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Was the German fuel discount passed on to consumers?

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ABSTRACT

In this article, I analyze whether German gasoline stations passed on the gasoline tax reduction to consumers. I use a difference-in-differences approach with France as the control group, as well as data for all countries in the European Union. The German fuel discount was in effect from June to August 2022. As I am the first to use complete French and German high-frequency data for the entire treatment period, I can examine how the pass-through of the tax cut evolved over time, varied for different brands, and in various geographic regions. I find a substantial variance in pass-through rates over time and space. On average, the pass-through of the fuel discount was very high but remained incomplete for all fuel types. The pass-through rates were systematically lower in rural regions and in the south of Germany.

1. Introduction - the fuel discount

The global energy crisis in 2022 was met by an unprecedented fiscal response from governments throughout Europe. Following the Coronavirus pandemic and the associated lockdowns to contain the pandemic, the economy of the European Union (EU) started to recover in the spring of 2021, with positive quarterly growth rates of real gross domestic product (OECD, 2023b) and gross domestic product[1] reaching its 2019 level again in 2021 (OECD, 2023a), and energy demand surged. Furthermore, the Russian invasion of Ukraine on February 24 and the Western sanctions in response (Bown, 2022) restricted the fuel supply to Europe and drove prices further up.[2]

Governments worldwide, especially in Europe, sought to mitigate the effects of enormously increased gasoline prices for consumers by introducing relief packages consisting of tax reductions and additional measures. The German parliament approved a gasoline tax reduction for the period between June 1 and August 31, the so-called fuel discount (referred to as "*Tankrabatt*" in the public debate), that is, a tax reduction of 14.04 Eurocent per liter (cpl) on diesel and 29.55 cpl on both types of petrol, petrol E5, and petrol E10 (Bundesregierung, 2022).[3] Additionally, the 19% value-added tax (VAT) does not apply to the saved tax. Overall, if the discount is fully passed on to consumers, prices should decline by 16.71 cpl for diesel and 35.16 cpl for both types of petrol.[4]

In this article, I analyze the pass-through rate of the temporary tax reduction on fuels in Germany, employing a DID strategy and using French gasoline stations as a control group. I am the first to analyze the temporary tax reduction with spatially granular high-frequency data covering the entire tax reduction period. Data from the same source have also been used by Montag et al. (2020) and Fuest et al. (2022) and contain the universe[5] of price changes at gasoline stations in Germany and France. I am the only one to use the DID strategy with station and date fixed effects and control for public and school holidays at the same time. Moreover, I conduct robustness checks based on data from the European Commission (2022) for the entire EU to show that my results do not depend on France being used as a control group.

Using France as a control group, I found average pass-through rates

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[1] OECD GDP – output approach, United Kingdom excluded.

[2] Bown (2022) provides a valuable timeline of international sanctions against Russia, which is kept up to date by the Peterson Institute For International Economics.

[3] There are two types of petrol in Germany: 1) petrol E5 (also called *Super E5*), which has an octane rating of 95 and a 5% share of ethanol, and 2) petrol E10 (also called *Super E10*), which has a 10% share of ethanol.

[4] Precisely, the effective price decrease, including saved value-added tax, should be 0.1404*1.19 = 0.167076 Euro per liter of diesel and 0.2955*1.19 = 0.351645 Euro per liter of petrol.

[5] All gasoline prices were reported to federal supervision authorities by those gasoline stations that were obliged to report their price changes in Germany and France.

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of 87% to 91%, depending on the fuel type. The complete high-frequency price data allows me to trace the evolution of pass-through rates over time. This analysis is based on daily estimates instead of weekly data, as used by Dovern et al. (2023), Seiler and Stöckmann (2023), and Bernhardt et al. (2023). The pass-through rates vary substantially over time, between −10% and 147% for diesel and between 47% and 114% for petrol E5. The results of weekly estimates based on data for 19 countries in the EU are very similar. Exploiting the granularity of the dataset with France as a control group, I found that pass-through rates vary considerably over space. Using the Eurostat definition for rural and urban areas, I found average pass-through rates of 82% in rural areas and 92% in urban areas. Moreover, pass-through rates vary notably over federal states, reaching an average of 60% in Bavaria and an average rate of 116% in Berlin.

The remainder of the article is structured as follows: Section 2 gives an overview of the related empirical literature. Section 3 introduces the data. I describe the identification strategy in section 4. Section 5 contains the results and is followed by a discussion of the threats to validity and robustness checks in section 6. I summarize and conclude in section 7.

2. Literature review

A wave of literature on the German tax reduction in, 2022 is currently emerging. Similar research is being conducted across Europe to examine the impact of policies to address the energy crisis. Before the end of the temporary German tax reduction, Fuest et al. (2022) published the first estimates of the pass-through rates for diesel and petrol (E5 and E10) based on a difference-in-differences (DID) approach using French gasoline stations as a control group but covering only the first two weeks after the tax reduction took effect. Based on high-frequency data for all German and French gasoline stations, they find a pass-through rate of about 100% for diesel, 82% for petrol E5, and 85% for petrol E10. Based on daily consumer price data for seven European countries(Austria, Estonia, Frane, Germany, Italy, Latvia, and Lithuania) from January 1 to August 31, Drolsbach et al. (2023) find pass-through rates of about 90% to 107% for diesel and 104% to 110% for petrol E5, excluding petrol E10 from their analysis. They scraped daily average price data from the information platform Fuelo (fuelo.net). The authors conclude that the pass-through rates vary substantially by fuel type and over time.

Schmerer and Hansen (2023) use price data from all German gasoline stations and daily data on regional petrol E5 and diesel prices from Austria for their DID approach since petrol E10 data is unavailable for Austria. They focus on median daily prices for Austria and all its states. Restricting the period to the first two weeks of June, they found 105% and 108% pass-through rates for petrol E5 and diesel, respectively. For the reinstatement of the regular taxation of gasoline, they focus on the last week of the tax reduction, hence the last week of August, to compare it to the first two weeks of September. They found a 67% and 19% pass-through rate for reinstating the gasoline tax for petrol E5 and diesel, respectively.

For the entire period of the fuel discount, Freitas and Syga (2022) find pass-through rates of 100% for both fuel types. They use weekly price data for Austria, Belgium, Germany, the Netherlands, Poland, and Sweden from the European Commission (2022), even though Sweden decreased its fuel taxes at the beginning of May and increased taxes to below the initial level at the beginning of October, 2022. Along with the DID approach, the researchers conducted an event study to estimate the amount of the tax discount passed on to consumers during different periods. They found that the fuel discount was not fully passed on in the initial weeks of June and towards the end of August.

Dovern et al. (2023) use the synthetic differences-in-differences (SDID) method and data for the entire tax reduction period. They conclude that the reduction was passed on to consumers. Moreover, they argue that pass-through started to decline in August while the tax reduction was still in effect. The diesel pass-through rate drops over the course of August, ultimately reaching a level of 50% by the end of the month. However, they only use weekly price data, presumably from the European Commission (2022). Drawing on the same data source and methodology, Bernhardt et al. (2023) focus on the period from January 2021 to the end of August, 2022. They find a pass-through of 97% to 99% for petrol E5 and 75% to 86% for diesel. Based on weekly price data, they compare their SDID results using “unregulated” EU countries as the control group with their results of a DID estimate using Franc as a control, obtaining the same results for the first six weeks of the tax reduction period. In contrast, they report different results for the second half of the tax reduction period.[6]

Seiler and Stöckmann (2023) employ the synthetic control method using weekly price data from the European Commission (2022) from January 3 to August 29, 2022. They restrict the donor pool to estimate the counterfactual to all euro area countries other than Germany and Malta, which raises the question of whether countries with policies of their own are included. They conclude that the pass-through was at least 85% and 65% for petrol E5 and diesel, respectively. It remains somewhat unclear what weight is assigned to what donor country. Moreover, they argue that there was no price increase in anticipation of the fuel discount.

Empirical evidence on the pass-through of tax changes provides several insights. When analyzing the French VAT reforms, Carbonnier (2007) and Benzarti and Carloni (2019) found a less-than-proportional pass-through for tax changes. Similarly, Carare and Danninger (2008) analyzed the German VAT increase in 2007 and reported less than full pass-through while Viren (2009) examined tax changes across EU countries and found less than full pass-through. Benedek et al. (2015) found mixed evidence for countries within the Eurozone. Specifically, they discovered less than full pass-through for reduced VAT rates but roughly 100% pass-through for the standard rate. Recently, Genakos et al. (2023) found higher pass-through in more competitive markets by examining changes in Greek value-added tax changes.

Conversely, Buettner and Madzharova (2021) and Chirakijja et al. (2009) found nearly complete pass-through in member states of the EU and Crossley et al. (2014) found similar results for the United Kingdom. However, Crossley et al. (2014) also noted that at least part of the pass-through of the VAT was reversed after a few months. Poterba (1996) observed full pass-through in the United States while Besley and Rosen (1999) reported over-shifting of sales tax increases.

Montag et al. (2020) recently analyzed the pass-through rate of the temporary value-added tax reduction in Germany. The tax reduction was a fiscal response to the coronavirus pandemic. Based on high-frequency data for Germany and France, they found pass-through rates of 83% for diesel, 40% for petrol E5, and 61% for petrol E10.

These studies focus on country pass-through estimates, usually based on average weekly prices or averages of price samples. They have not been able to analyze spatial differences in pass-through rates. My research fills this gap by drawing on complete high-frequency price data.

