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Abstract

We analyze the effectiveness of the German tax reduction on fuel prices (‘Tankrabatt’) that was introduced for three months, starting on 1 June 2022. We use the synthetic difference-in-differences estimator to compare actual retail prices of gasoline and diesel to those in a counterfactual situation without the tax reduction. We find that the tax reduction has been completely passed on to consumers for most of the period. A notable exception is that pass-through rates for diesel started to decline in August while the tax reduction was still in place. Our results are robust to different approaches of constructing the synthetic control group.

JEL-Codes: C220, E310, E650, H220, Q410.

Keywords: fuel, gasoline, diesel, taxes, synthetic control group.

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1 Introduction

The Russian invasion of Ukraine in February 2022 raised concerns about possible reductions of Russian exports of oil and gas to Germany. In response, fuel prices increased sharply. In order to relieve consumers, the German government proposed a tax reduction on fuel (known as 'Tankrabatt' in the German public discourse) for the months June through August 2022. The measure was ratified by both parliamentary chambers in mid-May and came into effect on 1 June. It was implemented via a temporary reduction of the energy tax on fuels (gasoline, diesel, liquefied gas, petroleum gas). The reduction (including value added tax savings) amounted to 35 cents per liter for gasoline and 17 cents per liter for diesel. Ever since the government announced the plan for the tax reduction at the end of March, there have been intense public discussions about the extent to which petroleum companies would pass the tax reduction on to consumers.

We study the impact of the tax reduction on fuel prices using weekly average gasoline and diesel prices for the period January 2020 to September 2022 in Germany and other European countries that did not implement similar tax reductions. We use the synthetic difference-in-differences (SDID) estimator of Arkhangelsky et al. (2021) that proceeds as follows. In the first step, synthetic fuel prices (henceforth: 'Doppelganger') are constructed as a weighted average of fuel prices in the countries which make up the control group (the so-called 'donor pool'). Country and time weights are chosen so that the Doppelganger mimicks the dynamics of German fuel prices between January 2020 and May 2022. In the second step, a difference-in-differences estimation is performed to identify the impact of the tax reduction. Our main finding is that the tax reduction was completely passed on to consumers. However, we observe declining pass-through rates for diesel in August. At the start of September, we observe an upward price jump for gasoline. For diesel, the change in prices remains below the size of the expiring tax reduction. We are not able to make a statement about the heterogeneity of price adjustments across different regions in Germany since our analysis is based on national averages.

The price impact of the fuel tax reduction in 2022 has received little academic attention so far. Fuest et al. (2022) compare daily prices for gasoline and diesel in Germany and France. They find that German prices fell by 30 cents (gasoline) and 17 cents (diesel) relative to those in France after 1 June. This implies pass-through rates of 85% for gasoline and 100% for diesel. Similarly, Montag and Schnitzer (2022) compare profit margins of German and French petroleum companies, i.e., the difference between net prices at fuel stations and the price of crude oil. Their findings suggest pass-through rates of approximately 90% for gasoline and 100% for diesel in the first weeks of June. We contribute to the literature by relying on the synthetic difference-in-differences estimator to assess pass-through rates. By focusing on a range of European countries with no tax reduction on fuel prices, we move beyond the analyses that focus solely on comparison with France. Using France for comparison is problematic since France also implemented a tax reduction which overlapped with that in Germany.[1] In addition, we consider the effectiveness of the tax reduction over its entire three-months duration while the other studies focus on the initial effect.

[1] The French tax reduction amounted to 18 cents on both gasoline and diesel prices for the period from June to August 2022.

Our analysis connects to a broader literature that analyzes the impact of tax reductions on retail prices. He and Sun (2022) examine the effect of a temporary gasoline tax holiday in the US states Maryland, Georgia and Connecticut. They find that tax cuts are mostly passed on to consumers, but not over the full duration of the tax holiday. Montag et al. (2021) explore the pass-through of the reduced value added tax in Germany in the second half of 2020 for the case of fuel retail prices. The results imply pass-through rates of 34-52% for gasoline and 79% for diesel. In a related study, Fuest et al. (2020) analyze the same tax reduction but focus on grocery prices. Contributions by, inter alia, Seiler et al. (2021), Doyle Jr and Samphantharak (2008), and Kenkel (2005) focus on various other product categories. In a more general setting Benedek et al. (2020) confirm full pass-through of VAT changes in 17 euro area countries.

