The Distributional Consequences of Tax Pass-Through: The Case of Germany's Fuel Tax Discount

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Abstract

Exploiting exogenous variation in retail fuel prices from a temporary fuel tax discount in Germany, we explore the distributional consequences emerging from differential pass-through rates over space and time. We draw on daily gasoline prices of virtually all gas stations in Germany and neighboring France, with France serving as a control site, and estimate an event study model covering the full period of the discount from June to August 2022. We find average pass-through rates on the order of 96% for diesel and 82% for petrol, but with substantial variability by regional income and station density. Our results additionally reveal heterogeneity over time: The magnitude of the pass-through rate dissipates sharply for both fuel types over the three months in which the discount was in effect, dropping to 46% for diesel and 74% for petrol by the final month, a pattern consistent with retailer responses to short-term changes in consumer attention. Taken together, our results indicate that average pass-through estimates may obscure spatial and temporal heterogeneity that bears upon the assessment of distributional effects: A back-of-the envelop calculation indicates that 62% of the discount's financial relief accrues to households with above-median incomes.

JEL codes: L13, L81, D43.

Keywords: Competition, demand elasticity, gasoline market.

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1 Introduction

The high visibility of gasoline prices makes motorists keenly aware when cost shocks reach the pump, often compelling policymakers to respond by reducing fuel taxes. Such was the context in Germany, as well as in many other countries, after the Russian attack on Ukraine in 2022, when fuel prices rose sharply to reach record levels of well over €2 per liter.

In response, the German government passed legislation to reduce the energy tax on fossil fuels – the Fuel Tax Discount (FTD) – for a period of three months, from June 1 to August 31, 2022. In this period, the energy tax on diesel of 47.04 Cents per liter was reduced to 33.0 Cents, the minimum tax rate required by the European Commission, and for petrol from 65.45 to the minimum tax rate of 35.9 Cents per liter. Accounting for the value-added tax (VAT) of 19%, the overall discount amounted to 35.16 Cents per liter for petrol and 16.71 Cents for diesel. The intent was to provide financial relief to motorists, the presumption being that retail filling stations would fully pass through the discount to consumers. Whether such "full shifting" in fact transpires is a fundamental question of public economics, one whose relevance extends to concerns about market power and distributional impacts.

The present study takes up this question. Drawing on a panel of station-level data from Germany and France, with France serving as a control site, we explore the sources of heterogeneity in pass-through over space and time both for petrol and diesel fuel. Germany offers a particularly interesting setting for addressing this issue because of a longstanding public perception that, quoting a widely read newspaper, "competition on the fuel market does not function particularly well" (SZ, 2022). This widely prevalent and persistent perception led Germany's Federal Cartel Office to undertake a study of price setting in 2011, which concluded that a handful of companies exercise market-dominating influence as oligopolists, leading to higher fuel prices than would otherwise prevail under perfect competition (FCO, 2011). A subsequent report by the International Energy Agency contradicts this assessment, concluding that "Germany has a largely deregulated and competitive oil market" with "a large number of independents in the refining and retail sectors" (IEA, 2012, p. 8).

Constituting an unanticipated and exogenous change to the fuel price, the introduction of the temporary tax discount, which was passed by the government only 10 days before going into effect on June 1, affords the opportunity to scrutinize these opposing perspectives by studying how retailers pass on the discount to consumers. Economic theory predicts that under perfect competition, the pass-through rate depends on the elasticities of supply and demand. With perfectly elastic supply and downward-sloping demand, it equals one, implying that the full discount from a tax reduction is passed through to consumers.

Recent analyses of Germany's fuel tax discount suggest that the pass-through rate was indeed close to one (Dovern et al., 2023; Fuest et al., 2022; Schmerer & Hansen, 2023), corroborating earlier studies that find near full shifting in the US market (Chouinard & Perloff, 2004, 2007; Li et al., 2014; Marion & Muehlegger, 2011). Kahl's (2024) analysis uncovers heterogeneity in the effect of the tax discount over space, with average pass-through rates of 82% in rural areas and 92% in urban areas. But exploration of heterogeneity with an eye toward deriving distributional implications remains scant. For example, few studies have directly addressed the question of which income segments reap the gains, or bear the burden, of changes in fuel tax policy as it relates to pass-through.

Drawing on both difference-in-differences and event study approaches, this paper's overarching contribution is to consider both the supply- and demand-side channels through which a tax discount is passed through to retail gas prices, recognizing that each channel is relevant to tax incidence and distributional impacts. Three features distinguish our analysis: First, using high-resolution data from RWI-GEO-GRID (Breidenbach & Eilers, 2018), we allow for differential pass-through rates according to regional income levels, measured by purchasing power, a thus far largely unexplored source of heterogeneity. To the extent that income moderates the demand elasticity for fuel (Kayser, 2000; Wadud et al., 2010), it is a potentially important determinant of pass-through, with implications for both incidence and distributional effects among consumer groups, as well as for the budgetary effects of fuel taxation. In one of the few papers to analyze this issue, Harju et al. (2022) find lower pass-through of a carbon tax in high-income areas of Finland, from which they conclude that ignoring pass-through heterogeneity leads to an underestimation of the regressivity of the tax.

Second, we also allow for differential pass-through rates according to the level of local competition. Theoretical analysis shows that the influence of competition depends fundamentally on the convexity of demand. Presuming that demand is not too convex, the pass-through rate increases with increases in competition, while it decreases when demand is highly convex (Weyl & Fabinger, 2013). A challenge facing empirical investigations is that the convexity of demand is typically unknown. Nevertheless, several studies of the gasoline market have found indicative evidence that, consistent with linear (or not too convex) demand, pass-through increases with competition (Alm et al., 2009; Byrne, 2019; Doyle & Samphantharak, 2008; Genakos & Pagliero, 2022).

Our analysis builds on this work by accounting for differences in regional competition using the ratio of retail fuel outlets to registered vehicles from across Germany. Drawing on insights from pass-through theory, we estimate auxiliary models of price responsiveness for both petrol and diesel fuel using household data from the German Mobility Panel (MOP, 2023). By revealing the extent of demand convexity, these estimates allow us to explore the effect of differences in competition on the pass-through rate.

Third, we complete the analysis by calculating the budgetary costs of the fuel tax discount and by identifying its beneficiaries, which is facilitated by coupling the differential pass-through rates with household data from the German Mobility Panel on fuel expenditures and income.

Among our key results is that the average pass-through rates of 96% for diesel and 82% for petrol obscure extensive heterogeneity. Allowing for differential effects over space reveals pass-through rates that range from about 50 to 130%, thereby reproducing the pattern of heterogeneity discovered by Genakos and Pagliero (2022) for Greek islands.[1] Like those authors, we find that highly competitive regions have higher pass-through rates, which is consistent with the quasi-linear demand identified from the household model of driving behavior using the German Mobility Panel data. Income levels also appear to play a role in the pattern of spatial differentiation, with regions of lower purchasing power having somewhat lower pass-through rates, contrasting with Harju et al.'s (2022) results from Finland.

With regard to temporal heterogeneity, we find that although the discount is passed on fully in the first days, its magnitude begins to dissipate roughly 30 days after its introduction. By the final month, the rate drops to 46% for diesel and 74% for petrol, thereby undermining the political endeavor of mitigating consumers' burden due to energy price shocks. We interpret this pattern through the lens of consumer search theory, positing that it reflects retailer responses to changes in consumer attention. The overall picture is thus one of pronounced heterogeneity over space and time, with a sizeable share of the population facing substantially less than full pass-through for much of the period. A back-of-the-envelop calculation reveals that overall effect of the discount is regressive, resulting from the higher pass-through among high-income households as well as the higher fuel consumption among such households.

The following section theoretically discusses the pass-through rate of tax changes, highlighting the role of competition and the impact of demand. Section 3 describes our data sources and empirical strategy. Section 4 presents results from a baseline difference-in-differences estimator, followed by the presentation of both spatial and temporal heterogeneity in Section 5 through Section 7. This discussion includes placebo regressions and additionally draws on work by Rambachan and Roth (2023) to explore robustness to violations of parallel trends. Section 8 estimates the budgetary costs of the tax discount and addresses the question of its distributional impact. The last section summarizes and concludes.

[1]Genakos and Pagliero, 2022 examine a tax change on petroleum products in isolated markets on Greek islands, allowing them to pinpoint how pass-through varies with changes in the number of competitors. This set-up yields estimates ranging from 40% in island markets with a single retailer to 100% on islands with four or more competitors, though the authors acknowledge that external validity may be limited by the particularities of petroleum markets on Greek islands.

2 Theoretical Background

The pass-through rate of a tax discount is defined as the ratio of the change in price p due to the tax discount t (see e.g. Weyl and Fabinger (2013)):

$$\rho := -\frac{dp}{dt}. \tag{1}$$

Under perfect competition, pass-through depends exclusively on the elasticities of demand and supply, ϵ_D and ϵ_S:[2]

$$\rho = \frac{1}{1 + \frac{\epsilon_D}{\epsilon_S}}, \tag{2}$$

where $\epsilon_D := -p/q \cdot dD(p)/dp$, $\epsilon_S := p/q \cdot dS(p)/dp$, and $D(p)$ and $S(p)$ denote demand and supply, respectively. Complete pass-through of the tax discount occurs when demand is perfectly inelastic, while zero pass-through occurs when demand is perfectly elastic. In other words, the more inelastic side of the market benefits disproportionately from a tax discount (or subsidy), whereas it bears disproportionately the burden of a tax.

To accommodate the possibility of imperfect competition, Weyl and Fabinger (2013) derive the following formula for pass-through rate ρ:

$$\rho = \frac{1}{1 + \frac{\theta}{\epsilon_\theta} + \frac{\epsilon_D - \theta}{\epsilon_S} + \frac{\theta}{\epsilon_{ms}}}, \tag{3}$$

where θ, the conduct parameter, is an indicator of competition and is defined as:

[2] Perceiving the tax discount as a subsidy, we start with the equilibrium condition $D(p) = S(p+s)$ and differentiate this condition with respect to subsidy s to derive formula (2):

$$D' \cdot dp/ds = S' \cdot (dp/ds + 1),$$

where $D' := dD(.)/dp$ and $S' := dS(.)/dp$ and hence:

$$\rho = -dp/ds = \frac{S'}{S' - D'} = \frac{\epsilon_S}{\epsilon_S + \epsilon_D}.$$

$$\theta := \frac{p - mc}{p}\epsilon_D, \tag{4}$$

with mc designating marginal costs. When θ equals zero, corresponding to perfect competition, formula (3) collapses to formula (2), whereas $\theta = 1$ indicates the polar case of pure monopoly.[3] The inverse elasticity of conduct parameter θ is defined by $1/\epsilon_\theta := q/\theta \cdot d\theta/dq$, while $1/\epsilon_{ms} := dms/dq \cdot q/ms$ is the inverse elasticity of the marginal consumer surplus, $ms := -qp' = -q \cdot dp/dq$. Parameter ϵ_{ms} determines the curvature of the logarithm of demand (Weyl & Fabinger, 2013).[4]

Empiricists typically make simplifying assumptions in estimating pass-through, one of which is that the competition parameter θ is invariant to changes in q, as is the case under Cournot competition, implying that $1/\epsilon_\theta = 0$. We correspondingly assume that θ is invariant to tax changes, that is, that the intensity of competition remains unaltered, an assumption that seems reasonable given that we do not expect entry or exit of stations owing to the short-term and unexpected introduction of the tax discount. A second typically invoked assumption is constant marginal costs, which implies that ϵ_S is infinite. This assumption likewise seems reasonable over the short-run interval of the tax discount of three months. With these two assumptions, the terms $\frac{\theta}{\epsilon_\theta}$ and $\frac{\epsilon_D - \theta}{\epsilon_S}$ vanish from formula (3), resulting in:

$$\rho = \frac{1}{1 + \frac{\theta}{\epsilon_{ms}}}. \tag{5}$$

[3]Note that the definition of parameter θ is due to the normalization of Lerner's rule, which states that the extent of the markup $p - mc$ depends on the elasticity of demand: $L := \frac{p-mc}{p} = 1/\epsilon_D$. While oligopolists and monopolists charge $p > mc$, so that the Lerner index is $L > 0$, firms in a perfectly competitive market charge $p = mc$, and, hence, $L = 0$, indicating that such a firm has no market power. By multiplying Lerner index L by demand elasticity ϵ_D, the resulting parameter θ is normalized: $0 \leq \theta \leq 1$, like the Lerner index L, which ranges from 0 to 1, as well.

[4]ϵ_{ms} is associated with the curvature of the logarithm of demand, because $(\log D)' = \frac{d \log D}{dp} = \frac{D'}{D} = \frac{1}{qp'} = -\frac{1}{ms}$, where $D = q$ and $D' = dD/dp = 1/(dp/dq) = 1/p'$ due to the derivative of the inverse function $D = (p(q))^{-1}$. The curvature of the logarithm of demand, given by the second derivative, then reads:

$$(\log D)'' = \frac{d}{dp}(-\frac{1}{ms}) = \frac{1}{ms^2}(\frac{d}{dq}ms) \cdot \frac{dq}{dp} = \frac{ms'}{ms^2} \cdot 1/p' = -\frac{1}{\epsilon_{ms}} \cdot \frac{1}{ms}(-\frac{1}{p'q}) = -\frac{1}{\epsilon_{ms}} \cdot \frac{1}{ms^2}.$$

Hence, the curvature crucially depends on ϵ_{ms}: $1/\epsilon_{ms} < 0$ always implies log-convex demand; log-concave demand always has $1/\epsilon_{ms} > 0$.