3. Data description

This section consists of two subsections. The first subsection introduces the reader to the datasets for the treatment group Germany, the control group France, and the weekly price dataset for all European Union countries. The second subsection is dedicated to the database for the spatially differentiated analysis for Germany.

[6] The SDID control group of “unregulated” EU countries includes Luxembourg and France. However, Luxembourg decreased its excise duties for both diesel and petrol in mid-April, 2022 European Commission (2022). It is stated that the first fuel discount in France was in place from April until July, 2022, although it was from April 14 to August 31, 2022. France changed the amount of the fuel discount from September 1, 2022.

3.1. Data for the Germany-wide analysis

The German Market Transparency Unit for Fuels collects German data on gasoline stations and prices. It was created to enable the German federal competition authority (Bundeskartellamt, 2023) to intervene in cases of market power abuse. The data is made publicly available by registered consumer information service providers. I downloaded the German data from tankerkoenig.de, which receives the data directly from the Market Transparency Unit. The data contain all price changes for all German gasoline stations. Montag et al. (2020) describe the German retail fuel market well.

French data are publicly available on the open data website of the French government (Ministère de l'Économie, des Finances et de la Souveraineté industrielle, 2022).[7] The data include all price changes for all gasoline stations that sell >500 m^3 of gasoline per year and are described in detail by Gautier and Le Saout (2015).[8] The availability of such high-frequency data in Europe is unique to France and Germany. A fuel discount has also been granted in France since April 1, 2022. Important for the DID strategy is that the development of gasoline prices over time in Germany and France was similar before the German tax reduction came into effect, as argued by Fuest et al. (2022). By using France as a control group, I follow Fuest et al. (2022), Freitas and Syga (2022), and Montag et al. (2020), among others, and discuss the assumption of parallel trends in detail in the following section.

My analysis starts on April 14, 2022, similar to previous research, but covers the entire period of the tax reduction and concludes with the termination of the tax reduction on August 31, 2022. I take the daily average price for each German and French gasoline station and date and work with daily data, similar to Montag et al. (2020) and Fuest et al. (2022).[9]

Crude oil prices are presented in descriptive statistics and approximated by the Brent price, as is commonly done in the literature. I retrieved the data from finanzen.net (2022)The crude oil price for days when the stock exchange was closed is approximated by the price from the previous date. I use the closing price when controlling for crude oil and present descriptive statistics in Table 1 of the Online Appendix (hereafter referred to as Appendix).[10] On average, the crude oil price approximated by the Brent closing price was 65.6 cpl before and 65.2 cpl after the tax reduction came into effect.

Data on public and school holidays in Germany come from Calendarpedia (2022). Data on public and school holidays in France are gathered from the French government website data.gouv.fr, created by Augusti (2022). Also, data on French communes were retrieved from that website, which was created by Badaoui (2022). Data on the French holiday zones is publicly available at vacances-scolaires-education.fr (2022).

In Table 1, I show descriptive statistics for the analysis of the German tax reduction with France as a control group. This table is for diesel and contains statistics before the tax reduction in panel a) and after the tax reduction in panel b), differentiating between the treatment group (German gasoline stations) and the control group (French gasoline stations).

Similar descriptive statistics tables for petrol E5 and petrol E10 are presented in Appendix Tables 2 and 3, respectively. The average French diesel price was about 189.3 cpl before the tax reduction and 199 cpl afterward. The average German diesel price was 203.1 cpl before and 197.7 cpl after the tax reduction. In France, about 37% of prices are reported during public or school holidays before the German tax reduction and about 61% afterward, compared to about 23% and 48% in Germany. Given the large proportion of school holidays coinciding with the tax reduction period, controlling for these holidays in the analysis becomes crucial.

Furthermore, I use a data set from the European Commission (2022) that contains weekly gasoline price data for all EU countries for diesel and petrol E5 (but not petrol E10). I exclude all countries with changes in excise duties or value-added taxes between April 14 and August 31, namely Croatia, the Czech Republic, Hungary, Luxembourg, Portugal, and Sweden. Tax changes and relevant relief packages are summarized in Appendix Table 4.[11] The European Commission (2022) also provides data on these changes.

Moreover, I exclude Malta, which regulated the prices for petrol and diesel for the entire year, and Slovenia because price caps were in place for several periods (Sgaravatti et al., 2021). In contrast to the case with daily price data and solely France as a control group, here, with the data for several European countries, I abstain from controlling for holidays when using countries of the EU as a control group.

On July 25, 2022, the Weekly Oil Bulletin data from the European Commission (2022) showed a drastic decrease in petrol and diesel prices for Estonia. Since there is no media coverage of any event that would have caused such a price drop, I assume this single data observation is false, and I exclude it.[12]

Austria did not change its tax during the observation period. Belgium decreased its tax between March 14 and 21 by 14.463 cpl and increased it in small steps starting before September 12 (by 3.305 cpl), but not during the German temporary tax reduction.

The French relief package did technically not consist of a tax or duty reduction but instead of a discount on petrol and diesel, namely *l'aide exceptionnelle à l'acquisition de carburants* (in English, exceptional aid for

Table 1
Descriptive statistics for France and Germany, diesel, April 14 to August 31

a. Descriptive statistics before tax reduction, diesel

	Mean	Median	SD	N
Control group:				
Daily average diesel price, EUR/l	1.893	1.889	0.08	430,300
Public or school holiday	0.367	0	0.482	428,648
Treatment group:				
Daily average diesel price, EUR/l	2.031	2.026	0.057	682,098
Public or school holiday	0.226	0	0.418	682,098

Descriptive statistics after tax reduction, diesel

	Mean	Median	SD	N
Control group:				
Daily average diesel price, EUR/l	1.99	1.985	0.132	828,432
Public or school holiday	0.609	1	0.488	825,212
Treatment group:				
Daily average diesel price, EUR/l	1.977	1.976	0.079	1,313,545
Public or school holiday	0.482	0	0.5	1,313,545

[7] The author would like to thank Lennart Seeger for help with data preparation.

[8] I focus on French gasoline stations on the mainland, therefore excluding islands like Corsica.

[9] I delete extreme outlier prices that lie above 300 cpl and fall below 50 cpl because such prices are likely mistakes in the data. For diesel, for example, there are 6275 observations below 50 cpl with a maximum value of 0, a mean of −0.000, and a standard deviation of 0.000. There are 1604 observations with a price above 300 cpl, a mean of 3.633, and a standard deviation of 0.54.

[10] The Online Appendix is available via Energy Economics as supplementary material accompanying this article.

[11] In April, 2022, no prices are available from the European Commission (2022) in the third week. Therefore, the data series starts on April 25.

[12] A request to the "Europe Direct Contact Centre" about this anomaly was not answered in a revealing manner. The author would like to thank the Estonian researcher Katri Urke for looking for relevant information in Estonian.

the acquisition of fuels), as described in the decree (Ministère de la Transition Énergétique, 2022). This subsidy is paid to the gasoline producers, specifically the distributors furthest up the distribution network, and only for quantities sold (Ministère de la Transition Énergétique, 2022). Therefore, it works like the tax reduction, which also occurs at a stage before retailing. I introduced the column "other relief changes" in Appendix Table 4 to account for such cases.

Also, Germany introduced reliefs other than tax reductions, namely the so-called 9-Euro-Ticket for local public transport, which was introduced simultaneously with the tax relief on June 1 and ended on August 31.[13] Based on the analysis of a nationally representative mobility tracking panel, Gaus et al. (2023) conclude that introducing this discounted public transport ticket did not lead to trips being made by public transport instead of by car in everyday mobility. They argue that this effect was exacerbated by the fact that the ticket was only available temporarily, and thus, no long-term incentives to switch to public transport could be established. In line with these findings, the assessment of mobile communication data conducted by the Federal Statistical Office of Germany (Statistisches Bundesamt, 2022), abbreviated DESTATIS, corroborates the limited extent of the transition from private car usage to public transportation.

Descriptive statistics for the weekly diesel prices of all EU countries in the control group plus Germany are presented in Appendix Table 5. There are data for six weeks before the German tax reduction and 13 weeks after the tax cut was put into force, covering the entire treatment period plus six weeks before the treatment.[14] Diesel prices (excluding Germany) are, on average, almost 8 cpl higher overall in all countries during the treatment period. Crude oil prices are only 4 cpl higher on average. Similar descriptive statistics for petrol E5 are moved to Appendix Table 6.

3.2. Data for the spatially differentiated analysis

For the spatial analysis, I use data and spatial definitions from the Federal Office for Building and Regional Planning (Bundesinstitut für Bau-, Stadt- und Raumforschung, 2023), abbreviated BBSR. I mostly use data on the municipality level because that is the finest granularity available. I focus on three research questions with respect to spatially differentiated pass-through rates. First, I analyze whether pass-through varies across federal states. I also look at differences in pass-through rates for East and West Germany as well as for city-states versus area federal states. Second, I analyze the pass-through rates for rural and urban regions using the Eurostat categorization for international comparability and the finest available categorization provided by the BBSR. Third, I show how the pass-through rates vary along all German border regions separately. Finally, I conduct and discuss robustness checks in the respective section.

