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Could Tax Incidence Help Explain the Yellow Vest Movement?

Evidence from France on tax incidence and heterogeneous effects of carbon and fuel taxation along the rural-urban spectrum

Ann-Charlott Pahl (41897) and Anton Persson (41870)

Abstract: There is a general consensus amongst economists that taxing carbon emissions is an efficient policy tool for combating climate change. To fully understand the thorny issues surrounding the political economy and distributional effects of carbon taxation, more attention should be paid to the rural-urban dimension. Using fuel station-level data from close to all stations in France and Germany, this study investigates the tax incidence of the diesel tax changes in France in the time period from 2014 to 2018. In particular, it examines whether there is heterogeneity along the rural-urban spectrum in how the tax increases are passed on to consumers. Employing a novel difference-in-differences strategy allows us to relax the assumption of exactly parallel trends to construct robust confidence intervals. We do not find evidence for the diesel tax increases in France being passed on to consumers at different rates depending on whether they live in urban or rural areas. However, there is consistent evidence for the tax leading to increases in the price of diesel by more than the full amount of the tax increase. These findings contribute to the literature which investigates whether the extent to which fuel taxes are passed on to consumers varies depending on location. The empirical approach also highlights the importance of making reasonable assumptions about the extent to which the parallel trends assumption holds when using difference-in-differences models.

Keywords: Carbon tax, fuel tax, tax incidence, distributional effects, difference-in-differences

JEL: H22, H23, Q41, Q54, Q58

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Examiner:	Wärneryd, Karl

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1 Introduction

There is a general concern about the impacts of carbon taxes on households. This is often paired with a particular concern regarding the effect of higher fuel prices on rural households who are perceived to be put at a disadvantage from carbon taxation – this has indeed been found to be the main concern associated with carbon taxation amongst the public in France and Sweden, two countries that have implemented carbon taxes in the past (Douenne & Fabre, 2020; Ewald et al., 2022). The political economy of taxing fossil fuels is further complicated by the political realignment observed in much of the Western world with a growing geographical divide between educated urban voters who tend to support ambitious environmental policies, and less educated rural voters concerned with being left behind and feeling neglected by urban elites (Ford & Jennings, 2020; Kenny & Luca, 2021; McKay, 2019; Scala & Johnson, 2017). In such a political climate, it is easy to see how fuel prices and carbon taxation can become salient issues. Public resistance and perceived unfairness are important explanations for why carbon taxes are underutilised in government efforts to curb carbon emissions (see for example Bergquist et al. (2022) and Carattini et al. (2018)). This implies that furthering our understanding of the distributional effects of carbon taxation, with a particular focus on the rural-urban dimension, should be a priority. A common explanation for why rural motorists are more affected by higher prices on fuel is that they drive more. However, there are good theoretical reasons to suspect that it could also be the case that the tax incidence – how the costs associated with a tax are divided between consumers and producers – differs between rural and urban areas.

Given the importance of the rural-urban divide for reasons of political economy as well as for distributional reasons, in this paper we investigate whether the incidence of a carbon tax and higher taxes on diesel differs between rural and urban areas in France. We investigate four separate tax increases between 2015 and 2018. In a recently published paper, Harju et al. (2022) find that people in rural areas face a larger increase in the price of diesel due to an increase in the Finnish carbon tax compared to those who live in urban areas. That is, in response to the increase of the tax, the authors find that prices increase more for those living in remote areas. This channel could therefore be important in determining the distributional effects of carbon taxation. We use high-frequency fuel station level data on retail prices to investigate this question in the French context, employing a difference-in-differences strategy to investigate the fuel tax increases which eventually became a focal point for the yellow vest protests in 2018. In doing this, we utilise a novel method of constructing robust confidence intervals developed in Rambachan and Roth (2022). An important contribution of our paper is that we add to the limited literature which investigates whether the pass-through rate of fuel taxes differ between rural and urban areas.[1] We find no economically significant differences in how the carbon tax is passed on to rural, suburban and urban motorists. Further, we find robust evidence for diesel prices increasing by more than the full amount of the tax for all four tax increases that we are analysing. This suggests a degree of market power within the French diesel market. To the best of our knowledge, this is the first study to analyse the incidence of the French carbon tax. Our study further highlights the importance of incorporating the uncertainty associated with deviations from parallel trends when employing a difference-in-differences strategy.

Taxing carbon emissions is widely regarded as an effective tool to combat climate change, with

[1] The only other study we are aware of which does this is Harju et al. (2022).

broad support within the economics profession.[2] Carbon emissions from the transport sector have proven difficult for policymakers to tackle and constitute a significant share of global greenhouse gas emissions. For example, the EU has managed to lower its total carbon emissions from 1990 to 2020 by 32 percent. Yet, carbon emissions from the transport sector have increased by 7 percent during the same time period (Eurostat, 2022a, 2022b). In 2020, the transport sector accounted for more than a fifth of all greenhouse gas emissions worldwide (EDGAR/JRC, 2021). Passenger cars accounted for 41 percent of transport emissions in 2020 (IEA, 2021). As transport contributes a large share of greenhouse gas emissions at the global level, implementing policies to lower emissions from the transport sector is of great importance to reach the goal agreed by world leaders in the Paris Climate Agreement: to limit warming to less than 2 degrees and preferably to 1.5 degrees compared to pre-industrial levels. Mitigating emissions from the transport sector will be crucial if the world is to meet this target. Putting a price on carbon emissions from the transport sector will need to play an important role if we are to do this in an efficient manner. This is reflected in the European Commission's Mobility Strategy which includes pricing carbon emissions from transports to achieve sustainable mobility and contribute to reaching the EU's goal of net zero carbon emissions by 2050 (European Commission, 2020). Given the prominent role that carbon taxation will need to play and the complicated political economy surrounding it, it is important that we further our understanding of this policy tool.

The yellow vest protests in France during the end of 2018 are a vivid illustration of the public concern regarding the social and political acceptability of carbon taxation. A main target of these protests was president Emmanuel Macron's proposed increase of the carbon tax. Another important theme in the protests was inequality and the perception that Macron was a "president for the rich" (Jetten et al., 2020). In a large survey conducted in early 2019, two thirds of the French stated that they support the movement (Douenne & Fabre, 2022). After weeks of protests, Macron abandoned the planned increase of the carbon tax for 2019 and stated in a speech from the Élysée Palace that he refused to let the green transition contribute to making life more difficult for citizens in rural areas (Macron, 2018). In the previously mentioned survey, the problem most often associated with a carbon tax and dividend policy, where the revenue from the carbon tax is recycled to households, was that it would hurt rural households (Douenne & Fabre, 2020). It is worth noting that this concern was substantially larger than the concern that the policy would hurt the poor. In a case study of Sweden, the country with the world's highest carbon tax, Ewald et al. (2022) find the same result. Ewald et al. (2022) further find that living in a rural area is more important than income to explain opposition to climate policies. Similarly, Harrison and Peet (2012) find that opposition to the carbon tax in the Canadian province of British Columbia was concentrated to rural areas. Kallbekken and Sælen (2011) find higher support for fuel taxes if there are alternative means of transportation available, a potential explanation to why people are particularly concerned about unfairness in relation to rural areas. Soaring fuel prices across Europe in 2021 and 2022 brought the concern regarding rural motorists into focus. In the United Kingdom, then chancellor Rishi Sunak said regarding the increasing cost of motor fuels, a few day before lowering the fuel tax, "I have a rural constituency, people are incredibly reliant on their cars and this is one of the biggest bills that people face..." (Hammond, 2022). Almost all EU-countries responded to rising prices by reducing energy taxes, including

[2]See for example The Economists' Statement on Carbon Dividends at econstatement.org which is signed by more than 3,000 economists including 28 Nobel laureates and four former chairs of the Federal Reserve. See also carbontax.org/economists for an overview of prominent economists statements in support of carbon taxation.

fuel taxes (Sgaravatti et al., 2021). Clearly, when analysing the distributive effects of carbon taxes, it is imperative that we consider the rural-urban dimension in addition to the income dimension which traditionally has received much attention.

As mentioned, the most common explanation for why rural motorists are more affected by increased carbon taxes is that people in rural areas drive more than people in urban areas. However, whether, and if so how the tax incidence of carbon taxation varies along the rural-urban spectrum is an additional channel which could explain why rural motorists are more heavily affected. There are many potential sources which could lead to heterogeneity along the rural-urban spectrum in how taxes on fuel are passed on to consumers. A classic theoretical result in tax incidence is that the more inelastic side of the market will face a greater share of the tax. This implies that, all else equal, the more inelastic demand is, the higher is the pass-through rate of a tax increase. That is, the more inelastic demand is the greater is the share of the total tax increase which is passed on to consumer prices. Intuitively, one would expect demand to be less elastic in rural areas given the lack of alternative means of transportation. Several studies have indeed found that demand for fuel is more inelastic in rural areas (Blow & Crawford, 1997; Lawley & Thivierge, 2018; Wadud et al., 2010). Another potential source of heterogeneity is that the degree of competition in retail fuel markets is likely higher in urban areas than in rural areas. However, the effect of this on the pass-through rate is theoretically ambiguous and depends on the type and intensity of firm competition (Anderson et al., 2001; Weyl & Fabinger, 2013).

The rest of this paper is structured as follows: Section 2 provides an overview of the relevant theoretical and empirical literature on tax incidence and Section 3 describes the French retail fuel market wherein we motivate why our analysis is focused on diesel. In Section 4 we present our data, discuss our identifying assumptions and describe our estimation strategy. In Section 5 we present our results and in Section 6 we discuss our findings. Section 7 concludes the paper.

2 Theoretical and empirical results on tax incidence

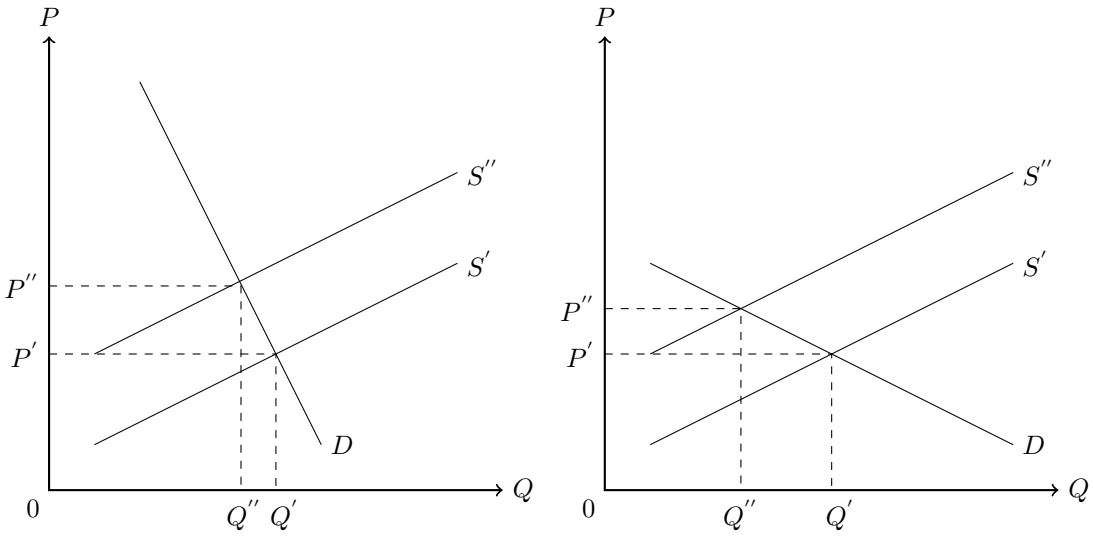
Tax incidence – how the burden of a tax is shared between consumers and producers – has long been studied by economists. One of the fundamental theoretical results on tax incidence is that the economic incidence of a tax is independent of the statutory incidence. That is, it does not make a difference whether the tax is physically paid by the producer or the consumer. For economic analysis it is thus, abstracting from administrative considerations, not relevant to consider who actually makes the transaction to the tax authority. The tax burden is instead generally split between the consumer and the producer.

The classic finding on tax incidence under perfect competition is that the pass-through rate depends on the relative elasticities of supply and demand, with the more inelastic side of the market facing a larger share of the tax burden. This canonical result is commonly represented as:

$$\frac{dp}{dT} = \frac{\eta}{\eta - \epsilon} \tag{1}$$

where p is the price of a good including the tax T, η is the price elasticity of supply and ϵ is the price elasticity of demand. With the reasonable assumption that the demand curve is not upward-sloping, that is $\epsilon \leq 0$, an inspection of Equation 1 shows that the pass-through rate in a

Figure 1: Tax incidence and the elasticity of demand



perfectly competitive market lies between 0 and 100 percent. The change in price with respect to a tax change is proportional to the relative elasticities of demand and supply. This intuition is illustrated in Figure 1. The imposition of an excise tax can be modeled as an increase in the marginal cost per unit, thereby shifting the supply curve up with the full amount of the tax from S' to S''. In the left panel, demand is steeper, that is more inelastic, than in the right panel of the figure. It is clear from inspection of the figure that in the scenario where demand is more inelastic, the price increase in response to the tax increase is greater.

In the extreme cases where consumer demand is perfectly inelastic ($\epsilon = 0$) or the supply side is perfectly elastic ($\eta \to \infty$) the tax is fully shifted on to the price, meaning that the tax is fully passed on to the consumers. Interestingly, this case is often what is assumed when analysing the effects of fuel taxes (see Ohlendorf et al. (2021) for an overview of this literature). A potential theoretical justification for this assumption is that in the long run, when supply is assumed to be perfectly elastic and there are zero profits, any tax increase would have to be entirely shifted on to the consumers. However, it seems implausible to assume that supply for motor fuels is perfectly elastic in the short run. Whilst demand for motor fuels is generally found to be inelastic in the short run, it is not completely inelastic (see Labandeira et al. (2017) for a meta-analysis).

Under imperfect competition, matters get significantly more complex. In such a market structure, the pass-through rate is not pinned down by the relative elasticities of supply and demand. The type of competition and strategic interaction between firms also influence the pass-through rates in this environment. In some settings where the demand curve is sufficiently convex – implying that demand responds less to price increases as the price goes up – pass-through rates can exceed 100 percent (Anderson et al., 2001; Weyl & Fabinger, 2013). The economic intuition behind this theoretical result is that if the demand curve is sufficiently convex, it can be steeper than the marginal revenue curve at the profit maximising equilibrium.

The effect of imperfect competition on pass-through rates is theoretically ambiguous in the absence of strong assumptions about the market structure and the type of strategic behaviour firms engage in. Further, under imperfect competition ad valorem and excise taxes are not equivalent. In a broad set of theoretical models of imperfect competition excise taxes are shifted on to consumers at a higher rate for a given amount of government tax revenue (Adachi & Fabinger,

2022; Delipalla & Keen, 1992; Hamilton, 1999; Suits & Musgrave, 1953). This theoretical result is relevant to keep in mind regarding the external validity of our results since the results could be different for, say, a change in the VAT rate.

When it comes to the empirical literature on pass-through rates, there have been many studies that look at how fuel taxes are passed on to retail consumers. Most of these studies estimate the average pass-through rate of changes to fuel taxes within states or countries. In general, recent studies have found full pass-through or close to full pass-through of fuel taxes on to consumers. For example, using state-level data from the US, Marion and Muehlegger (2011) estimate that on average fuel tax changes are fully passed on to consumers. Consistent with the classic theoretical model of tax incidence they find that in periods where the supply of fuel is more inelastic due to supply chain constraints, the pass-through rate is lower. Other recent studies of pass-through rates in the US from changes to state and federal fuel taxes find similar results. Silvia and Taylor (2016) find evidence for the state fuel tax in Washington being fully passed through to consumers for both petrol and diesel. Alm et al. (2009) find that state excise taxes on fuel are fully passed on to consumers with the exception of rural states where pass-through is lower. They suggest that this could be due to lower competition in rural areas. Doyle and Samphantharak (2008) find close to full pass-through of tax increases but lower pass-through of tax decreases in the US states of Illinois and Indiana, indicating asymmetry. It is however worth keeping in mind that the US is an outlier in fuel taxation amongst industrialised countries due to the low tax level.

In a European setting, using regional data from Spain, Bello and Contín-Pilart (2012) find full shifting of regional gasoline taxes to retail prices whereas Harju et al. (2022) find less than full shifting of an increase in the tax on diesel on to consumers. More recently, there have been two German studies examining the German fuel tax cut that was enacted to shield motorists from increasing fuel prices in the wake of the Russian invasion of Ukraine in 2022. Dovern et al. (2022) find that the German fuel tax reduction in early June 2022 was fully passed on to consumers. Studying the same event, Fuest et al. (2022) find full pass-through of the tax reduction for diesel and close to full pass-through for petrol. In another study on German fuel taxation, Montag et al. (2021) examine changes to the fuel tax that took place during the pandemic in 2020 when the government temporarily lowered the standard rate of VAT and in 2021 when this policy was reversed and a carbon price was introduced. They find significantly lower pass-through rates for petrol than for diesel where the pass-through of the tax changes is close to full. The three German studies are similar to ours in that they use France to construct their counterfactual to Germany, the reverse of our approach, and utilise data from the same sources that we use.

Although findings of tax overshifting – meaning that prices increase by more than the full amount of the tax – are rare in the fuel taxation literature, it has been observed in previous studies. Stolper (2016) examines the Spanish retail market for diesel and finds that there is significant variation in how much of the fuel tax that is passed on to consumers in different locations. He finds rates varying from 70 to 115 percent – indicating some overshifting – with a central tendency around 90 to 95 percent. Erutku (2019) finds evidence of overshifting of carbon taxes in the wholesale fuel market in Canada. Examining the pass-through of carbon pricing in the provinces Ontario and Quebec, he finds that there is overshifting of carbon prices in Ontario but not in Quebec and attributes the difference to a higher degree of competition in Quebec.

