (6)	$\tau_{it} \leq \tau_{jt}$ (7)	$\tau_{it} > \tau_{jt}$ (8)
0-10km	55.89 (11.39)	116.2 (5.65)	56.97 (11.44)	115.6 (5.48)	56.62 (11.67)	116.26 (5.78)	57.47 (11.53)	109.03 (5.92)
10-20km	91.81 (10.53)	115.27 (3.02)	95.56 (10.74)	113.08 (3.02)	92.08 (10.64)	112.33 (3.25)	88.7 (10.48)	108.00 (3.11)
20-30km	94.06 (6.28)	127.53 (3.09)	94.71 (6.3)	123.19 (3.01)	93.59 (6.46)	123.15 (3.36)	90.01 (6.38)	119.13 (3.10)
30-40km	95.29 (4.34)	126.82 (2.92)	97.42 (4.38)	120.21 (3.06)	94.96 (4.57)	121.2 (3.37)	92.22 (4.5)	117.75 (2.96)
40-50km	94.95 (6.65)	117.56 (3.00)	94.73 (6.63)	113.17 (2.89)	94.72 (6.75)	113.48 (3.22)	91.79 (6.74)	110.58 (2.87)
50-60km	93.3 (5.32)	88.61 (2.72)	93.24 (5.35)	87.45 (2.81)	93.18 (5.51)	88.7 (3.12)	92.08 (5.39)	86.38 (2.83)
60-70km	91.13 (5.38)	91.22 (4.08)	91.97 (5.38)	91.5 (4.31)	91.11 (5.57)	92.5 (4.4)	89.31 (5.59)	91.92 (4.22)
70-80km	91.08 (5.00)	85.77 (4.96)	92.15 (5.02)	86.75 (5.07)	90.71 (5.23)	89.86 (5.14)	89.46 (5.16)	87.2 (5.01)
80-90km	102.57 (4.68)	102.76 (4.33)	103.93 (4.72)	105.53 (4.48)	102.69 (4.9)	100.83 (4.33)	101.1 (4.85)	103.28 (4.42)
90-100km	97.64 (4.36)	87.21 (5.69)	98.59 (4.4)	89.93 (5.71)	97.73 (4.61)	86.52 (5.74)	95.92 (4.53)	89.66 (5.62)
N (obs)	2,428,919		2,428,919		2,428,919		2,428,919	

Notes: This table provides spatial incidence using alternative specifications, including baseline results for a tax disadvantage (column 1) and a tax advantage (column 2) relative to the closest competitor; controlling for the second closest competitor from a different Autonomous Community for a tax disadvantage (column 3) and a tax advantage (column 4); controlling for quintiles of the level of competition on the effect of pass-through for a tax disadvantage (column 5) and a tax advantage (column 6); quintiles of province level income on the effect of pass-through for a tax disadvantage (column 7) and a tax advantage (column 8). Standard errors clustered at the province level in parenthesis.

Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

Table 6: 2SLS diesel spatial avoidance effects of spatial taxes

	(1)	(2)	(3)	(4)
$\ln(p_{it})$	-2.51*** (0.43)	-0.89 (0.92)	-0.66 (0.96)	-1.05 (0.98)
$\ln(p_{it}) - \ln(p_{jt})$		-1.72* (0.88)	-2.50* (0.98)	-1.56 (2.59)
No border $\times (\ln(p_{it}) - \ln(p_{jt}))$			2.02* (0.93)	
$\mathbf{1}\{\ln(p_{it}) > \ln(p_{jt})\} \times (\ln(p_{it}) - \ln(p_{jt}))$				-0.56 (2.78)
First stage (F-stat)	324.81	22.44	12.25	2.81
Endogenous variables	1	2	3	4
N (obs)	7,286	7,286	7,286	7,286

Notes: This table provides 2SLS results on the effect of diesel prices and diesel price differentials from neighbouring provinces on diesel sales. The Kleibergen-Paap rk Wald F-statistic is reported for instrument relevance. Province observations are weighted by the number of petrol stations. Standard errors clustered at the province level in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Spanish National Markets and Competition Commission (CNMC).