In Germany, there are 16 federal states (German Bundesstaaten), of which three, Berlin, Bremen, and Hamburg, are city-states (German Stadtstaaten). The next smaller administrative subdivisions are the districts (German Landkreise or Kreise) and district-free cities. Germany had 294 districts and 106 district-free cities in 2022 (Statistisches Bundesamt, 2023b). The lowest level of administrative division is the municipality level (German Gemeinde). There were 10,786 municipalities in Germany in 2022 (Statistisches Bundesamt, 2023a). Often, major cities that are municipalities are not part of such a district subdivision but form a district of their own that consists only of the municipality itself. Most data I use are available on the smallest administrative division level, thus, at the municipality level (Bundesinstitut für Bau-, Stadt- und Raumforschung, 2023). I have assigned all retailers to the municipalities by zip code. Detailed zip code data were used from the open data platform www.suche-postleitzahl.org (Marco Schwochow, 2023), which is based on raw data from the OpenStreetMap contributors.

There are 16 federal states in Germany. The number of gasoline retailers per state is listed in Table 2. The first column shows the name, and the second column is the federal state abbreviation according to DESTATIS (Statistisches Bundesamt, 2024). The third column contains the number of gasoline stations for each federal state. When comparing pass-through rates for German federal states, it should be kept in mind that three city-states (Berlin, Bremen, and Hamburg) differ fundamentally from the territorial states and are more comparable to metropolitan areas. Federal states located in East Germany were part of the German Democratic Republic (German Deutsche Demokratische Republik, DDR) before the reunification in 1990 and are marked with an asterisk in the table. For the second research question regarding the spatial analysis, I adopt the Eurostat categorizations of rural and urban areas. This allows for comparison of future international research. The Eurostat categorization differentiates between "predominantly rural," "intermediate," and "predominantly urban" regions. According to this definition, 3202 German gasoline stations are located in predominantly rural areas, 6892 in intermediate regions, and 5033 in predominantly urban regions. Alternatively, I use the most differentiated typology of rural and urban areas in the BBSR data set. This distinguishes between 17 categories. Table 3 shows the category, the original German phrase, and the number of German gasoline stations located in the respective area. This is a hierarchical order reaching from a Metropolis (category 1) to a small town in a peripheral rural region (category 17), as described by the DESTATIS (Statistisches Bundesamt, 2020).

For the third spatial research question, I use district-level information from the BBSR dataset (Bundesinstitut für Bau-, Stadt- und Raumforschung, 2023). The dataset contains information for each administrative district on whether it is located at a German external border and to which other national state this administrative district borders. At this granularity level, I can identify all border regions and the retailers located there. Germany shares borders with nine countries: Austria, the three Benelux states (Belgium, Netherlands, and Luxembourg), the Czech Republic, Denmark, France, Poland, and Switzerland. I follow the border region definition of the BBSR and show the number of retailers in each border region in Table 4. I focus on the seven border regions to Austria, Benelux, the Czech Republic, Denmark, France, Poland, and Switzerland. There are at least 122 gasoline stations in a border region (Denmark) and at most 1021 (Benelux).

Table 2
The number of gasoline stations in the German federal states.

Federal state	Abbreviation	Number of gasoline stations
Baden-Württemberg	BW	1949
Bavaria (Free State)	BY	2623
Berlin*	BE	281
Brandenburg*	BB	434
Bremen (Hanseatic City)	HB	102
Hamburg (Hanseatic City)	HH	214
Hesse	HE	1160
Mecklenburg-Western Pomerania*	MV	357
Lower Saxony*	NI	1949
North Rhine-Westphalia	NW	3068
Rhineland-Palatinate	RP	773
Saarland	SL	167
Saxony (Free State)*	SN	590
Saxony-Anhalt*	ST	439
Schleswig-Holstein	SH	605
Thuringia (Free State)*	TH	416

Abbreviations and English names from the Federal Statistical Office of Germany (Statistisches Bundesamt, 2024). *Federal states located in East Germany. *Berlin was divided before the German reunification and is considered separately in this analysis.

[13] The ticket was valid for the month of acquisition. Thus, if it was acquired on June 20, then it could be used until the end of June. It was valid for the local public transport in Germany.

[14] For Estonia, there are only 12 weeks because one week was excluded, as discussed before.

Table 3
The 17 regional statistical areas as defined by the BBSR.

Category	Key	English	German	Number of gasoline stations
1	111	Metropolis in metropolitan city region	Metropole in metropolitaner Stadtregion	1547
2	112	Large city in metropolitan city region	Großstadt in metropolitaner Stadtregion	815
3	113	Medium-sized city in metropolitan city region	Mittelstadt in metropolitaner Stadtregion	1080
4	114	Urban area in metropolitan city region	Städtischer Raum in metropolitaner Stadtregion	1257
5	115	Small town, rural area in metropolitan city region	Kleinstädtischer, dörflicher Raum in metropolitaner Stadtregion	474
6	121	Regional center in regiopolitan city region	Regiopole in regiopolitaner Stadtregion	962
7	123	Medium-sized city in regiopolitan city region	Mittelstadt in regiopolitaner Stadtregion	500
8	124	Urban area in regiopolitan city region	Städtischer Raum in regiopolitaner Stadtregion	869
9	125	Small town, rural area in regiopolitan city region	Kleinstädtischer, dörflicher Raum in regiopolitaner Stadtregion	722
10	211	Central city in rural region near city region	Zentrale Stadt in stadtregionsnaher ländlicher Region	594
11	213	Medium-sized city in rural region near city region	Mittelstadt in stadtregionsnaher ländlicher Region	546
12	214	Urban area in rural region near city region	Städtischer Raum in stadtregionsnaher ländlicher Region	919
13	215	Small town, rural area in rural region near city region	Kleinstädtischer, dörflicher Raum in stadtregionsnaher ländlicher Region	1424
14	221	Central city in peripheral rural region	Zentrale Stadt in peripherer ländlicher Region	423
15	223	Medium-sized city in peripheral rural region	Mittelstadt in peripherer ländlicher Region	503
16	224	Urban area in peripheral rural region	Städtischer Raum in peripherer ländlicher Region	617
17	225	Small town, rural area in peripheral rural region	Kleinstädtischer, dörflicher Raum in peripherer ländlicher Region	1875

4. Identification strategy

This section outlines the proposed estimation strategy and examines the control groups. The first subsection presents the econometric model. The second subsection discusses using French gasoline stations as a control group. In contrast, the third subsection examines the use of countries in the European Union as an additional control group.

4.1. Difference-in-differences model

I applied DID estimation techniques to test whether the German fuel discount had been passed on to consumers. First, I use French gasoline stations as the control group, and then I use several countries in the EU as a control group. The model can be formalized as follows:

Table 4
The number of gasoline stations in the border regions by country.

Border region types	Frequency
Austria	376
Austria and the Czech Republic	19
Austria and Switzerland	15
Benelux	1022
Benelux and France	11
Coastal region Baltic Sea	376
Czech Republic	420
Czech Republic and Poland	86
Denmark	123
France	584
France and Switzerland	34
No border region	11,721
Poland	193
Switzerland	147

$$p_{i,t} = \beta_0 + \beta_1 d_i + \beta_2 a_t + \beta_3 a_t {}^* d_i + u_{i,t} \tag{1}$$

with the dependent variable $p_{i,t}$ being the price of gasoline stations. The coefficient β_0 is the constant. The regressor d_i is a dummy variable that indicates whether a station *i* is treated. Therefore, it takes the value 1 for German stations and 0 for the control group (e.g., French stations). The coefficient β_1 captures the pre-shock difference in the price between Germany and the control group. The regressor a_t takes the value 1 for the observations in the after-treatment period and 0 otherwise. Thus, β_2 captures the average change in the price from the pre- to post-treatment periods for the control group. Finally, the main coefficient β_3 captures the effect of the tax reduction, hence the average treatment effect (ATE).

I include fixed effects on the station and the date level and control for public and school holidays. The inclusion of the holiday control variable, as well as time and station fixed effects, changes the formal model to:

$$p_{i,t} = \beta_0 + \beta_1 a_t {}^* d_i + \beta_2 h_{i,t} + \mu_i + \delta_t + u_{i,t}. \tag{2}$$

In eq. (2), the ATE is captured by the coefficient β_1 now. The control variable for public and school holidays is $h_{i,t}$. The μ_i and δ_t are station- and date-fixed effects, respectively. Since holidays are collected for each individual retailer and, therefore, vary across entities and time, inserting date-fixed effects does not render controlling for holidays redundant. Finally, I present several robustness checks in section 6 of this article.

4.2. France as a control group

As a neighboring country of Germany, the French economy is similar to the German economy in many ways. Both countries are of similar size and wealth and located in the west of Europe, which alleviates concerns that transitory shocks could affect them differently. Both countries established mechanisms to promote transparency in the gasoline market, ensuring the availability of very accurate price data.

Two assumptions must be satisfied to causally identify the effect of the German tax reduction on gasoline prices. Firstly, there should be no economic shocks affecting Germany and France asymmetrically other than the tax reduction. Secondly, there should be no spillover effects from the German tax reduction on the French gasoline market.

I use fixed effects on the station level to control for any time-invariant differences between gasoline stations in Germany and France. Date-fixed effects are used to control for symmetric shocks. Due to their geographic proximity, supply shocks should affect German and French gasoline stations similarly and are therefore controlled for through date-fixed effects. Furthermore, both countries are members of the European Single Market; hence, there are no border controls, and regulations are harmonized. Moreover, I control in detail for public and school holidays because they could affect the demand side notably. During the period studied, there were no travel restrictions due to the pandemic in either country.

Figs. 1, 2, and 3 show that the assumption of common trends for Germany and France was fulfilled before the treatments for diesel, petrol E5, and petrol E10, respectively. Also, Appendix Figs. 1–3 show the common trend depicting the evolution of the difference between average prices in Germany and France over time.