There is also a small literature which looks at heterogeneity in the pass-through rates of fuel taxes. When it comes to our focus on rural-urban heterogeneity, Harju et al. (2022) is the study

with an approach most similar to ours. Examining an increase in the carbon tax on diesel in Finland, they use consumer-reported prices of fuel at the station level to examine the effects of a carbon tax increase across the urban-rural spectrum as well as the income spectrum. Fuel stations are grouped into seven different categories depending on their level of urbanisation. The authors employ a difference-in-differences strategy where they use the price of petrol, which was less affected by the tax reform, at the same station as a counterfactual to the price of diesel. They find heterogeneity in pass-through rates: more urban areas face a lower pass-through rate than rural areas. It is however only between the most rural areas and the most urban areas that the difference is statistically significant at the 5 percent level. Further, the pass-through rate is found to be lower the higher the income of an area is. The pattern of more urban areas facing a lower pass-through rate is less pronounced but survives controlling for income. However, the authors acknowledge that they lack sufficient statistical power to fully test the interdependence of these two factors. The findings of Harju et al. (2022) suggest that not accounting for heterogeneity in pass-through rates will lead to an underestimation both of the degree of regressivity and the degree to which it affects the urban-rural divide.

Another study which examines heterogeneity and its distributional effects is Stolper (2016) who uses station-level data on the price of diesel in Spain. Using housing prices as a proxy for wealth, he finds, in contrast to Harju et al. (2022), that the heterogeneity in the pass-through rate makes Spanish fuel taxes more progressive. This differs from the income approach taken by Harju et al. (2022). It could be argued that housing prices approximate life-time income better than current income since people normally borrow against their future incomes when buying a house. Andersson and Atkinson (2020) find that the Swedish carbon tax on transport fuels is progressive when estimating it against life-time incomes but regressive when estimating it against annual incomes. This could potentially offer a way of reconciling these seemingly contrasting results.

Montag et al. (2021) also focus on heterogeneity in the pass-through of fuel taxes but their focus is on heterogeneity due to differences in consumer information. Specifically, they theorise that consumers who are more prone to shop around for the lowest fuel price will also face higher pass-through rates. Employing a synthetic difference-in-differences strategy to construct the relevant counterfactual at the station level, they find that the pass-through rate is significantly larger for diesel than it is for petrol both for a fuel tax increase and for a fuel tax decrease. Diesel cars are more expensive to purchase but are normally cheaper to drive per kilometer compared to a petrol car. Montag et al. (2021) argue that this means that diesel drivers have selected to trade-off lower driving costs for a larger initial investments and that they therefore are more informed about prices. Consistent with this, they find that diesel drivers are more prone to search for fuel prices than drivers of petrol cars. It is important to note that this channel is different from the standard price elasticity of demand channel that is traditionally explored in the literature on pass-through rates. It is not the aggregate demand for fuel that responds to prices, but rather that informed consumers seek out the lowest price to meet their demand. Luco (2019) also investigates how consumer search behaviour affects fuel markets. Studying the introduction of a mandatory price-disclosure policy for motor fuels in Chile, he finds that heterogeneity in consumer search behaviour plays a role in determining how prices evolve in the wake of the policy's implementation. He argues that whether such a disclosure policy is pro- or anti-competitive depends on whether consumer search behaviour or supply side price-coordination dominates. Consistent with this, he finds that prices decrease in areas with high search intensity and increase in areas with lower search intensity.

3 Institutional background

3.1 Diesel, E5 and E10

We have price data on three different fuels for both France and Germany at the station level: diesel, E5 and E10. E5 and E10 are variants of 95 octane petrol and a majority of petrol cars can run on either of these fuels. The difference between them is that E5 contains 5 percent ethanol and E10 contains 10 percent ethanol. There is only one type of diesel sold at retail fuel stations in France and Germany. In both France and Germany, the diesel blend contains a share of biodiesel. The shares of biodiesel in the two countries are very similar and remained stable during the time period we are examining (IEA Bioenergy, 2021a, 2021b). We choose to focus our analysis on diesel for the following reasons. First, the evidence for parallel trends between the fuel markets in France and Germany is significantly weaker for petrol than for diesel (see Appendix A). Second, there are important differences in the views that consumers have of E10 between the countries. During the time period we are studying, E10 was on an upward trajectory in France and became the most popular option for petrol drivers with a market share of 38.5 percent after overtaking E5 during 2017 (Sherrard, 2017). This indicates that the petrol market was changing in France during this time period. In Germany, it is E5 which is the default option for petrol drivers and sales of E10 are low by European standards. In 2017, E10´s share of the German petrol market was only 13.4 percent (Bioenergy International, 2018). The reputation of E10 in Germany has been damaged ever since the fuel was introduced in 2011 when many motorists feared that the fuel would damage their engines (Tosun, 2018). The differing trends in the uptake of E10 in conjunction with quite large deviations from parallel trends make Germany a less suitable counterfactual for petrol markets in France. We therefore limit our analysis to the diesel market.

Diesel is the main fuel for passenger cars in France. The share of diesel among French passenger cars was slightly above 60 percent for all years between 2014-2018 (Comité des Constructeurs Français d'Automobiles, 2022). Given the total number of registered passenger cars in France, this implies there were between 22 and 23 million diesel cars in France during this period (Ministère de la Transition écologique et de la Cohésion des territoires, 2021). The share of diesel cars is higher in France than in Germany. There were just above 15 million diesel cars in Germany in 2017, and their share of the total passenger car fleet was about 33 percent (KBA, 2022). The difference in the share of diesel cars between the two countries suggests that there might be a difference in consumer preferences. If households with diesel cars in Germany differ from households in France with diesel cars, this could be a source of concern. However, the fact that we observe very similar trends between the prices in diesel for France and Germany suggests that consumers do not react very differently to changes in prices (see Section 4.3.1), which is what we are concerned with for our current purposes.

Diesel cars cannot run on petrol so it is not possible to substitute between the fuels unless one has both a diesel and a petrol car or if one replaces one's diesel car with a car that runs on a different fuel. However, since diesel is cheaper per litre than petrol and is also more fuel efficient, it seems unlikely that people would substitute away from diesel into petrol to reduce the cost of driving in response to the diesel tax going up at a quicker rate than the petrol tax (more on this in Section 3.2).

Our analyses focus on diesel for passenger cars since prices for truck diesel are not reported to the Market Transparency Unit in Germany. Further, the markets for passenger and truck diesel are largely separate. Trucks do not fill up at the same pumps as passenger cars. They instead fill up at pumps that dispense diesel much quicker. In the French data, there is no distinction between prices for truck diesel and diesel for passenger cars. However, this does not mean that trucks actually pay the advertised price. To the extent they can, trucks driving for the larger transport firms fill up at private tanks at a transport depot. Prices for this fuel are not observed. Further, the real price that trucks face is lower than the one paid by passenger cars since they get reimbursed around 40 percent of the fuel excise tax (Entreprende.Service-Public.fr, 2020). This further justifies our focus on passenger cars. Trucks that fill up at public fuel stations would mainly do so during long hauls along highways. To investigate if this could have an effect on the pass-through rate we conduct a robustness check where we exclude fuel stations along French highways.

3.2 Carbon and fuel taxation in France

In 2014, a carbon tax was introduced in France by including a carbon component into the already existing excise tax on fossil fuels used for transports and heating buildings. The tax was introduced at a level of 7 euros per tonne of carbon. However, this was offset by reductions of other components of the excise tax in order for the introduction of the tax to be revenue and cost neutral in 2014, meaning that the total tax rate did not change (Hanafi et al., 2019; Rocamora, 2017). A future trajectory for the carbon tax was also proposed, and the tax subsequently increased to 14.5 euros per tonne in 2015, to 22 euros per tonne in 2016 with a medium term goal of reaching 100 euros per tonne in 2030 (Hanafi et al., 2019; Rocamora, 2017). All of the tax increases from 2015 to 2018 took place on the 1st of January. The original plan was for the tax rate to increase annually by 8.5 euros per tonne of carbon from 2017 to 2019. In the budget for 2018 the carbon tax was instead increased by 14.1 euros to 44.6 euros per tonne and the annual increase from 2019 until 2022 was set to 10.4 euros per tonne. This would have resulted in a carbon tax of 86.2 euros per tonne in 2022 (Hanafi et al., 2019). However, as a result of the yellow vest protests in November and December of 2018 the government abandoned this trajectory and froze the tax rate at its 2018 level.

When it comes to attempts at carbon taxation, France has a troubled past. This background is given in detail in Rocamora (2017). Already in 2000 an attempt was made to introduce an ecotax that would put a price on carbon emissions. After public consultations and lobbying from industry, a number of exemptions and differential rates were worked into the proposal in order to promote social acceptability and to protect competitiveness. This eventually led the Constitutional Council to declare the law unconstitutional with reference to the 1789 Declaration of the Rights of Man and the Citizen and its principle of equal treatment of taxpayers. A second attempt was made in 2009 with a new version of a carbon tax and dividend policy. This proposal eventually faced the same fate as the ecotax when it was deemed unconstitutional by the Constitutional Council on similar grounds.

Fossil motor fuels in France are subject to two taxes: an excise tax, *la taxe intérieure de consommation sur les produits énergétiques* (TICPE), and a value-added tax (VAT). The French carbon tax was implemented by incorporating a carbon component into TICPE. There is also a regional component in TICPE. Between 2014 and 2016 all regions in continental France except

one, Poitou-Charentes, chose to levy an extra 1.35 cents per litre of diesel on top of the nationally determined rate of TICPE to increase regional funding. Poitou-Charentes instead chose to lower TICPE by 1.15 cents per litre compared to the national rate. The island of Corsica also has a lower rate of TICPE as well as a lower rate of VAT on fuel which implies that all tax increases are lower in Corsica when accounting for VAT. This together with its special geography leads us to exclude the region from our analysis altogether. None of the regions changed the regional component of TICPE in the period between 2014 and the first half of 2016 (Ministère de l'Economie et des Finances, 2014; Ministère des Finances et des Comptes publics, 2015a, 2015b).

However, two changes were made to the regional components in two different regions during the latter half of 2016 and the start of 2017. First, the region of Poitou-Charentes was merged with two other regions in 2016 which led it to align its fuel tax rate with the rest of the new region by increasing the excise tax by 2.5 cents (Rondonnier, 2016). The new region of Nouvelle-Aquitaine imposed the same fuel tax rate as the rest of metropolitan France. Second, the region of Île-de-France which includes Paris increased its tax level by 1.89 cents per litre compared to the rest of the country in January 2017 (Ministère de l'Economie et des Finances, 2016). No further changes were made to the regional component of TICPE in 2018 (Ministère de l'Action et des Comptes Publics, 2018). These regional changes introduce empirical challenges which we describe in Section 4.2.

It was not only the carbon component of TICPE which increased during this period for diesel. Diesel has historically faced a lower tax rate than petrol. In 2014 the VAT-exclusive excise tax on petrol was 60.69 cents per litre and 42.84 cents per litre for diesel. To end this favourable tax treatment of diesel, the policymakers decided, on largely environmental grounds, to remove the taxation gap between petrol and diesel with the original plan being to close this gap by 2021 (Rocamora, 2017). This means that the total tax on diesel increased at a quicker rate than for petrol and that the fuel tax increase for diesel was larger than the magnitude of the increase of the carbon tax even though the carbon tax stood for the lion share of the increase. Since these changes occurred at the same time as the carbon component was introduced as well as within the same tax instrument we cannot disentangle them empirically. About 25 percent of the total tax increase on diesel from 2015 until 2018 comes from this readjustment meaning that the carbon component is responsible for roughly 75 percent of the tax increase.

Petrol and diesel are also subject to the standard rate of VAT which is 20 percent. VAT is paid on the net price of fuel, which includes TICPE. This means that VAT must be applied to the increase of TICPE to obtain the total tax increase. Table 1 shows the evolution of the diesel taxation incorporating the standard regional component of 1.35 cents per litre from 2014 to 2018.

Table 1: Changes in the diesel tax rate in France, 2014-2018

	Excise tax (ct/l)[1]	Excise tax including VAT (ct/l)	VAT-inclusive increase (ct/l)[2]
2014	44.19	53.03	-
2015	48.17	57.80	4.78
2016	51.16	61.39	3.59
2017	54.42	65.30	3.91
2018	60.75	72.90	7.60

[1] The excise tax includes the most common regional component. Between 2014 until the 1st of July 2016 the VAT-exclusive excise tax rate in Poitou-Charentes was 2.5 cents lower than in the rest of metropolitan France. In 2017 and 2018 the VAT-exclusive tax rate in Île-de-France was 1.89 cents higher than in the rest of metropolitan France.
[2] Due to rounding the increase can differ from the difference between the VAT-inclusive tax rates between consecutive years reported in the table.

3.3 Germany as a counterfactual

The role of Germany in our empirical strategy is to provide the counterfactual diesel price trend that would have been observed in France in the absence of tax increases. The price levels for diesel in France and Germany are similar in 2014 when we start our analysis as are taxation levels. The excise tax on diesel in Germany between 2014 and 2018 was 47 cents per litre and the VAT rate during the period was 19 percent. This tax level is very close to the one that France had in 2015 after the the first tax increase.

There are several other reasons for choosing Germany as our counterfactual. Both France and Germany are members of the Eurozone and European Union. This means that there is large overlap in how markets are regulated and in environmental standards between the two countries. Germany and France have the largest and second largest populations out of all EU countries respectively (Eurostat, 2022c). They are also similar in terms of GDP per capita (World Bank, 2022). Further, both countries have imposed mandatory reporting of fuel prices which could influence the way the fuel market operates (see for example Luco (2019)). Whilst school holidays in Germany differ somewhat between the federal states, the school holidays in France and Germany largely overlap implying that travel patterns will be similar. As neighbouring countries, they are also similarly situated geographically. This suggests that they utilise similar infrastructure to get fuel to fuel retailers and that fuel is sourced from similar sources. This implies that shocks emanating from the supply side should be correlated to a larger degree than if the countries were further apart geographically which helps our analysis since asymmetrical supply side shocks would cause deviations from parallel trends. There were no changes to the taxation of diesel in Germany between 2014 and 2018.

4 Estimation strategy, data and identifying assumptions

We use a difference-in-differences strategy to estimate the causal effect of the tax increases in France on the price of diesel. In this section we describe the data used, explain how we address the empirical challenges introduced by the regional tax changes in 2016 and 2017, explain our identifying assumptions and describe the method which allows us to relax the strict assumption

of exactly parallel trends. We conclude the section by describing our estimation procedure.

4.1 Data

4.1.1 Fuel station data

For our analysis, the two main data sources we employ are publicly available price data for individual fuel stations in France and Germany. Our data set covers nearly all fuel stations in Germany and France. In both countries, fuel stations are obliged to report changes in the price of diesel, E5 and E10 in real time to a government agency to promote price transparency. In France, this data is posted on a government website.[3] In Germany, the Federal Cartel Office makes this data available to approved third parties who offer platforms where consumers can obtain information about prices for fuel stations in Germany. We have retrieved our data set from Tankerkönig[4] which is a platform that provides researchers and fuel consumers with current and historical fuel price data based on what has been reported to the Market Transparency Unit. In both data sets, information is provided about the GPS coordinates for each station and the address including the postal code which allows us to assign each station to a category on the rural-urban spectrum. In the French data, but not in the German data, we have information about whether the station is located along a highway. The data manipulation process is described in more detail in Appendix B.

Corsica is an outlier in France given that it has a significantly lower fuel tax rate than the rest of metropolitan France and its geography is also special given that it is an island. We therefore exclude all 136 stations in Corsica from our dataset. The French data does not include stations from French overseas territories. Stations that sell less than 500 cubic metres (equivalent to 500.000 litres) of fuel per year are not obliged to report price changes to the government, but may do so if they wish. This is a potential source of bias if these stations choose not to report and systematically differ from other stations. For example, it seems plausible that smaller fuel stations are more likely to be located in rural areas and this could be a problem given our focus on the rural-urban dimension. Nonetheless, we believe that it is unlikely that missing reports from stations that fall below this threshold will have a significant impact on our estimates. First, for the potential absence of these small French stations to affect our estimates it would have to be the case that they follow a separate trend compared to the rest of the French stations or that they react very differently to the increase of fuel taxes on diesel compared to stations that sell more fuel. We do not see a good reason for why these stations would follow a very different price trajectory compared to all other French fuel stations. A difference in levels compared to other stations would not be a problem since this would not impact our estimates as what we are analysing is *changes* to the diesel price. Second, the average medium- or large sized fuel station in France sold more than 5.200 cubic metres of fuel in 2018. The average independent/small fuel station sold more than 2.700 cubic metres of fuel in the same year and these volumes have not fluctuated much during the period we are examining (UFIP, 2021). This latter average is more than 5 times the obligatory reporting threshold. Given this, it seems unlikely that a large number of stations fall below the threshold of 500 cubic metres. Further, even if a significant

[3] https://www.prix-carburants.gouv.fr/rubrique/opendata/

[4] https://dev.azure.com/tankerkoenig/tankerkoenig-data

number of stations fall below this threshold some of them might still choose to report and thus they would be included in our analysis. We therefore do not believe that this exception from obligatory reporting introduces a bias into our empirical strategy.

4.1.2 Degree of urbanisation

Since we are interested in whether there is heterogeneity in the pass-through rates depending on the degree of urbanisation we need a systematic method for categorising areas along the rural-urban spectrum. To do this we use Eurostat's Local Administrative Unit (LAU) system. The LAU system covers all local administrative units in France and Germany and uses the same classification criteria for all EU countries to assess the degree of urbanisation for each LAU. As suggested by the name, the LAU system is structured around administrative units like municipalities and communes. Eurostat (2019) describes how this classification works in detail. Each LAU is assigned to one of three degree of urbanisation categories: city, town/suburb or rural. We will throughout be using "urban", "suburban" and "rural" respectively to refer to these three categories. The classification is mainly based on population density and geographical contiguity. Importantly for our purposes, in LAUs classified as cities, at least 50 percent of the population lives in urban centres with at least 50,000 inhabitants. In towns/suburbs, at least 50 percent of the population lives in urban clusters with at least 5,000 inhabitants and less than 50 percent of the population in urban centers. A LAU is classified as rural if more than 50 percent of the population lives outside of urban areas. As can be seen from Table 2, the shares of gas stations located in urban, suburban and rural areas are relatively similar between France and Germany.

Table 2: : Summary statistics on the diesel market in France and Germany

	France	Germany
No. of fuel stations	11,682	16,296
Share of fuel stations in urban regions	34.1%	31.6%
Share of fuel stations in suburban regions	39.0%	47.4%
Share of fuel stations in rural regions	26.9%	21.0%
Share of diesel cars	62.3%	33.0%

Notes: All numbers except for the share of diesel cars are calculated based on the datasets from the Ministère de l'Économie, des Finances et de la Souveraineté industrielle and Tankerkönig with the urbanisation classification from Eurostat's LAU codes. Data on the share of diesel cars is sourced from the Kraftfahrt-Bundesamt and the Comité des Constructeurs Francais d'Automobiles.