We use the novel SDID estimator of Arkhangelsky et al. (2021), which combines the construction of a synthetic control group with a two-way fixed effects estimation of the treatment effect. Campos et al. (2022) use this method to analyze the productivity effects of Norway's decision not to institutionally integrate with the EU in 1995. Abman and Longbrake (2023) use it to study the political and economic consequences of the construction of the Chad-Cameroon oil pipeline. The SDID estimator builds upon the synthetic control method (SCM) of Abadie and Gardeazabal (2003), which they use to analyze the effect of terrorism on per-capita income in the Basque country by comparing actual wealth to that in a synthetic control region without terrorism. Abadie et al. (2010) use the same methodology to estimate the effectiveness of a tobacco control program in California on cigarette sales. Abadie et al. (2015) investigate the economic impact of the German reunification on per-capita income in West Germany. Born et al. (2019) explore the effect of the Brexit vote on real GDP in the UK and Born et al. (2021) estimate the impact of the decision by the Swedish government not to introduce lockdowns during the COVID-19 pandemic on infections, deaths, mobility rates and GDP growth. See Abadie (2021) for a discussion of the methodological and data challenges when using the SCM.

The remainder of this paper is organized as follows. Section 2 describes the data. Section 3 discusses the synthetic difference-in-differences estimator. Section 4 presents the main results. We assess the robustness of our findings in Section 5. Section 6 concludes.

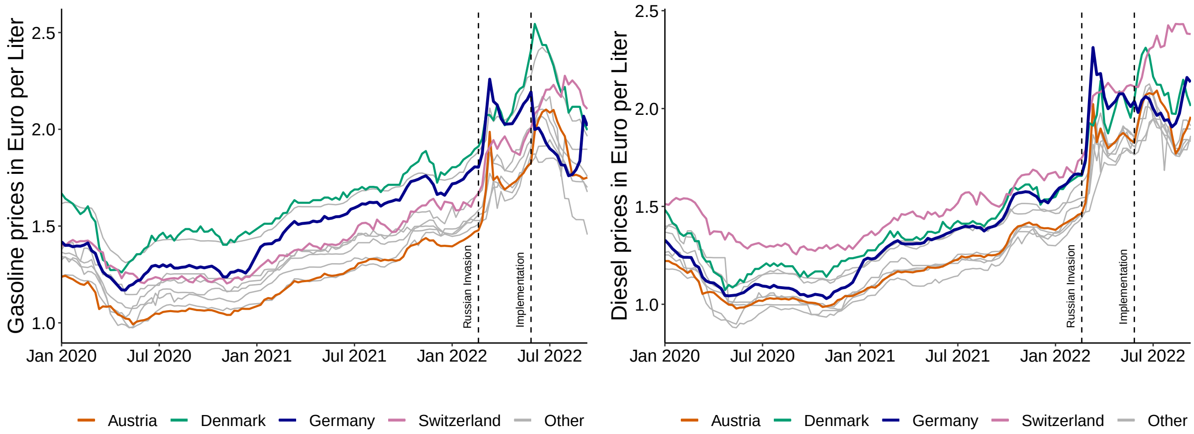
2 Data

In our analysis, we compare actual and synthetic German fuel prices. The latter are derived as weighted averages of fuel prices in selected countries which serve as the control group (Abadie et al., 2010). To ensure validity of the treatment, the donor pool must consist only of countries that did not implement policy measures which—similar to the German tax reduction—potentially directly affected fuel prices (Abadie, 2021). However, many European countries also implemented policy measures aimed at reducing fuel prices in response to the energy crises (see Table A.1 in the Appendix for an overview). This leaves nine countries for our donor pool: Austria (AT), Switzerland (CH), Denmark (DK), Croatia (HR), Estonia (EE), Greece (GR), Latvia (LV), Lithuania (LT) and Slovakia (SK).[2] Three of these countries are neighbors of Germany (AT, CH, DK).