In 2022, the French mainland saw several fuel discounts. The first discount of 18 cpl was introduced on April 1, and it was increased to 30 cpl on September 1. Thus, a robustness check to check for treatment reversal is difficult. The French discount changed to 10 cpl on November 16 and ended on December 31. Overall, there were no tax changes or reforms during the period studied (April 14 to August 31).

4.3. Countries in the European Union as a control group

Figures 4 and 5 show the weekly diesel price for Germany and those German EU neighboring countries with no tax changes in the relevant period (April 14 to August 31).[15] Similarly, Figs. 6 and 7 show prices for petrol E5.

I exclude all countries that implemented tax changes or reforms in the relevant period, as described in the data section. Again, prices in all these EU countries seem to have followed a similar trend, apart from Germany, before and after the German tax reduction. Price levels, however, vary substantially across different countries. Therefore, I conduct robustness checks with different country groups.

Again, I use station and date-fixed effects in DID regressions to control for time-invariant differences and symmetric shocks. The fact that the EU data are weekly price data makes it redundant to control in detail for public and school holidays because holidays vary substantially from day to day and throughout the regions of each country.

5. Results

The present section is partitioned into two subsections. The first subsection features the general regression outcomes when French gasoline stations are used as a control group. In the second subsection, I show detailed results for different geographical areas.

5.1. Results with France as a control group

Table 5 shows the results for diesel and petrol. The period considered reaches from April 14 to August 31, and French gasoline retailers are the control group.

In Table 5, column 1, the first coefficient of the ordinary least squares estimation (OLS), “Treated Stations,” indicates that German gasoline retailers demanded, on average, 12.81 cpl more than their French counterparts before the duty reduction. In columns 1 and 2, the second coefficient, “Discount Period,” shows that diesel prices were about 11.22 cpl higher on average for the control group in June, July, and August compared to April 14 to May 31. The coefficient is the same regardless of the use of station-fixed effects.

The third coefficient, “Treated Stations # Discount Period,” indicates that the ATE was an average price reduction of 14.89 cpl. It is very similar for all three estimation techniques and most precisely estimated in column 3, the specification with entity and time fixed effects. This corresponds to an average pass-through rate of 89% for diesel. According to the fourth coefficient, “Public or School Holiday,” holidays accounted for 1.3 cpl lower diesel prices on average in the entire data set.

Similarly, gasoline stations’ average pass-through of the tax reduction was 91% and 87% for petrol E5 and E10, respectively, as shown in the columns to the right of Table 5. The effect of public and school holidays is smaller in magnitude and only statistically significant at the 1% confidence level. I present analogous tables to Table 5 for petrol E5 and E10 in Appendix Table 7. Surprisingly, the outcomes obtained from the various specifications with and without fixed effects hardly change (only marginally for petrol E5 and E10). This may be interpreted as evidence that unobserved heterogeneity is not very important in explaining differences in pass-through rates. Therefore, it does not seem too serious that including fixed effects was often overlooked in previous studies.

The next question is how the pass-through of the tax reduction evolved over time. Appendix Figs. 1, 2, and 3 show the difference between German and French prices over time. Three observations can be made from these descriptive graphs: 1) It is difficult to tell whether German gasoline stations increased their prices prior to the tax reduction relative to the French stations from looking at the graphs, 2) The difference in prices seems to vary substantially over time, and 3) The German diesel price appears to reach its pre-treatment difference by the end of August, indicating no pass-through of the tax reduction towards the end of the fuel discount.

Next, I turn to whether gasoline stations increased their prices before the tax reduction. I use a DID estimation, focusing on three “pre-treatment” periods to compare them with the entire period before.

The first pre-treatment period is the whole week before the discount, hence the last week of May, because the discount took effect on June 1. The second pre-treatment period would be the last two days, and the third pre-treatment period would be the last day of May. These three periods are compared to the entire time before, e.g., April 14 to May 23 for the first case. I present the results for diesel in Table 6. Again, station and date fixed effects are used, and I control for public and school holidays.

All coefficients are statistically significant and positive, indicating a price increase before the tax discount took effect. However, the absolute change in average German gasoline prices is tiny, 0.5 to 0.8 cpl. Thus, the price increase was, on average, below 1 cpl.

The pass-through rate is shown as a negative number, which can be interpreted similarly to the pass-through rate of previous tables. Thus, the average German price increase for the week before the tax discount took effect was 3% of the tax discount of around 16.71 cpl for diesel and even increased to 5% for the last two days of the month.

In contrast to these results for diesel, the German gasoline stations slightly lowered the average price for petrol E5 and E10 already in the week before the tax reduction, Appendix Table 8. This price reduction corresponds to a 4% and 10% pass-through rate for petrol E5 and E10, respectively. The effect disappears when focusing on the last two days of the month for petrol E5 and stays roughly the same for petrol E10. Economically, such an early price reduction can result from decreased consumer demand in anticipation of the tax reduction. But why can we observe this price reduction only for petrol E5, an even sharper price reduction for petrol E10, and on the other hand, a weak increase in diesel prices?

Plausibly, diesel is predominantly used for business vehicles and large cars, hence by a group that is either inelastic or unconcerned about prices. Such a lower price elasticity of demand for diesel compared to petrol in the short run is also documented by Bach et al. (2019), Frondel and Vance (2014), Alberini et al. (2022), and Quack and Mechtel (n.d.) (forthcoming). Suppose demand does not decrease before a tax reduction. In that case, gasoline stations can easily maintain a high price, which I observe as a slight statistically significant increase in the average diesel price before the tax reduction. Furthermore, if German gasoline stations want to pretend to pass on the entire tax reduction, then they could raise the price before the tax reduction to achieve an artificially high reference price from which to lower their prices by the amount of the tax reduction while in fact not passing on the entire tax reduction. However, this only works if demand is sufficiently inelastic.

Private households in Germany predominantly use petrol cars. In 2022, a share of about 64% of German passenger cars ran on petrol E5 or E10 and about 31% on diesel, with the remaining 5% fueling liquid gas, natural gas, or electric (Bundesministerium für Digitales und Verkehr,

[15] See Appendix Table 4 for country codes.

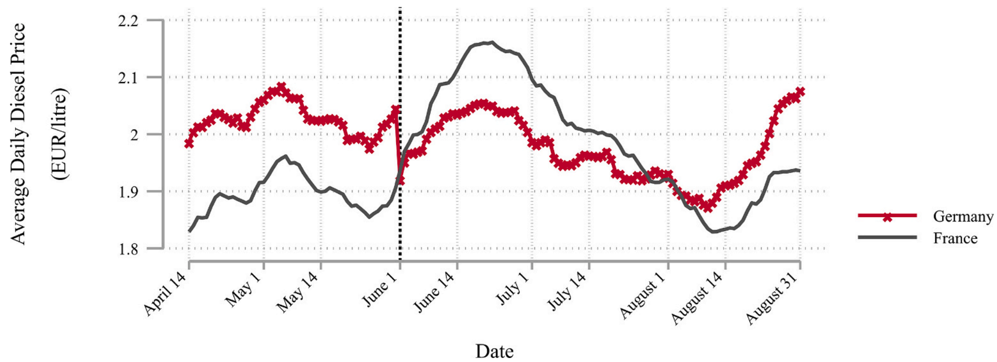


Fig. 1. Average diesel price Germany and France, April 14 to August 31, 2022.

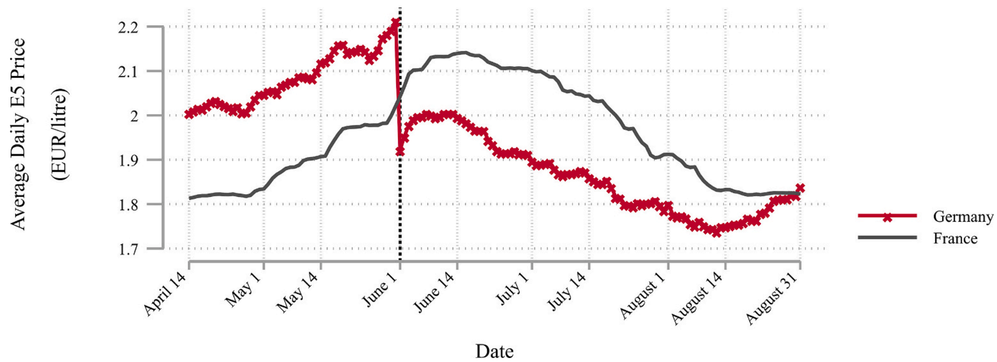


Fig. 2. Average petrol E5 price Germany and France, April 14 to August 31, 2022.

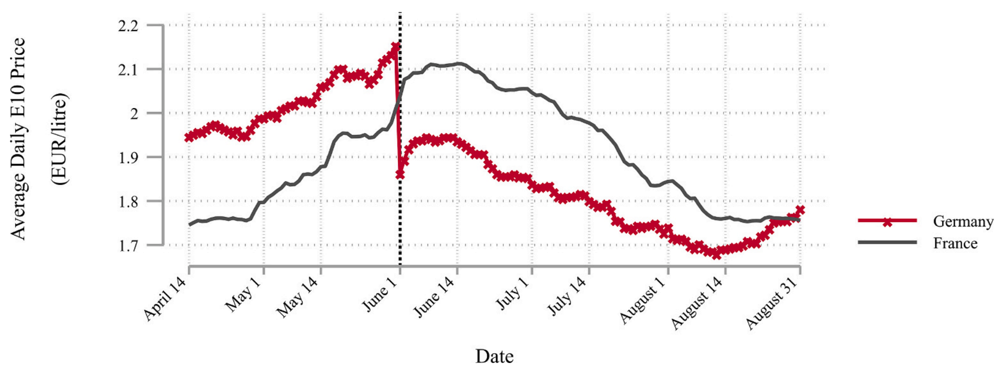


Fig. 3. Average petrol E10 price Germany and France, April 14 to August 31, 2022.