4.2 Regional fuel tax changes

As was noted in Section 3.2, in 2016 and 2017 there were two changes made to the regional components of the French fuel excise tax beyond the changes at the national level. The region of Poitou-Charentes which previously had a lower fuel tax rate than the rest of metropolitan France was incorporated with the new region of Nouvelle-Aquitaine in 2016 whose diesel tax rate aligned with the rest of metropolitan France. This led fuel taxes in Poitou-Charentes to increase

by 2.5 cents per litre in July 2016 as they were aligned with the rest of the region (Rondonnier, 2016). A further change was made at the start of 2017 when the excise tax on diesel in the region Île-de-France, the region which includes Paris, increased by 1.89 cents per litre compared to the rest of the country. The fact that different parts of the country faced different increases in the tax on diesel poses a challenge. To get around this issue, we exclude stations in Poitou-Charentes and Île-de-France from our main specification for the tax increase in 2017. Stations in Poitou-Charentes are excluded from the 2017 tax increase as they are affected by a tax increase in the pre-treatment period. Since the region of Île-de-France is the most populous in France we want to make sure that excluding it does not have a large effect on our results. As a robustness check we therefore include a regression on the sample of stations in France but including a dummy variable for stations in Île-de-France. This allows us to capture the effects of the different tax increases separately for Île-de-France and the rest of the country.

4.3 Identifying assumptions

4.3.1 Parallel trends

The canonical identifying assumption for a difference-in-differences strategy is that trends in the control unit and the treatment unit would have been parallel in the absence of treatment which in our case is the increase in the tax on diesel in France. We begin by describing our approach in a setup where we are estimating the countrywide effect before proceeding to discuss how we apply an analogous approach to estimate the effect along the rural-urban dimension. In the countrywide setting the parallel trends assumption implies that we assume that diesel prices in France and Germany would have been parallel in the absence of changes to the diesel taxation in France. This assumption is often investigated by considering the trends prior to treatment. In Section 4.4.1 we describe a method for relaxing this assumption to obtain more robust confidence intervals. The parallel trends assumption cannot be tested directly since the counterfactual scenario is never observed, but it is made significantly more plausible if trends are parallel prior to treatment – that is, prior to the diesel tax increases in France.

The data covers June 2014 to June 2018. This avoids including potential effects of the increase in the standard VAT rate from 19.6 percent to 20 percent that took place in France in January 2014. We end our analysis on the 30th of June 2018 to avoid the turbulence which occurred in the German fuel market during the latter half of 2018 when water levels in the Rhine ran very low. This meant that fuel could not be transported along the river which led to reports of shortages. The situation eventually forced the German government to release fuel from the strategic oil reserve ("Drought-hit Rhine forces Germany to tap oil reserves", 2018). These supply chain issues increased the price of diesel in Germany but not in France. As previously mentioned, Germany made no changes to the way fuel was taxed between 2014 and 2018, nor have we found any other reforms which might plausibly impact the fuel market in Germany during this time period.

Figures 2 and 3 show the trends for the average weekly price of diesel in France and Germany from June 2014 to June 2018. The trends in the data trace each other closely apart from the tax increases that occur at the beginning of each year. There is one notable exception: in May and June 2016 there is an increase in the price of diesel in France and we do not see a

corresponding price change in Germany. During this period, French refinery workers were on strike to protest new labour laws. The refinery strike affected the supply of fuel to many fuel stations in the country (Chrisafis, 2016). A natural effect of this supply side disruption was that diesel prices increased asymmetrically in France. Since this rather large deviation from parallel trends occurred at the same time as the refinery strike we feel confident in attributing this deviation to that event. We do not believe that this temporary deviation is a cause of concern for our analysis since it occurred at a convenient time for our purposes. As the strike happened close to the middle of the year, we can leave this period out in our analysis of the preceding and succeeding tax increases and still have enough data to estimate the effect of the tax changes on the price of diesel. Overall, a visual examination of the trajectories of diesel prices in France and Germany supports our assumption of parallel trends apart from the tax increases in France and the asymmetrical shock emanating from the refinery strike in 2016.

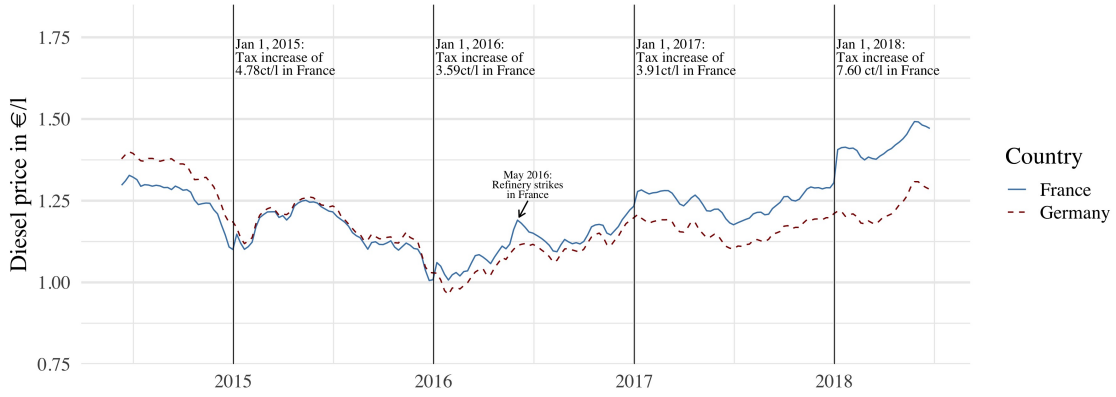


Figure 2: Weekly average diesel prices in Germany and France, 2014-2018

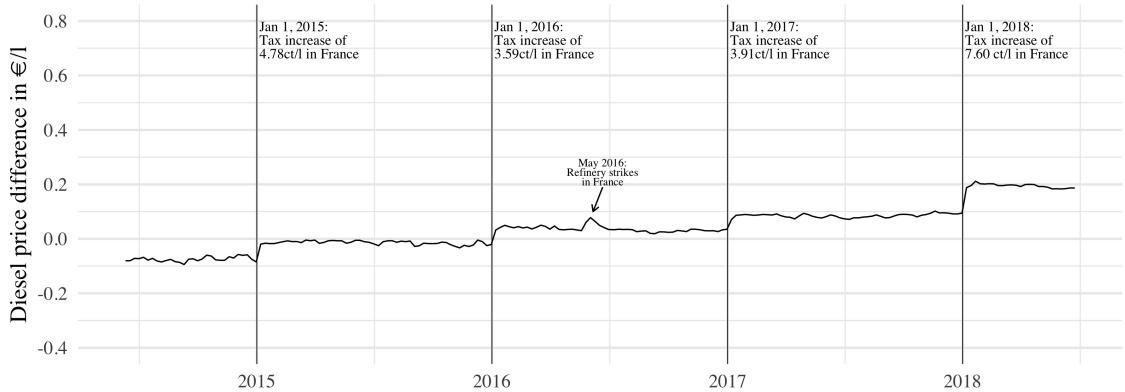


Figure 3: Weekly average difference between diesel prices in Germany and France, 2014-2018

Kahn-Lang and Lang (2020) argue that to further bolster the credibility of the parallel trends assumption the researcher should also explain why levels differed in the first place and why the factor that made the levels differ would not also lead to a difference in trends. As can be seen from Figures 2 and 3, diesel price levels in France and Germany were very similar at the start of our analysis and the shifts in price levels during the period we study occurred in conjunction with

tax changes. On a similar note to Kahn-Lang and Lang (2020), Roth (2022) urges researchers to use contextual and economic knowledge to inform the analysis of the parallel trends assumption and possible violations of it. We believe that there are good reasons to think that diesel prices in France and Germany follow parallel trends. Diesel is a commodity which can be easily stored and transported, and the tax-exclusive price of diesel is largely decided by shifts in the price of crude oil which is traded on a global market with an essentially global price. Further, since France and Germany are neighbouring countries they also share much of the same supply side arrangements to get diesel to consumers. Since these reasons apply for the entire time period that we are analysing, they strengthen our belief that the diesel price trends are largely parallel during the period we are interested in and that level shifts are due to changes in taxes.

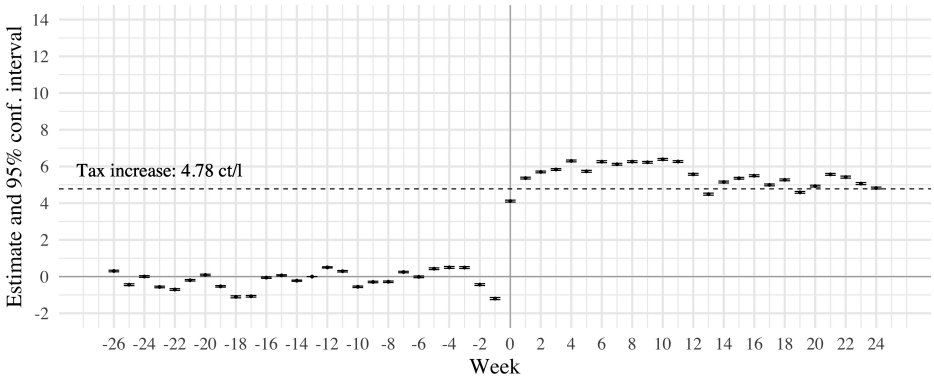
To get a further indication of the degree to which the trends in France and Germany are parallel before the tax increases we run an event study regression where we estimate a model which includes lags and leads. Specifically, we estimate:

$$P_{s,t} = \phi_1 + \sum_{x \neq r} 1(x = t) France_s \phi_{2,x} + \tau_t + \sigma_s + e_{s,t} \tag{2}$$

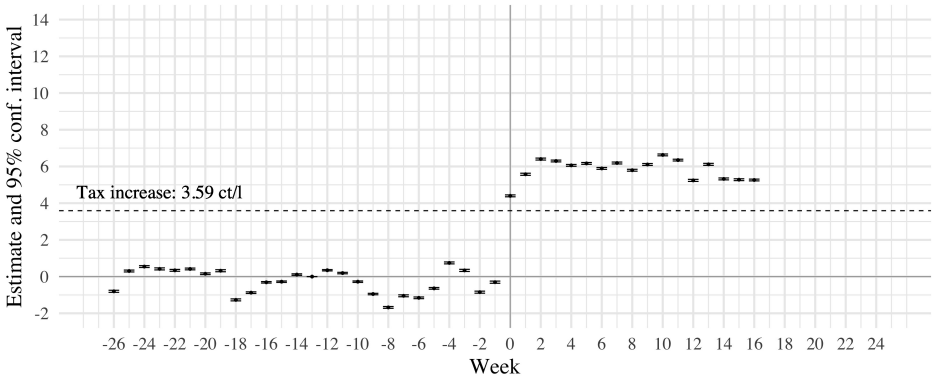
for all four carbon tax increases separately where $P_{s,t}$ is the average weekly price of diesel in week t at station s. $France_s$ is a dummy variable which equals one if the station is in France. The index x runs over all 26 pre-treatment and 25 post-treatment periods, with the exception of year 2016, when it only captures 17 post-treatment periods due to excluding weeks that were affected by the French refinery strike. The time series is re-centered so that $t = 0$ in the week that the tax increase occurs. The parameter τ_t captures time fixed effects which are common to both countries and σ_s captures time-invariant station characteristics. In estimating Equation 2 we obtain weekly coefficients, $\phi_{2,t}$, which indicate how the price level in France changes in relation to the price level in Germany for each week. The values of these coefficients are plotted in Figure 4 for the four tax increases occuring on January 1st between 2015 and 2018. The carbon tax increase occurs in week 0. To convey a representative picture of the magnitudes involved, we choose as our reference week, that is, the omitted week r, the most representative week in the pre-treatment period for each year.[5] Standard errors are clustered at the station level as we expect errors to be correlated at the station level.

From Figure 4 we see that the value of the coefficients prior to the tax increases in $t = 0$ are generally small, only 13 percent are above 1 cent. However, almost all of the deviations are statistically significant at the 1 percent level, indicating evidence for a deviation from the null hypothesis of exactly parallel trends. In many studies, this type of test is used as a formal test for whether trends are parallel. There are several problems associated with this practice. Failing to reject the null hypothesis that trends are exactly parallel does not entail that one should accept the null hypothesis. Roth (2022) surveys papers that use this technique for detecting deviations from parallel trends and shows that many of them suffer from low statistical power and fail to detect violations of parallel trends. This is not a problem for us given that we have a large number of observations and obtain very small standard errors. However, as pointed out by Roth et al. (2022) and Bilinski and Hatfield (2020), there are problems associated with this practice

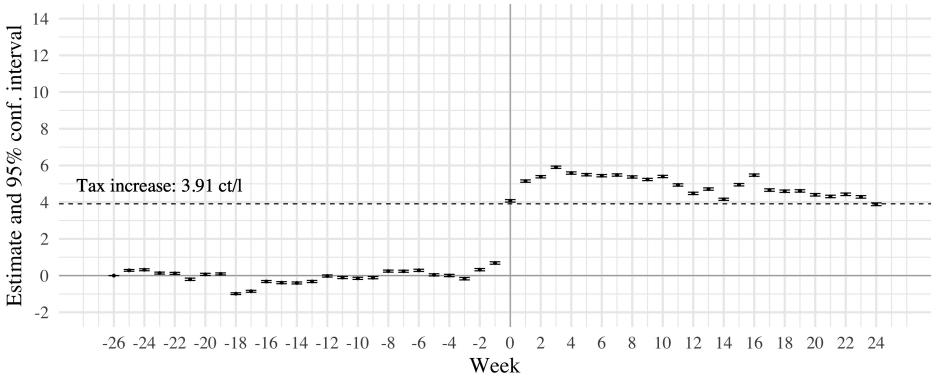
[5] As the reference week, we choose the most representative week for the pre-treatment period as a whole, defined by the week with the median coefficient value from an initial estimation of Equation 2.



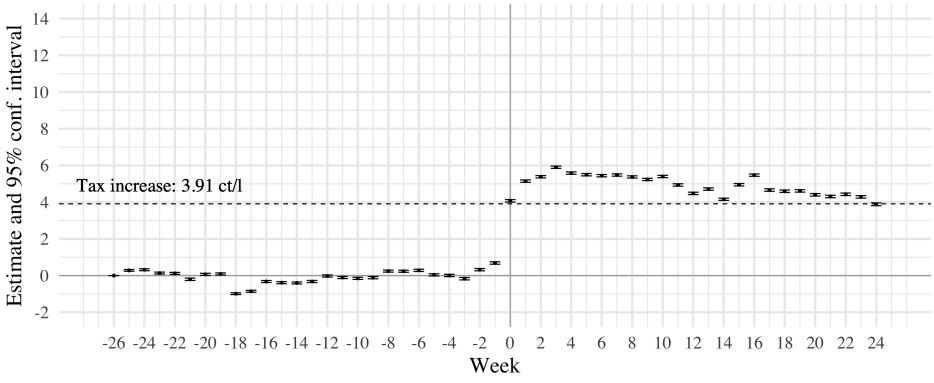
(a) Tax increase 2015



(b) Tax increase 2016



(c) Tax increase 2017



(d) Tax increase 2018

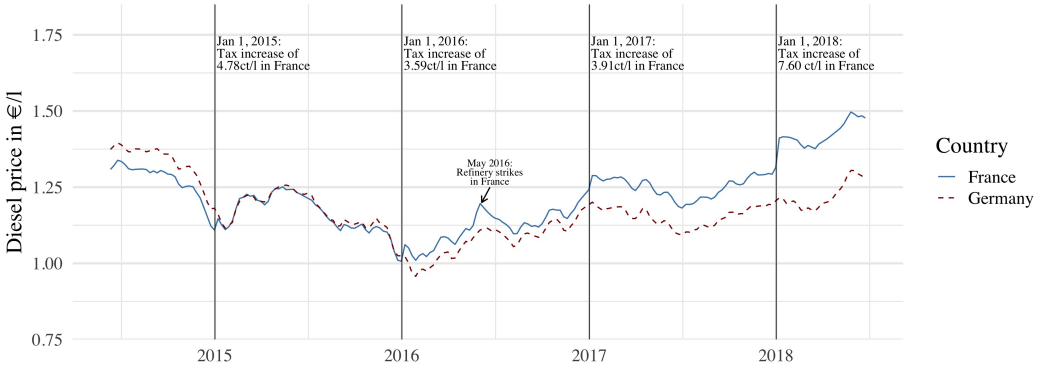
Figure 4: Event-study plots for the diesel tax increases 2015-2018

in our situation as well: as the number of observations increases and the standard errors shrink we would eventually find statistically significant deviations from parallel trends in practically every case. In the real world, we would not expect to find that trends are exactly parallel even if they exhibit the same pattern to a very high degree. There will always be some noise and small asymmetric shocks – even in settings where we have strong economic reasons to think that trends follow a common pattern.

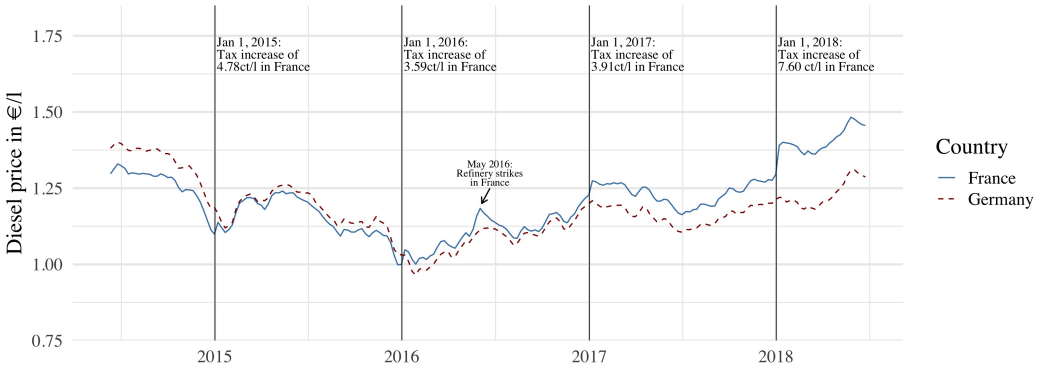
Our analysis of the extent to which trends are parallel convinces us that we can appropriately proceed with a difference-in-differences approach, but we need to account for the uncertainty associated with deviations from parallel trends. As mentioned, the deviations from parallel trends in Figure 4 are small. There are several reasons for thinking that our trends are essentially parallel beyond the graphical evidence offered in Figures 2 and 3. Here, the many time periods we are investigating offer important evidence. First, there is no apparent trend in the pre-treatment deviations. Specifically, it is not true that the magnitude of the deviations increase monotonically over time and they do not increase in one specific direction. Had we found such a pattern in Figure 4 that would have been an indication that trends are diverging over time. It should also have been evident from inspection of Figures 2 and 3. The absence of such a pattern reassures us that the deviations we observe can be thought of as non-persistent deviations from parallel trends. Therefore, we do not expect our point estimates to be biased in a particular direction. However, the fact that there are deviations from parallel trends increases the uncertainty associated with our causal estimates of the effect of the tax increases on the price of diesel. Intuitively, we can think of there being two sources of uncertainty in our setup: one is the uncertainty arising from point estimates being imprecisely estimated and the second arises from the fact that we also see deviations from parallel trends. In traditional difference-in-differences studies, only the first source of uncertainty is typically considered. To account for the second source of uncertainty, we use a novel method developed in Rambachan and Roth (2022) which incorporates the deviations in the pre-treatment period to construct more robust confidence intervals. This method is further described in 4.4.1.