A third – but more difficult to justify – assumption is that demand is linear, implying that $\epsilon_{ms} = 1$.[5] When met, this assumption implies that the pass-through rate ρ equals $1/(1+\theta)$, meaning that ρ increases with decreases in θ, that is, with competition. Violations of the linear-demand assumption, however, open the door to alternative outcomes: When demand is sufficiently convex, a case investigated by Pless and van Benthem (2019), increases in competition *reduce* pass-through, and also allow the rate to exceed one. Consequently, the estimation of demand curvature that complements our analysis of pass-through frees us from the third assumption. Specifically, we fail to reject quasi-linear demand based on a model of mobility behavior using household data, supporting the hypothesis of a positive relationship between the degree of competition and the pass-through rate.

3 Data and Empirical Strategy

Data on fuel prices from Germany is drawn from an online portal referred to as the Market Transparency Unit for Fuels (MTU), established in 2013 under legislation requiring that retail fuel stations in Germany continually post prices for diesel and petrol when prices are changed. The MTU additionally records sundry station characteristics, such as the station's geographical coordinates, brand name, and opening hours. We retrieved this data from a repository that hosts all station-level data since the MTU's initiation – see the website creativecommons.tankerkoenig.de, where the data are offered for scientific purposes.

Our estimation strategy relies on neighboring France as a control group, which likewise maintains an online portal, Le Prix des Carburants, from which we retrieved prices for diesel and petrol, as well as the station coordinates. Upon appending these two sources, our data set contains information on 15,188 gas stations from Germany and 9,154 gas stations from France, effectively covering the entire market in each coun-

[5] Assume a linear demand function of the form $p(q) = a \cdot q + b$ with $a < 0$, then $p'(q) = a$ and marginal consumer surplus becomes $ms = -p' \cdot q = -a \cdot q$, so that $ms' := dms/dq = -a$. Hence, $\epsilon_{ms} := ms/(q \cdot ms') = -a \cdot q/(-a \cdot q) = 1$.

try. Considering the five-month daily coverage from April through August in our estimation sample, we are left with about 2.2 million observations from Germany and 1.4 million observations from France.

Our analysis of heterogeneity in the pass-through rate is facilitated by merging the fuel price data with data of RWI-GEO-GRID, a repository of socioeconomic variables covering all of Germany on a one-square-kilometer grid – see the comprehensive description of RWI-GEO-GRID by Breidenbach and Eilers (2018). Two variables are drawn from this source and aggregated to the level of a municipality:[6] the number of registered motor vehicles and the annual purchasing power per person, measured as monthly disposable income after taxes. We construct the measure of competition by dividing the number of fuel stations in a municipality by the number of registered vehicles. Figure C4 and Figure C5 in the appendix present cartographic depictions of this variable as well as of purchasing power, demonstrating pronounced spatial heterogeneity in both measures.

To investigate the pass-through of the German fuel tax discount, we begin with a difference-in-differences (DiD) approach incorporating two-way fixed effects:

$$p_{it} = \beta \cdot FTD_t \times GER_i + \gamma_i + \tau_t + \epsilon_{it}, \tag{6}$$

where p_{it} designates the price of station i on day t, γ_i denote station-fixed effects, τ_t time-fixed effects at the daily level, and ϵ_{it} is an idiosyncratic error term. *FTD* denotes a dummy variable indicating the three-month period from June through August, 2022, in which the Fuel Tax Discount was in effect. *GER* is a dummy variable indicating stations in Germany, the reference case being stations in France.

Two versions of the DiD approach are estimated, one in which p stands for prices for diesel and one in which it measures prices for E10, a petrol variant with a 10% share of ethanol. Of the roughly 48.5 million cars that were registered in Germany, about 31 million were petrol cars in 2022 and about 14.8 million were diesel cars (see FMDT,

[6] There are about 11,000 municipalities in Germany, having an average size of 32 square kilometers.

2022).

The parameter of interest is the coefficient β of the interaction term $FTD \times GER$, whose estimate, $\hat{\beta}$, gives the average treatment effect on the treated. With this estimate and Definition 1 of pass-through, $\rho = -\frac{dp}{dt}$, the pass-through rate $\hat{\rho}$ is given by:

$$\hat{\rho} = -\frac{\hat{\beta}}{FTD}, \tag{7}$$

where FTD either equals 35.16 Cents in case of E10 or 16.71 Cents for Diesel (see Table 1).

To allow for differential pass-through rates over the observation period, we estimate an event study specification:

$$p_{it} = \sum_{t=1}^{T} \beta_t \cdot Day_t \times GER_i + \gamma_i + \tau_t + \epsilon_{it} \ , \tag{8}$$

where the dummy variable for German stations is interacted with variable Day_t, indicating day t and commencing on April 1. The reference day is May 31, the last day before the introduction of the tax discount, and T indicates the end of the time period during which the tax discount was in effect, that is, August 31, 2022. β_t denotes the day-specific coefficients to be estimated in this event study approach.

By allowing for dynamic treatment effects, the event study approach in Equation 8 facilitates insight into both the speed of adjustment to the discount and the persistency of its effect. Moreover, the event study's resulting graphical summary of results can be used to visually scrutinize one of the key identification assumptions that underpins it, parallel trends: In the absence of treatment, the difference in the fuel prices between treatment and control group is assumed to be constant over time.

While the assumption of parallel trends cannot be formally tested, visual support can be gleaned by studying patterns before the event. Showing the evolution of daily prices of diesel and E10 for both countries in 2022, Figure 1 already provides the basis for a preliminary assessment: As of March 2022, fuel prices in Germany are seen to be

Table 1: Fuel Tax Discounts in Germany and France in 2022

Announced	Implemented	Country	Energy Tax Relief in Cents per Liter		VAT relief on Energy Tax in Cents	
			Diesel	Petrol	Diesel	Petrol
May 23	June 1 – August 31	Germany	14.04	29.55	2.67	5.61
March 12	April 1 – August 31	France	18		3.6	
August 23	September 1 – November 15	France	30		6.0	
August 23	November 16 – December 31	France	10		2.0	

Sources: Bundesregierung (2022), French Republic (2023), and Reuters (2022).

higher than those in France, a pattern that extends until Germany's introduction of the rebate on June 1, when the price level in Germany drops below that of France. Note also that the French price evolution prior to treatment tracks closely with those of other European countries. – see Figure C1 in Appendix C.

Nevertheless, various events over the time frame of our analysis threaten to violate parallel trends, one being the introduction of a fuel discount of 18 cents in France on April 1, 2022, which was increased on September 1 to 30 cents, just as the German FTD was terminated (see Table 1). The outcome of this confluence is clearly evidenced in Figure 1 as of September, when prices in the two countries sharply diverge.[7] The initial introduction of France's discount is likewise seen by the price drop on April 1, though the difference in price trends thereafter remains relatively steady through April and May. Whether the difference is sufficiently steady to justify parallel trends is open to interpretation, but a further opportunity to assess this will be afforded by closer scrutiny of the event study estimates. Moreover, in robustness exercises, we will provide more formal support by referencing placebo regressions and by drawing on the "honest DiD" framework developed by Rambachan and Roth (2023).

An additional potential threat to the parallel trends assumption was the introduction of a subsidized public transit ticket in Germany, the so-called €9 ticket, whose

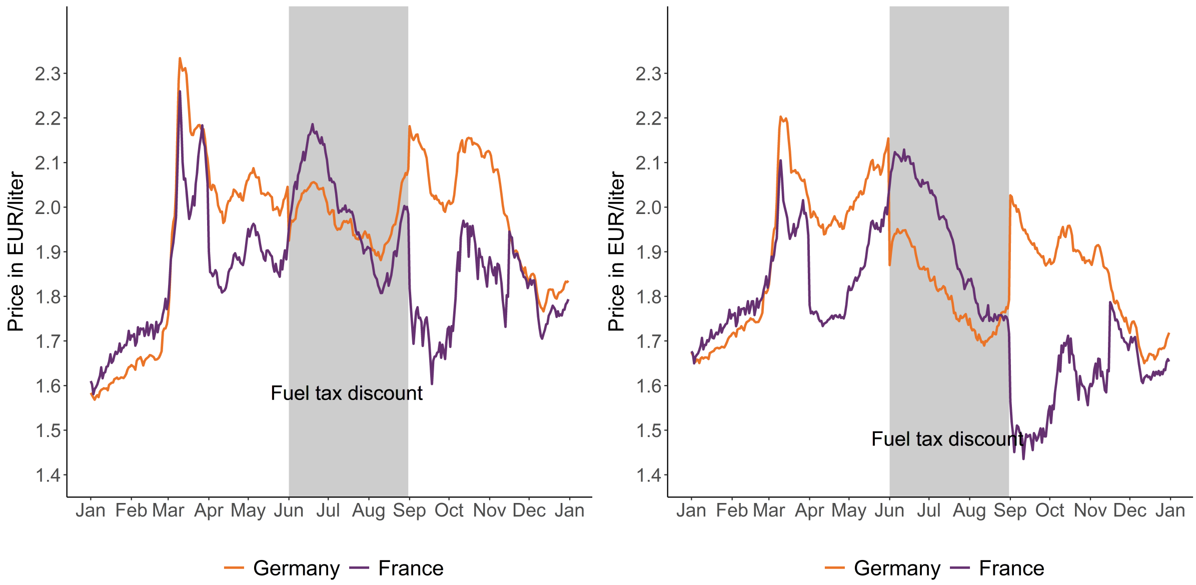
[7]The drop in French prices exceeds by about 18 cents the increase in the discount there, while the rise in German prices falls short of the discount's removal (in the case of petrol by about 19 cents). A partial explanation for this overshooting may be the 10% drop in Brent oil prices between August and September of that year.

period of validity, from June through August, overlapped with that of the fuel tax discount. This measure may have incentivized a modal shift from the car to public transit, particularly in urban areas with dense transit infrastructure, potentially affecting the demand for fuel and its price. While we cannot completely rule out this possibility, existing evidence suggests that the effect of subsidized transit on mode choice is weak. Liebensteiner et al.'s (2024) analysis of the €9 ticket, for example, finds that the ticket encouraged only a small decrease in car use, ranging between 1 and 5%. These studies corroborate experimental evidence from Andor et al. (2025), who likewise find that the provision of subsidized public transit tickets in Germany has a negligible effect on car travel. Similarly, earlier studies from Japan (Fujii & Kitamura, 2003), Norway (Tørnblad et al., 2014), and Chile (Bull et al., 2021) find a moderate effect of transit subsidies on modal shift.

A more general concern is that parallel trends is violated by differential trends in wholesale prices or in other determinants of retail fuel prices by region. For example, media reports from this period referenced a dry spell that afflicted some parts of southern Germany through the summer of 2022, which may have differentially impacted car travel and fuel deliveries. To explore the effect of weather conditions, we estimate a model that includes a measure of local temperature (see Figure C7 in the appendix), finding this has no bearing on the results. Moreover, we present a robustness check in Section 7 that partitions the data by Germany's 16 federal states, allowing us to compare whether results are similar across regions that are distinguished by varying climatic conditions and degrees of urbanization. Among these federal states are the city-states Berlin, Bremen, and Hamburg, which are characterized by the highest population densities in Germany and extensive networks of public transit infrastructure.

In addition to the parallel trends assumption, identification requires a stable unit treatment value assumption (SUTVA), implying that the treatment solely exerts a direct effect on the unit being treated, thereby excluding general equilibrium effects and treatment externalities. France's long border with Germany and comparative economic conditions lend it as a propitious control site, but, as noted by Montag et al.,

Figure 1: Average Daily Diesel and Petrol (E10) Prices in Euros per Liter in Germany and France, January – December 2022.



(a) Diesel

(b) Petrol (E10)

Notes: The gray area marks the period during which the German Fuel Tax Discount was in effect.

2023, also raise the concern that SUTVA could be violated. It is conceivable, for example, that French stations near the border lower their prices in an effort to prevent "fuel tourism", reflected by their customers driving across the border to take advantage of the discount-induced cheaper fuel in Germany.

To visually explore this possibility, we plotted the daily prices of French stations near the German border (see Figure C2 in the appendix), where such an incentive would presumably be strongest. We find that the price evolution of these stations does not differ substantially from the national level in France, assuaging concerns about spatial spillovers. We provide additional econometric support for this conclusion in Section 6.1.

4 Baseline Estimation Results

Table 2 reports results from the estimation of Equation 6, estimated using two different estimation samples: Following Fuest et al. (2022) and Schmerer and Hansen (2023), who use stations in France and Austria as controls, respectively, Columns 1 and 3 present estimates from a sample that extends two weeks following the introduction of the discount, which is balanced by a sample that extends two weeks prior.[8] Columns 2 and 4 report estimates based on the entire three months of the FTD and the two months preceding it. Standard errors are clustered at the station level. As documented in the appendix, we also explored clustering at the county and zip code level, as well as two-way clustering by station and day, finding the results to be robust across these alternatives.

Table 2: Estimation Results on the Pass-through of the Fuel Tax Discount from the Difference-in-Differences Approach given by Equation 6

	Diesel				Petrol (E10)			
	Two Weeks		Three Months		Two Weeks		Three Months	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
FTD × GER	-0.177***	(0.000)	-0.160***	(0.000)	-0.277***	(0.001)	-0.288***	(0.001)
Pass-through rate (%)	105.7***	(0.003)	96.0***	(0.003)	78.9***	(0.002)	81.8***	(0.002)
Station fixed effects	✓		✓		✓		✓	
Time fixed effects	✓		✓		✓		✓	
# Observations	736,374		3,642,497		710,914		3,516,646	
R^2	0.890		0.768		0.932		0.866	

Note: Standard errors, clustered at the station level, are in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

In the case of diesel, the pass-through estimates range between 105.7% in Column 1 to 96.0% in Column 2. By way of comparison, the corresponding estimate of Fuest et al. (2022) is 102% while that of Schmerer and Hansen (2023) is 108%. We find more moderate differences in the pass-through estimates for petrol across the two samples, ranging between 78.9% and 81.8%, compared with 85% and 105% for Fuest et al. (2022)

[8]Note that the samples of Fuest et al. (2022) and Schmerer and Hansen (2023) do not have this symmetry: the study of Fuest et al. (2022) extends the pre-treatment period to six weeks, while that of Schmerer and Hansen (2023) extends it to one week.

and Schmerer and Hansen (2023), respectively.