[2] We also exclude Malta because its fuel prices were fixed over the period of observation.

We use national weekly average retail prices for gasoline or diesel in euros. The data are taken from the Weekly Oil Bulletin published by the European Commission. Our sample covers the period spanning the first calendar week of 2020 through the 36th calendar week of 2022 ($T = 141$). The tax reduction was implemented in the 22nd calendar week of 2022. Thus, the time series for each country includes 126 weekly fuel prices for the pre-treatment period, 14 weeks for the treatment period and the first full week after the tax reduction ran out (36th calendar week). Figure 1 shows the times series of fuel prices for Germany and the donor pool over the sample period. The series for Germany and the three neighboring countries are colored differently from the other six non-neighboring countries, which are shown in gray.

Figure 1: Fuel prices in Germany and European countries without tax holidays



Notes: The graphs show the evolution of prices for gasoline (left) and diesel (right) in Germany and European countries that did not implement a tax holiday in 2022. The two vertical lines indicate the timing of the Russian invasion of Ukraine and the implementation of the German tax reduction, respectively.

A few things stand out. First, there is clear comovement between German fuel prices and those in the other countries. When focusing on the pre-treatment period, the correlations range from 0.88 (gasoline prices in Germany and Switzerland) to 0.98 (diesel prices in Germany and Lithuania). Second, German fuel prices are within the range of prices in the other countries throughout nearly the entire pre-treatment period. This is important because the synthetic control method—which we use in a robustness check—constructs the synthetic prices as weighted averages of the prices in the donor pool. Third, German fuel prices increased sharply following the Russian invasion of Ukraine and exceed the prices of the donor pool in the first few weeks of the war. To assess how this development affects our estimates of the treatment effects, we exclude the weeks between the outbreak of the war and the implementation of the tax reduction from the construction of the synthetic price series in a robustness check. Fourth, German fuel prices decrease in the first couple of weeks following the introduction of the tax reduction whereas the prices in several of the other countries increase, which is a first descriptive indication that the tax reduction was passed on to consumers.

3 Synthetic difference-in-differences estimator

To estimate the effect of the fuel tax reduction on prices, we use the SDID estimator of Arkhangelsky et al. (2021). This estimator combines the construction of a synthetic control group with a two-way difference-in-differences estimation of the treatment effect. While the approach is conceptually similar to the SCM of Abadie and Gardeazabal (2003), there are differences in the construction of the synthetic control group. Whereas the SCM aims to match the pre-treatment behavior of the treatment group and the donor pool as closely as possible, the SDID estimator merely seeks to parallelize their time trend while allowing for a level shift which is then captured by entity fixed effects in the difference-in-differences estimation. The SDID estimator also tends to display lower concentration of the unit (here: country) weights than the SCM. Finally, SDID includes time weights which balance pre- and post-treatment trends in the fuel prices of countries in the donor pool.

Based on the data described in Section 2, we estimate the following two-way fixed effects regression model:

$$\underset{\mu,\alpha,\beta,\tau}{\arg\min} \left\{ \sum_{i=1}^{10} \sum_{t=1}^{139} (X_{it} - \mu - \alpha_i - \beta_t - D_{it}\tau)^2 w_i \lambda_t \right\}, \tag{1}$$

where μ is a constant, α_i is a country fixed effect and β_t is a week fixed effect. The dependent variable X_{it} denotes either the price for gasoline or diesel in country $i = 1, \ldots, 10$ and week $t = 1, \ldots, 139$. Germany is the first country ($i = 1$). We exclude the final two weeks in our sample from the estimation because they cover the period after the tax reduction expired. Since the tax reduction was introduced in week $t = 127$, the treatment indicator is defined as

$$D_{it} = \begin{cases} 1 & \text{if } i = 1 \text{ and } t \geq 127 \\ 0 & \text{else.} \end{cases} \tag{2}$$

The main parameter of interest is τ, which captures the impact of the tax reduction on German fuel prices. The null hypothesis is that producers completely pass on the tax reduction to consumers. In this case, τ is negative and close to the size of the tax reduction. Under the one-sided alternative of imperfect pass through, τ is smaller than the size of the tax reduction.