We now turn to the analogous parallel trends assumption for the setup where we estimate how the tax changes impacted rural, suburban and urban France. There are some subtle differences to the parallel trends assumption in this setting. Rather than having Germany as a whole acting as a counterfactual for France, we now have that urban Germany acts as a counterfactual for urban France, suburban Germany acts as a counterfactual for suburban France and rural Germany acts as a counterfactual for rural France. To point-estimate the causal effects we now need that in the absence of the tax increases the parallel trends assumption would have held between each pair within our rural-urban classification scheme. For example, it needs to be the case that the trend in rural France would have been parallel to the trend in rural Germany in the absence of a tax change. The analogous parallel trends assumptions need to hold for the urban and suburban categories. This approach allows us to separately estimate the pass-through rates for urban, suburban and rural France for each of the tax increases between 2015 and 2018. As before, we cannot test the parallel trends assumption directly but it is made more plausible if trends are parallel prior to the tax increases. Starting again by investigating the visual evidence, we plot the weekly average price of diesel along the rural-urban dimension in Figure 5.

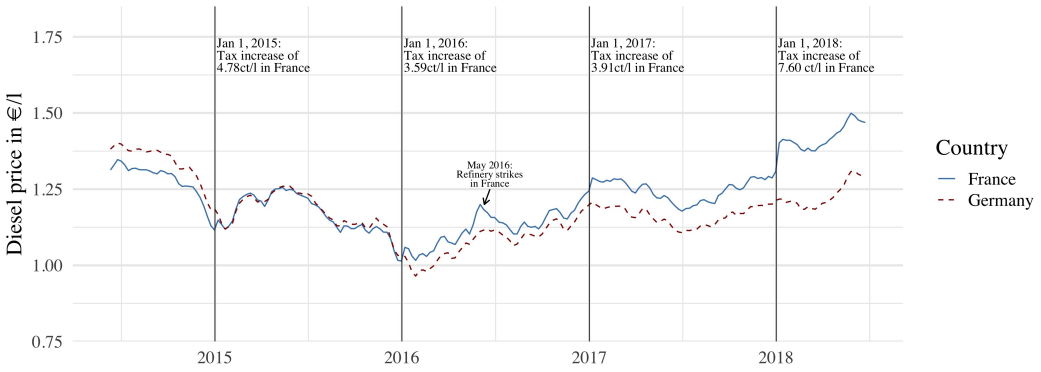
The price trends in Figure 5 appear to support the analogous parallel trends assumptions. Again, there is a clear violation of the parallel trends assumption in May and June in 2016 in conjunction with the refinery strike in France for urban, suburban as well as rural areas. We therefore exclude



(a) Weekly average diesel prices in urban areas in Germany and France 2014-2018



(b) Weekly average diesel prices in suburban areas in Germany and France 2014-2018



(c) Weekly average diesel prices in rural areas in Germany and France 2014-2018

Figure 5: Average weekly diesel prices in France and Germany per degree of urbanisation classification 2014-2018

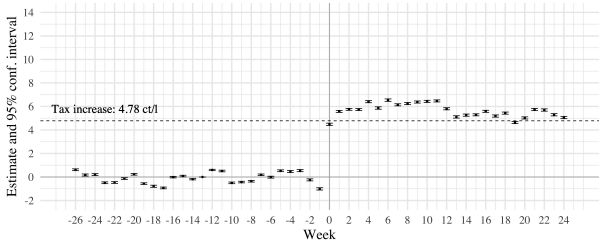
observations from May and June of that year from our analysis. We also estimate an event study-type equation that is analogous to Equation 2 for our rural-urban setting to get a better understanding of the dynamics of the tax increase and to get a sense of the extent to which trends are parallel. Specifically, we estimate the equation:

$$\begin{aligned} P_{s,t} =& \gamma_1 + \sum_{x \neq r} 1(x = t) France_s \gamma_{2,x} + \sum_{x \neq r} 1(x = t) \boldsymbol{G'}_s \boldsymbol{\gamma}_{3,x} + \sum_{x \neq r} 1(x = t) France_s \boldsymbol{G'}_s \boldsymbol{\gamma}_{4,x} \\ &+ \tau_t + \sigma_s + z_{s,t} \end{aligned} \tag{3}$$

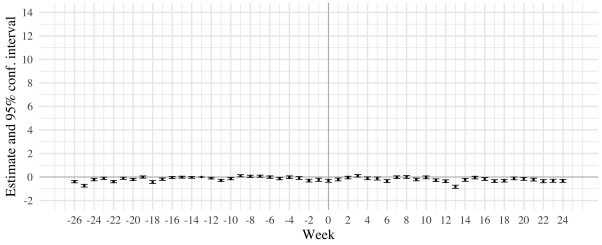
where $\boldsymbol{G'_s} = \begin{bmatrix} G_{s,suburban} & G_{s,rural} \end{bmatrix}$ represents the dummy variables identifying the degree of urbanisation with urban areas being the omitted category. $\gamma_{2,t}$ captures the effect of the diesel tax increase on the price of diesel in urban areas in week t. The vector $\boldsymbol{\gamma}'_{4,t} = \begin{bmatrix} \gamma_{4,t,suburban} & \gamma_{4,t,rural} \end{bmatrix}$ captures the effects of the tax increase on the price of diesel in comparison to the effect it had on prices in urban areas, that is in relation to $\gamma_{2,t}$ in week t. $\boldsymbol{\gamma}'_{4,t} = 0$ would indicate that there are no differences along the rural-urban spectrum in how the tax increase affects the price of diesel in a given period. Again, the tax increase occurs in $t = 0$. Figure 6 plots the values of these weekly estimates for the four tax increases we are investigating for each category along the rural-urban spectrum. Ideally, we would allow the time fixed effects to vary between stations depending on their degree of urbanisation classification. However, when doing so there are issues with multicollinearity. We investigate this further in Appendix C and reassuringly find that in the cases when it is possible to allow the fixed effects to vary, the differences in results compared to our main specifications are very small.

Urban areas act as the reference category, so it is unsurprising that we can see a clear level shift in conjunction with the tax increase for this group. As in the analogous plots for the countrywide weekly estimates in Figure 4, there are small but statistically significant deviations from the null hypothesis of exactly parallel trends in the pre-treatment period. Even though we have now effectively split our sample into three subgroups, the coefficients are still estimated with a high degree of precision. The plots for urban areas look quite similar for all four tax increases. We note that there is no trend to the pre-treatment deviations and that they are non-persistent in the sense that the weekly coefficients revert towards the reference value eventually. Interpreting the estimates for suburban and rural areas is more nuanced than interpreting them for urban areas given that they are estimated in relation to urban areas and that we are in dealing with a triple interaction. The coefficients for suburban and rural areas thus represent to what extent the coefficients for these areas deviate from urban areas, in relation to their counterparts in Germany. Heterogeneity in the pass-through rates between suburban or rural areas and urban areas would be represented by a level shift in the plots as the tax is introduced.

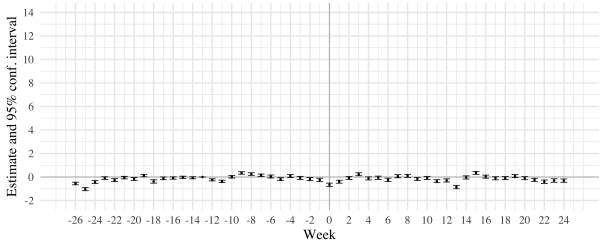
Observing the pre-treatment coefficients for suburban and rural areas gives us an idea of the extent to which these areas diverge from urban areas when there is no tax increase, in relation to their German counterparts. Large pre-treatment deviations would have implied that we should be more cautious about any observed heterogeneity in the post-treatment period as it might as well be the outcome of one of these shocks.



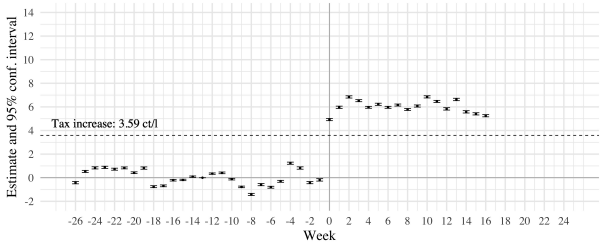
(a) Tax increase in 2015: Urban regions



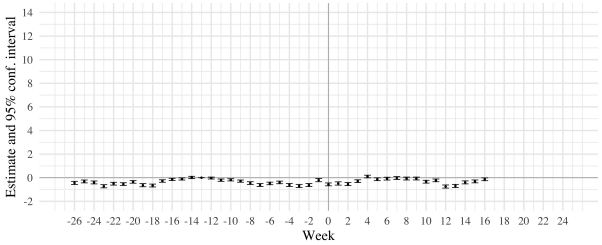
(b) Tax increase in 2015: Suburban regions



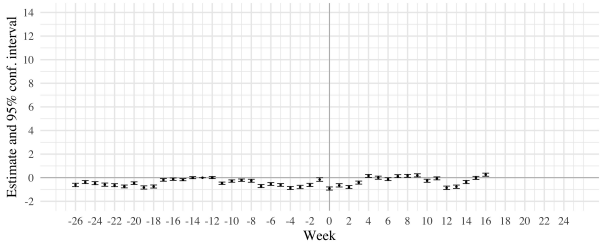
(c) Tax increase in 2015: Rural regions



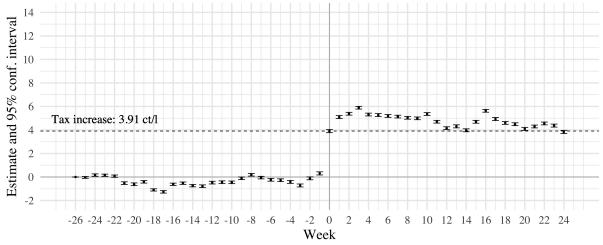
(d) Tax increase in 2016: Urban regions



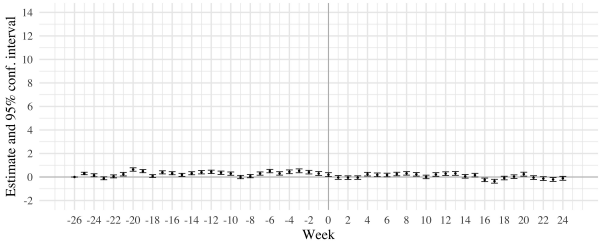
(e) Tax increase in 2016: Suburban regions



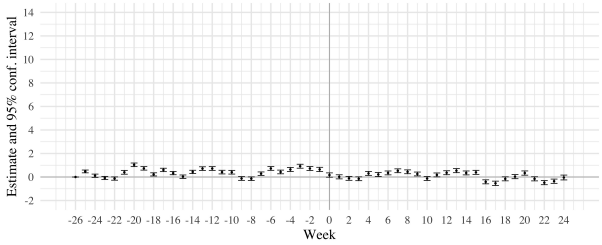
(f) Tax increase in 2016: Rural regions



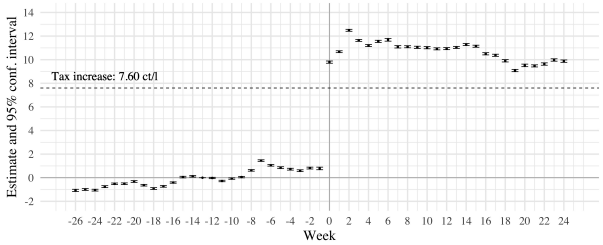
(g) Tax increase in 2017: Urban regions



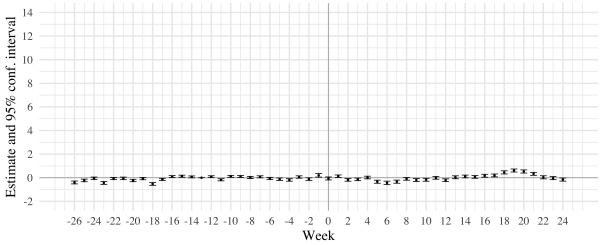
(h) Tax increase in 2017: Suburban regions



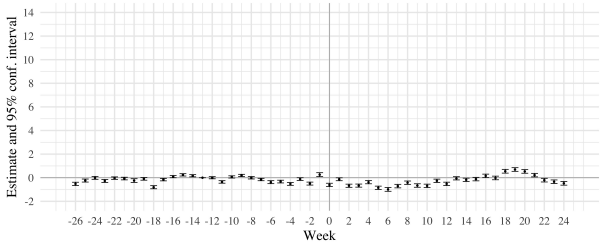
(i) Tax increase in 2017: Rural regions



(j) Tax increase in 2018: Urban regions



(k) Tax increase in 2018: Suburban regions



(l) Tax increase in 2018: Rural regions

Figure 6: Event-study plot estimates for all tax increases by region

However, the deviations from zero are very small for the coefficients for suburban and rural areas across all four tax increases – albeit that some are statistically significantly different form zero. Even though the pre-treatment deviations are small, these deviations from the null hypothesis of no difference in how suburban and rural areas trend in relation to their German counterparts should be taken into account when estimating whether there is heterogeneity in the pass-through rates between urban, suburban and rural areas. As in the countrywide setup, we employ a method which allows us to relax the assumption of exactly parallel trends and incorporate the deviations in the pre-treatment period to estimate robust confidence intervals.

In this section we have not explicitly estimated the degree to which diesel price trends are parallel between suburban France and suburban Germany and rural France and rural Germany. We therefore also estimate Equation 2 separately for these areas. The results are very similar to the ones presented for urban areas and are shown in Appendix D. That the trends are very similar to the ones in urban areas is unsurprising given that we can see from Figure 8 that the difference in coefficients between suburban and urban areas and between rural and urban areas in relation to their German counterparts are very small in both the pre- and post-treatment periods.

4.3.2 SUTVA and potential spillover and anticipation effects

We now turn to another assumption which is important to our analysis, namely the stable unit treatment value assumption (SUTVA). In our case, this assumption implies that there should be no spillovers from the fuel tax increase in France on diesel prices in Germany. Interpreted strictly, this assumption is theoretically dubious. A price change in France brought about by a higher diesel tax could plausibly have a dampening effect on demand for diesel in France. Since the market for diesel is highly integrated, a decrease in demand in France could theoretically influence German prices by marginally lowering demand for diesel in the European market. However, even though France is a large country by European standards, it seems unlikely that a small change in French demand caused by a tax increase would have more than a negligible effect on prices in Germany. Further, any such effect would be unlikely to skew our comparison of the pass-through rates along the rural-urban spectrum as we see no reason why such an effect would vary depending on the degree of urbanization. A potential spillover channel which could be more problematic comes from the fact that France and Germany share a border. For motorists that live close to the border, there is an incentive to cross the border to fuel up on diesel if there is a sufficiently large price difference. There is some evidence for this type of border effects. For instance, Doyle and Samphantharak (2008) find that the pass-through rate of fuel tax cuts is affected by cross-border competition. As a robustness check we therefore estimate Equations 7 and 8 excluding stations which lie within 10 kilometers from a fuel station in the other country.

Estimating Equation 2, which includes leads and lags, can also indicate the presence of the type of anticipatory effects of a fuel tax change that has been found in Coglianese et al. (2017). Since the increases in the tax on diesel were planned far in advance (see Section 3.2 for a description of the planned trajectory of the carbon tax), it is possible that fuel retailers and producers change their behaviour in anticipation of the tax. A possible way in which this channel could work is that motorists would try to fill up their car one last time at the lower tax rate in the weeks before the tax is increased since it seems reasonable to think that people's storage capability extends to what they can store in their car's tank. With data on quantities of fuel sold this would show up

as an increase in the amount of fuel sold where there is bunching in the days and weeks leading up to the tax increase as described in Harju et al. (2022). Unfortunately we lack sufficiently granular data on the quantities of diesel sold in France. However, the increase in demand that such anticipation of the tax would result in could potentially be seen in a divergence of the trends of diesel prices in Germany and France. That is, diesel prices in France would increase in relation to prices in Germany. Such a divergence would constitute a violation of the parallel trends assumption and would bias our estimates downward. Inspecting Figures 4 and 6 we do not see evidence of an anticipation effect. If there were an anticipation effect we would expect to see a high positive value on the coefficients in the last few weeks leading up to the tax increase. However, as a robustness check we estimate the equations for our main results excluding the last four weeks leading up to the tax increase. This is further described in Appendix E.

4.4 Estimating the pass-through of the tax increases

4.4.1 A more robust approach to parallel trends

In this section, we explain our main specifications which allow us to relax the assumption of parallel trends in detail. Several methods have been proposed to capture the uncertainty associated with deviations from parallel trends for difference-in-differences estimates (see Roth et al. (2022) for a summary of recent developments). As was previously mentioned, that two trends in the real world would be exactly parallel does intuitively seem implausible even if they share an underlying common trend due to being subject to common economic forces. Building on this intuition Rambachan and Roth (2022) provide an alternative method which allows for violations of parallel trends in the pre-treatment period to construct confidence intervals which incorporate both sources of uncertainty that we mentioned in Section 4.3.1: the uncertainty arising from parameters being estimated imprecisely which is commonly considered and the uncertainty arising from deviations from parallel trends. The basic intuition behind this approach is that the deviations from parallel trends that we observe in the pre-treatment period are informative about the deviations we would expect in the post-treatment period. This allows us to relax the assumption of exactly parallel trends. Consequently, this increases the confidence intervals and conveys a more accurate quantification of the uncertainty associated with our estimates.