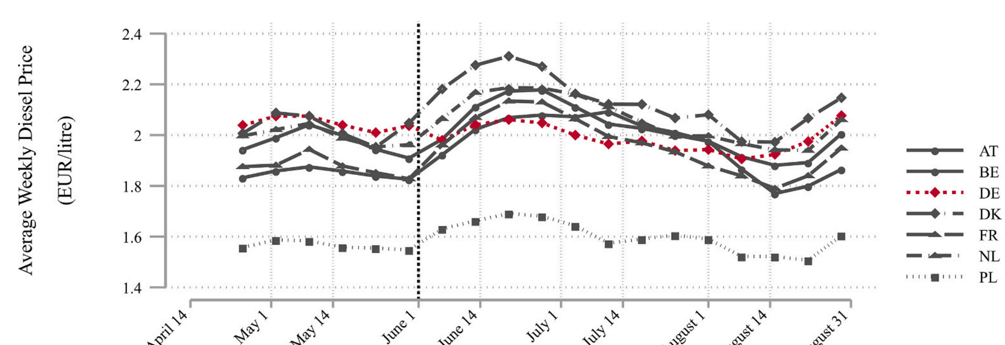


Fig. 4. Weekly diesel price for German EU neighbour countries (without tax changes), April 14 to August 31, 2022.

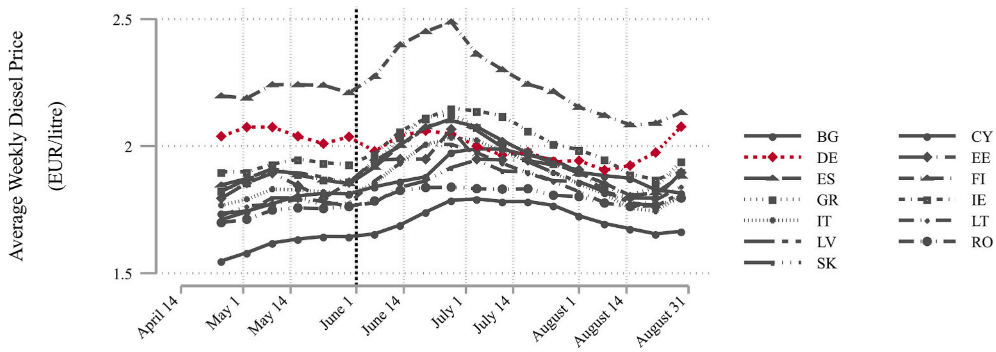


Fig. 5. Weekly diesel price for further EU countries (without tax changes), April 14 to August 31, 2022.

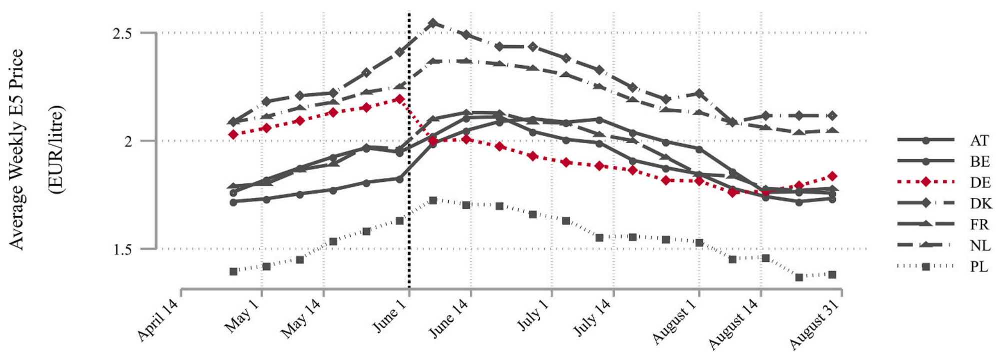


Fig. 6. Weekly petrol E5 price for German EU neighbour countries (without tax changes), April 14 to August 31, 2022.

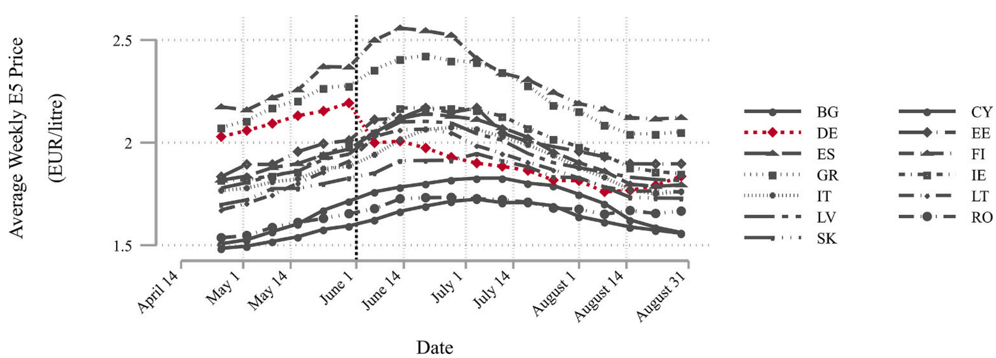


Fig. 7. Weekly petrol E5 price for further EU countries (without tax changes), April 14 to August 31, 2022.

2022). Petrol E5 and E10 are not taxed differently; however, petrol E10 prices are, on average, almost 6 cpl lower than petrol E5.[16] This may be partly driven by the relative prices of ethanol and crude oil and partly by a minimum quota of biofuels required to be sold by German gasoline stations (Montag et al., 2020). Thus, price-sensitive consumers are likely to fuel petrol E10 rather than petrol E5 and are also more likely to react by drastically decreasing gasoline demand when expecting a tax decrease. Such a demand reduction negatively affects the market price, which I observe as an economically relevant reduction in the average petrol E10 price before the tax reduction took effect. However, the overall price changes before the tax reduction were relatively small.

How did the pass-through rates of the German gasoline tax reduction evolve? I conducted DID regressions to estimate the pass-through rates for each week and day in the treatment period (June, July, and August) compared to the entire pre-treatment time (April 14 to the end of May). The results of DID estimates for every week in the treatment period, which I compare separately to the entire period before the tax reduction, are presented in Appendix Tables 9 to 11 for diesel, petrol E5, and petrol E10, respectively. The first week runs from Wednesday, June 1, to Tuesday, June 7; the second week begins on Wednesday, June 8, and so on. The last week extends for eight days, from Wednesday, August 24, to Wednesday, August 31. I use station and date fixed effects and control for public and school holidays. Results for weekly pass-through rates for all fuel types are summarized in Appendix Fig. 4.

Similar to the weekly analysis, I conducted DID regressions to estimate pass-through rates for every single day. These results are summarized in Fig. 8.[17] Pass-through rates for petrol E5 and petrol E10 evolve very similarly over time. The pass-through rates are below 100% for the first two weeks of June and rise slightly above afterward, peaking at 114% and 110%, respectively, on July 2. The rate for petrol E5 fell

[16] See descriptive statistics in Appendix Tables 1 and 2.

[17] It is one DID regression with station and date-fixed effects, controlling for public and school holidays for each day and fuel type, hence 276 regressions overall that underlie Fig. 8. Results tables are provided on demand.

Table 5
Average pass-through estimates for Germany with France as a control group.

	OLS, Diesel	Station FE, Diesel	Station Date FE, Diesel	Station Date FE, E5	Station Date FE, E10
Treated stations	0.1315***	0.0000			
	(0.0008)	(.)			
Discount period	0.1095***	0.1095***			
	(0.0004)	(0.0004)			
Treated stations # Discount period	−0.1490***	−0.1488***	−0.1489***	−0.3189***	−0.3056***
	(0.0004)	(0.0004)	(0.0004)	(0.0009)	(0.0006)
Public or school holiday	−0.0422***	−0.0427***	−0.0130***	−0.0006**	−0.0081***
	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
Brent crude oil closing price	0.6609***	0.6624***			
	(0.0026)	(0.0026)			
Constant	1.4750***	1.5549***	1.9345***	1.9680***	1.8868***
	(0.0018)	(0.0016)	(0.0003)	(0.0003)	(0.0003)
Observations	3,249,503	3,249,503	3,249,503	2,466,599	2,825,185
Adjusted R^2	0.302	0.399	0.651	0.886	0.884
Pass-through rate	89%	89%	89%	91%	87%
Station FE	No	Yes	Yes	Yes	Yes
Date FE	No	No	Yes	Yes	Yes
No. clusters	24,113	24,113	24,113	18,492	20,946

Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6
Was there a price increase in the last week/last two days/last day before the tax cut? Average pass-through estimates for Germany with France as a control group, diesel.