Table 7: 2SLS price elasticities for different subsets of provinces

	All Spain (1)	Integrated			No border (5)
		Center (2)	North (3)	East (4)	
ε	-2.51*** (0.43)	-4.98*** (0.64)	-4.50* (1.85)	-4.51*** (0.98)	-0.64 (0.44)
First stage (F-Stat)	324.81	436.56	232.37	34.54	54.84
Endogenous variables	1	1	1	1	1
N (obs)	7,286	1,060	1,210	1,534	1,222

Notes: This table provides the diesel price elasticities for different subsets of provinces in Spain, including all provinces in Spain apart from the Canary Islands, Ceuta and Melilla (column 1), central Autonomous Communities (Madrid, Toledo, Avila, Segovia, Guadalajara, Cuenca and Soria) (column 2), the northern area (Cantabria, Basque Country, Navarre, Rioja, Burgos (Castile-Leon) and Huesca (Aragon)) (column 3), eastern area (Aragon, Catalonia and Valencian Community) (column 4) and provinces not sharing a border with another region (Balearic Islands, Girona, Barcelona, A Coruña, Pontevedra, Valladolid, Cadiz and Malaga) (column 5). The Kleibergen-Paap rk Wald F-statistic is reported for instrument relevance. Province observations are weighted by the number of petrol stations. Standard errors clustered at the province level in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Spanish National Markets and Competition Commission (CNMC).

Appendix to

Incidence and Avoidance Effects of Spatial Fuel Tax
Differentials: Evidence using Regional Tax Variation in
Spain.

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A Appendix: Robustness checks on spatial pass-through

This Appendix presents the robustness checks on our baseline results on spatial incidence for petrol station brands differing on their market power. Table A.1 presents spatial incidence for top petrol station brands using alternative specifications and Table A.2 presents the robustness of our results for smaller petrol station brands. Furthermore, Figure A.1 displays the spatial incidence for top (Figure A.1a) and smaller (Figure A.1b) petrol station brands depending on the travel time to the closest cross-border competitor.

Table A.1: Spatial incidence of diesel excise taxes for top petrol stations

	Baseline results		Control 2 nd closest		Control competition		Control prov income	
	$\tau_{it} \leq \tau_{jt}$ (1)	$\tau_{it} > \tau_{jt}$ (2)	$\tau_{it} \leq \tau_{jt}$ (3)	$\tau_{it} > \tau_{jt}$ (4)	$\tau_{it} \leq \tau_{jt}$ (5)	$\tau_{it} > \tau_{jt}$ (6)	$\tau_{it} \leq \tau_{jt}$ (7)	$\tau_{it} > \tau_{jt}$ (8)
0-10km	87.03 (8.92)	121.82 (4.69)	88.56 (7.5)	120.6 (4.54)	90.98 (8.73)	124.83 (4.6)	90.74 (9.7)	112.49 (5.23)
10-20km	104.75 (5.45)	125.25 (3.37)	110.09 (5.74)	123.18 (3.3)	107.4 (5.33)	125.25 (2.92)	102.01 (5.32)	116.93 (3.23)
20-30km	95.91 (6.79)	128.22 (3.64)	98.23 (6.69)	124.55 (3.67)	97.83 (6.71)	125.27 (3.37)	92.01 (6.82)	117.48 (3.49)
30-40km	93.85 (5.1)	126.54 (3.68)	96.73 (5.21)	121.36 (3.92)	96.16 (5.09)	122.15 (3.54)	91.47 (5.24)	114.22 (3.62)
40-50km	99.33 (5.44)	115.86 (3.37)	100.97 (5.51)	112.81 (3.43)	101.63 (5.41)	114.13 (3.15)	97.19 (5.39)	106.42 (3.08)
50-60km	98.76 (7.42)	88.77 (3.25)	101.59 (7.49)	88.65 (3.36)	101.97 (7.46)	93.69 (3.22)	100.62 (7.22)	88.49 (3.19)
60-70km	88.1 (5.89)	89.57 (4.69)	90.33 (5.98)	91.12 (4.89)	91.37 (5.91)	94.96 (4.77)	89.12 (6.25)	93.38 (4.58)
70-80km	85.29 (5.3)	81.85 (7.07)	88.22 (5.41)	83.75 (7.15)	87.76 (5.33)	89.43 (7.11)	86.92 (5.54)	84.72 (6.97)
80-90km	96.02 (4.36)	96.09 (4.67)	99.4 (4.43)	98.78 (4.9)	98.97 (4.37)	96.88 (4.26)	97.82 (4.65)	96.56 (4.44)
90-100km	89.66 (4.98)	84.13 (5.98)	92.29 (5.05)	86.61 (6.17)	92.58 (4.97)	86.33 (6.02)	90.71 (5.2)	87.81 (5.02)
N (obs)	1,197,862		1,197,862		1,197,862		1,197,862	

Notes: This table provides spatial incidence for petrol stations from top brands (Repsol, BP and Cepsa) using alternative specifications, including baseline results for a tax disadvantage (column 1) and a tax advantage (column 2) relative to the closest competitor; controlling for the second closest competitor from a different Autonomous Community for a tax disadvantage (column 3) and a tax advantage (column 4); controlling for quintiles of the level of competition on the effect of pass-through for a tax disadvantage (column 5) and a tax advantage (column 6); quintiles of province level income on the effect of pass-through for a tax disadvantage (column 7) and a tax advantage (column 8). Standard errors clustered at the province level in parenthesis.

Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

Table A.2: Small petrol stations: Spatial incidence of diesel excise taxes

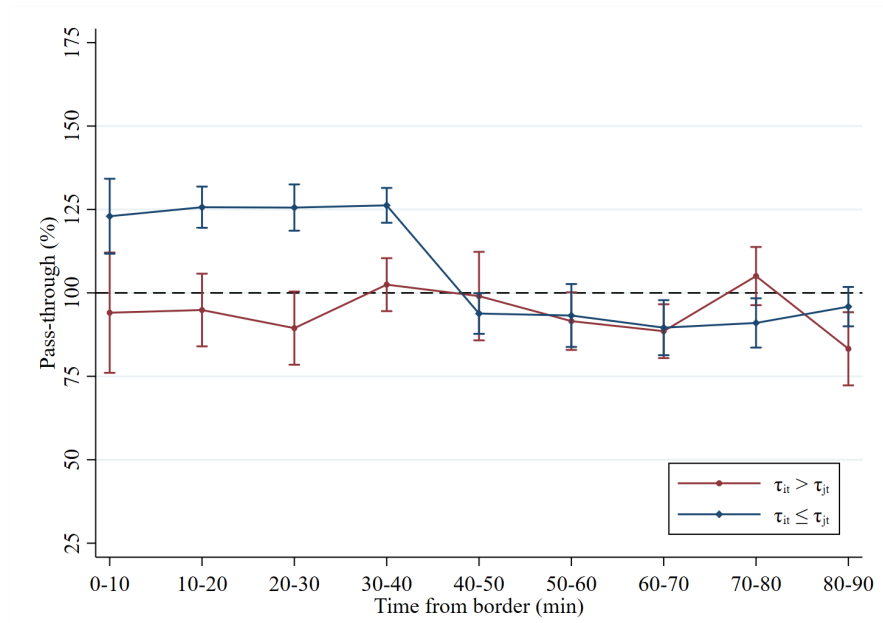
	Baseline results		Control 2 nd closest		Control competition		Control prov income	
	$\tau_{it} \leq \tau_{jt}$ (1)	$\tau_{it} > \tau_{jt}$ (2)	$\tau_{it} \leq \tau_{jt}$ (3)	$\tau_{it} > \tau_{jt}$ (4)	$\tau_{it} \leq \tau_{jt}$ (5)	$\tau_{it} > \tau_{jt}$ (6)	$\tau_{it} \leq \tau_{jt}$ (7)	$\tau_{it} > \tau_{jt}$ (8)
0-10km	23.92 (19.87)	113.86 (9.48)	26.91 (23.29)	114.83 (9.11)	25.8 (20.2)	115.84 (9.37)	24.63 (20.02)	107.9 (9.8)
10-20km	85.47 (16.74)	105.31 (4.2)	89.52 (16.77)	103.95 (4.22)	88.41 (16.59)	105.23 (4.16)	82.74 (16.57)	98.94 (4.57)
20-30km	94.22 (10.41)	124.29 (5.12)	95.68 (10.35)	120.9 (4.84)	96.93 (10.45)	124.42 (4.97)	90.47 (10.6)	117.42 (5.14)
30-40km	100.35 (6.15)	123.48 (4.76)	103.88 (6.09)	118.29 (4.58)	102.45 (6.16)	122.98 (4.51)	97.27 (6.48)	116.96 (4.79)
40-50km	85.55 (10.34)	116.91 (5.39)	86.05 (10.37)	114.28 (4.98)	87.63 (10.31)	116.2 (5.24)	81.82 (10.54)	112.58 (5.23)
50-60km	89.18 (7.77)	89.44 (4.6)	89.01 (7.6)	89.47 (4.63)	90.7 (7.83)	89.81 (4.65)	86.65 (8.13)	86.57 (4.85)
60-70km	98.48 (8.58)	93.65 (7.1)	99.68 (8.62)	94.54 (7.4)	100.42 (8.62)	95.99 (7.27)	95.43 (8.86)	93.7 (7.39)
70-80km	95.51 (7.71)	89.76 (6.44)	97.14 (7.72)	91.94 (6.73)	97.24 (7.75)	95.21 (6.5)	92.3 (8.03)	91.74 (6.71)
80-90km	102.16 (5.27)	113.83 (7.49)	103.8 (5.35)	118.82 (7.67)	104.52 (5.29)	114.66 (7.12)	99.11 (5.64)	116.6 (7.95)
90-100km	101.27 (6.05)	91.86 (10.23)	102.67 (6.11)	96.48 (10.05)	103.51 (6.1)	93.11 (10.07)	98.31 (6.39)	95.56 (10.94)
N (obs)	1,231,057		1,231,057		1,231,057		1,231,057	