To offer a more formal explanation of this intuition, let ω be a coefficient that we estimate in an event-study setting. Following the exposition in Rambachan and Roth (2022)[6] we can decompose ω in the following way:

$$\omega = \begin{bmatrix} \lambda_{pre} \\ \lambda_{post} \end{bmatrix} + \begin{bmatrix} \theta_{pre} \\ \theta_{post} \end{bmatrix} \tag{4}$$

where the λ parameters represent effects from treatment – in our case the fuel tax increase – and the θ parameters represent deviations from parallel trends. Assuming that there is no effect from treatment before it occurs means that $\lambda_{pre} = 0$. The parameter we want to recover is λ_{post} which in our case represents the increase in the price of diesel caused by a certain tax increase.

[6] Our notation differs from the one used in Rambachan and Roth (2022) in order to stay consistent with our previous notation.

θ_{pre} represents the deviations from parallel trends prior to treatment and θ_{post} the deviations after treatment. Assuming perfectly parallel trends implies that $\theta_{pre} = \theta_{post} = 0$. This is a very unlikely scenario in general and highly unlikely in our scenario given that $\theta_{pre} \neq 0$ as several pre-treatment coefficients are statistically significantly different from zero. We have no good reason to believe that the post-treatment period is any different from the pre-treatment period with regards to these non-persistent deviations. Assuming that there is no anticipation effect of the diesel tax increase (see Appendix E for our robustness check regarding this) we have that $\lambda_{pre} = 0$. It follows that when we estimate the parameter ω in the pre-treatment period, ω_{pre}, what we recover is θ_{pre} which represents the deviations from parallel trends in the pre-treatment periods. Assuming that $\theta_{pre} = \theta_{post}$ we can see that when we estimate the parameter ω in the post-treatment period, ω_{post}, what we estimate is actually $\omega_{post} = \lambda_{post} + \theta_{post}$. Although this does not in expectation bias the result of this estimation since we observe no trend in deviations from parallel trends, this clearly increases the uncertainty with which we can estimate λ_{post} which is the causal estimate we are interested in. This implies that our confidence intervals for λ_{post} are too narrow if we do not incorporate the potential variation coming from θ_{post}.

To implement these insights and capture the uncertainty that the deviations from parallel trends impart on our analysis we use the *HonestDiD*[7] R-package which can also be found in the Rambachan and Roth (2022) paper which describes the method in detail. The method uses the maximum violation of parallel trends in the pre-treatment period to quantify the uncertainty of the post-treatment coefficient. Equation 5 represents our preferred specification for the countrywide estimation and Equation 6 which includes dummy variables indicating the degree of urbanisation, represents our preferred specification to estimate the degree of heterogeneity along the rural-urban dimension.

$$P_{s,t} = \psi_1 + \sum_{\substack{x=-26 \\ x \neq r}}^{0} 1(x = t) France_s \psi_{2,x} + \tau_t + \sigma_s + z_{s,t} \tag{5}$$

$$\begin{aligned} P_{s,t} =& \mu_1 + \sum_{\substack{x=-26 \\ x \neq r}}^{0} 1(x = t) France_s \mu_{2,x} + \sum_{\substack{x=-26 \\ x \neq r}}^{0} 1(x = t) \boldsymbol{G'}_s \boldsymbol{\mu}_{3,x} + \sum_{\substack{x=-26 \\ x \neq r}}^{0} 1(x = t) France_s \boldsymbol{G'}_s \boldsymbol{\mu}_{4,x} \\ &+ \tau_t + \sigma_s + z_{s,t} \end{aligned} \tag{6}$$

Variables are defined as in Equations 2 and 3 which are the event study specifications including coefficients for all weeks individually. The difference between Equations 2 and 3 and those specified above is that for the equations above we pool all post-treatment periods into one single time period to estimate an average treatment effect. As before, treatment occurs in time period $t = 0$. When $t < 0$, the size of the estimates of $\psi_{2,t}$ or $\mu_{2,t}$ and $\boldsymbol{\mu}_{4,t}$ represents a deviation from parallel trends in the pre-treatment period. When $t = 0$, these estimates capture the causal effect of the tax increase on the price of diesel. Specifically, $\psi_{2,0}$ recovers the countrywide effect while $\mu_{2,0}$ captures the effect of the tax increase on prices in urban regions and $\boldsymbol{\mu}_{4,0}$ represents

[7]The code package can be found at https://github.com/asheshrambachan/HonestDiD.

how the tax incidence in suburban and rural areas in France differs from the incidence in urban French areas. It is worth pointing out that these estimates are unweighted averages as we do not have access to the quantity of fuel sold at the station level.

We as researchers also need to assume how large we expect the post-treatment deviations to be in relation to the maximum pre-treatment deviations. Concretely, we need to choose a value $\bar{M}$ which bounds the worst-case post-treatment violation of parallel trends in relation to the largest pre-treatment violation. In the traditional difference-in-differences setup we have that $\bar{M} = 0$ since pre-treatment deviations are not accounted for. If we instead were to choose $\bar{M} = 1$ we would bound the estimate of the effect of the fuel tax increase on the price of diesel by the largest deviation observed in the pre-treatment period whilst additionally taking into account that this violation was estimated with some imprecision.

Our preferred value of is $\bar{M} = 0.5$ and consequently, this is the value we use in our main specification. To see why this value is conservatively chosen we need to take into account that in the post-treatment period we are pooling several weeks into the same period. Specifically, we pool 25 weeks in the post-treatment period for the tax increases in 2015, 2017 and 2018, and 17 weeks in post-treatment period for the tax increase in 2016. To see why this value of $\bar{M}$ is conservative, recall that our pre-treatment deviations are non-persistent in the sense that they tend to fade away after a few weeks as the coefficient values revert to the reference value (see Section 4.3.1 for more on this). The ratio between the means of the deviations for the weekly coefficients obtained from estimating Equations 5 and 6 and the maximum deviations observed in the pre-treatment periods ranges between 0.18 and 0.46 and is in no period higher than 0.5. It is worth pointing out that these deviations go in both directions, positive and negative, for all of our estimations. Setting $\bar{M} = 0.5$ thus allows for a deviation in the post-treatment period which is greater than the average weekly deviation and which is working in the same direction for all weeks in the post-treatment period. We have not seen any evidence of such a deviation in any of our pre-treatment periods. Thus, we believe such a scenario to be unlikely and therefore feel confident that $\bar{M} = 0.5$ will give us a 95 percent confidence interval which would cover the true effect in at least 95 percent of all cases. In Appendix F we conduct sensitivity analysis to further show how sensitive our estimates are to different assumptions about the magnitude of post-treatment deviations.

4.4.2 Two-period difference-in-differences

In addition to our preferred specification which we described in the previous section, we also estimate a two-period difference-in-differences model. With this model we lose the ability to construct robust confidence intervals as now we only have a single average pre-treatment period which makes it impossible to measure deviations from a trend. However, the two-period setup allows us to estimate the effect of the tax increase in relation to the pre-treatment period as a whole as the reference point rather than a specific week in the pre-treatment period. In addition, estimating Equations 7 and 8 can give an indication of how robust our findings are to different model specifications.

$$P_{s,t} = \alpha_1 + \alpha_2 France_s Post_t + \tau_t + \sigma_s + \zeta_{s,t} \tag{7}$$

$$P_{s,t} = \beta_1 + \beta_2 France_s Post_t + Post_t \boldsymbol{G'}_s \boldsymbol{\beta_3} + France_s Post_t \boldsymbol{G'}_s \boldsymbol{\beta_4} + \tau_t + \sigma_s + \xi_{s,t} \quad (8)$$

As before, $France_s$ is a dummy variable which equals one if the station is in France and thus eventually affected by the tax increase. $Post_t$ is a dummy variable which equals one if the observation occurred after the tax increase. α_2 captures the causal effect of the tax increase on the average weekly diesel price in France. Since we are interested in the effect that the tax increase has on the price of diesel, $France_s$ and $Post_t$ do not have to enter Equation 7 separately as in the textbook version of a difference-in-differences equation without station and time fixed effects, i.e. without σ_s and $_t$. Standard errors are clustered at the station level.

The analogous Equation 8 allows us to estimate whether the pass-through of the fuel tax varies depending on the degree of urbanisation. The baseline category is stations located in urban areas. The other variables are defined as in Equation 7. If the assumption of exactly parallel trends holds, β_2 identifies the causal effect of the tax change on the weekly average price in urban stations and $\boldsymbol{\beta_4'} = \begin{bmatrix} \beta_{4,suburban} & \beta_{4,rural} \end{bmatrix}$ identifies how the causal effect on the weekly average price from the tax increase differs from β_2. Again, we avoid overspecification by not including terms that are already absorbed by the fixed effects. As a robustness check we also run versions of Equations 6 and 8 which allow the time-fixed effect to vary between the rural-urban categories. Results from this specification are very similar to the ones from the main specification and can be found in Appendix C. However, these estimations suffer from multicollinearity which we take as further indication that trends are very similar along the rural-urban spectrum.

5 Results

5.1 Countrywide pass-through rates

As described in Section 4.4, we estimate Equation 5 (*Event study*) to capture the countrywide pass-through for all four tax increases. This specification allows us to relax the assumption of exactly parallel trends and construct robust confidence intervals. We also estimate Equation 7 (*Two-period DiD*) to provide us with a reference point with which to compare the results from estimating Equation 5. Table 3 shows the main results for the countrywide regressions. Panel A shows the point-estimates from Equation 5 and associated standard errors and robust confidence intervals as well as the transformation into easily readable pass-through rates with respect to the corresponding tax increase in each year. Panel B presents the point estimates, standard errors and pass-through rates from Equation 7, the two-period difference-in-differences setup. The robust confidence intervals for other values of $\bar{M}$ are illustrated in Appendix F. Our main takeaway from Table 3 is that we find robust evidence for the tax increase being more than fully shifted on to consumers for all four tax increases under our preferred specification of $\bar{M} = 0.5$ which allows for a persistent deviation from parallel trends at a size greater than the average weekly deviation in the pre-treatment period. We also see that the differences between the point estimates of our two-period model and the event-study model are very small. This implies that our finding of prices increasing by more than the full amount of tax is not sensitive to our model specification. To get a better sense for the magnitude of the overshifting, adding up all of the

point-estimates from the two-period difference-in-differences specification implies that the tax increases led to an increase in the price of diesel of 27.28 cents per litre from 2014 to 2018. The total increase in the tax on diesel during this time period was 19.87 cents per litre. It is worth noting that we do not observe a clear pattern between the size of the tax increase and the degree of overshifting. In Section 5.4 we show that these results are robust to a number of robustness checks.

Table 3: Estimation results for the countrywide pass-through rate

	Dependent variable: Diesel price (in ct/l)			
	2015	2016	2017	2018
Diesel tax increase (in ct/l)	4.78	3.59	3.91	7.60
Panel A: Event study				
France:Post	5.505	5.823	4.848	10.575
	(0.019)	(0.021)	(0.027)	(0.021)
Robust 95% conf. interval ($\bar{M}$=0.5)	[4.865, 6.126]	[5.015, 6.637]	[4.264, 5.435]	[10.060, 11.111]
Pass-through rate	115.3%	162.3%	123.9%	139.2%
95% conf. intervals				
$\bar{M}$=0	[115.1%, 115.7%]	[161.5%, 163.2%]	[122.8%, 125.1%]	[138.8%, 139.6%]
$\bar{M}$=0.5	[102.4%, 128.4%]	[140.0%, 185.1%]	[109.0%, 138.9%]	[132.4%, 146.3%]
Panel B: Two-period DiD				
France:Post	5.645	6.053	4.886	10.700
	(0.012)	(0.014)	(0.014)	(0.016)
Pass-through rate	118.2%	168.7%	124.9%	140.9%
95% conf. interval	[117.7%, 118.8%]	[168.0%, 169.5%]	[124.2%, 125.6%]	[140.4%, 141.2%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	928,772	824,777	911,666	954,031

Notes: Standard errors are clustered on the station level and reported in round brackets underneath the point estimate. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.

5.2 Results on heterogeneity in pass-through rates

Table 4 shows the point estimates and confidence intervals from estimating Equations 6 (*Event study*) and 8 (*Two-period DiD*), both of which allow for the pass-through of the tax increases to differ along the rural-urban spectrum. Equation 6 also allows us to relax the assumption of exactly parallel trends. In Table 4 we include the robust confidence intervals constructed under our chosen value of $\bar{M} = 0.5$. We report confidence intervals under $\bar{M} = 0$ and $\bar{M} = 1$ in

Table 11 in Appendix G. The evidence for differences in the pass-through of fuel tax increases between urban, suburban and rural regions is weak and only one regional coefficient (*Suburban* in 2016) is significantly different from zero at the 5 percent level under our preferred *Event study* specification with $\bar{M} = 0.5$. Contrasting the results from our preferred specification of $\bar{M} = 0.5$ to the results from the *Two-period DiD* specification highlights the importance of accounting for the uncertainty associated with deviations from parallel trends. Were we not to take this uncertainty into account, we would find that a majority of the coefficients for suburban and rural areas were statistically significantly different from zero.

Further, considering the sign of the point estimates for the rural and suburban regions no clear pattern emerges. It is not the case that the point estimate consistently indicates that there is heterogeneity in one specific direction. The evidence is particularly weak for the result found in Harju et al. (2022), namely that rural areas face a higher pass-through given that the point estimate in three out of four cases, if anything, indicates a very weak effect to the opposite.

Table 5 summarises our main findings regarding heterogeneity across the rural-urban dimension based on the information in Table 4. The point estimates and robust confidence intervals are here translated into pass-through rates for each of the tax increases in urban, suburban and rural areas. Again, we see that there is only one instance where the robust confidence interval does not cover zero and it is evident from the bottom panel that the evidence for heterogeneity in how diesel taxes are passed on to consumers to the disadvantage of people in rural areas is very weak.

5.3 The role of competition

The theoretical literature on tax incidence in general and the empirical literature on the pass-through of fuel taxes suggest that competition is a potential source of heterogeneity in pass-through rates. To explore this channel, we calculate the number of stations within 10 kilometers of each station in our dataset. We use this number as a proxy for the degree of competition which an individual station faces. We aggregate the station data by terciles into three categories reflecting the degree of competition. By doing so, low competition is characterised by 10 or less stations in a 10km radius, medium competition by 10-29 potential competitors and high competition by 29 or more potential competitors. In an analysis similar to the one in Harju et al. (2022), we estimate how the pass-through rate varies between these terciles by replacing the degree of urbanisation dummy variables in Equation 8 with dummy variables indicating the competition tercile the stations falls into. The omitted category is the tercile including the stations with the least stations within 10 kilometers. The results from this analysis can be found in Appendix H. Our results suggest that competition, as captured by our competition measure, does not correlate with the extent to which fuel tax increases are passed on to consumers to a significant degree.

Table 4: Estimation results for the tax pass-through rate along the rural-urban spectrum

Dependent variable: Diesel price (in ct/l)				
	2015	2016	2017	2018
Diesel tax increase (in ct/l)	4.78	3.59	3.91	7.60
Panel A: Event study				
Urban				
France:Post	5.659	6.023	4.745	10.661
	(0.04)	(0.04)	(0.05)	(0.04)
Robust 95% conf. interval ($\bar{M}$=0.5)	[5.075, 6.196]	[5.180, 6.862]	[4.339, 5.180]	[10.190, 11.136]
Suburban				
France:Post:suburban	-0.215	-0.297	0.039	-0.001
	(0.05)	(0.05)	(0.07)	(0.05)
Robust 95% conf. interval ($\bar{M}$=0.5)	[-0.566, 0.135]	[-0.601, -0.005]	[-0.285, 0.415]	[-0.320, 0.310]
Rural				
France:Post:rural	-0.162	-0.258	0.029	-0.287
	(0.05)	(0.05)	(0.07)	(0.06)
Robust 95% conf. interval ($\bar{M}$=0.5)	[-0.566, 0.240]	[-0.636, 0.100]	[-0.460, 0.521]	[-0.776, 0.205]
Panel B: Two-period DiD				
France:Post	5.714	5.973	5.090	10.712
	(0.027)	(0.026)	(0.027)	(0.028)
France:Post:suburban	-0.068	0.089	-0.249	0.081
	(0.034)	(0.033)	(0.035)	(0.036)
France:Post:rural	-0.041	0.180	-0.388	-0.146
	(0.036)	(0.037)	(0.038)	(0.043)
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	928,772	824,777	911,666	954,031

Notes: Standard errors are clustered on the station level and reported in round brackets underneath the point estimate. Results for suburban and rural areas are reported in relation to the results for urban areas. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.

Table 5: Estimation results for the tax pass-through rate along the rural-urban spectrum

Dependent variable: Diesel price (in ct/l)				
	2015	2016	2017	2018
Panel A: Urban				
Pass-through rate	118.5%	167.9%	121.3%	140.4%
Robust 95% conf. interval ($\bar{M}$=0.5)	[106.3%, 129.7%]	[144.4%, 191.2%]	[110.9%, 132.4%]	[134.2%, 146.6%]
Panel B: Suburban				
Difference in pass-through rate	-4.5%	-8.3%	1.0%	0.0%
Robust 95% conf. interval ($\bar{M}$=0.5)	[-11.8%, 2.8%]	[-16.7%, -0.1%]	[-7.3%, 10.6%]	[-4.2%, 4.1%]
Panel C: Rural				
Difference in pass-through rate	-3.4%	-7.2%	0.7%	-3.8%
Robust 95% conf. interval ($\bar{M}$=0.5)	[-11.8%, 5.0%]	[-17.7%, 2.8%]	[-11.8%, 13.3%]	[-10.2%, 2.7%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	928,772	824,777	911,666	954,031

Notes: The reported results are from the event study specification with one average post-treatment period. Standard errors are clustered on the station level and reported in round brackets underneath the point estimate. Results for suburban and rural areas are reported in relation to the results for urban areas. The differences in pass-through rates between suburban and urban areas and rural and urban areas are reported in percentage points. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.