	Last Week of May	Last Two Days of May	Last Day of May
Treated stations # Discount period	0.0047***	0.0082***	0.0068***
	(0.0005)	(0.0005)	(0.0005)
Public or school holiday	0.0020***	0.0014***	0.0015***
	(0.0002)	(0.0002)	(0.0002)
Constant	1.9242***	1.9246***	1.9245***
	(0.0003)	(0.0003)	(0.0003)
Observations	1,110,746	1,110,746	1,110,746
Adjusted R^2	0.480	0.480	0.480
Pass-through rate	−3%	−5%	−4%
Station FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
No. clusters	23,969	23,969	23,969

Robust standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

below 100% on July 25 and reached its trough of 47% on August 31. On July 11, the rate for petrol E10 fell below 100%, reaching its trough of 40% on August 31. The pass-through rate was at least 100% on 38 and 27 days out of 92 days for petrol E5 and E10, respectively.

However, for diesel, the deviations from complete pass-through are more extreme. The rate starts at 86% on June 1 and increases subsequently, reaching full pass-through on June 8. The rate rises further and reaches its peak of 147% on June 28 and June 30. It decreases with more substantial fluctuations, reaching a trough of −10% on August 31. The pass-through rate of 100% was reached or exceeded on 48 out of 92 days.

Overall, there were relatively small price changes before the gasoline tax reduction took effect. However, pass-through rates vary substantially over time, and full pass-on of the tax reduction was reached on about half the days for diesel, substantially fewer days for petrol E5, and even fewer days for petrol E10. It can be concluded that, on average, German petrol stations passed on the entire tax discount on about 52% of the days for diesel, 41% for petrol E5, and 29% for petrol E10. The gasoline tax reduction was, on average, not passed on fully, with rates of 89%, 91%, and 87% for diesel, petrol E5, and petrol E10, respectively. All results are statistically significant at the 0.1% confidence level.

5.2. Spatial results

In this subsection, I present results for the spatial analysis of pass-through rates for diesel because the patterns are very similar for the other fuel types. This analysis is only feasible based on the dataset with France as a control group because this dataset provides the fine geographic granularity required for such an analysis.

In Table 7, I present the pass-through rates by federal states. There are substantial differences in pass-through rates, ranging from an average of only 60% in Bavaria to 116% in Berlin. The average pass-

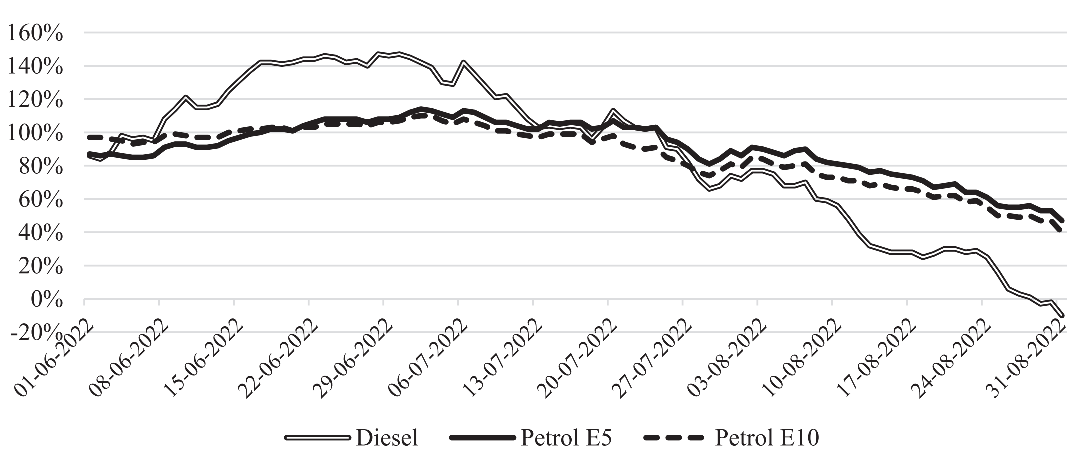


Fig. 8. Daily pass-through rates of the German gasoline tax reduction over time (France as control group), 2022.

Table 7
Average pass-through estimates for the German federal states with France as a control group, diesel.

	BB	BE	BW	BY	HB	HE	HH	MV	NI	NW	RP	SH	SL	SN	ST	TH
Discount period # Treated stations	−0.181***	−0.194***	−0.131***	−0.100***	−0.177***	−0.141***	−0.185***	−0.171***	−0.174***	−0.168***	−0.138***	−0.181***	−0.128***	−0.140***	−0.159***	−0.144***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Public or school holiday	−0.007***	−0.003***	−0.002***	−0.016***	0.001**	0.015***	−0.002***	−0.010***	−0.008***	−0.053***	0.011***	−0.010***	0.004***	−0.004***	−0.004***	−0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	1.839***	1.834***	1.855***	1.867***	1.830***	1.837***	1.833***	1.841***	1.862***	1.898***	1.833***	1.845***	1.829***	1.839***	1.838***	1.835***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	1,312,895	1,292,488	1,504,884	1,578,159	1,267,486	1,408,493	1,281,794	1,303,241	1,509,860	1,668,902	1,356,291	1,338,059	1,276,138	1,334,340	1,313,939	1,309,326
Adjusted R2	0.826	0.829	0.731	0.691	0.830	0.780	0.831	0.825	0.818	0.802	0.792	0.828	0.819	0.814	0.822	0.818
Pass-through rate	108%	116%	78%	60%	106%	84%	111%	103%	104%	101%	82%	108%	77%	84%	95%	86%
Station FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. clusters	9421	9267	10,941	11,607	9088	10,145	9193	9344	10,936	12,055	9759	9600	9153	9577	9426	9402

Robust standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

through rates for East and West Germany are not shown but are estimated to be 94% and 88%.

I excluded Berlin when presenting the rates for East and West Germany because Berlin was divided before the German reunification. Thus, East Germany consisted of today's federal states Brandenburg, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt, and Thuringia. The difference of 6 percentage points in pass-through rates is relatively small compared to the difference between federal states. Hence, differences in pass-through rates do not appear to be due to historically evolved disparities in East and West Germany. Such East-West differences could have manifested themselves in systematically different infrastructures, which could be due to different economic policies, or the disparities could have resulted from differences in behavior. Therefore, in the next step, I present the pass-through rates by federal state to reveal possible patterns.

In the map in Fig. 9,[18] the different pass-through rates for the respective states are illustrated by different shading. The shading reveals a systematic difference between the north of Germany, which has high pass-through rates illustrated by lighter shading, and the south of Germany, which has low pass-through rates highlighted by darker shading. The average pass-through rate for the city-states (Berlin, Bremen, and Hamburg) is 112% compared to only 88% for area states. This difference of 24 percentage points is remarkable and could be driven by better outside options in urban areas. Better availability of public transport in urban regions can lead to a higher price elasticity of demand and, thus, result in lower demand as prices increase. Lower demand leads to lower prices that yield higher pass-through rates.[19] Therefore, I will present pass-through rates that differentiate between urban and rural areas next.[20]

Table 8 displays estimation results for the geographical regions according to the Eurostat definition. The pass-through rate is, on average, 82% in predominantly rural areas and 92% in predominantly urban areas.

The finest granularity with respect to urban-rural classification available from the BBSR dataset provides a hierarchical categorization differentiating 17 urbanization categories as listed in Table 3. I present the respective regression results in Appendix Table 12. The pass-through rate in a Metropolis, larger city, or medium-sized city in a metropolitan city region is, on average, between 94% and 96% (categories 1 to 3). The pass-through rate is between 77% and 88% in urbanization categories 12 to 17, which are either rural or peripheral rural regions. The remaining areas have experienced pass-through rates between 85% and 92%. These results underpin the previous results, which I obtained using the Eurostat definition. The results are visualized in Appendix Fig. 5. Specifically, it supports the finding of higher pass-through rates in urban areas and lower rates in rural areas, but with a slightly higher pass-through rate in very rural areas. This higher pass-through rate in very rural areas may be due to higher price elasticity of demand. Such higher elasticity may result from the fact that people in very rural regions regularly visit commercial centers (nearby towns or cities) for everyday supplies and, thus, drive more kilometers regularly, giving them more choices about where to fuel.

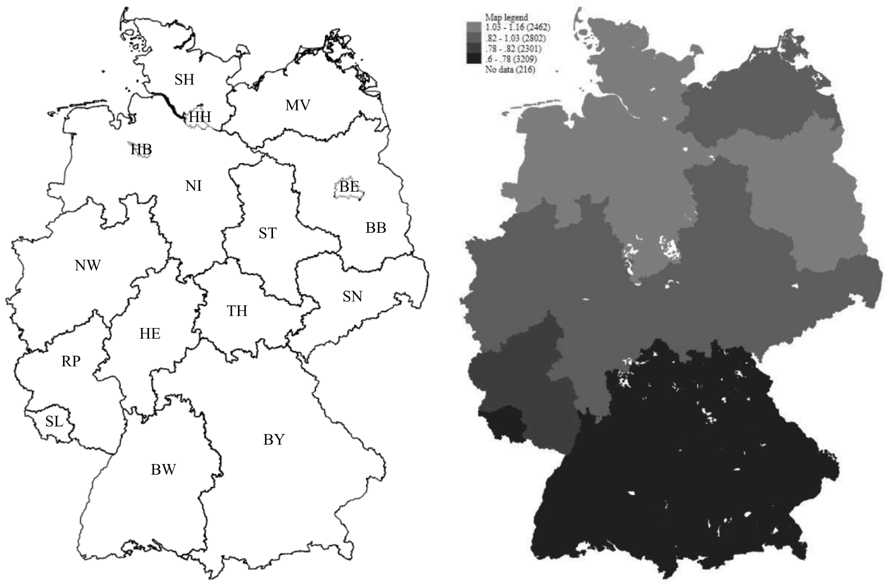
Next, I present results for different border regions in Table 9. Pass-through rates are much lower at the borders in the south of Germany than in the German inland and much higher at the borders to Denmark, Benelux, Poland, and the Coast to the Baltic Sea.