5 Heterogeneity over Space

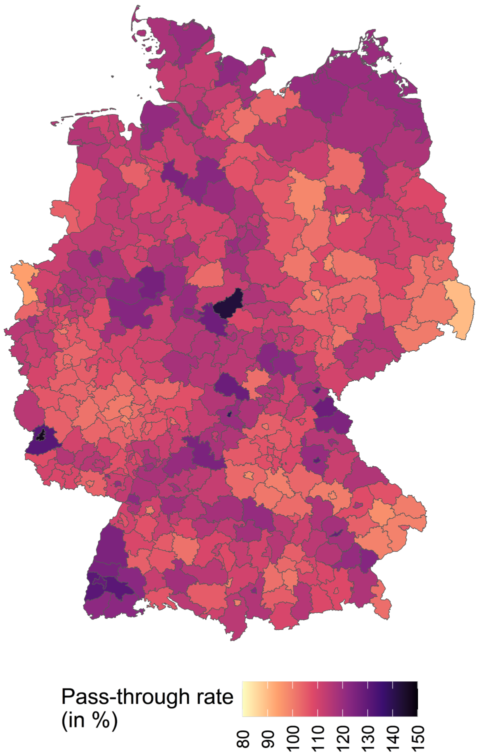
To allow for heterogeneity over space, we estimate an alternative version of Equation 6 in which the dummy for Germany is replaced with dummy variables for each of Germany's 401 counties. As above, in the analyses that follow we consider both the first two weeks of the discount as well as the full three month period.

The results of this exercise are plotted in Figure 2, which illustrates the estimates for each county. Several features stand out. As seen in the top panel, the variation in pass-through rates over the first two weeks is substantial, spanning a range of about 60 percentage points for diesel and 40 percentage points for E10. When considering the full period, the bottom panel indicates that the range is even wider, about 80 and 50 percentage points. Moreover, a spatial clustering of pass-through rates for both fuel types emerges over this longer period, evolving broadly along a north-south gradient similar to that identified by Kahl (2024). Particularly high pass-through values are seen in the Northeast, while particularly low values are seen in the Southeast.

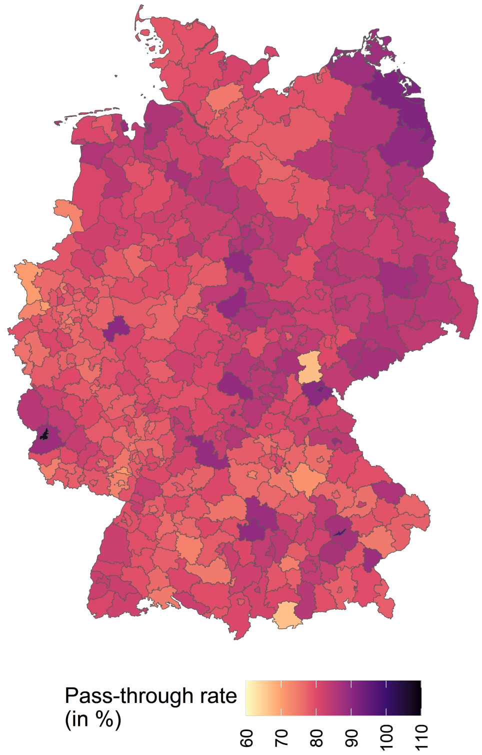
The question arises as to the mediating roles of supply and demand conditions in accounting for the above patterns. In particular, as is evident from Figure C4 and Figure C5 in the appendix, some degree of spatial clustering in the measures of competition and purchasing power is discernible, both of which are potential sources of differentials in the pass-through rates. Strong levels of competition prevail across large swaths in the north, while clusters of higher income are visible in the northwest and southeast. Although the patterns in Figure C4 and Figure C5 do not follow a clear north-south gradient, they do evidence pockets of distinctly varying socioeconomic conditions that could bear on both retail prices levels (Haucap et al., 2017) and pass-through.

With respect to the degree of local competition, theory would suggest that, conditional on linear fuel demand, areas characterized by stronger competition would see

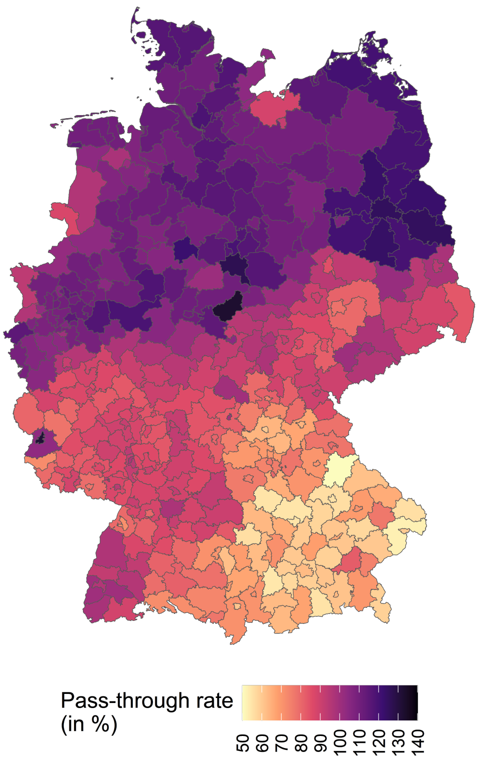
Figure 2: Heterogenous Regional Pass-Through Rates of the Fuel Tax Discount



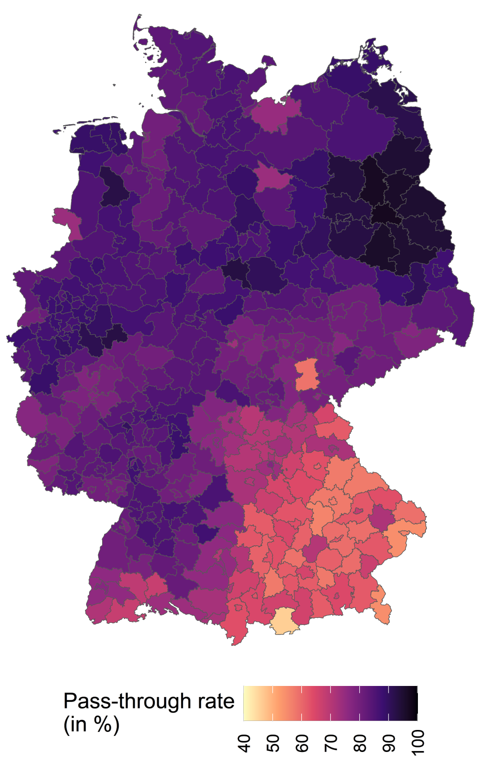
(a) Diesel - First two weeks



(b) Petrol (E10) - First two weeks



(c) Diesel - Complete three months

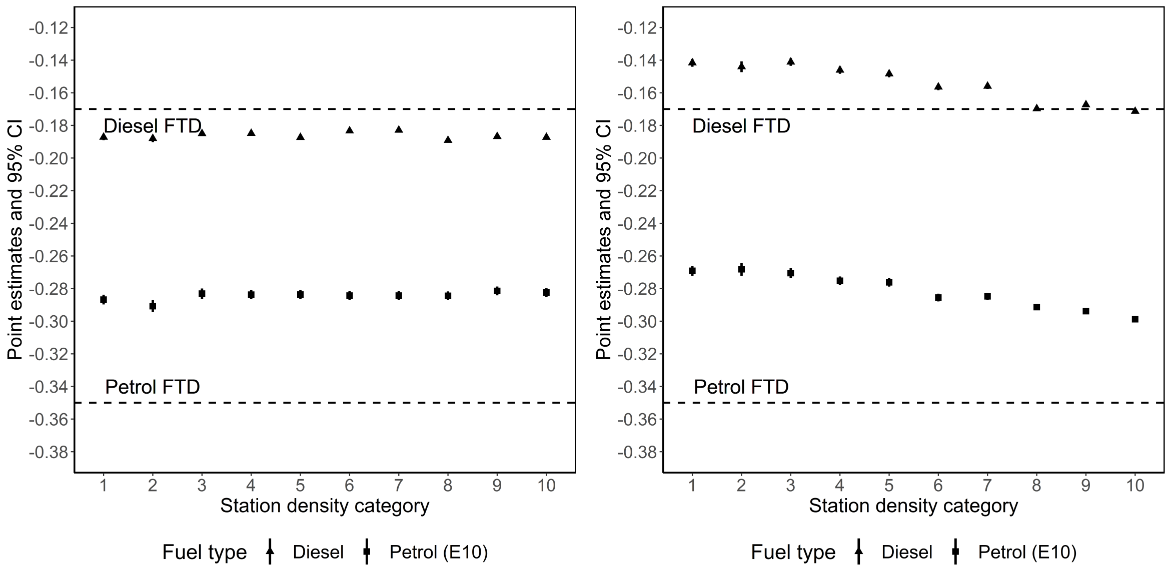


(d) Petrol (E10) - Complete three months higher pass-through rates. To pursue this hypothesis, we first assess the extent of linearity in demand by exploring fuel price responsiveness using panel data from the German Mobility Panel (MOP, 2023), a publicly available travel survey commissioned and financed by the German Federal Ministry of Transport and Digital Infrastructure since 1994. As documented in Appendix A, we estimate fixed effects models of distance driven on the fuel price, following Alberini et al. (2022) in allowing for a differential effect between petrol and diesel cars. The models include the square of the fuel price to allow for non-linear effects, and are estimated in levels and in logs. They consistently indicate no evidence for highly convex demand, supporting the hypothesis of increasing pass-through in the level of competition.

Returning to the difference-in-difference approach specified in Equation 6, we proceed to test this hypothesis by estimating individual effects for each of the deciles of competition presented in Figure C4. This entails partitioning the data into subsets by decile and estimating Equation 6 for each decile. The resulting pattern of estimates and their 95% confidence intervals are plotted in Figure 3. While the first two weeks reveal no evidence for a differential magnitude of pass-through by the degree of competition, consideration of the complete time frame reveals an increasing pass-through rate with increasing competition intensity for both fuel types, consistent with linear demand. For the first three deciles having the weakest level of competition, the pass-through is around 85% for diesel and 77% for E10. For the three deciles with the highest degree of competition, we obtain pass-through rates of about 101% for diesel and 84% for E10. A general pattern of higher pass-through for diesel than for E10 is also evident, which aligns with the smaller (in magnitude) demand elasticity for diesel presented in Table A1.

We repeat the analysis for income, using Equation 6 to estimate pass-through rates by purchasing power decile, which are plotted in Figure 4. To the extent that high-income households spend a smaller share of their budget on fuel, theory would suggest that they have a lower price elasticity of demand than low-income households. This, in turn, would lead us to predict an increasing pass-through rate with increasing income.

Figure 3: Competition Results: Fuel Tax Discount and Deciles of Relative Station Density

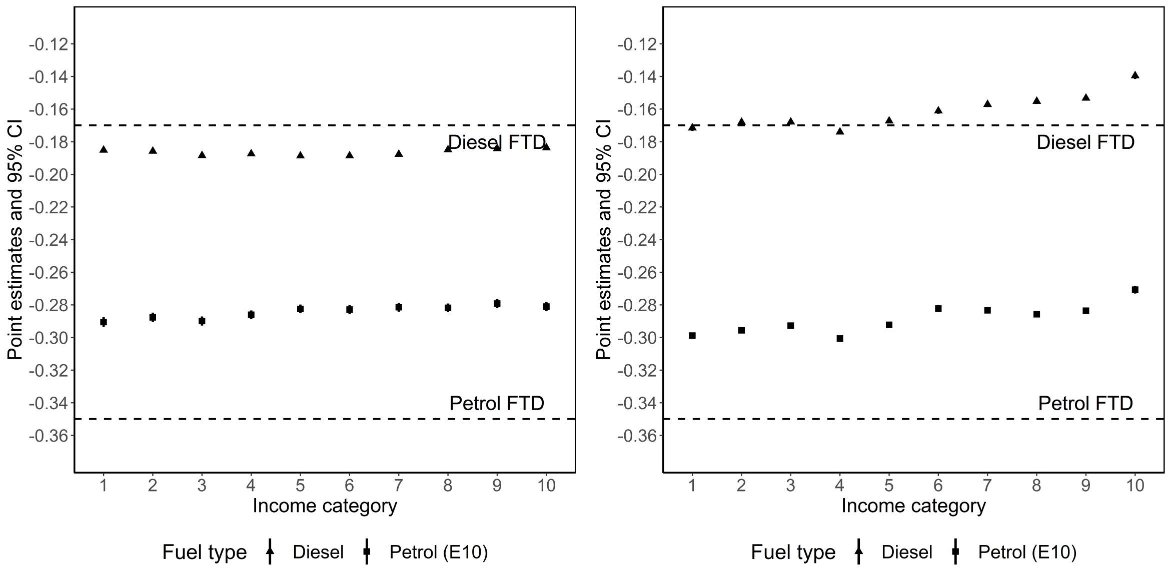


(a) First two weeks (b) Complete three months

Note: Category 1 indicates low station density and weak competition, Category 10 high station density and strong competition levels. Dashed lines indicate the tax discount levels: 16.71 Cents for diesel and 35.16 Cents for E10.

The plot in the right panel instead shows the opposite pattern: pass-through rates decline in higher purchasing power deciles for both diesel and petrol. This unexpected finding aligns with Harju et al. (2022), who also report that pass-through decreases with income. Section 7, however, documents that a reevaluation is warranted when partitioning the data by Germany's 16 states. The pattern in Figure 4b vanishes, and in some states, the expectation of increasing pass-through with increasing income is confirmed.