5.4 Robustness checks

5.4.1 The 2017 regional tax change in Île-de-France

In our main specifications for the 2017 tax increase we excluded fuel stations from Ïle-de-France to avoid the empirical complications associated with fuel stations in this regions facing changes to the fuel tax rates which was greater than the tax increase for the rest of France. Île-de-France is the most populous region in France so we want to investigate whether excluding it significantly affects our results for. In Table 6 we present the results from estimating Equation 5 while including dummy variables for fuel stations located in Île-de-France. We do this for all four tax increases between 2014 and 2018. Reassuringly, we find that the pass-through rate for the 2017 tax increase in Île-de-France is similar to the pass-through rate in the rest of France, and the confidence intervals for our preferred specification are overlapping. This result suggests that our exclusion of fuel stations in Île-de-France for 2017 does not have a have a large effect on our estimates for 2017.

Table 6: Estimation results from including Île-de-France region

Dependent variable: Diesel price (in ct/l)				
	2015	2016	2017	2018
Rest of France				
Diesel tax increase in France	4.78	3.59	3.91	7.60
France:Post	5.495	5.771	4.848	10.597
	(0.020)	(0.022)	(0.027)	(0.022)
Pass-through rate	115.0%	160.8%	123.9 %	139.5%
95% conf. intervals $\bar{M} = 0.5$	[102.5%, 127.6%]	[137.3%, 184.1%]	[109.0%, 138.9%]	[132.4%, 147.1%]
Île-de-France				
Diesel tax increase in Île-de-France	4.78	3.59	6.18	7.60
Île-de-France:Post	5.474	6.197	6.887	10.548
	(0.045)	(0.036)	(0.056)	(0.041)
Pass-through rate	114.6%	172.7%	111.4%	138.9%
95% conf. intervals $\bar{M} = 0.5$	[101.9%, 126.4%]	[149.8%, 195.8%]	[102.5%, 122.0%]	[132.8%, 144.7%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	928,772	824,777	945,951	954,031

Notes: The reported results are from the event study specification with one average post-treatment period. Standard errors are clustered on the station level and reported in round brackets underneath the point estimate. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period. $\bar{M}$=0.5 is the preferred value to construct the robust confidence intervals.

5.4.2 Countrywide pass-through with Oil Bulletin data

As an additional robustness check to our finding of consistent over-shifting of the French tax on diesel we use data from the European Commission's Oil Bulletin which provides weekly data on the average price of fuel in all EU countries.[8] The French prices that are reported each week are the ones that were in effect the previous Friday. The data is collected from a variety of operators weighted for each chain or operator by their market share. The German data reported in the Oil Bulletin are prices in effect on Mondays and are computed as a simple arithmetic average based on the reporting to the Market Transparency Agency for Fuels. We estimate Equation 7 for the average prices for France and Germany reported in the Oil Bulletin. The results are shown in Table 7. The results are qualitatively similar to the ones we obtain using our main dataset which contains real time prices for almost all fuel stations in France and Germany. The point-estimate indicates overshifting for each of the tax increases and for all but the tax increase for 2015 the confidence interval for the pass-through rate does not cover 100 percent. However, as we do not take pre-treatment deviations into account for this estimation – we have far too few observations to get a reasonable estimate of these deviations with this dataset – we believe that these confidence intervals are too narrow. Nonetheless, it is reassuring that the results from this exercise are similar to the ones we find using our main dataset.

Table 7: Countrywide estimation results using Oil Bulletin data

	Dependent variable: Diesel price (in ct/l)			
	2015	2016	2017	2018
France:Post	4.988	4.801	4.962	12.300
	(0.373)	(0.494)	(0.389)	(0.680)
Pass-through rate	104.4%	133.8%	126.9%	161.9%
95% CI	[88.7%, 120.1%]	[105.9%, 161.7%]	[106.8%, 146.8%]	[144.0%, 179.9%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	No	No	No	No
Observations	98	80	100	100

Notes: The reported results are from the two-period difference-in-differences specification with one average post-treatment period. Standard errors are clustered on the week and reported in round brackets underneath the point estimate.

5.4.3 Further robustness checks

A potential concern for our empirical strategy is the presence of spillover effects on Germany from the tax increase in France (see Section 4.3.2 for more on this). To investigate whether our results are affected by this type of cross-border competition, we estimate Equations 5 and 6 whilst excluding all fuel stations in France and Germany that lie within 10 kilometers from a fuel station in the other country. The results from this analysis are reassuringly very similar

[8] https://energy.ec.europa.eu/data-and-analysis/weekly-oil-bulletin

to the ones presented in 3 and can be found in Appendix I. This indicates that cross-border competition and spillover effects are not a driver of our results. A relating concern is that fuel stations along highways are more prone to sell more truck diesel and that this could have an effect on the rate at which taxes are passed on to consumers. We therefore re-estimate our results excluding stations along highways in France. We find that the results are very similar to the ones from our main specifications – indicating that our results are not driven by fuel stations along highways reacting differently to tax increases. The results from this analysis can be found in Appendix J.

Another potential problem with our empirical strategy is that the tax increase could have an effect on prices before it is implemented. Coglianese et al. (2017) shows that this can lead to bias in estimates of how consumers react to fuel taxes. To exclude potential effects from consumers and retailers anticipating the tax increase we rerun our analysis whilst excluding the last four weeks leading up to each tax increase. The results from this robustness check can be found in Appendix E. The resulting estimates are very similar to those from our main specifications, which indicates that our results are not significantly affected by potential anticipatory behaviour from consumers and retailers.

6 Discussion

Our finding of consistent overshifting of the French carbon tax points toward the existence of some degree of market power in the French diesel market. As discussed in Section 2, in a perfectly competitive market the pass-through rate is bounded by 0 and 100 percent. Findings of pass-through rates greater than 100 percent can thus be used as evidence for the existence of market power (Pless & van Benthem, 2019). The rich theoretical literature on tax incidence further suggests that demand for diesel in France is very inelastic and convex. Our exploratory competition analysis suggests that the number of stations within a 10 kilometer radius does not offer evidence which suggests why overshifting occurs. If we had found that the pass-through rates were generally higher amongst stations with fewer potential competitors in their vicinity, this would have offered an indication that local competition could be a part of the explanation for why we find overshifting. Our results suggest a need for further investigation of supply side mechanisms and market structure. For example, it would be fruitful to construct a structural model which attempts to theoretically ground our findings of overshifting.

An important contribution of our paper is that we find no evidence for heterogeneity in how fuel tax increases are passed on to consumers along the rural-urban spectrum. This finding has direct policy implications. Policymakers and the public at large might be concerned about the impact that a carbon tax has on the rural-urban divide. Besides a uniform increase in the price of fuel having a greater effect on rural motorists who drive more, policymakers could also be concerned about heterogeneity in how the tax is passed on to consumers – especially if this heterogeneity disadvantages rural motorists. This would be an argument for additional compensatory measures, in comparison to a scenario where such heterogeneity does not exist. Our findings suggesting that this channel does not exists suggests that the argument for this type of additional compensatory measures due heterogeneity in pass-through rates is made significantly weaker.

However, the concern that rural motorists are more affected by a tax increase even when facing

the same price change remains, and could be particularly salient in the case of overshifting of the tax. Whilst we do not find evidence for economically significant heterogeneity in pass-through rates between rural and urban households the fact that we find overshifting of taxes on to consumers could still be important in relation to the rural-urban divide which has become so politically salient in French politics. Bureau (2011) models the effects of a French carbon tax assuming everyone faces the same additional fuel cost and finds that rural households are more negatively impacted than other households given that they drive more. The same logic applies to the tax increases from 2015 to 2018. The overshifting of the tax on to consumers has a larger impact on rural motorists who drive more compared to those who live in cities and, on average, drive less. It is therefore important to consider tax incidence in relation to the rural-urban divide even if everyone effectively face the same tax increase.

It is interesting to contrast our findings with those of Harju et al. (2022) which is the paper that is most similar to ours in its focus on heterogeneity in tax incidence along the rural-urban spectrum. Unlike us, they find that the increase in the Finnish carbon tax are passed on to rural motorists at a higher rate than for urban motorists. There are several important differences between our study and Harju et al. (2022) which could explain this. First, they group fuel stations into seven different groups along the urban-rural spectrum, from inner urban areas at the one extreme to sparsely populated rural areas at the other extreme. The only statistically significant difference in pass-through rates that they find is between the two extremes at the end of the spectrum. Since we needed a classification that was common between two different European countries, we had to rely on Eurostat's less granular classification which only has three categories along the rural-urban spectrum. It is not impossible that we had found heterogeneity if we had compared the very most urban areas to the most sparsely populated rural areas. However, one could argue that if such heterogeneity exists in France at the level suggested by Harju et al. (2022) we should have been able to pick it up given that our large number of price observations allow us to estimate any heterogeneity quite precisely and the point estimates do not generally have the right sign.

Second, Harju et al. (2022) use data from two different websites/apps where consumers themselves report prices. This means that there is selection in what prices get reported which is not the case for our data. It is not impossible that such selection could introduce a bias – especially since there are fewer observations within each group when there are seven different degrees of rural-urban classifications that are being considered. For example, if rural motorists are marginally more prone to report price changes after a price increase – or less prone to report price changes after a price decrease – this would introduce a bias in the direction which is observed in Harju et al. (2022). Third, it could be the case that institutional differences between the countries explain why there is heterogeneity which hurts rural motorists in Finland but not in France. A potential channel here is that there are differences in the consumer search behaviour between France and Finland. Finland does, unlike France and Germany, not have mandatory price disclosure for fuel stations. It seems reasonable that the degree of consumer-search behaviour is at least partially determined by how easily accessible price information is. This suggests that consumer-search intensity could be higher in France than in Finland. Since the effect of competition on tax incidence is theoretically ambiguous (see section 2) it is difficult to speculate what this means for the tax incidence in general. That mandatory price disclosure can have an effect on retail fuel markets has been demonstrated by Luco (2019) who explores the effects of the introduction price disclosure in the Chilean retail fuel market. He finds that the introduction of price-disclosure in itself has heterogeneous effects. Whether price-disclosure leads to more or less

competition depends on whether consumer-search intensity or price coordination on the supply side dominates. Luco (2019) finds that in areas with high search intensity markets become more competitive whilst they become less competitive in areas with lower consumer search intensity.

However, what we are interested in is to explain how the consumer-search intensity story could be a potential mechanism explaining why Harju et al. (2022) find heterogeneity between rural and urban areas whilst we do not. One potential explanation is that mandatory price-disclosure equalises the costs associated with shopping around for the best deal between urban and rural dwellers. In the absence of mandatory price-disclosure a motorist living in an urban area might pass several signs displaying fuel prices in a day, whilst a motorist in a rural area might only pass one sign displaying prices. For the urban motorist the introduction of mandatory price-disclosure might not make a big difference as the relevant information was already provided at little to no cost simply by moving around. For the rural motorist the difference would be greater as the relevant information was not available at a low cost but would involve driving out of ones way to obtain price information. With price disclosure this information would instead be readily available online. This line of reasoning suggests the possibility of an interaction between consumer information and heterogeneity in pass-through rates of fuel taxes between urban and rural motorists – an interaction which could be explored in future research.

We would also like to point out some potential extensions and refinements of our study. Like many other studies on retail fuel markets we do not have access to data on the volumes sold. Had we had access to such data we could have weighted stations by the amount of fuel sold to obtain an estimate of the causal effect of the tax change which more accurately represents how the tax increases impacted households in France. However, the fact that we do not see evidence of much heterogeneity means that this is less likely to be of practical concern. Volume data would also allow us to further examine potential issues related to the 500 cubic metre sales threshold for obligatory price reporting. With access to volume data we could also have done a more thorough analysis of whether there is evidence for the type of anticipation effect described in Coglianese et al. (2017). It would also be interesting to repeat our analysis with a finer categorisation along the rural-urban spectrum. Given the increased political salience of the rural-urban divide a potentially fruitful venue for future research could be to provide easily applicable criteria for sorting areas along the rural-urban spectrum in different countries.

To round off the discussion part of this paper we would like to briefly touch upon the relevance of our findings in relation to the yellow vest movement. These protests are after all the dramatic endpoint to which the carbon tax increases in one way or another contributed. We can of course not determine what type of protests there would or would not have been had there been no French carbon tax or if it had been designed or passed on to consumers in a different way. However, it seems fair to say that the fact that the tax was overshifted on to consumers did at least not make it more popular – it seems more plausible to draw the opposite conclusion. However, it is also worth noting that it was not until fuel prices started going up when oil prices increased during 2018 that the protests against the tax really started to take off. It seems like any plausible explanation of the yellow vest protests would need to take a multitude of factors into account. Nonetheless, we believe that how taxes are passed on to consumers is something that policymakers should take into consideration when thinking about how to implement or increase carbon taxes and the policies necessary to ensure social and political acceptability.

7 Conclusion

Carbon taxes will play a pivotal role if we are to meet the goals set out in the Paris climate agreement in an efficient manner. The rural-urban divide is crucial to the political economy of carbon taxation and it is important to gain a deeper understanding of the distributional effects of carbon taxes along the rural-urban dimension. One potential channel which could have been important in influencing the distributional effects along this dimension is heterogeneity in the incidence of carbon taxes. Investigation this issue, we use a dataset containing real-time price changes on diesel for almost all fuel stations in France and Germany to examine the tax incidence of the French carbon tax and higher taxes on diesel. We exploit the variation introduced by successive yearly increases of the tax rate between 2015 and 2018 before the it was frozen in the wake of the yellow vest protests. Drawing on recent advances in the literature on the difference-in-differences method for causal inference, we employ a novel method presented in Rambachan and Roth (2022) which allows us to relax the traditional assumption of exactly parallel trends by incorporating non-persistent deviations from parallel trends and obtain more robust confidence intervals. In contrast to earlier findings by Harju et al. (2022), we find no evidence of economically significant heterogeneity depending on the degree of urbanisation. However, we find robust evidence for French diesel prices increasing by more than the full amount of the tax increase for all of the increases we analyse. This suggests that there is a degree of market power in the French diesel market.

We would not claim that it was overshifting that eventually led to the yellow vest protests which made the carbon tax a focal point of their demands. Nor would we argue that it would a significant role in the correct explanation of the protests. Nonetheless, our finding of prices increasing by more than the full amount of the tax highlights the importance of considering tax incidence when analysing the economic impacts of fuel and carbon taxes.

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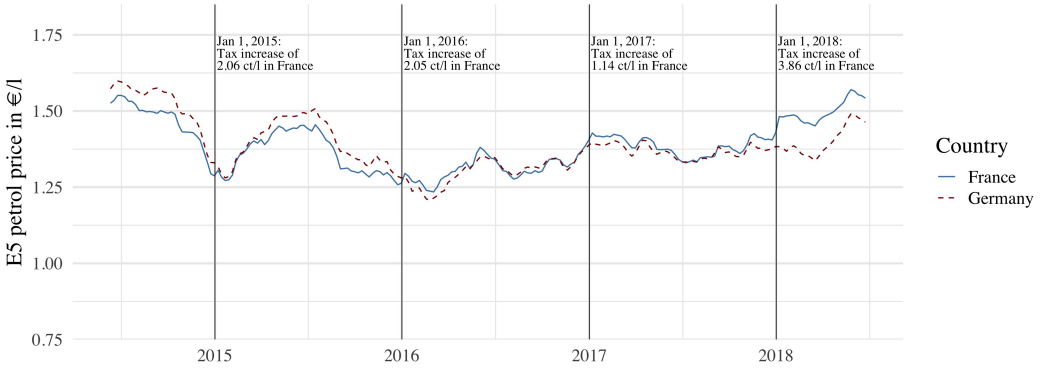
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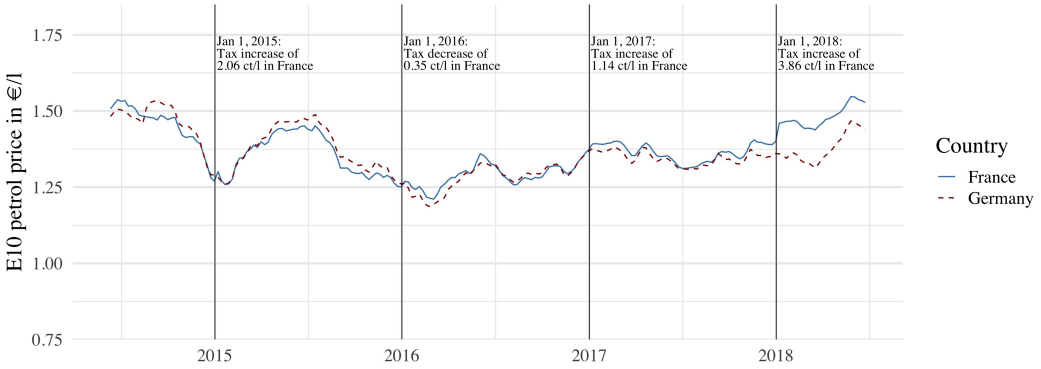
Appendices

A Trends graphs for E5 and E10

From visual inspection of Figure 7 the assumption of parallel trends in E5 and E10 prices between France and Germany seems dubious. This in conjunction with the arguments provided in Section 3.1 regarding the German petrol market being an inappropriate counterfactual to the German one leads us to focus our analyses on diesel.



(a) Weekly average E5 petrol prices in Germany and France 2014-2018



(b) Weekly average E10 petrol prices in Germany and France 2014-2018

Figure 7: Average weekly diesel prices in France and Germany per degree of urbanisation classification 2014-2018

B Data manipulation process

After obtaining the fuel price data from the French Finance Ministry and Tankerkönig, we match the fuel stations with the degree of urbanisation according to Eurostat's LAU codes. The matching criteria are postal code and town through which we are able to uniquely identify and match most stations with their corresponding degree of urbanisation. However, even after accounting for special characters (e.g., ö, ä, ü, ß, é, è, ê etc.) and differences in spellings between

the station dataset and the LAU dataset, some stations remain unmatchable due to missing data or mislabeled addresses. For example, some fuel stations list the name of the municipality instead of the town name. Those inconsistencies and, in some instances, mistakes could only be corrected manually for which we did not have resources. The fuel stations that could not be matched are removed from the estimations that include the rural-urban dimension but still enter the model in which we estimate countrywide effects. Moreover, we suspect that in some cases, fuel stations are duplicated in the data but assigned different identifiers which make them difficult to filter out. Reassuringly, from the inspection of a few examples it seems that the duplicates would not report prices in the same time period. It is however difficult to know with certainty how many duplicates there are and exactly how they would affect our dataset and estimations.