The Map in Appendix Fig. 6 visualizes each border region's different

[18] The author would like to thank Jonas Dix for help with visualizing the results on maps.

[19] The higher price elasticity of demand in urban areas may have been boosted by the introduction of a discounted ticket for local public transport, as discussed in detail in section 6.

[20] Detailed estimation results for East and West Germany, as well as for city-states, are available on request.



a) Federal states b) Pass-through rates

Fig. 9. Pass-through rates for different geographical regions, diesel.

Table 8
Average pass-through estimates for German rural and urban areas following the Eurostat definition with France as a control group, diesel.

	Predominantly rural	Intermediate	Predominantly urban
Discount period # Treated stations	−0.137***	−0.150***	−0.154***
	(0.001)	(0.001)	(0.001)
Public or school holiday	−0.011***	−0.015***	−0.023***
	(0.000)	(0.000)	(0.000)
Constant	1.872***	1.906***	1.896***
	(0.000)	(0.000)	(0.001)
Observations	1,660,901	2,160,964	1,935,358
Adjusted R^2	0.722	0.700	0.725
Pass-through rate	82%	90%	92%
Station FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
No. clusters	12,219	15,902	14,033

Robust standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

pass-through rates and the geographical demarcation of the border regions. This demarcation is carried out in accordance with the BBSR's definition of border regions at the county level. The pass-through rates are remarkably different for the various border regions and, again, appear to be lowest in the south of Germany.

Overall, there are substantial geographical differences with respect to the pass-through rates of the fuel discount in Germany. Two findings persist across all estimation results. Firstly, the rates are lower in rural regions than in the urban areas, and secondly, the rates are lower in the south than in the north of Germany. Further research is needed to explain these geographical differences. Future research may focus on differences in infrastructure and transportation costs. The latter may have varied due to droughts in the summer months. Droughts can have a significant impact on transportation costs because goods can no longer be transported south by water, which is the usual transport route for fuels (de Haas, 2019).

Differences in infrastructure may be related to different mobility policies pursued by the various federal states. States with a large automotive industry may have relied more heavily on the car as a means of transportation. Finally, the media coverage and, thus, the topic salience of the fuel tax reduction may have differed in the federal states, which could have led to differences in the price elasticity of demand and hence contributed to the enormous differences in pass-through rates.

6. Discussion of threats to validity and robustness checks

In this section, I focus on weekly EU price data first, then look at

Table 9
Average pass-through estimates for regions at Germany's external borders, with France as a control group, diesel.

	AT	BE, NL, LU	CH	CZ	Coast	DE	DK	FR	PL
Discount period # Treated stations	−0.090***	−0.162***	−0.120***	−0.130***	−0.173***	−0.150***	−0.193***	−0.136***	−0.182***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
Public or school holiday	−0.007***	−0.027***	−0.000	−0.005***	−0.009***	−0.014***	−0.002***	0.003***	−0.003***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	1.838***	1.856***	1.831***	1.838***	1.842***	1.924***	1.831***	1.836***	1.833***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
Observations	1,303,037	1,386,647	1,272,653	1,318,988	1,305,616	2,808,188	1,270,592	1,334,159	1,280,503
Adjusted R^2	0.804	0.811	0.821	0.811	0.826	0.664	0.830	0.795	0.828
Pass-through rate	54%	97%	72%	78%	104%	90%	116%	81%	109%
Station FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. clusters	9394	10,022	9133	9493	9365	20,716	9109	9607	9179

Robust standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

typical robustness checks and discuss possible threats to validity. Thus, I present the regression results for estimates utilizing all countries within the EU that have maintained constant tax policies throughout the period analyzed as a control group in the first subsection. The second subsection shows a placebo test and various further robustness checks. I end with a discussion of the external validity.

6.1. Results with countries in the European Union as a control group

The results presented in the results section are based on DID estimates with high-frequency data from all French gasoline stations as a control group. Even though France is commonly used as a control group, as discussed in the introduction, and the common trend assumption seems to be fulfilled, as discussed in section 4.2, I use weekly data for all countries in the EU for further analysis. Also, I stick to data from the European Commission (2022) for Germany and France. First, I look at the average pass-through rate; second, I focus on whether German gasoline stations increased their prices before the tax reduction took effect; and third, I focus on the evolution of pass-through rates over time.

In Table 10, I show the results of DID estimation for diesel and petrol E5 with station and date fixed effects. I use data for all countries in the EU that did not change taxes during the relevant period from April 14 to August 31, 2022. Recall that it is not controlled for public and school holidays, as discussed in section 4.3. Furthermore, there are no data available for petrol E10. The coefficients are statistically significant at the 0.1 confidence level. The pass-through rates are close to the ones estimated with France as the control group. Namely, the average pass-through rate for diesel is about 85% and about 94% for petrol.

Again, the next question I aim to answer is whether gasoline stations increased their prices prior to the tax reduction. I compare the last week before the tax reduction (the last week of May) to the weeks before. In contrast to the case where I used France as the control group, I cannot present daily results here because there is only weekly data. I cannot find any price increase or decrease the week before the tax reduction, as shown in Appendix Table 13. The coefficients are statistically insignificant and positive for both diesel and petrol E5. The pass-through rate is 2% and 3%, respectively. The last week of May corresponds to one observation in the weekly data for countries in the EU. It is, therefore, not as well suited for analysis of short periods as the data source with high-frequency data for Germany and France.

Finally, I show how the pass-through rate changes over time when using countries in the EU as a control group instead of French gasoline stations. I visualize the pass-through rates in Fig. 10, which is based on EU countries as a control group and very similar to Appendix Fig. 4, which was based on France as a control group. I present the regression output underlying Fig. 10 in Appendix Tables 14 and 15 for diesel and petrol E5, respectively.

The pattern of the evolution of pass-through rates of the German tax reduction over time, which is based on the analysis of weekly data from 19 countries in the EU, matches the results based on high-frequency data for Germany and France. The pattern appears to be less pronounced when using all countries in the EU which did not change taxes. The rates for diesel appear to be systematically lower (than in the case with France as the control group), starting at 78% and peaking at 130% in Week 5 (in contrast to 92% and 144%, respectively, in the France case). Then, the rate decreases, very similar to the case with France, to about 0% pass-through at the end of August.

The evolution of pass-through rates for petrol E5 when using countries in the EU as a control group is very similar to the results when using France as a control group. They start at 82% and 86%, peak at 115% and 111% in week 5, and decrease to 60% and 53% for the EU and France cases, respectively. Differences in topic salience could explain this difference in pass-through rates over time because pass-through increases with the share of well-informed consumers, as discussed by Montag et al. (2023). Dovern et al. (2023) suspect that a rise in demand before the termination of the tax reduction and increasing transportation costs due to lower river water levels resulting from the drought in the summer of 2022 may have led to lower pass-through rates towards the end of August.

The average weekly pass-through rates for diesel and petrol E5 were six weeks above and seven weeks below full pass-through for EU data. When using solely French gas stations as a control group, the average weekly pass-through rate for diesel was seven weeks above full pass-through. However, diesel rates dropped very far below full pass-through towards the end of August in this latter case.

Overall, the results are insensitive to changing the control group from French gasoline stations to weekly data on gasoline prices for countries in the EU. On average, pass-through rates were below 100% for all gasoline types. The average estimates are pass-through rates of 89% and 85% for diesel and 91% and 94% for petrol E5 for the control groups France and the EU.

I present two robustness checks with respect to varying the control group, which consists of countries in the EU. Firstly, I excluded the three countries with the lowest price levels, and secondly, I have only included countries that are not neighboring countries of Germany.

For simplicity, I exclude the three countries with the lowest price levels. I look at the mean price from the descriptive statistics tables, Appendix Tables 5 and 6, for diesel and petrol E5, respectively. Namely, I exclude Bulgaria, Poland, and Romania and present results analogous to Table 10 in Appendix Table 16. Results are robust with respect to this selection – only the pass-through rate for diesel increases by about one percentage point.

Next, I look at pass-through rates when the control group is limited to German non-neighboring countries in the EU that did not change their taxes in the relevant period. I present the results in Appendix Table 17. The pass-through rate for diesel is one percentage point above the one in Table 10, and the pass-through rate for petrol E5 is three percentage points higher. Overall, the weekly analysis using different countries in the EU is very similar.

6.2. Further robustness checks

For the placebo test, I split the month of May in half, treating the second half as if it were the policy period. Thus, I took the data from May 1 to May 31 and set May 15 as the first treatment day. I include station- and date-fixed effects. Additionally, I control for public and school holidays in the case of French gasoline stations as the control group. The results for the case with French stations as the control group are presented in Appendix Table 18. There is a slightly negative pass-through rate of −3% for diesel and low positive rates of 3% for petrol E5 and 8% for petrol E10. This could still be biased by what happened in the last week. Excluding the last week of May and setting the first treatment day to May 13 decreases all pass-through rates to 0%, 1%, and 6%,

Table 10
Average pass-through estimates for Germany with EU countries as a control group.