Notes: This table provides spatial incidence for petrol stations from smaller brands (those except from Repsol, BP and Cepsa) using alternative specifications, including baseline results for a tax disadvantage (column 1) and a tax advantage (column 2) relative to the closest competitor; controlling for the second closest competitor from a different Autonomous Community for a tax disadvantage (column 3) and a tax advantage (column 4); controlling for quintiles of the level of competition on the effect of pass-through for a tax disadvantage (column 5) and a tax advantage (column 6); quintiles of province level income on the effect of pass-through for a tax disadvantage (column 7) and a tax advantage (column 8). Standard errors clustered at the province level in parenthesis.

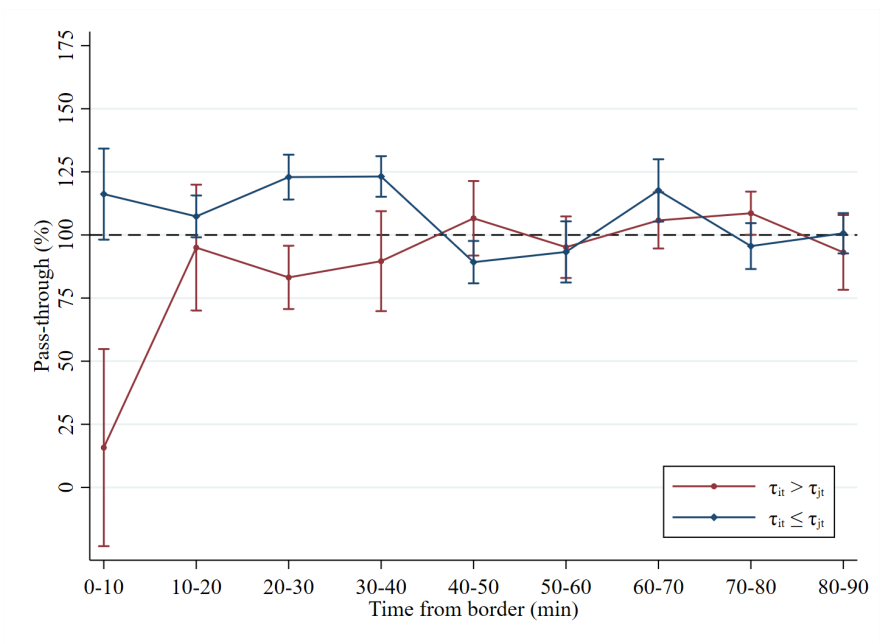
Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

Figure A.1: Spatial incidence by type of petrol station

(a) Top petrol station brands



(b) Other brands



Notes: The figure shows the spatial incidence of diesel taxes depending on the travel time to the closest cross-border competitor provided for the top petrol station brands (panel a) and the rest of the petrol stations (panel b). The red line represents the spatial incidence for petrol stations whose excise tax is larger than cross-border competitors. The blue line indicates that own diesel taxes are smaller than cross-border competitors.

Source: Spanish Ministry of Ecological Transition and Demographic Challenge.

B Appendix: Robustness checks on sales responses

Not weighting results by petrol stations. We assess the robustness of our results to not using province level weights for the total petrol stations from whom the fuel data is collected.

Table B.1 and Table B.2 show that our results and their interpretation are very similar.

Table B.1: Unweighted 2SLS diesel spatial avoidance effects of spatial taxes

	(1)	(2)	(3)	(4)
$\ln(p_{it})$	-3.10*** (0.65)	-0.79 (1.40)	-0.65 (1.44)	-0.80 (1.47)
$\ln(p_{it}) - \ln(p_{jt})$		-2.38* (1.11)	-2.96* (1.25)	-1.31 (2.66)
No border $\times (\ln(p_{it}) - \ln(p_{jt}))$			2.17* (0.88)	
$\mathbf{1}\{\ln(p_{it}) > \ln(p_{jt})\} \times (\ln(p_{it}) - \ln(p_{jt}))$				-0.87 (2.58)
First stage (F-stat)	420.456	21.38	13.66	4.31
Endogenous variables	1	2	3	4
N (obs)	7,286	7,286	7,286	7,286

Notes: This table provides 2SLS results on the effect of diesel prices and diesel price differentials from neighbouring provinces on diesel sales. The Kleibergen-Paap rk Wald F-statistic is reported for instrument relevance. Province observations are weighted by the number of petrol stations. Standard errors clustered at the province level in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: Spanish National Markets and Competition Commission (CNMC).