Figure 4: Purchasing Power Results for Low- to High-Income Regions (Income Categories 1 – 10)



(a) First two weeks

(b) Complete three months

Note: Category 1 represents low-income regions, Category 10 high-income regions. Dashed lines indicate the tax discount levels: 16.71 Cents for diesel and 35.16 Cents for E10 petrol.

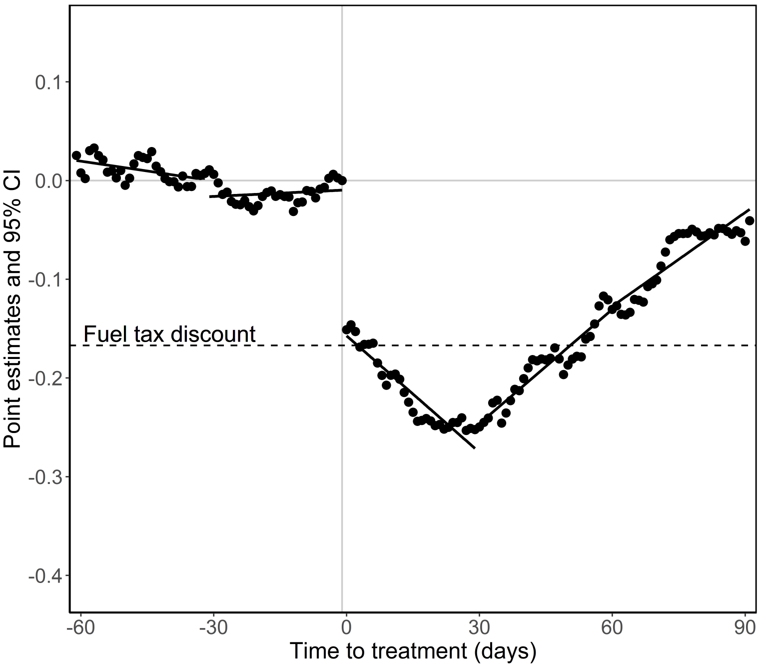
6 Heterogeneity over Time

Beyond its magnitude, the speed of adjustment and the persistency of the pass-through rate are also of relevance to its welfare effects. To explore these aspects, we estimate the event study specification of Equation 8, which allows for differential effects by day, covering 60 days prior to the introduction of the discount and the full 90 days of its implementation.

6.1 Event Study Estimates

The results for diesel are presented in Figure 5, where confidence intervals are hardly visible, as well as in other figures, because the standard errors are typically around 0.001. Three features bear noting: First, the estimates for the 60 days leading up to the discount straddle relatively close to zero. Even if most of the estimates are statistically significant, there is no clear evidence for trending that would suggest a violation of of parallel trends. Second, the speed of adjustment to the discount is immediate; in fact, an overshooting of the pass-through rate for diesel occurs through most of the first month. Third, the rate begins to abate rapidly as of day 30, reaching a level of about 78% by day 60, which is similar to the pattern identified by Dovern et al. (2023). Using a synthetic difference-in-differences estimator, they find that the abatement in the pass-through rate for diesel commences as of August, that is, day 60.

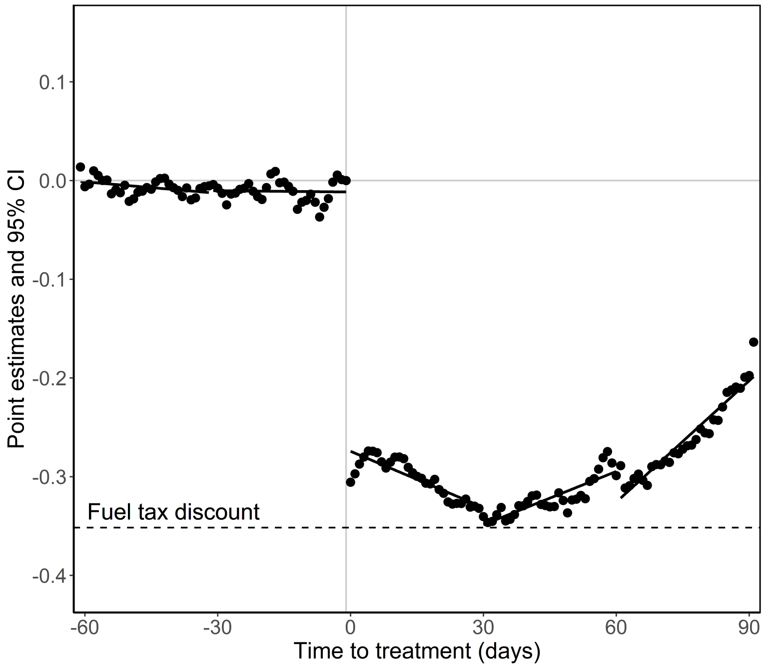
Figure 5: Pass-through Estimation Results over Time for Diesel



Note: The figure shows the results for diesel with respect to May 31, the last day before the introduction of the tax discount. Black solid lines indicate the monthly trend. The dashed line represents the magnitude of the tax discount: 16.71 Cents per liter.

The pattern for E10 petrol, presented in Figure 6, shares similarities with that of diesel. For starters, notwithstanding statistically significant estimates prior to treatment, the magnitude of the estimates only negligibly deviates from zero, providing some support for parallel trends. During the treatment period, however, the speed of adjustment to the discount is slower than in the case of diesel. Moreover, no overshooting is evident. A rate of nearly 100% pass-through is reached by day 30, which, after holding for about a week, begins to abate.

Figure 6: Pass-through Estimation Results over Time for E10 Petrol



Notes: The figure shows the baseline results for E10 with respect to May 31, the last day before the introduction of the tax discount. The black solid lines indicate the monthly trend, the dashed line represents the magnitude of the price discount: 35.16 Cents per liter.

To rule out that the temporal patterns for diesel and petrol are in some way driven by spatial spillovers, we undertook a robustness check that eliminated observations located in the German states that border France, thereby establishing a buffer of several hundred kilometers. This restriction reduced the number of stations in our sample by about 21%. As presented in Figure C3 in the appendix, the overall pattern of estimates remains unchanged.

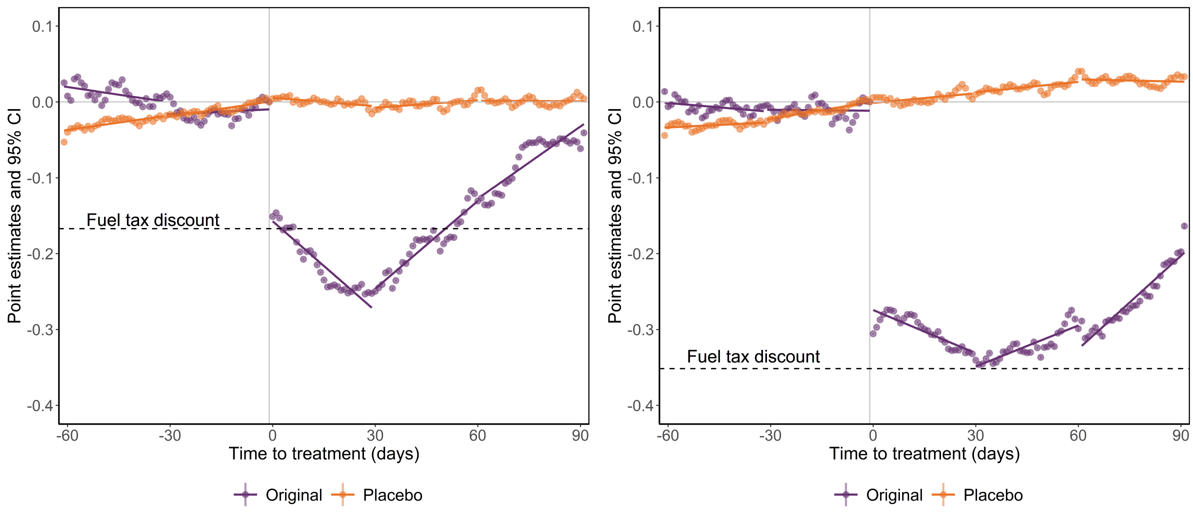
6.2 Reexamining Parallel Trends

While the price trends plotted in Figure 1 provide visual support for the assumption of parallel trends, the event study plots in the preceding section are more ambiguous, owing to the non-overlap of the confidence intervals prior to treatment. To glean further insight into the implications for identification, we avail of two auxiliary analyses, one using placebo regressions and the other applying the "honest DiD" method developed by Rambachan and Roth (2023), a robust inference approach that yields confidence intervals under violations of parallel trends.

Our placebo regression is based on the premise that fuel prices in France and Germany are expected to follow similar trends in a typical year. Were this not the case, then the impacts identified in Section 6.1 could presumably come from some other source of differences in trends, such as alternative start dates to the summer vacation season in the two countries. We explore the possibility of such factors by estimating event study models that use data assembled from the same time frame over two of the preceding years, in 2021 and 2020.

Figure 7 and Figure 8 plot the corresponding trends. The figures additionally include the original estimates as a basis for comparison. These latter estimates reestablish the pattern of price trends spanning the implementation of the FTD in 2022. By contrast, the pattern from each of the preceding years hovers reasonably close to zero before and after June 1. visually establishing the absence of shocks or a clear trend as the normal circumstance.

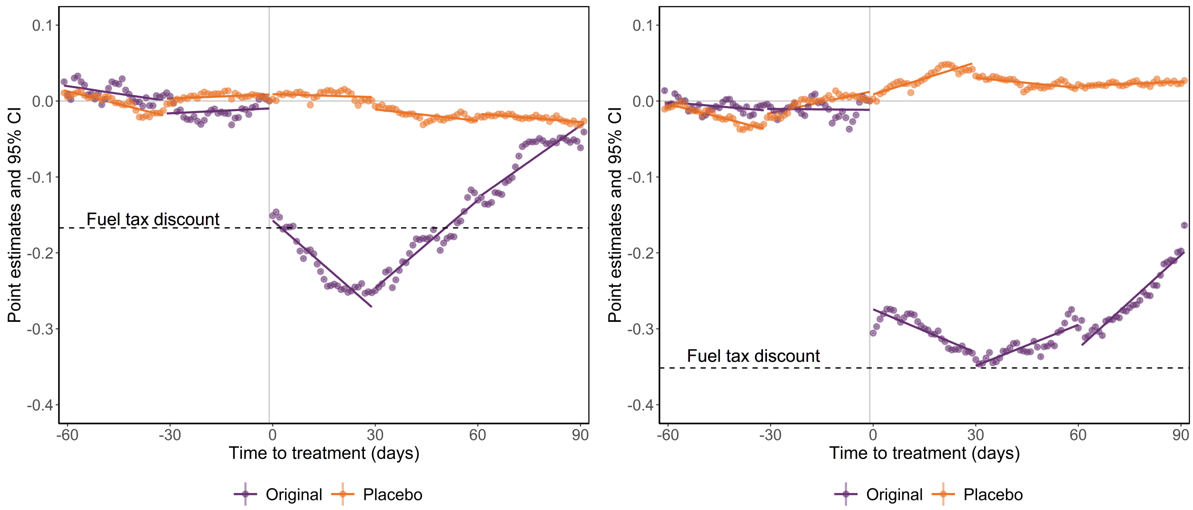
Figure 7: Placebo and Original Event Study Approach, June to August 2021



(a) Diesel (b) Petrol (E10)

The Honest Difference-in-Differences (DiD) approach of Rambachan and Roth (2023) affords an alternative angle by which to scrutinize the parallel trends assumption. By imposing restrictions on the model, the method reveals how far the assumption can be violated to still obtain significant estimates that can be interpreted causally.

Figure 8: Placebo and Original Event Study Approach, June to August 2020



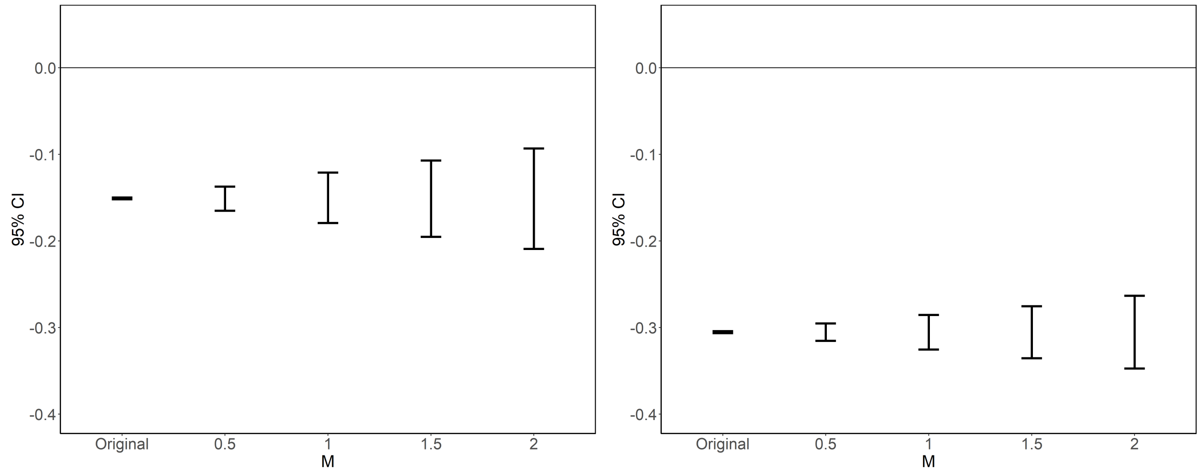
(a) Diesel

(b) Petrol (E10)

One such restriction – also discussed by Manski and Pepper (2018) – is the relative magnitudes restriction, which assumes that the maximum violation of parallel trends in the treatment periods equals the maximum violation of parallel trends in the pre-treatment periods times the multiple $\bar{M}$. This allows us to perform a sensitivity analysis for a sequence of $\bar{M}$ ranging from 0.5 to 2. The interpretation of $\bar{M} = 2$, for example, is that the violations of parallel trends in the treatment period cannot be greater than twice the violations in the pre-treatment periods to still obtain significant results.