We then take the station-level daily price averages as most stations report multiple price changes per day. We remove prices below 0.75€/l and above 2.00€/l as we consider them as implausibly low or high. This excludes less than 0.001% of all observations. We also remove observations from all 136 listed stations in Corsica due to its different tax rate and special geographical location.

Finally, we take the station-level weekly price average to reduce computational power and the influence of daily fluctuations.

C Estimation with interacted time and regional fixed effects

In this Appendix we present our robustness check wherein we allow for the time fixed effects to vary between areas depending on their degree of urbanisation. To do this we estimate:

$$P_{s,t} = \rho_1 + \sum_{\substack{x=-26 \\ x \neq r}}^{0} 1(x = t) France_s \rho_{2,x} + \sum_{\substack{x=-26 \\ x \neq r}}^{0} 1(x = t) France_s \boldsymbol{G'}_s \boldsymbol{\rho}_{3,x} + \kappa_{s,t} + \sigma_s + \nu_{s,t} \quad (9)$$

where κ_{st} absorbs time trends that are common within each urbanisation category. This equation above is analogous to Equation 6 but in replacing τ_t with κ_{st} we allow for the time fixed effects to vary between urban, suburban and rural areas. The results from these estimations are shown in Table 8. Trends across these categories are very similar. Due to the resulting multicollinearity, we cannot estimate the results for 2018. The effect of the tax increases on the prices of diesel in urban areas are captured by $\rho_{2,0}$. How the effects of the diesel tax increase differs from urban areas in suburban and rural areas is captured by the vector $\boldsymbol{\rho}_{3,0}$.

Reassuringly, the results from this specification are very similar to the ones from our main specification, indicating that our results are not affected by different time trends in urban, suburban and rural areas.

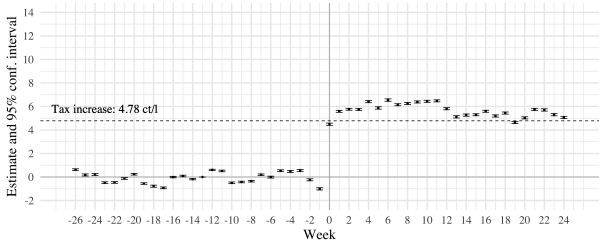
Table 8: Results on heterogeneity in pass-through including interacted fixed effects

Dependent variable: Diesel price (in ct/l)				
	2015	2016	2017	2018
Urban				
France:Post	5.659	6.023	4.746	-
	(0.35)	(0.38)	(0.53)	(-)
Pass-through rate	118.5%	167.9%	121.3%	-
Robust CI ($\bar{M}$ =0.5)	[106.3%, 129.7%]	[144.4%, 191.2%]	[110.9%, 132.4%]	[- , -]
Suburban				
France:Post:suburban	-0.261	-0.297	0.036	-
	(0.045)	(0.051)	(0.067)	(-)
Diff. in pass-through	-4.5%	-8.3%	0.9%	-
Robust CI ($\bar{M}$=0.5)	[-11.8%, 2.8%]	[-16.7%, -0.1%]	[-8.2%, 10.6%]	[- , -]
Rural				
France:Post:rural	-0.161	-0.258	0.036	-
	(0.051)	(0.053)	(0.073)	(-)
Diff. in pass-through	-3.4%	-7.2%	0.9%	-
Robust CI ($\bar{M}$ =0.5)	[-11.8%, 5.0%]	[-17.7%, 2.8%]	[-10.9%, 13.3%]	[- , -]
Time fixed effects	Yes	Yes	Yes	-
Station fixed effects	Yes	Yes	Yes	-
Observations	928,772	824,777	911,666	-

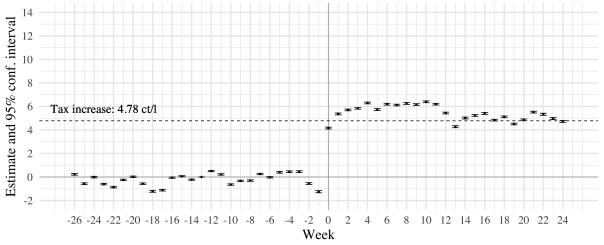
Notes: Standard errors are clustered on the station level and reported in round brackets underneath the point estimate. Results for suburban and rural areas are reported in relation to the results for urban areas. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.

D Event study plots by degree of urbanisation category

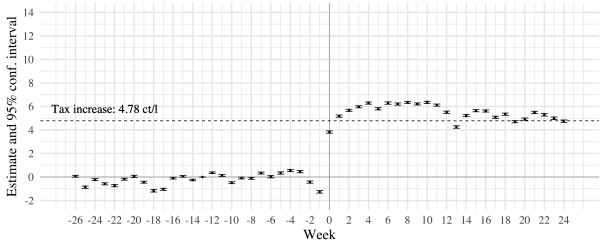
In this appendix we provide evidence showing that the price trends for rural and suburban areas are very similar to the price trends in urban areas. We also show the extent to which trends for the weekly average price of diesel are parallel between suburban areas in France and suburban areas in Germany, as well as between rural areas in France and rural areas in Germany. We do this by splitting our dataset into three groups: one for urban areas in France and Germany, one for suburban areas in France and Germany and one for rural areas in France and Germany. For each of these groups we estimate Equation 2 and plot the weekly coefficients in Figure 8. Whilst the event-study plot for urban areas have already been shown in Figure 6 we include it here as well to facilitate comparisons. The patterns for each tax increase are very similar across all three categories which further supports our finding of no economically significant heterogeneity in the pass-through of the tax increases depending on the degree of urbanisation.



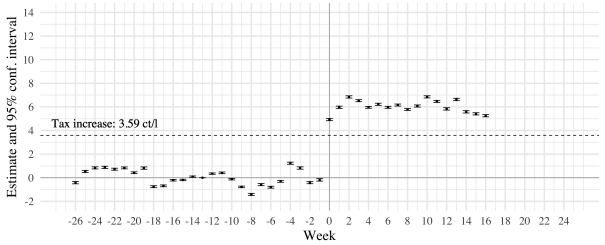
(a) Tax increase in 2015: Urban regions



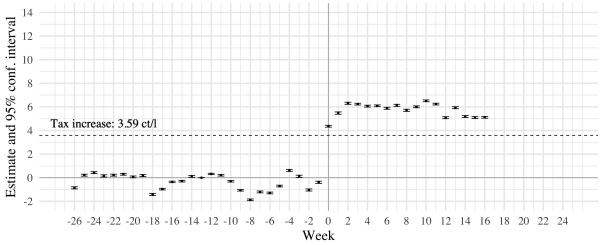
(b) Tax increase in 2015: Suburban regions



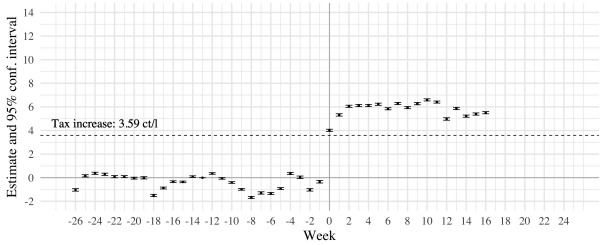
(c) Tax increase in 2015: Rural regions



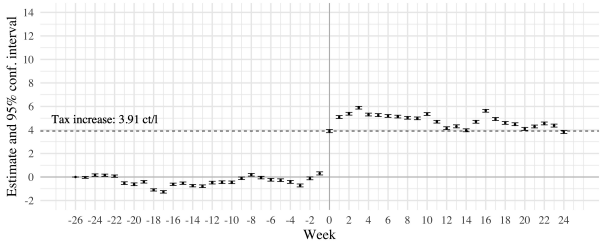
(d) Tax increase in 2016: Urban regions



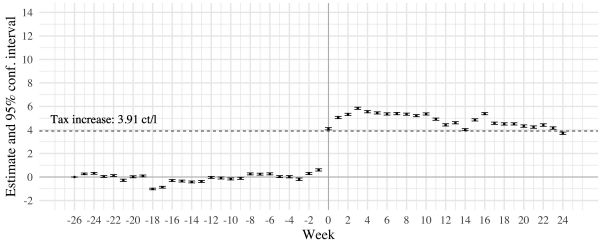
(e) Tax increase in 2016: Suburban regions



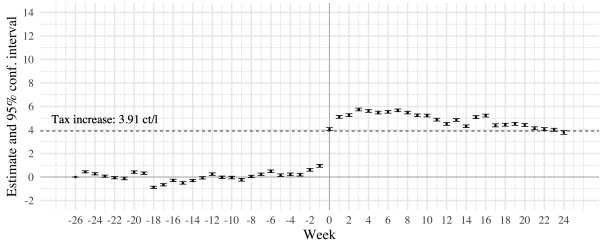
(f) Tax increase in 2016: Rural regions



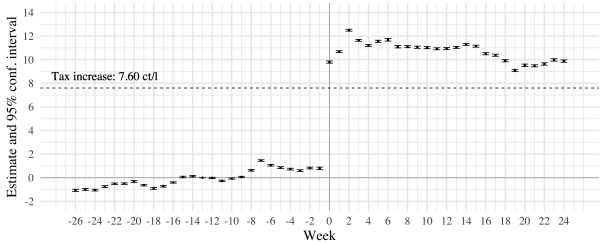
(g) Tax increase in 2017: Urban regions



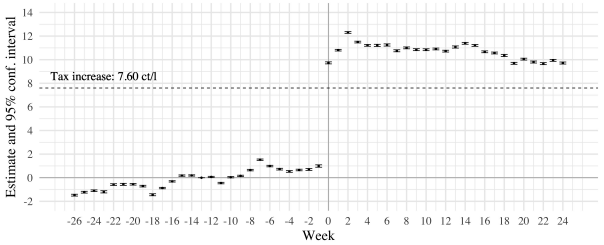
(h) Tax increase in 2017: Suburban regions



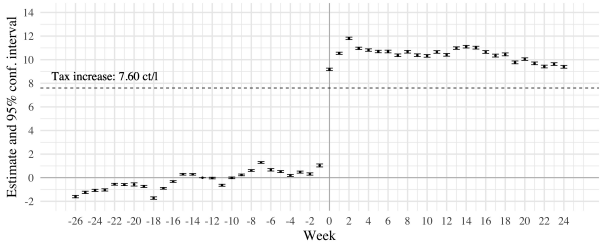
(i) Tax increase in 2017: Rural regions



(j) Tax increase in 2018: Urban regions



(k) Tax increase in 2018: Suburban regions



(l) Tax increase in 2018: Rural regions

Figure 8: Event-study plot estimates for all tax increases by degree of urbanisation category

E Estimation results from anticipation robustness check

That prices would respond in anticipation of the tax increases is a potential concern for our main specification wherein we assume that there are no effects on the price of diesel from the tax increase before it is implemented. As a robustness check we therefore estimate Equations 5 and 6 whilst excluding the last four weeks leading up to each tax increase. Results are presented in Tables 9 and 10. Differences compared to our main specification are small, implying that anticipation effects do not significantly impact our results.

Table 9: Countrywide pass-through when excluding the four weeks leading up to a tax increase

	Dependent variable: Diesel price (in ct/l)			
	2015	2016	2017	2018
Diesel tax increase (in ct/l)	4.78	3.59	3.91	7.60
France:Post	5.509	5.824	4.845	10.579
	(0.019)	(0.021)	(0.027)	(0.021)
Pass-through rate	115.3%	162.3%	123.9%	139.3%
95% conf. intervals				
$\bar{M}$=0.5	[104.4%, 126.4%]	[139.8%, 185.0%]	[109.0%, 138.9%]	[133.6%, 145.1%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	852,387	746,354	834,894	883,081

Notes: The reported results are from the event study specification with 1 average post-treatment period. Standard errors are clustered on the station level and reported in round brackets. All observations in the last four weeks leading up to each of the tax increases are excluded. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.

Table 10: Regional pass-through when excluding the four weeks leading up to a tax increase

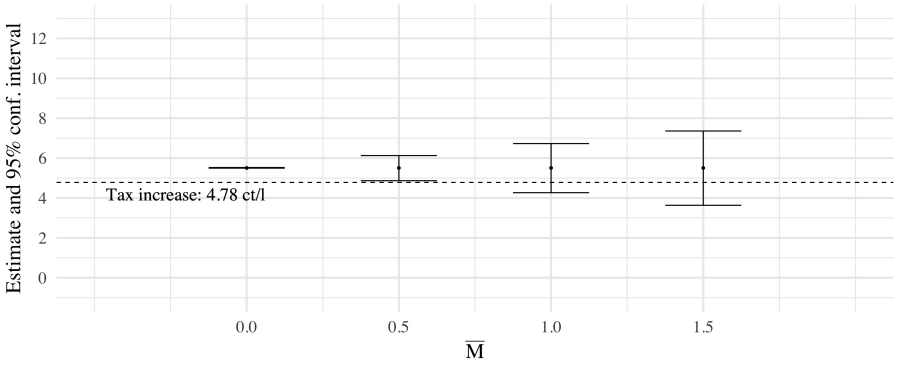
	Dependent variable: Diesel price (in ct/l)			
	2015	2016	2017	2018
Diesel tax increase (in ct/l)	4.78	3.59	3.91	7.60
France:Post	5.662	6.026	4.741	10.665
	(0.035)	(0.038)	(0.053)	(0.038)
France:Post:suburban	-0.279	-0.298	0.067	0.050
	(0.045)	(0.051)	(0.067)	(0.050)
France:Post:rural	-0.162	-0.263	0.033	-0.286
	(0.051)	(0.052)	(0.074)	(0.058)
Urban				
Pass-through rate	117.0%	166.6%	118.2%	139.6%
95% conf. intervals				
$\bar{M}$=0.5	[106.9%, 130.2%]	[144.8%, 191.7%]	[110.5%, 132.0%]	[134.4%, 147.1%]
Suburban				
Diff. in pass-through rate	-4.6%	-8.3%	1.0%	0.0%
95% conf. intervals				
$\bar{M}$=0.5	[-11.3%, 2.5%]	[-16.7%, -0.8%]	[-7.7%, 10.7%]	[-4.3%, 4.3%]
Rural				
Diff. in pass-through rate	-3.4%	-7.3%	0.8%	-3.8%
95% conf. intervals				
$\bar{M}$=0.5	[-11.9%, 5.0%]	[-19.3%, 3.3%]	[-11.5%, 13.0%]	[-5.9%, 6.7%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	852,387	746,354	834,894	883,081

Notes: The reported results are from the event study specification with one average post-treatment period. Standard errors are clustered on the station level and reported in round brackets. All observations in the last four weeks leading up to each of the tax increases are excluded. Results for suburban and rural areas are reported in relation to the results for urban areas. The differences in pass-through rates between suburban and urban areas and rural and urban areas are reported in percentage points. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.

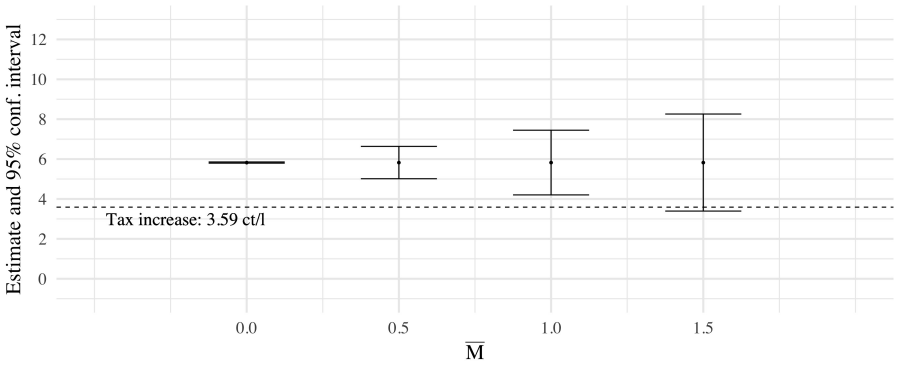
F Sensitivity graphs

In this appendix we illustrate the sensitivity of our estimates to deviations from parallel trends in the post-treatment period. By allowing the values of $\bar{M}$ to increase, and thus allowing for greater and greater deviations from parallel trends, we can see how the confidence intervals evolve and thus how sensitive our analysis is to violations of the parallel trends assumption. Figure 9 shows how the confidence interval evolves in our countrywide setup when we allow $\bar{M}$ to vary

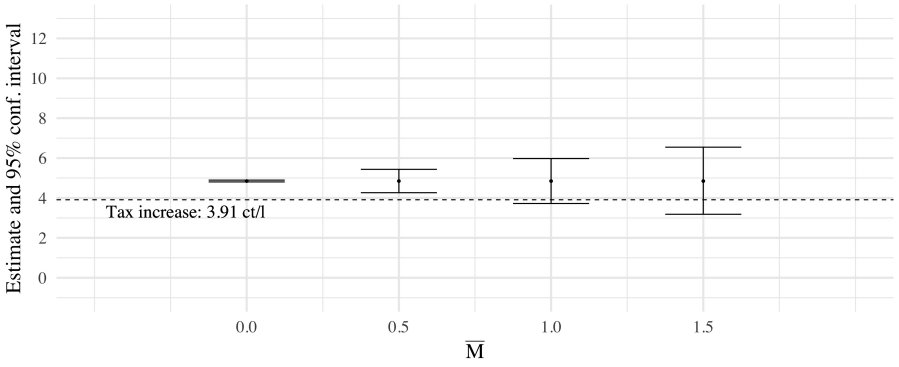
when estimating Equation 5 for all four tax increases. Figure 10 shows the analogous results for our sensitivity analysis when we estimate Equation 6 for all four tax increases we are analysing. Recalling that urban areas act as the reference value, heterogeneity in the pass-through rate is indicated by deviations from zero in the estimates for suburban and rural areas. Naturally, as we allow for greater values of $\bar{M}$ the confidence intervals grow. The estimated confidence intervals for $\bar{M} = 0$ represent the confidence intervals we would obtain if we do not relax the assumption of exactly parallel trends. Seeing how the confidence intervals evolve as $\bar{M}$ grows highlights the importance of reasonable assumptions regarding the size of post-treatment deviations from parallel trends and highlights the importance of allowing this source of uncertainty to be captured in one's estimation procedure.