Table B.2: Unweighted 2SLS price elasticities for different subsets of provinces

	All Spain (1)	Integrated			No border (5)
		Center (2)	North (3)	East (4)	
ϵ	-3.10*** (0.65)	-3.51*** (0.96)	-4.74* (2.01)	-5.77*** (1.50)	-0.70* (0.31)
First stage (F-Stat)	420.46	182.11	254.66	19.36	97.71
Endogenous variables	1	1	1	1	1
N (obs)	7,286	1,060	1,210	1,534	1,222

Notes: This table provides the diesel price elasticities for different subsets of provinces in Spain, including all provinces in Spain apart from the Canary Islands, Ceuta and Melilla (column 1), central Autonomous Communities (Madrid, Toledo, Avila, Segovia, Guadalajara, Cuenca and Soria) (column 2), the northern area (Cantabria, Basque Country, Navarre, Rioja, Burgos (Castile-Leon) and Huesca (Aragon)) (column 3), eastern area (Aragon, Catalonia and Valencian Community) (column 4) and provinces not sharing a border with another region (Balearic Islands, Girona, Barcelona, A Coruña, Pontevedra, Valladolid, Cadiz and Malaga) (column 5). Standard errors clustered at the province level in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: Spanish National Markets and Competition Commission (CNMC).

Keeping anticipation observations. We also assess the sensitivity of results when not dropping the observations immediately before and after an excise tax change, which are dropped in our baseline specification to control for anticipation. Table B.3 and Table B.4 show that dropping these observations to account for the effect of anticipation to the reform has a very small effect on the estimated price elasticities.

Table B.3: 2SLS diesel spatial avoidance effects of spatial taxes

	(1)	(2)	(3)	(4)
$\ln(p_{it})$	-2.50*** (0.41)	-0.87 (0.90)	-0.64 (0.94)	-1.02 (0.94)
$\ln(p_{it}) - \ln(p_{jt})$		-1.73* (0.87)	-2.50* (0.97)	-1.32 (2.57)
No border $\times (\ln(p_{it}) - \ln(p_{jt}))$			2.01* (0.91)	
$\mathbf{1}\{\ln(p_{it}) > \ln(p_{jt})\} \times (\ln(p_{it}) - \ln(p_{jt}))$				-0.77 (2.72)
First stage (F-stat)	324.81	22.65	12.44	2.76
Endogenous variables	1	2	3	4
N (obs)	7,488	7,488	7,488	7,488

Notes: This table provides 2SLS results on the effect of diesel prices and diesel price differentials from neighbouring provinces on diesel sales. The Kleibergen-Paap rk Wald F-statistic is reported for instrument relevance. Province observations are weighted by the number of petrol stations. Standard errors clustered at the province level in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: Spanish National Markets and Competition Commission (CNMC).

Table B.4: 2SLS price elasticities for different subsets of provinces

	All Spain (1)	Integrated			No border (5)
		Center (2)	North (3)	East (4)	
ϵ	-2.50*** (0.41)	-4.93*** (0.62)	-4.45* (1.84)	-4.35*** (0.95)	-0.66 (0.44)
First stage (F-Stat)	362.19	449.30	233.69	41.28	59.66
Endogenous variables	1	1	1	1	1
N (obs)	7,488	1,092	1,248	1,560	1,248

Notes: This table provides the diesel price elasticities for different subsets of provinces in Spain, including all provinces in Spain apart from the Canary Islands, Ceuta and Melilla (column 1), central Autonomous Communities (Madrid, Toledo, Avila, Segovia, Guadalajara, Cuenca and Soria) (column 2), the northern area (Cantabria, Basque Country, Navarre, Rioja, Burgos (Castile-Leon) and Huesca (Aragon)) (column 3), eastern area (Aragon, Catalonia and Valencian Community) (column 4) and provinces not sharing a border with another region (Balearic Islands, Girona, Barcelona, A Coruña, Pontevedra, Valladolid, Cadiz and Malaga) (column 5). Standard errors clustered at the province level in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: Spanish National Markets and Competition Commission (CNMC).