Figure 9 shows the implementation of the Rambachan and Roth (2023) framework for the first week following the discount introduction. Higher values of $\bar{M}$ along the vertical axis indicate stronger violations of parallel trends, corresponding to wider confidence intervals. The figure shows that for both fuel types, the violation of parallel trends holds up to $\bar{M} = 2$. Following the logic of the method, this implies that statistically significant results of average pass-through over the referenced time period are robust to allowing for violations of parallel trends up to twice as big as the maximum violation in the pre-treatment period. Note that for $\bar{M} = 0$, the case that there are no parallel trend violations, the confidence interval collapses to the coefficient estimate.

Figure 9: Honest Difference-in-Differences (DiD) Confidence Intervals for June 1, 2022



(a) Diesel

(b) Petrol (E10)

7 Heterogeneity over Space and Time

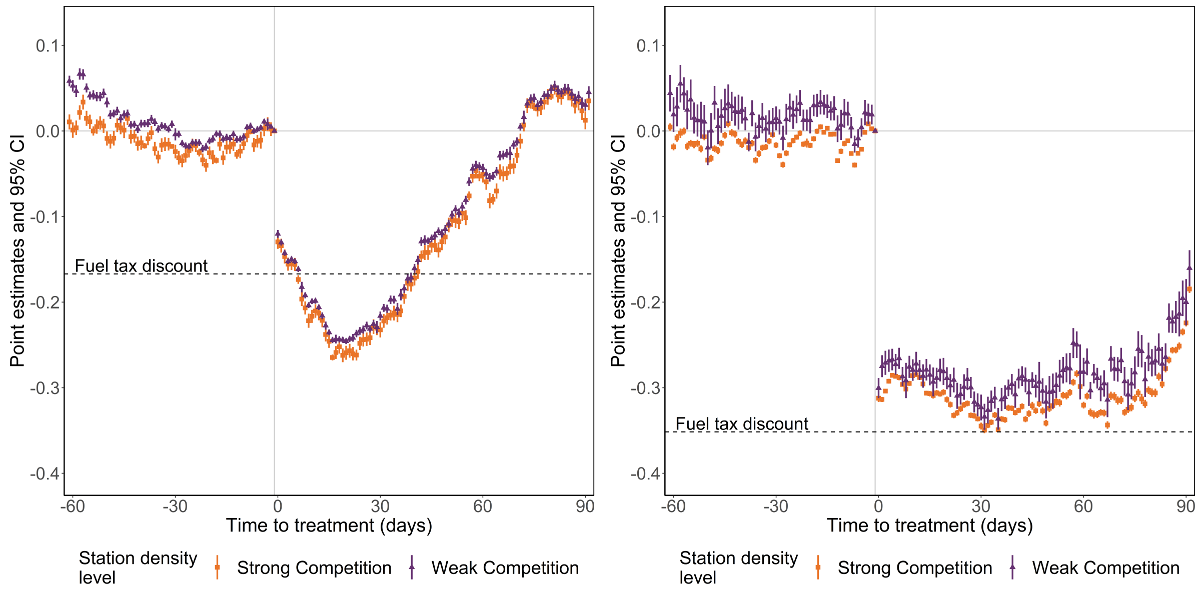
Recognizing the possibility that unobserved factors, such as differences in wholesale prices, may be an important source of regional and temporal heterogeneity, our final models are estimated after separating the data by each of Germany's 16 federal states. These models are specified to additionally allow for differential effects across the highest and lowest deciles of the measures of competition and purchasing power analyzed above. Three main takeaways emerge, which, to keep the presentation tractable, we illustrate with results from select federal states.[9]

First, with respect to competition, we generally confirm the finding from Figure 3b of Section 5: The pass-through rate is higher where the density of fuel stations relative to cars is higher. Examples of this pattern are seen for Bavaria for diesel and for Lower Saxony for petrol in panel (a) and panel (b) of Figure 10, where, throughout the period of the discount, the pass-through rate is higher where competition is stronger, though only by about one to two cents per liter. Other states, including Saarland and Baden-Wuerttemberg, show a similar pattern (presented online). The picture is murkier in

[9]The full set of results can be found here: https://github.com/PThie/Fuel-Price-Discount. We note that in some states, such as the city states of Berlin, Bremen, and Hamburg or the less populous states in the East, a breakdown by income- and competition decile was not possible because of insufficient variation.

Germany's most populous state of North Rhine-Westphalia, seen in panel (c) and (d), where there is no discernible difference in pass-through by competition for diesel or petrol.

Figure 10: Pass-through Estimation Results for Weak and Strong Competition among Filling Stations for select Federal States



(a) Diesel - Bavaria

(b) Petrol (E10) - Lower Saxony

(c) Diesel - North Rhine-Westphalia

(d) Petrol (E10) - North Rhine-Westphalia

Notes: The figure shows the price effect of the tax discount over time relative to May 31. The results are shown for high station densities (strong competition) and low station densities (weak competition). The dashed lines indicate the discount levels: 16.71 Cents for diesel and 35.16 Cents for petrol E10.

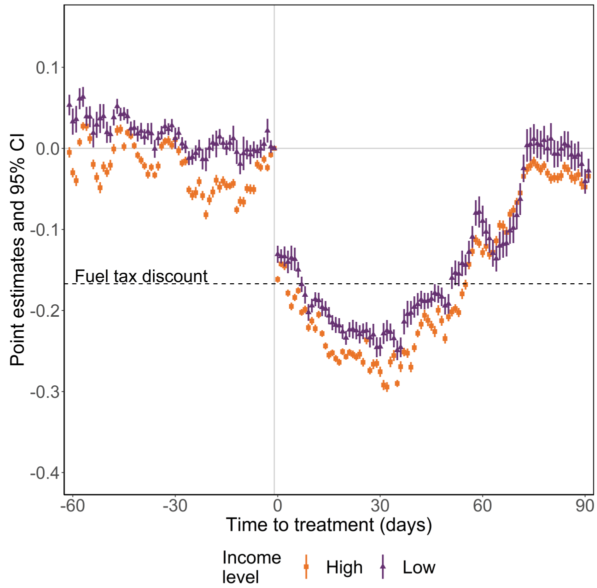
Second, contrasting with Figure 4b in Section 5, we fail to find decreasing pass-through with income. Instead, and consistent with the expectation of a higher fuel price elasticity among poorer households, we find that in some states pass-through is higher where purchasing power is higher, pointing to a regressive impact of the discount. As seen in panel (a) and (b) of Figure 11, examples include the state of Hessen for diesel and Baden-Wuerttemburg for petrol, where the difference reaches as high as five cents per liter. The example from North Rhine-Westphalia presented in panels (c) and (d), however, shows again that a clear distinction along this dimension is not evident across all of the states.

Last, the state-level estimates confirm the temporal pattern of a weakening pass-through rate throughout the period of the discount, approaching zero in some states like Hessen. What accounts for the declining magnitude? The conduct-parameter approach to pass-through discussed in Section 2, being a static framework, is ill-equipped on its own to provide a full explanation. We therefore draw on consumer search theory for additional insight, acknowledging that data constraints prevent us from reaching more than speculative conclusions. A central premise of consumer search theory is that the information available in the marketplace has a bearing on the prices that firms charge. When prices and costs are decreasing, consumers tend to search less (Byrne & de Roos, 2017; Lewis & Marvel, 2011). Less search, in turn, implies a less elastic demand and a higher pass-through rate.

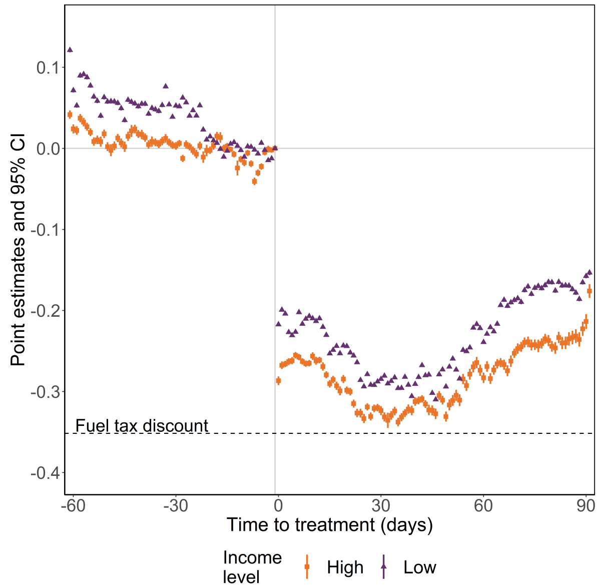
Such was the context with the introduction of the fuel price discount. While relatively sudden, the discount was well covered in the media. Many newspapers reported and speculated about whether service station operators would pass on the tax discount to consumers or whether the tax reductions would instead amount to a subsidy to the oil companies – see, for example, ZDF (2022) on May 31, 2022, and Tagesschau (2022) on June 1, 2022.

This media attention plausibly created an environment of highly informed consumers, increasing competition among retailers, and ultimately resulting in lower retail margins and higher pass-through (Lewis & Marvel, 2011). Some support for this narrative is seen in Figure 12, which shows the results of a Google trends search for

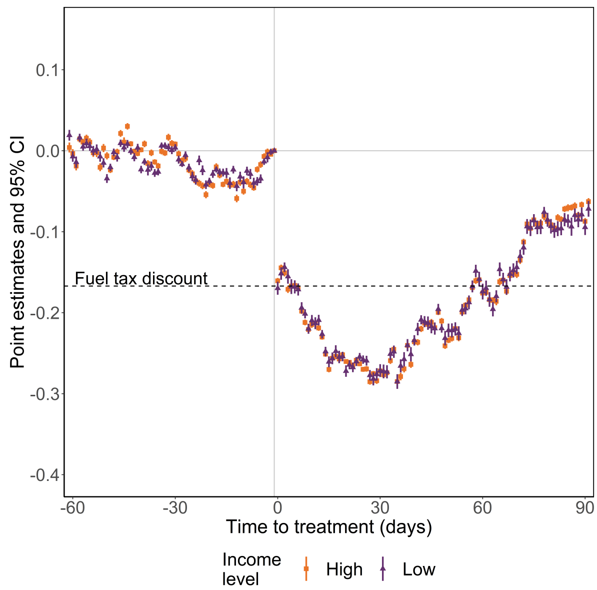
Figure 11: Pass-through Estimation Results for select Federal States and Regions with Low- and High Purchasing Power



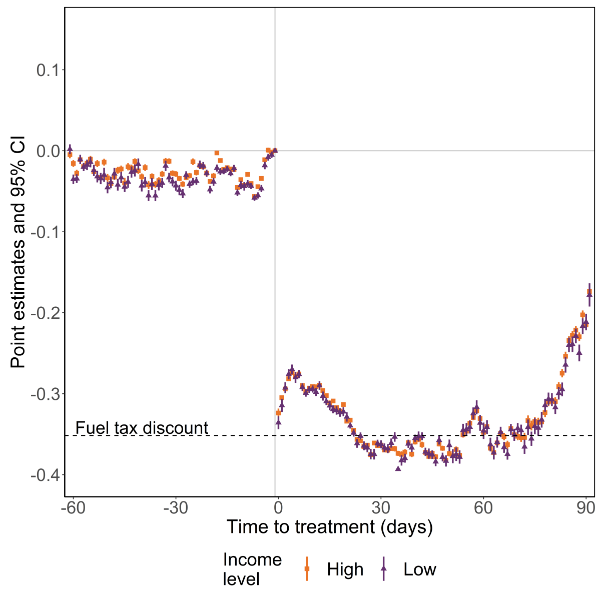
(a) Diesel - Hessen



(b) Petrol (E10) - Baden-Wuerttemberg



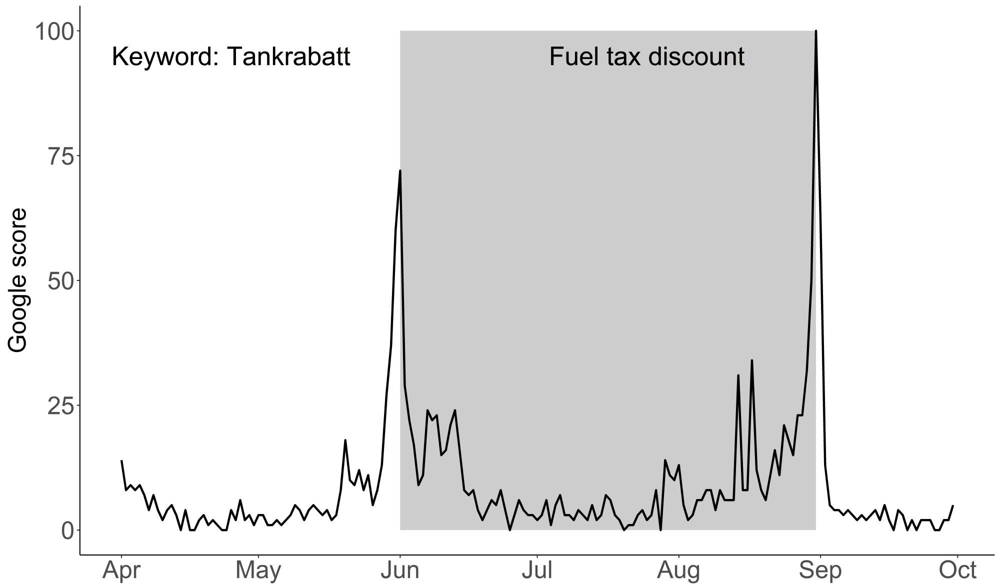
(c) Diesel - North Rhine-Westphalia



(d) Petrol (E10) - North Rhine-Westphalia

Note: The figure shows the price effect of the FTD over time relative to May 31. Dashed lines indicate the fuel tax discount levels: 16.71 Cents for diesel and 35.16 Cents for petrol E10.