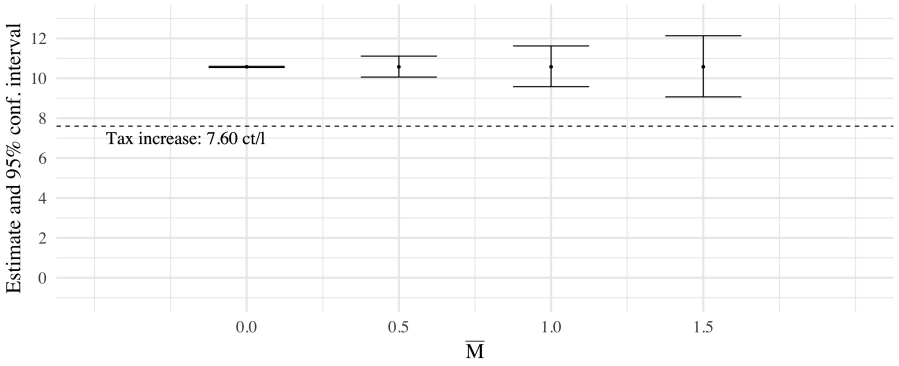
(a) 2015



(b) 2016

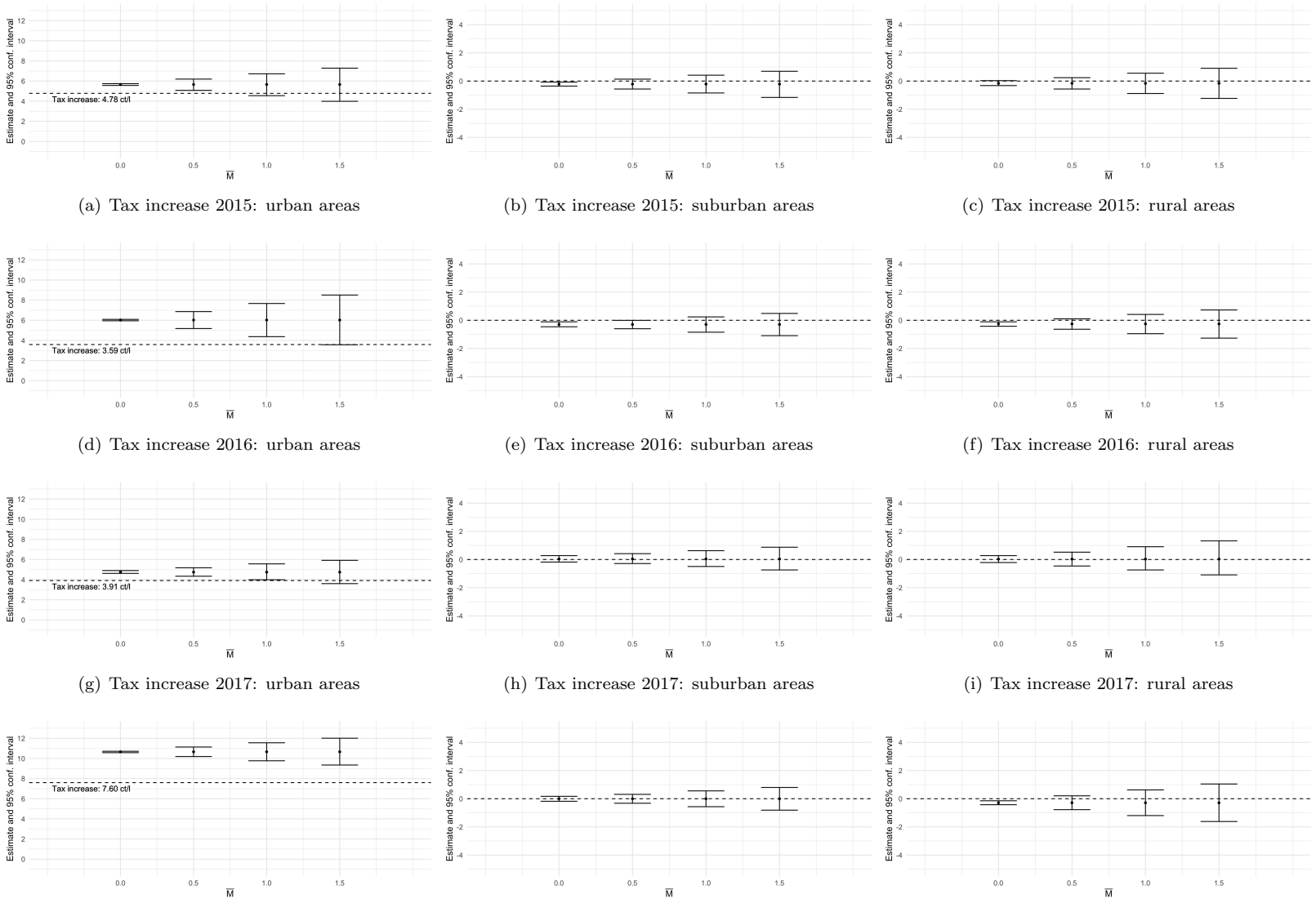


(c) 2017



(d) 2018

Figure 9: Sensitivity of countrywide estimates to deviations from parallel trends



(a) Tax increase 2015: urban areas (b) Tax increase 2015: suburban areas (c) Tax increase 2015: rural areas

(d) Tax increase 2016: urban areas (e) Tax increase 2016: suburban areas (f) Tax increase 2016: rural areas

(g) Tax increase 2017: urban areas (h) Tax increase 2017: suburban areas (i) Tax increase 2017: rural areas

(j) Tax increase 2018: urban areas (k) Tax increase 2018: suburban areas (l) Tax increase 2018: rural areas

Figure 10: Sensitivity of estimates to deviations from parallel trends along the urban-rural dimension

G Extended estimation results for rural-urban heterogeneity in pass-through

Table 11: Extended results on heterogeneity in pass-through

Dependent variable: Diesel price (in ct/l)				
	2015	2016	2017	2018
Urban				
Event study				
Pass-through rate	118.5%	167.9%	121.3%	140.4%
95% conf. intervals				
$\bar{M}$=0	[116.5%, 120.2%]	[165.9%, 169.8%]	[118.1%, 125.3%]	[139.2%, 141.1%]
$\bar{M}$=0.5	[106.3%, 129.7%]	[144.4%, 191.2%]	[110.9%, 132.4%]	[134.2%, 146.6%]
$\bar{M}$=1	[95.3%, 140.7%]	[121.9%, 213.7%]	[102.0%, 142.3%]	[128.6%, 152.1%]
Two-period DiD				
Pass-through rate	119.7%	166.5%	130.1%	141.0%
95% conf. interval	[118.5%, 120.8%]	[165.1%, 167.9%]	[128.8%, 131.5%]	[140.3%, 141.7%]
Suburban				
Event study				
Difference in pass-through rate	-4.5%	-8.3%	1.0%	0.0%
95% conf. intervals				
$\bar{M}$=0	[-7.4%, -1.6%]	[-12.8%, -3.1%]	[-4.6%, 7.0%]	[-2.4%, 2.2%]
$\bar{M}$=0.5	[-11.8%, 2.8%]	[-16.7%, -0.1%]	[-7.3%, 10.6%]	[-4.2%, 4.1%]
$\bar{M}$=1	[-17.7%, 8.7%]	[-23.6%, 6.7%]	[-12.7%, 16.0%]	[-7.4%, 7.3%]
Two-period DiD				
Difference in pass-through rate	-1.4%	2.5%	-6.4%	1.1%
95% conf. interval	[-2.8%, 0.0%]	[0.7%, 4.3%]	[-8.1%, -4.6%]	[0.1%, 2.0%]

Rural				
Event study				
Difference in pass-through rate	-3.4%	-7.2%	0.7%	-3.8%
95% conf. intervals				
$\bar{M}$=0	[-6.7%, 0.6%]	[-11.9%, -3.1%]	[-5.5%, 7.0%]	[-5.6%, 1.9%]
$\bar{M}$=0.5	[-11.8%, 5.0%]	[-17.7%, 2.8%]	[-11.8%, 13.3%]	[-10.2%, 2.7%]
$\bar{M}$=1	[-18.4%, 11.6%]	[-26.5%, 11.6%]	[-18.9%, 23.2%]	[-15.7%, 8.2%]
Two-period DiD				
Difference in pass-through rate	-0.9%	5.0%	-9.9%	-1.9%
95% conf. interval	[-2.3%, 0.6%]	[3.0%, 7.1%]	[-11.8%, -8.0%]	[-3.0%, -0.8%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	928,772	824,777	911,666	954,031

Notes: Standard errors are clustered on the station level and reported in round brackets underneath the point estimate. Results for suburban and rural areas are reported in relation to the results for urban areas. The differences in pass-through rates between suburban and urban areas and rural and urban areas is reported in percentage points. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.

H Estimation results from competition analysis

To tentatively investigate whether the degree of competition affects pass-through rates and should therefore be considered a mechanism through which regional disparities can arise, we estimate a specification that includes dummy variables for the degree of competition. Following the approach of Harju et al. (2022), we first compute the number of other gas stations within a 10 kilometre radius for each stations. It is worth noting that not all of those stations necessarily has to represent a competitor as they may belong to the same station operator. We would like to take this into account but lack information on fuel station brands in the French data set. We estimate the following model:

$$P_{s,t} = \chi_1 + \sum_{\substack{x=-26 \\ x \neq r}}^{0} 1(x=t) France_s \chi_{2,x} + \sum_{\substack{x=-26 \\ x \neq r}}^{0} 1(x=t) \boldsymbol{C'}_s \boldsymbol{\chi}_{3,x} + \sum_{\substack{x=-26 \\ x \neq r}}^{0} 1(x=t) France_s \boldsymbol{C'}_s \boldsymbol{\chi}_{4,x} + \tau_t + \sigma_s + \nu_{s,t} \tag{10}$$

where $\boldsymbol{C'_s} = \begin{bmatrix} C_{s,medium} & C_{s,high} \end{bmatrix}$ represents a vector of the two dummy variables identifying the degree of competition with low competition being the omitted category. $\chi_{2,t}$ captures the effects of the diesel tax increase on the price of diesel in a low competition setting. The vector $\boldsymbol{\chi}_{4,t} =$

$\left[\chi_{4,t,medium} \quad \chi_{4,t,high}\right]$ captures the effects of the tax increase on the price of diesel in medium and high competition settings in comparison to the effect it had on prices in a low competition setting, that is in relation to $\chi_{2,t}$.

Table 12: Results on heterogeneity in pass-through by degree of competition

Dependent variable: Diesel price (in ct/l)				
	2015	2016	2017	2018
Diesel tax increase (in ct/l)	4.78	3.59	3.91	7.60
Low competition				
France:Post	5.518	5.767	4.938	10.577
	(0.034)	(0.033)	(0.046)	(0.040)
Pass-through rate	115.5%	160.7%	126.2%	139.2%
Robust 95% conf. interval ($\bar{M}$=0.5)	[101.1%, 129.0%]	[139.5%, 182.5%]	[108.2%, 145.9%]	[130.9%, 148.0%]
Medium competition				
France:Post: mediumcomp	0.003	-0.087	-0.342	-0.006
	(0.049)	(0.051)	(0.066)	(0.055)
Difference in pass-through rate	0.1%	-2.4%	-8.7%	-0.1%
Robust 95% conf. interval ($\bar{M}$=0.5)	[-5.2%, 5.0%]	[-9.9%, 4.7%]	[-20.7%, 0.8%]	[-4.7%, 4.1%]
High competition				
France:Post: highcomp	0.006	0.305	-0.235	0.075
	(0.047)	(0.050)	(0.068)	(0.053)
Difference in pass-through rate	0.1%	8.5%	-6.0%	1.0%
Robust 95% conf. interval ($\bar{M}$=0.5)	[-8.7%, 8.7%]	[-2.1%, 19.4%]	[-20.7%, 7.0%]	[-5.1%, 7.3%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	928,772	824,777	911,666	954,031

Notes: Standard errors are clustered on the station level and reported in round brackets. Results for medium and high competition are reported in relation to the results for low competition. The differences in pass-through rates between medium and low competition stations and high and low competition stations are reported in percentage points. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded.

I Estimation results from border exclusion

To investigate whether spillover effects from cross-border competition affects our results we estimate Equations 5 and 6 whilst excluding all stations that are within 10 kilometers from a

station in the other country. Such spillovers would imply that the control unit, Germany, is also affected by the tax increase which would bias our estimates. The results from these estimations are presented in Tables 13 and 14. The differences in coefficients between this specification and our main specification are very small, suggesting that cross-border competition does not have a significant effect on the results of our main specification and reassures us that spillover effects do not significantly affect our results.

Table 13: Countrywide pass-through when excluding border stations

Dependent variable: Diesel price (in ct/l)				
	2015	2016	2017	2018
Diesel tax increase (in ct/l)	4.78	3.59	3.91	7.60
France:Post	5.508	5.843	4.849	10.590
	(0.019)	(0.021)	(0.028)	(0.022)
Pass-through rate	115.3%	162.9%	123.9%	139.4%
95% conf. intervals				
$\bar{M}$=0.5	[101.9%, 128.3%]	[139.8%, 185.8%]	[109.0%, 138.9%]	[132.8%, 146.3%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	920,647	817,481	903,295	945,643

Notes: Standard errors are clustered on the station level and reported in round brackets. All stations within 10 kilometers from a station in the other country are excluded. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.

Table 14: Heterogeneity in pass-through when excluding border stations

Dependent variable: Diesel price (in ct/l)				
	2015	2016	2017	2018
Diesel tax increase (in ct/l)	4.78	3.59	3.91	7.60
France:Post	5.664	6.068	4.720	10.677
	(0.036)	(0.038)	(0.053)	(0.038)
France:Post:suburban	-0.219	-0.326	0.069	0.003
	(0.047)	(0.051)	(0.067)	(0.050)
France:Post:rural	-0.163	-0.296	0.067	0.003
	(0.051)	(0.052)	(0.074)	(0.058)
Urban				
Pass-through rate	118.6%	169.1%	120.7%	140.6%
95% conf. intervals				
$\bar{M}$=0.5	[106.3%, 130.2%]	[145.6%, 192.5%]	[109.8%, 132.0%]	[134.4%, 147.1%]
Suburban				
Pass-through rate	-4.6%	-9.1%	1.8%	0.0%
95% conf. intervals				
$\bar{M}$=0.5	[-11.9%, 3.1%]	[-17.6%, -0.8%]	[-6.9%, 11.5%]	[-4.0%, 4.3%]
Rural				
Pass-through rate	-3.4%	-8.3%	1.7%	-3.9%
95% conf. intervals				
$\bar{M}$=0.5	[-11.9%, 5.0%]	[-18.4%, 2.5%]	[-10.7%, 15.4%]	[-10.3%, 2.4%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	920,647	817,481	903,295	945,643

Notes: The reported results are from the event study specification with 1 average post-treatment period. Standard errors are clustered on the station level and reported in round brackets underneath the point estimate. All stations within 10 kilometers from a station in the other country are excluded. Results for suburban and rural areas are reported in relation to the results for urban areas. The differences in pass-through rates between suburban and urban areas and rural and urban areas are reported in percentage points. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.

J Estimation results from highway exclusion

Fuel stations along highways are likely different from other fuel stations in a number of ways. For example, it seems likely that trucks are more prone to fill up along a highway station as they are more likely to lie along long-haul trucking routes. To investigate whether this affects the results of our main specification we, as a robustness check, estimate Equations 5 and 6 whilst excluding all fuel stations along a highway in France. The results are presented in Table 15 and

16. Differences compared to our main specifications are very small, implying that our results are not sensitive to fuel stations along highways potentially reacting differently to tax increases.

Table 15: Countrywide pass-through rates when excluding highway stations in France

Dependent variable: Diesel price (in ct/l)				
	2015	2016	2017	2018
Diesel tax increase (in ct/l)	4.78	3.59	3.91	7.60
France:Post	5.506	5.794	4.865	10.597
	(0.019)	(0.021)	(0.028)	(0.021)
Pass-through rate	115.3%	161.5%	124.4%	139.5%
95% conf. intervals				
$\bar{M}$=0.5	[101.9%, 128.3%]	[138.9%, 184.1%]	[109.0%, 139.7%]	[132.4%, 146.7%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	852,387	746,354	834,894	883,081

Notes: The reported results are from the event study specification with one average post-treatment period. Standard errors are clustered on the station level and reported in round brackets. All observations from French gas stations located at a highway are excluded. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.

Table 16: Regional pass-through rates when excluding highway stations in France

Dependent variable: Diesel price (in ct/l)				
	2015	2016	2017	2018
Diesel tax increase (in ct/l)	4.78	3.59	3.91	7.60
France:Post	5.654	6.016	4.743	10.669
	(0.036)	(0.038)	(0.053)	(0.037)
France:Post:suburban	-0.206	-0.307	0.033	-0.005
	(0.047)	(0.051)	(0.067)	(0.050)
France:Post:rural	-0.163	-0.320	0.100	-0.247
	(0.052)	(0.053)	(0.074)	(0.059)
Urban				
Pass-through rate	118.4%	167.7%	121.2%	140.5%
95% conf. intervals				
$\bar{M}$=0.5	[106.3%, 130.2%]	[144.0%, 191.7%]	[110.5%, 132.8%]	[134.4%, 147.1%]
Suburban				
Pass-through rate	-4.3%	-8.5%	0.8%	-0.1%
95% conf. intervals				
$\bar{M}$=0.5	[-11.9%, 3.1%]	[-16.7%, 0.0%]	[-7.7%, 10.7%]	[-4.3%, 4.3%]
Rural				
Pass-through rate	-3.4%	-8.9%	2.6%	-3.3%
95% conf. intervals				
$\bar{M}$=0.5	[-13.2%, 6.3%]	[-20.1%, 2.5%]	[-10.0%, 16.1%]	[-10.3%, 3.6%]
Time fixed effects	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Observations	914,803	811,485	899,521	939,734

Notes: The reported results are from the event study-specification with one average post-treatment period. Standard errors are clustered on the station level and reported in round brackets. All observations from French gas stations located at a highway are excluded. Results for suburban and rural areas are reported in relation to the results for urban areas. The differences in pass-through rates between suburban and urban areas and rural and urban areas are reported in percentage points. For the 2016 tax increase, observations for the months of May and June 2016 are excluded from the post-treatment period due to the strike that took place at French refineries. For the 2017 tax increase, stations in Poitou-Charentes and Île-de-France are excluded. The value of $\bar{M}$ bounds the deviations from parallel trends with reference to the magnitude of the maximum deviations in the pre-treatment period.