	Diesel	E5
Discount period # Treated stations	−0.1412***	−0.3310***
	(0.0065)	(0.0106)
Constant	1.8330***	1.7914***
	(0.0069)	(0.0059)
Observations	360	360
Adjusted R^2	0.771	0.847
Pass-through rate	85%	94%
Station FE	Yes	Yes
Date FE	Yes	Yes
No. clusters	19	19

Robust standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

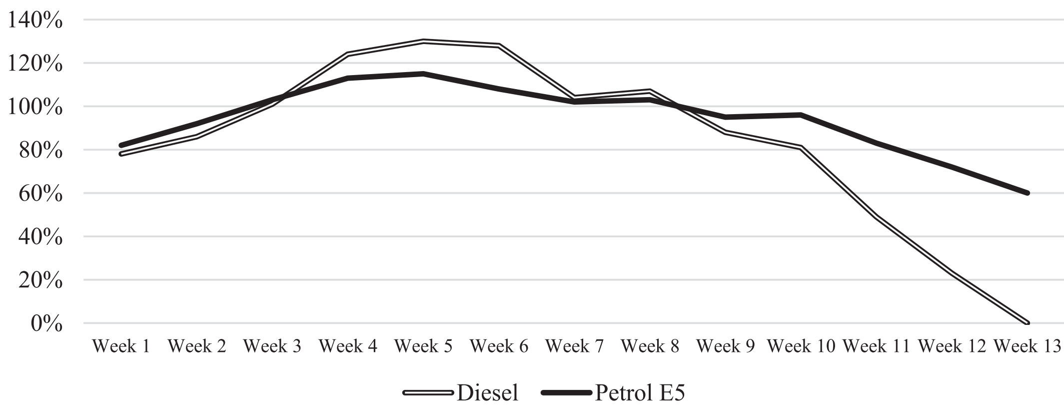


Fig. 10. Weekly pass-through rates of the German gasoline tax reduction over time (EU as control group), 2022.

respectively (Appendix Table 19). It appears that there was a minor decrease in petrol E10 prices.[21] Overall, the placebo test yields the expected results, namely that there is no effect, supporting the common-trend assumption. Moreover, German pass-through rates obtained using French gasoline stations as the control group may be less robust towards the end of the tax reduction because France reduced its fuel discount on September 1, 2022.

My results show that the pass-through rate in Germany varies over time. This time-varying rate follows a clear pattern over the fuel discount period. On average, the pass-through rate is below 100% in the first week and above full pass-through in the following weeks, eventually declining in the last half of the treatment period. If the same time-varying nature of pass-through rates also applies to the French case, then the time-varying results are blurred when using France as a control group. Thus, estimates of the pass-through rates for longer periods are not reliable. However, the results are supported by estimates that use all countries of the EU as a control group, which may indicate that there is no or a less pronounced temporal variation in the pass-through rates of the French reliefs.

Due to the availability of high-frequency data on the station level for France and Germany, average pass-through rates for single brands can be estimated. I found no significant differences in the major brands' pass-through rates (Aral, Shell, Esso, Total, and Jet), as presented for diesel in Appendix Table 20.[22]

I present robustness checks for the spatial analysis in Appendix Tables 21 and 22. For the robustness checks, I used different spatial delineation definitions offered by the BBSR, as indicated in the first row below the title. In Appendix Table 21, the first definition refers to the population. According to this definition, there are marginally lower pass-through rates in predominantly rural areas compared to predominantly urban areas. The spatial delineation with respect to location reveals higher pass-through rates in very central regions compared to peripheral regions. However, higher pass-through rates for very peripheral regions indicate a U-shaped relation between urbanization and pass-through rates with higher pass-through rates in urban and very peripheral regions. The BBSR classification of rural and urban confirms that pass-through rates are lower in rural areas. I present estimates for the BBSR settlement structure types in Appendix Table 22, which confirm a U-shape relation. The second classification for which I present estimates in this table distinguishes the cities and municipalities according to their size. Larger cities and towns have higher pass-through rates compared to smaller ones. Rural municipalities have marginally higher pass-through rates than smaller towns.

The results are similar for the other fuel types. Pass-through estimates for federal states for petrol E5 and E10 are less pronounced than for diesel and are presented in Appendix Tables 23 and 24, respectively. For petrol E5 (E10), the average pass-through rate in predominantly rural areas was 87% (83%) and in predominantly urban areas 93% (90%). The pattern along the border regions is similar to the one for diesel but less pronounced.[23]

Pass-through rates may be slightly overestimated because, at the same time as the tax reduction on gasoline, the German government introduced a monthly 9-Euro-Ticket for local public transport, which could have negatively affected demand during the gasoline tax reduction. This negative demand shock could have led to lower gasoline prices than the counterfactual. Hence, the estimates presented here, which already suggest an under-proportional pass-through, are high in the sense that they may already capture price-lowering effects from the negative demand shock caused by the 9-Euro-Ticket. In other words, pass-through estimates might have been lower in the absence of the 9-Euro-Ticket because demand might have been higher. However, this effect is expected to be small because switching from care usage to public transport was rare (Gaus et al., 2023; Statistisches Bundesamt, 2022), as discussed in the data description section. The external validity might still be limited when looking at exact pass-through rates; however, the mechanisms are likely to occur as observed here in similar gasoline markets, such as the evolution of the pass-through rates over time.

Finally, I am providing estimation results of robustness checks with respect to relaxing the parallel trends assumption following Rambachan and Roth (2023). This robustness check is limited to the dataset with EU countries as a control group.[24] The post-treatment coefficients appear to reflect a substantial pass-through rate compared to any pre-treatment coefficients (Appendix Fig. 7). This visualization shows that there appears to have been a difference in trends before the treatment. Nevertheless, the post-treatment coefficients appear to be substantially larger in magnitude than any of the pre-treatment coefficients. Appendix Fig. 8 shows robust confidence sets for the treatment effect in the first period using different values for the maximum parallel trends violation, abbreviated $\overline{M}$ (Mbar). For example, $\overline{M} = 1$ implies that I restrict the post-treatment violations of parallel trends to be no larger than the maximal pre-treatment violation (Rambachan and Roth, 2023). I present the confidence bands for various values of $\overline{M}$ in Appendix Fig. 8, to the right of the original confidence set. The conclusion of a significant pass-through rate holds even if I restrict post-treatment violations of parallel trends to be no larger than three times as large as the maximal

[21] Results for the very same placebo test based on data with countries of the EU as a control group are not statistically significant at the 0.1% level.

[22] There are no surprises with respect to the results for single brands and petrol E5 or petrol E10.

[23] Detailed estimation results for petrol E5 and E10 are available on request.

[24] Estimation based on the far more extensive dataset with French gasoline stations as a control group was not feasible, presumably due to a lack of computing power.

pre-treatment violation.

7. Conclusion

Governments of Western economies worldwide introduced relief packages to mitigate the effects of rocketing energy prices during the global post-pandemic economic recovery and the Russian aggression towards Ukraine. Germany reduced the gasoline tax from the beginning of June to the end of August 2022. The German gasoline market is being intensively researched, and all price data are collected by federal authorities to be able to intervene in cases of market power abuse.

I am the first to present results based on high-frequency data for Germany and France and on weekly data for all countries in the EU for the entire period in which the tax reduction was in effect. I control for public and school holidays when using high-frequency data for Germany and France. In addition to providing precise estimates of the average pass-through of the tax reduction, I present results for different brands and results on the evolution of pass-through rates over time. Moreover, I am the first to reveal the enormous differences in pass-through rates over space. General results show that the average pass-through is high but incomplete, with rates of 85% to 89% for diesel, 91% to 94% for petrol E5, and 87% for petrol E10. In contrast to public opinion, there was no price increase before the tax reduction came into effect.

Furthermore, the high-frequency data yielded interesting insights into the evolution of pass-through rates over time. Pass-through was incomplete at the beginning of the tax reduction and decreased to zero for diesel and about 45% to 60% for petrol by the end of August, just before the tax reduction terminated. Thus, pass-through rates vary substantially over time, which could be explained by falling media attention, decreasing presence in the public debate, higher demand in anticipation of rising taxes, and higher costs in southern Germany due to lower river water levels resulting from the drought in summer 2022.

Finally, the price dataset's geographical granularity, with French gasoline stations as the control group, allows for estimating pass-through rates for different areas. There are substantial differences in pass-through rates for the German federal states, reaching from 60% for Bavaria to 116% for Berlin. There is only a slight difference between average pass-through rates for East and West Germany. City-states have much higher pass-through rates on average than area federal states. The estimates reveal considerably higher pass-through rates in the north of Germany compared to the south. Various specifications provide robust evidence that the pass-through rates are higher in urban than in rural regions. According to the Eurostat spatial delineation of rural and urban areas, the average diesel pass-through rate is 82% in predominantly rural and 92% in predominantly urban areas. Tremendous differences in pass-through rates over border regions seem to be driven by the south-north differences. These results are very similar for the various fuel types. Furthermore, I found no differences in the major brands' pass-through rates.

Generally, results are confirmed when using weekly data for all countries in the EU as a control group, which did not change their taxes during the relevant period, compared to using all French gasoline stations as a control group. Not surprisingly, the peaks are more moderate when looking at the evolution of pass-through rates over time using countries in the EU as a control group because weekly averages instead of daily data are used. Results are robust to changes in the composition of the control group.

The key results are that pass-through was high but incomplete on average and that pass-through rates of the tax reduction varied substantially over time and space. Further research may focus on the determinants of these anomalies in pass-through rates over time and space and spillover effects in border regions. The results of this article suggest that the urban structure and the available infrastructure should be looked at closely. Furthermore, transportation costs and media attention may explain the differences in pass-through rates over space and time.

CRediT authorship contribution statement

Mats Petter Kahl: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2024.107843.

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