Figure 12: Public Attention on the Fuel Tax Discount in terms of the Google Score based on a Search for the German Keyword ”Tankrabatt”.



Note: The figure shows the results of the Google Trends search for the German keyword ”Tankrabatt” (fuel tax discount) for April 1 to September 30, 2022. The gray area marks the period of the German fuel tax discount, which lasted from June 1 to August 31, 2022. The Google Score is defined as interest over time relative to the highest point in the observed period. A value of 100 represents the highest search popularity. *Source*: The raw data is based on Google Trends.

the keyword fuel tax discount (German: ”Tankrabatt”). The figure indicates that public interest in this keyword was high at the outset, but that it quickly dropped during June, with interest only reviving shortly before the discount came to an end at the end of August.

With interest in and information about the tax discount dissipating, fuel retailers may have seen an opportunity to start increasing prices toward the end of the first month. The literature on consumer search has established that rising prices stimulate more search, corresponding to a more elastic demand. From Equation (5), it follows that when demand elasticity increases, pass-through rates fall, which would account for the decreasing pass-through rates documented above.

8 Economic Impacts of the Fuel Tax Discount

The foregoing analysis demonstrates a high degree of heterogeneity in the pass-through rate over space and time, which is otherwise obscured in the fixed-effects estimates presented in Table 2. The question remains as to the economic impacts of this heterogeneity, both on the economy as a whole and on different consumer segments. We examine this question by first estimating the discount's net budgetary costs, followed by an assessment of who benefited.

The gross budgetary costs implied by the tax discount consist of reduced revenues from the energy taxes on diesel and petrol and the foregone value-added tax. These costs are obtained by multiplying the total volume of petrol and diesel consumed over the three months June, July and August by the respective tax reductions: 35.16 and 16.71 cents per liter including value-added tax. Altogether, gross budgetary costs sum to a total of €4.14 billion (Table 3).

Table 3: Gross Budgetary Costs of the Fuel Tax Discount in Terms of Forgone Energy and Value-added Tax Revenues

	Fuel consumption (in million liters)		Costs (in million euros)	
	Diesel	Petrol	Diesel	Petrol
June	3,625.6	2,213.8	605.8	778.4
July	3,591.2	2,033.2	600.1	714.9
August	3,930.4	2,227.1	656.8	783.0
Total	11,147.2	6,474.0	1,862.7	2,276.3
		Total cost:	4,139.0	

Note: Gross budgetary costs are calculated based on the tax discounts of 16.71 cents per liter for diesel and 35.16 cents for petrol, where the value-added tax (VAT) is included.

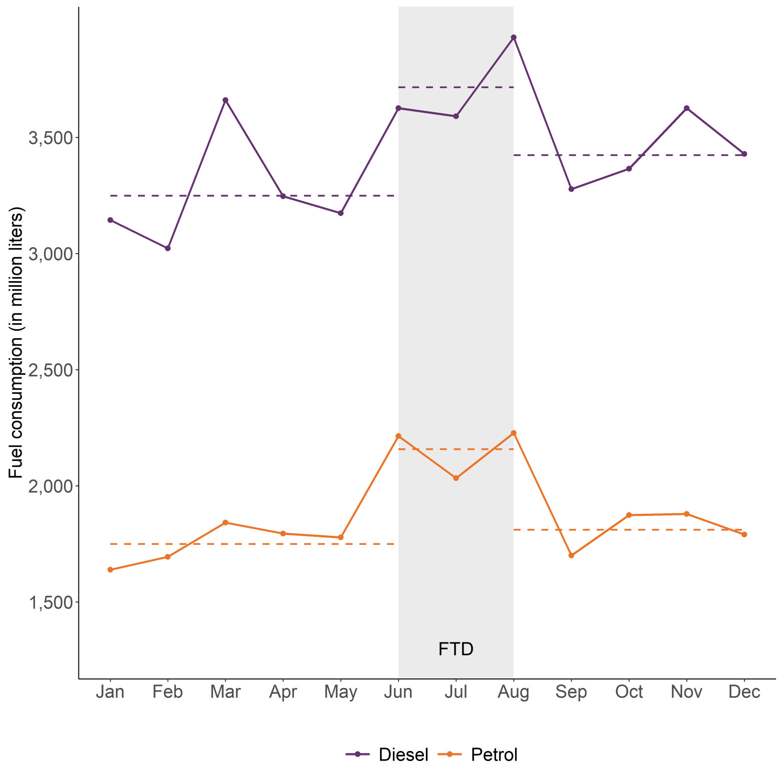
These costs are partially offset by higher tax revenues due to consumption increases during the three-month period during which the discount is valid (Figure 13). Our crude estimate of these revenues results from subtracting the average consumption during the two months prior to the introduction of the tax discount from the respective fuel consumption in the discount months June, July and August (Table 4). Multiplying these differences with the minimum energy taxes required in the EU of 33.0 and 35.9 cents per liter of diesel and petrol, respectively, yields additional energy tax revenues of about €901 million (Table 4). Accounting for additional value-added tax revenues of about €170 million due to a tax rate of 19%, our estimation yields tax revenue gains of a bit more than one billion euros for the three-month period in which the tax discount was valid. Subtracting this figure from the €4.1 billion presented in Table 3, we arrive at the net budgetary cost of the tax discount, which amounts to about €3.07 billion. To its credit, the government reached an almost identical estimate when it anticipated the cost of the measure to be €3.1 billion in a publication released prior to the implementation of the FTD (see FMF, 2022). This figure comprises about 4% of Germany's €80 billion budget deficit in 2023 (FMF, 2024) or roughly 26% of its €11.7 billion annual outlay for official development assistance (FMECD, 2024).

Table 4: Additional Energy and Value-Added Tax Revenues due to the Discount-induced Higher Fuel Consumption in June, July and August 2022

Months	Fuel consumption (in million liters)		Difference in consumption (in million liters)		Additional tax revenues (in million euros)	
	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol
April & May	3,209.9	1,786.2	–	–	–	–
June	3,625.6	2,213.8	415.7	427.6	137.2	153.5
July	3,591.2	2,033.2	381.3	247.0	125.8	88.7
August	3,930.4	2,227.1	720.5	440.9	237.8	158.3
Total	14,357.1	8,260.2	1,517.5	1,115.5	500.8	400.5
Total energy tax revenues in million euros:					901.3	

Identifying the beneficiaries of the discount-induced cost savings at the pump requires information on the distribution of (1) the pass-through rate and (2) the volume of fuel consumption. The analysis of the preceding section shows that pass-through may change with different levels of purchasing power, indicating partially a regressive effect that may be exacerbated by lower fuel consumption among poorer households. To glean further insight, we reference the monthly average fuel consumption figures for diesel- and petrol cars from the MOP, separating households according to whether they earn above or below the median income. We multiply these figures by three to obtain the average fuel consumption over three months, the duration of the FTD, for diesel and petrol cars in the two income groups.

Figure 13: Monthly Petrol and Diesel Consumption in 2022 in Million Liters



Note: The dashed lines represent the average fuel consumption in the respective periods.

We then take these figures to the RWI-GEO-GRID data, which records the number of diesel and petrol cars by income category, allowing us to calculate the total number of cars of each fuel type among households below and above the median income. Multiplying these figures by those from the MOP yields estimates of the total fuel consumption by income level and fuel type over three months, presented in the first two columns of Table 5. Households below the median income consume roughly 37% of fuel by volume of both diesel and petrol; households above the median consume the remaining 63%.[10]

In a final step, we multiply these figures by the average pass-through rates for

[10]Our estimate of about 6.2 billion liters of petrol consumption in Table 5 aligns tightly with the figure of 6.5 billion liters, published by the association of oil-producing companies (en2x, 2023). Our diesel estimate of about 4 billion liters is lower than the official estimate of about 11 billion liters, which owes to the fact that our calculations do not include freight transportation by truck.

Table 5: Purchasing Power and Gains of the Fuel Tax Discount

Purchasing power group	Fuel consumption (in million liters)		Gains from FTD based on estimation (in million Euros)	
	Diesel	Petrol	Diesel	Petrol
Below median	1,477.3	2,344.5	246.9	683.5
	(37.0%)	(37.8%)	(37.3%)	(37.7%)
Above median	2,515.6	3,853.1	415.1	1,129.6
	(63.0%)	(62.2%)	(62.7%)	(62.3%)
Total	3,992.9	6,197.6	662.0	1,813.1
	(100%)	(100%)	(100%)	(100%)
		Total household gains:	2,475.1	

Note: The gains based on the pass-through estimation consider the difference between purchasing power groups and rely on the estimated FTD effect of 16.7 Cents for diesel and 29.2 Cents for petrol for below-median levels and 16.5 Cents for diesel and 29.3 Cents for petrol for above-median levels.

diesel and petrol, using the estimates based on the state analysis separated in income deciles. As reported in the final two columns of Table 5, both for diesel and petrol fuel, about 62% of the gains accrue to households earning above the median income. Thus, the overall effect of the FTD appears to be regressive, primarily a consequence of the higher fuel consumption among high-income households. The degree of regressivity suggested by these figures is likely to be conservative, as it does not reflect the roughly 15% of German households that own no car.[11]

9 Summary and Conclusion

When fuel prices spike, many governments, including those of France, Germany, the UK, and several states in the US, have introduced temporary tax discounts to mitigate hardship. Given this objective, it is important to assess the extent to which the tax relief reaches consumers, as well as the distribution of beneficiaries. Using both

[11] While a deeper examination of regressivity would also consider the share of the household budget spent on fuel, figures presented by Kaestner et al. (2024) suggest that this would not bear fundamentally on our conclusions. They find little variation in the share of income spent by German households on motor fuel, with the first and fifth income quintiles spending about 3% and the middle three quintiles spending about 4% (see Figure 12, p. 198).

difference-in-differences and event-study approaches, this paper has investigated the pass-through of Germany's three-month fuel tax discount introduced in 2022 to mitigate consumers' burden at the pump due to the fuel price shock in the aftermath of Russia's attack on the Ukraine.

Expanding on the related literature on fuel tax incidence, our analysis has considered both demand- and supply-side channels through which the pass-through rate may be moderated. To this end, we have explored the roles of purchasing power and competition, additionally allowing for variation in the magnitude of the pass-through rate over time. Three key results emerge. First, we find that pass-though estimates are subject to a high degree of spatial and temporal heterogeneity. In the case of diesel, estimates vary between 50 and 133%, while they vary between 46 and 97% for petrol.

Second, the results indicate that some part of this heterogeneity owes to the mediating influences of regional competition and income. Specifically, in theoretical consistency with our identification of not excessively convex demand for mobility, we find that the magnitude of the pass-through rate increases with the intensity of competition. When partitioning the data by state, we also find that pass-through tends to be higher where purchasing power is higher, which contrasts with the inverse relationship between income and pass-through found by Harju et al. (2022) in Finland.

Third, our application of an event study approach reveals a pronounced abatement in the magnitude of the pass-through rate over the three months that the discount was in effect. By the final month, the rate was about 46% for diesel and and 74% for petrol, thereby undermining the political endeavor to mitigate consumers' burden due to energy price shocks. We surmise that this pattern can be ascribed to waning consumer attention, but this is a question that warrants additional investigation.

We completed the analysis by exploring the budgetary costs of the fuel tax discount and, using the econometric estimates, the distribution in the incidence of financial relief to households. Over its three-month implementation, the costs totaled about €3.07 billion, reaching over a quarter of Germany's annual budget for foreign aid. Our calculations further show that roughly 62% of tax relief accrues to households earning above the median level of purchasing power, suggesting a regressive impact of the tax discount.

These findings have important policy implications that likely extend to other countries contemplating the implementation of fuel tax discounts. In particular, the spatial and temporal heterogeneity revealed by the econometric estimates point to the importance of assessing local economic conditions in guiding policy decisions on where and when to adjust fuel taxes. Based on the German experience, we conclude that the economic logic of the fuel discount was dubious, amounting to a distortion of market signals that encouraged higher fuel consumption – and primarily benefiting wealthier households – at a time when scarcity induced by the Russian attack on the Ukraine would have instead called for conservation.

Appendix

A Table: Testing Convexity of Fuel Demand

We begin by replicating a model presented by Alberini et al. (2022). Using MOP data covering the period 2005 through 2019, they estimate a fixed-effects model of logged distance driven on the logged fuel price, allowing for a differential effect between petrol and diesel cars. The estimates, presented in the first column of Table A1, indicate a fuel price elasticity of -0.37 for petrol cars and one essentially equal to zero for diesel cars.

Table A1: Test for Convexity of Demand based on Data of the German Mobility Panel

	logarithmic specification				linear specification			
	Model 1		Model 2		Model 3		Model 4	
	log(Monthly km driven)		log(Monthly km driven)		Monthly km driven		Monthly km driven	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
$\log$ p	-0.371**	(0.180)	-0.202	(0.243)	–	–	–	–
$(\log$ p$)^2$	–	–	-0.322	(0.386)	–	–	–	–
$\log$ p$\times$ diesel	0.386**	(0.179)	0.315	(0.193)	–	–	–	–
p	–	–	–	–	-265.489*	(137.166)	-553.623	(937.454)
p^2	–	–	–	–	–	–	102.184	(332.102)
$p \times$ diesel	–	–	–	–	393.416***	(148.383)	428.746**	(184.489)
Constant	6.704***	(0.132)	6.688***	(0.132)	1231.724***	(228.211)	1432.582**	(682.677)
# Observations	10,856		10,856		10,856		10,856	
R^2	0.729		0.729		0.717		0.717	

Note: Robust standard errors are in parentheses. ***, **, and * denote statistical significance at 1%, 5% and 10%, respectively.

Expanding on the analysis of Alberini et al. (2022), Model 2 additionally includes the square of the logged fuel price to allow for curvature in the logarithm of demand. The estimates in this case are uniformly statistically insignificant. Models 3 and 4 measure the price and distance driven in levels rather than logs, where a similar pattern emerges. Specifically, Model 4 indicates no evidence for highly convex demand, supporting the hypothesis of increasing pass-through in the level of competition.

B Table: Testing Robustness Clustering

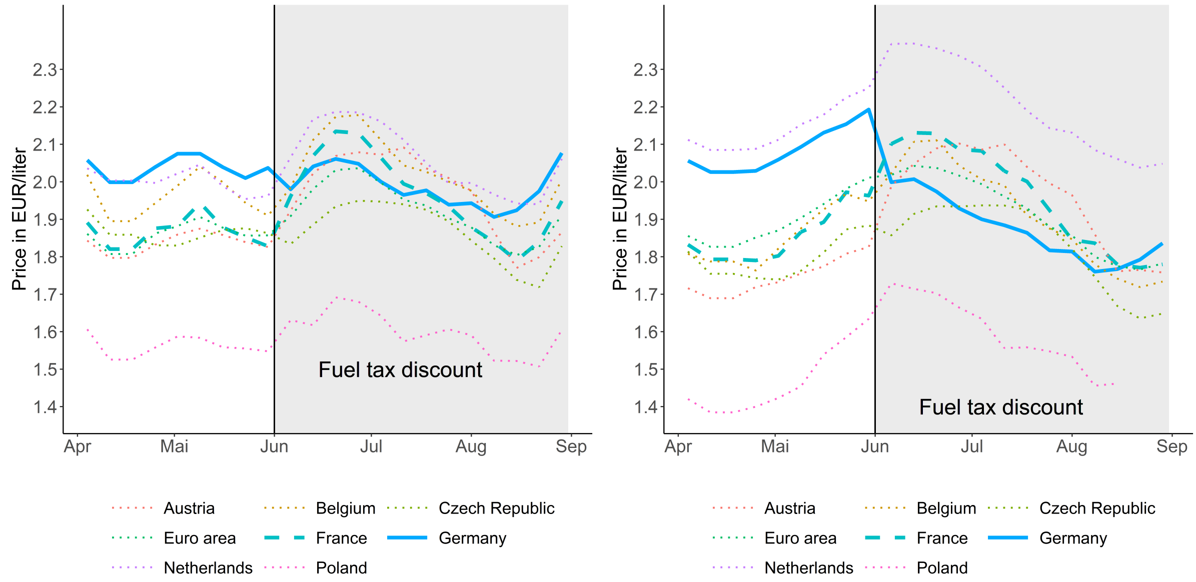
Table B1: Estimation Results on the Pass-through of the Fuel Tax Discount from the Difference-in-Differences Approach with varying Clustering

Cluster-level	County		Municipality		Two-way	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Panel A: Diesel						
FTD $\times$ GER	-0.161***	(0.002)	-0.161***	(0.001)	-0.160***	(0.008)
Observations	3,452,526		3,609,657		3,642,497	
R^2	0.76389		0.76698		0.76762	
Panel B: Petrol (E10)						
FTD $\times$ GER	-0.288***	(0.003)	-0.288***	(0.002)	-0.288***	(0.004)
Observations	3,326,970		3,484,101		3,516,646	
R^2	0.87004		0.86642		0.86565	
Station fixed effects	✓		✓		✓	
Time fixed effects	✓		✓		✓	

Note: Due to differences in how regions are defined in Germany and France, we assume the following similarities: German counties align with French departments and German municipalities represent French communes. Two-way clustering is performed by interaction the individual station with the day variable. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

C Figures

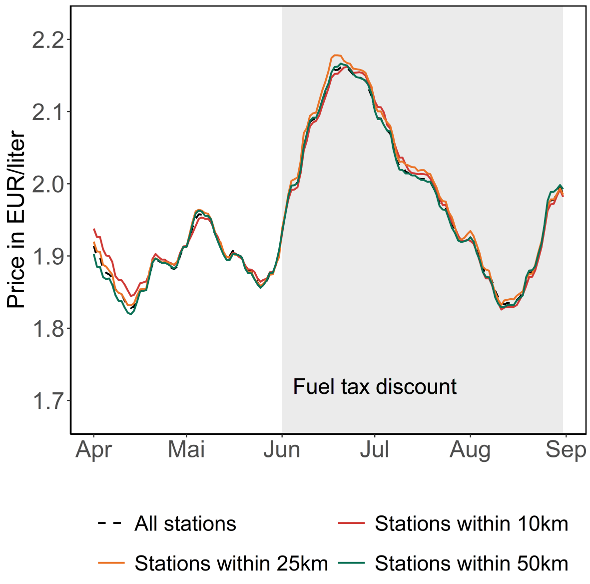
Figure C1: Weekly Diesel and Petrol Prices in selected European Countries, including France and Germany



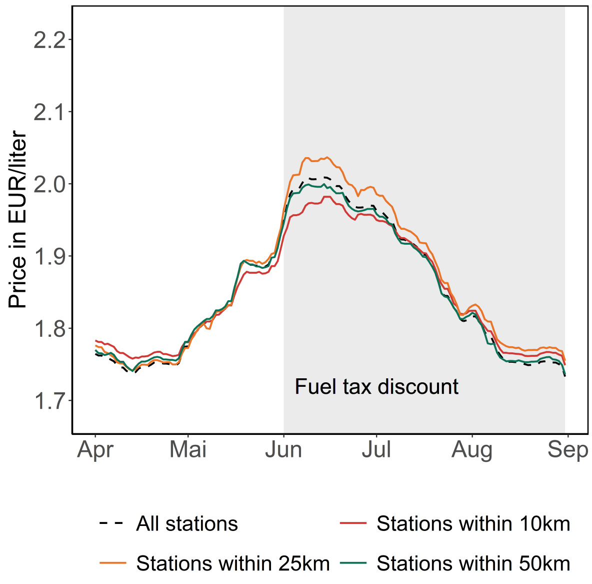
(a) Diesel

(b) Petrol (E10)

Figure C2: Fuel Prices of French Stations Close to the German Border



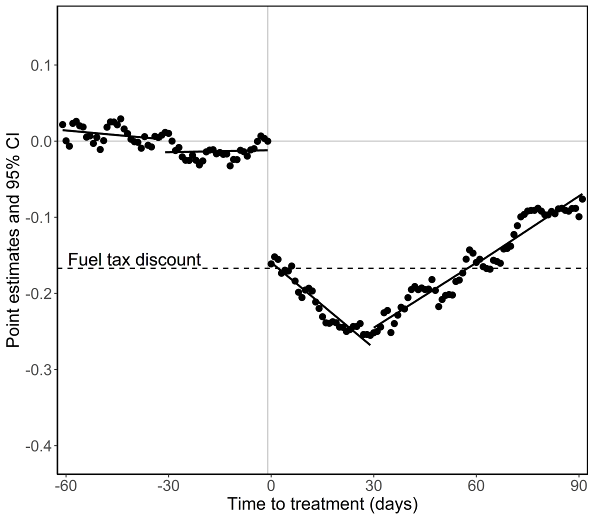
(a) Diesel



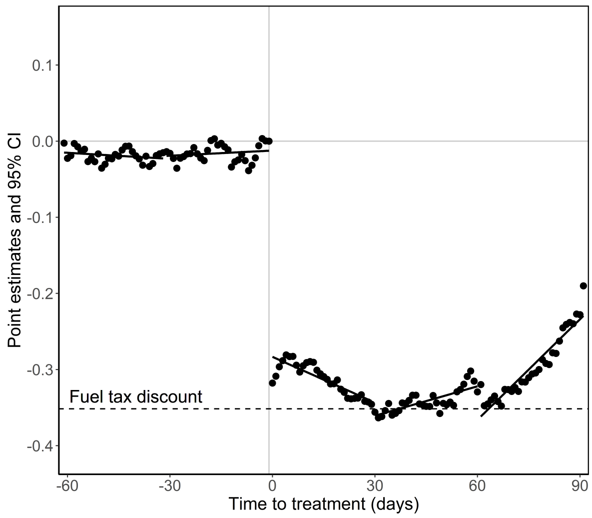
(b) Petrol (E10)

Note: French fuel prices for all stations and for stations within 10 km, 25 km, or 50 km from the French-German border.

Figure C3: Pass-through Estimation Results over Time without Federal States that Border France



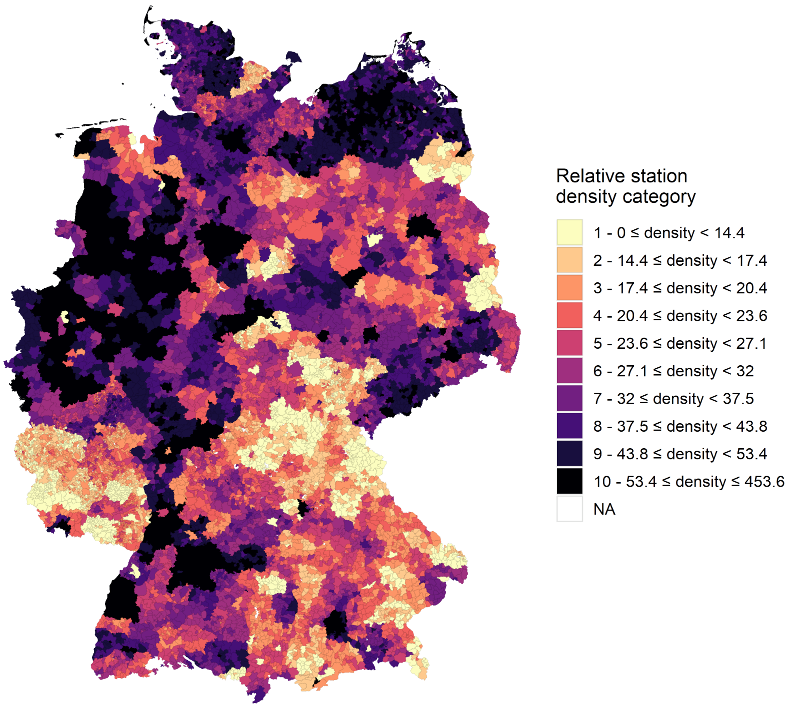
(a) Diesel



(b) Petrol (E10)

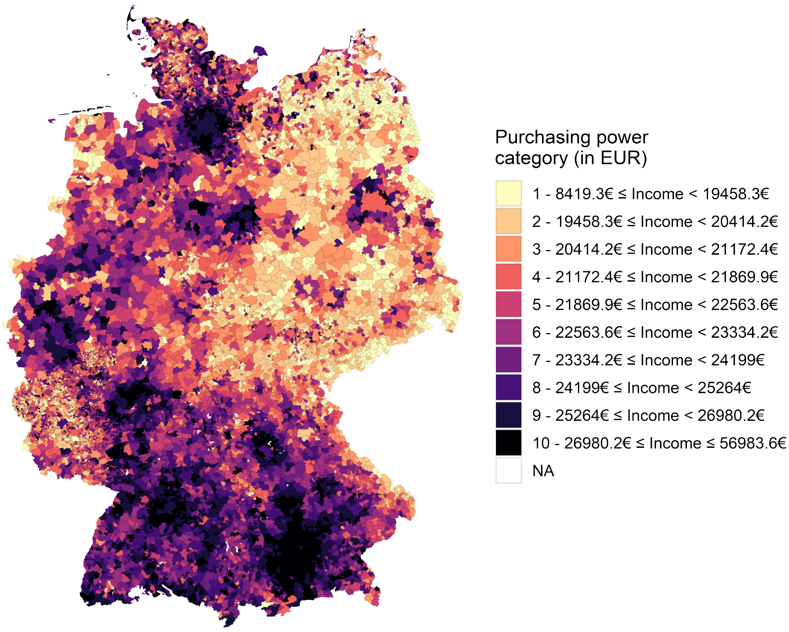
Note: The figure shows the baseline results with respect to May 31, the last day before the introduction of the FTD. The black solid lines indicate the monthly trend, the dashed lines represent the magnitude of the price discount (16.71 Cents per liter for diesel and 35.16 Cents per liter for petrol). The sample excludes the German states of Saarland, Rhineland-Palatinate, Baden-Württemberg.

Figure C4: Deciles of the Number of Gas Stations per Car per Household at the Municipality Level



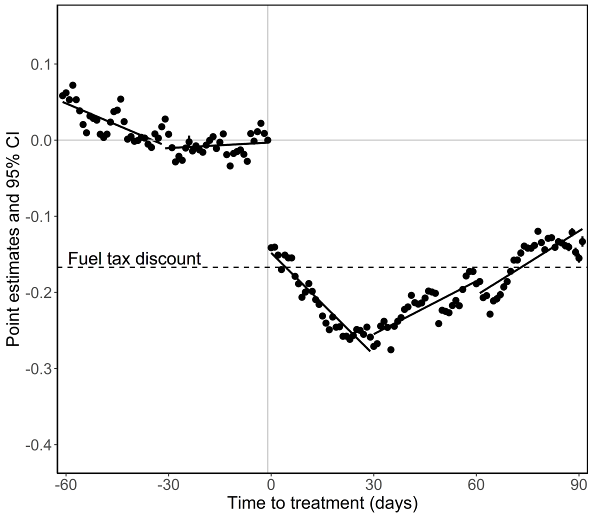
Notes: The map shows the deciles of relative station density at the municipality level, reflecting the number of gas stations per car per household. Some municipalities have missing values as they are not populated.
Source: RWI (2022) provides the raw data on cars per household.

Figure C5: Purchasing Power Categories at the Municipality Level

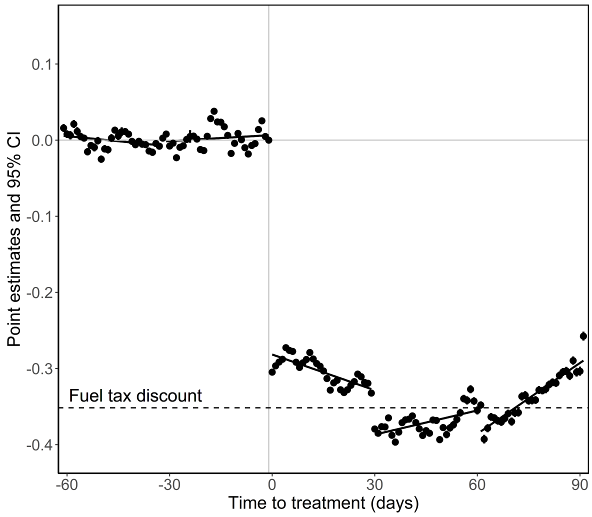


Notes: The map shows the purchasing power categories (based on deciles) for Germany at the municipality level. Some municipalities have missing values as they are not populated.
Source: RWI (2022) provides the raw data on purchasing power.

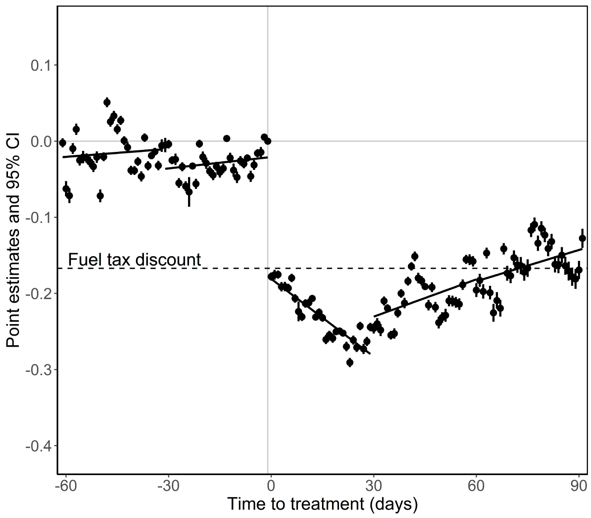
Figure C6: Pass-through Estimation Results over Time - Individual States



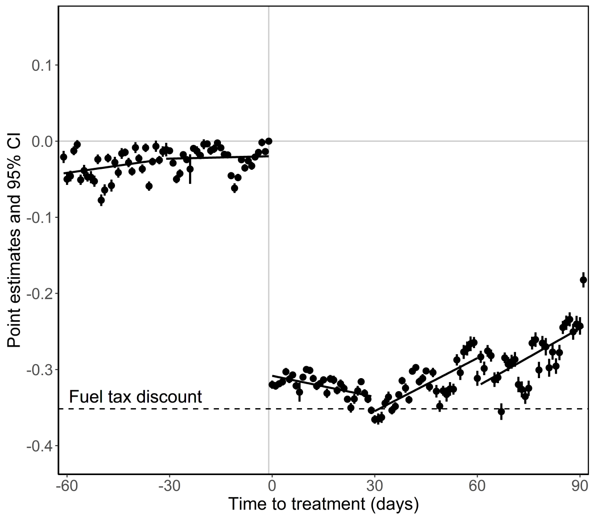
(a) Berlin - Diesel



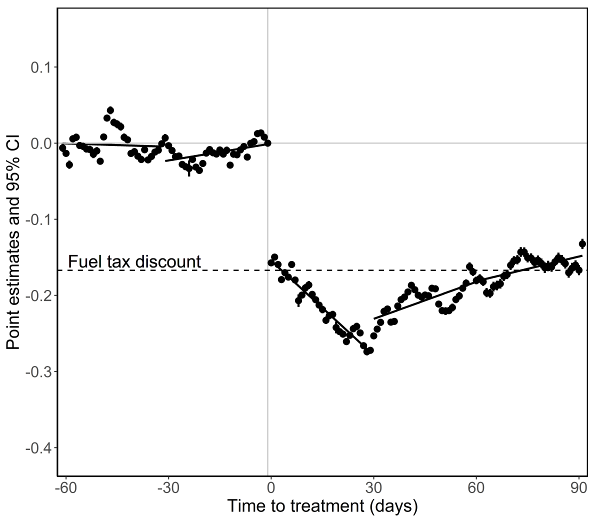
(b) Berlin - Petrol (E10)



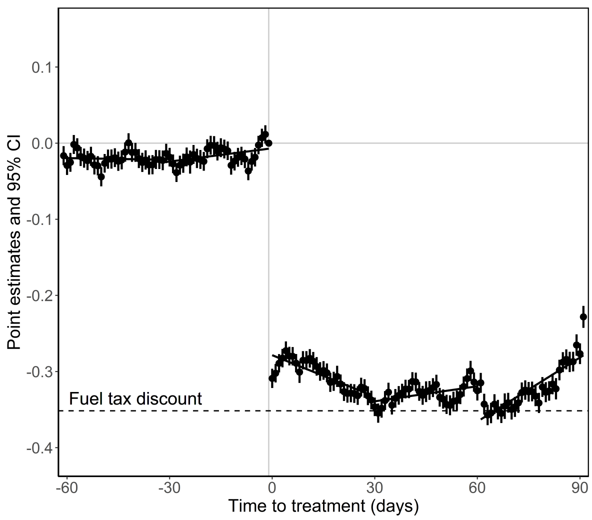
(c) Bremen - Diesel



(d) Bremen - Petrol (E10)

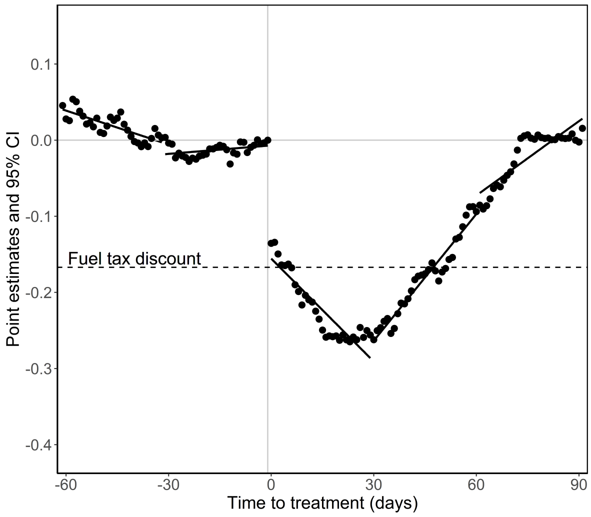


(e) Hamburg - Diesel

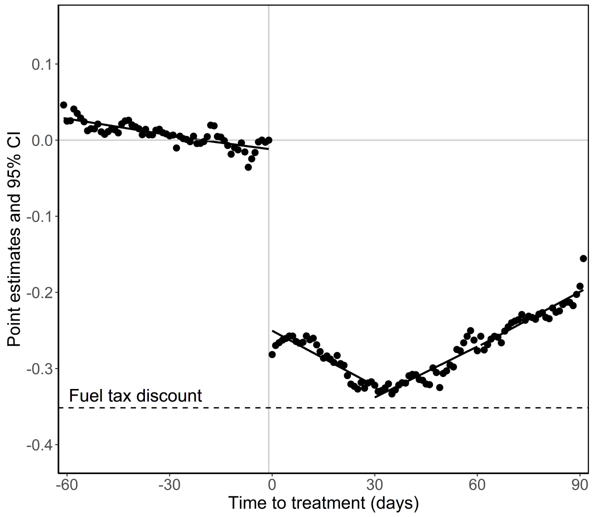


(f) Hamburg - Petrol (E10)

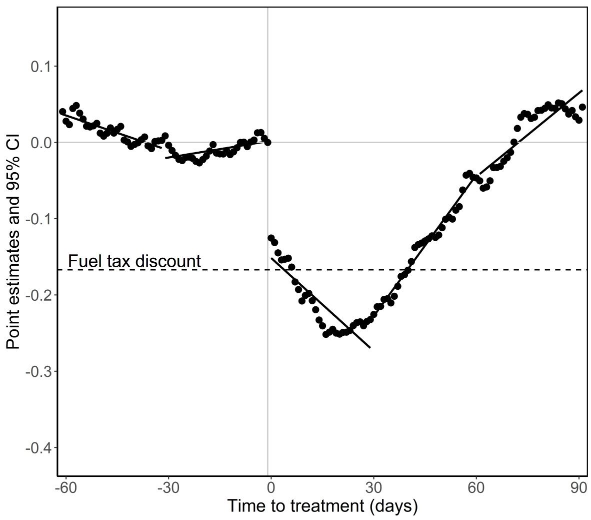
Figure C6: Pass-through Estimation Results over Time - Individual States (cont.)



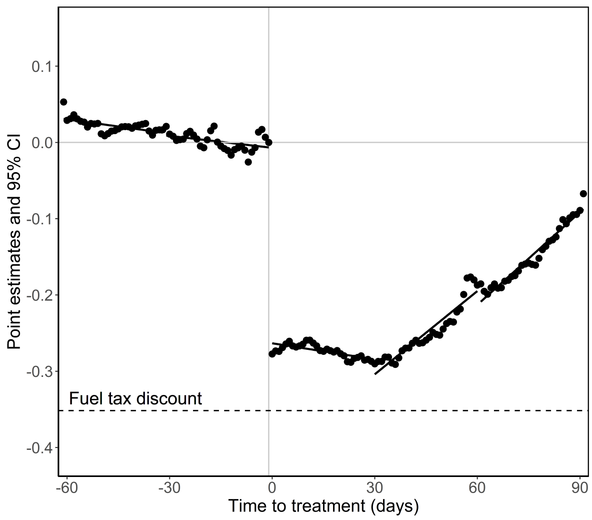
(a) Baden-Wuerttemberg - Diesel



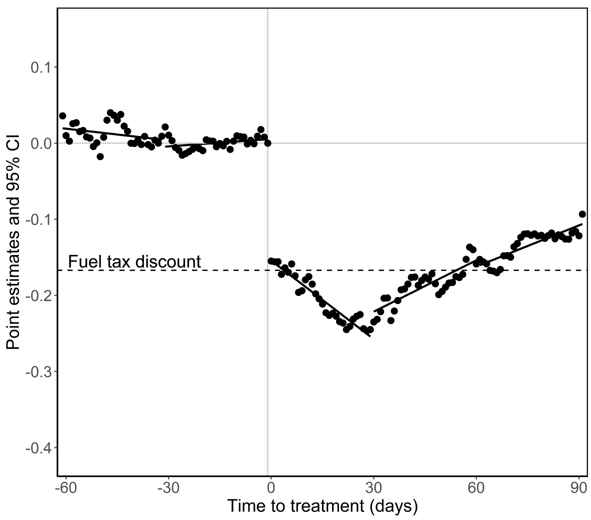
(b) Baden-Wuerttemberg - Petrol (E10)



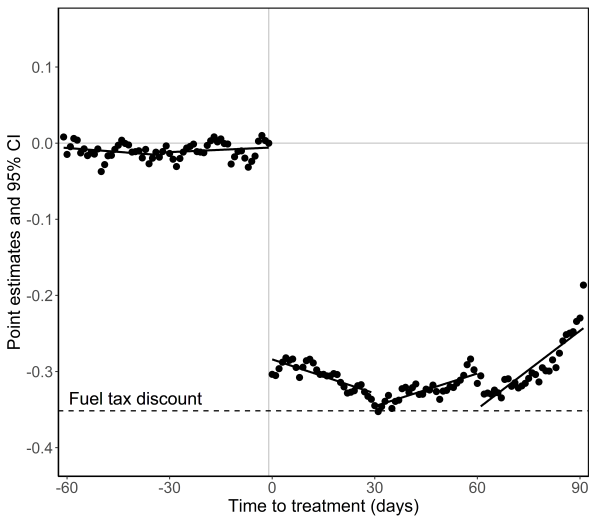
(c) Bavaria - Diesel



(d) Bavaria - Petrol (E10)

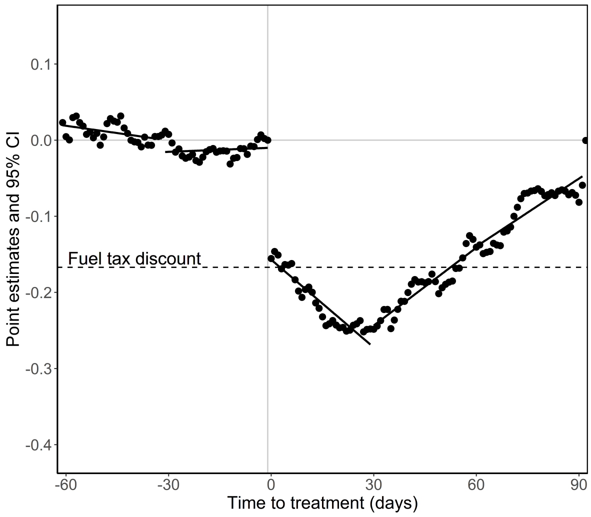


(e) Lower Saxony - Diesel

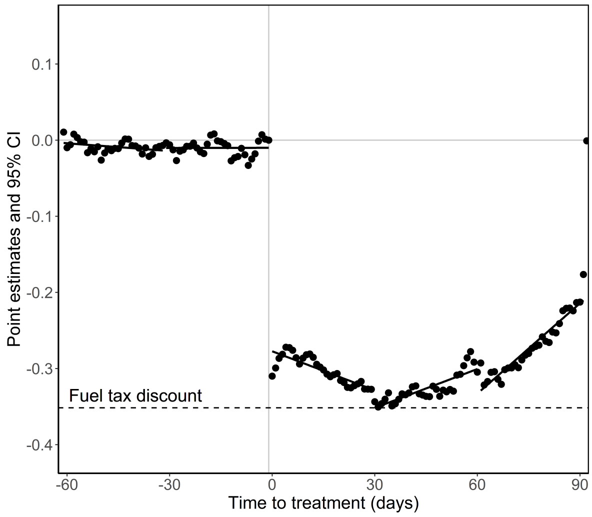


(f) Lower Saxony - Petrol (E10)

Figure C7: Pass-through Estimation Results over Time - Controlling for Temperature



(a) Diesel



(b) Petrol (E10)

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