Eqn. (1) includes non-negative country and time weights, w_i and λ_t, with $\sum_{i=2}^{10} w_i = 1$ and $\sum_{t=1}^{126} \lambda_t = 1$. As in the SCM, the country weights align pre-treatment trends in the fuel prices of Germany and the donor pool. A key difference is that the weights are chosen to make the time trends in pre-treatment fuel prices of Germany and the donor pool parallel, but not necessarily identical. Any constant differences between countries are absorbed by the country fixed effects, α_i. Therefore, the SDID approach aims to match pre-treatment trends rather than both pre-treatment trends *and* levels (as in the SCM). Another difference is that the country weights are regularized, so that they are usually less concentrated than the SCM weights. The time weights, λ_t, balance pre- and post-treatment weeks for the donor pool. The procedure assigns a higher weight to pre-treatment weeks that are similar to post-treatment weeks in the sense that the weighted average of historical fuel prices for the donor pool predicts their average fuel prices in the treatment period up to a constant. See Arkhangelsky et al. (2021) for details on the weight selection process. Note that we estimate different country and time weights for gasoline and for diesel.

4 Results

This section presents our main findings. After describing the country weights and Doppelgangers for each fuel type, we discuss the full-sample estimates of the impact of the tax reduction as well as week-by-week estimates of the treatment effect.

4.1 Constructing the Doppelganger

Since the Doppelgangers are weighted averages of the donor pool countries, we first examine which countries are assigned nonzero weights. Table 1 shows the country weights for gasoline and diesel.

Table 1: SDID country weights

	AT	CH	HR	DK	EE	GR	LV	LT	SK
Gasoline	0.20	0.10	0.00	0.24	0.06	0.13	0.15	0.10	0.00
Diesel	0.24	0.08	0.00	0.21	0.07	0.07	0.12	0.21	0.00

Notes: This table presents the optimal country weights based on the SDID method.

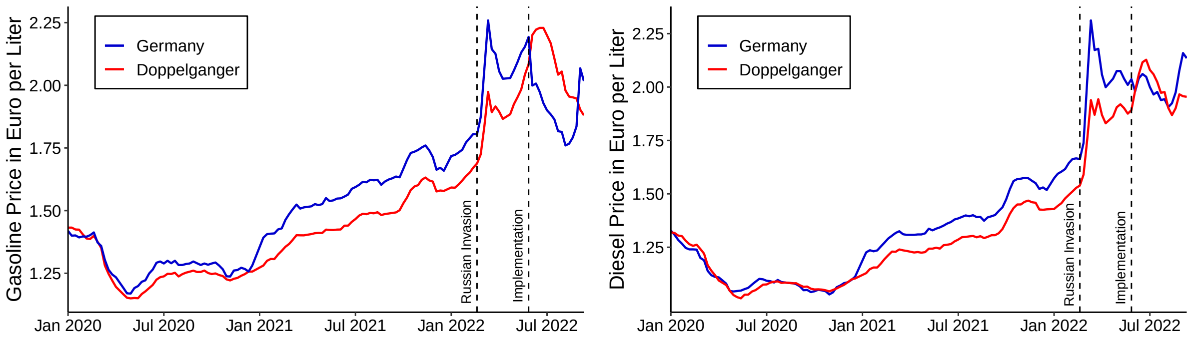
The SDID procedure assigns nonzero weight to almost all countries in the donor pool. Only Croatia and Slovakia receive a weight of zero. None of the country weights exceed 25%. Notably, however, the neighboring countries tend to receive large weights. Austria, Switzerland, and Denmark together account for 54% (53%) of the country weights in our main specification in the case of gasoline (diesel). It is likely that their close proximity to Germany makes the neighboring countries more comparable with respect to fuel market developments (e.g., supply chains).

The blue lines in Figure 2 show actual prices for gasoline (left plot) and diesel (right plot) in Germany. The red lines are the series for the respective Doppelganger. Recall that—unlike the SCM—the SDID approach does not aim to perfectly match actual and synthetic prices. Instead, it seeks to parallelize the series, so that the difference can be removed via the entity fixed effects in the regression.

Starting in January 2021, the Doppelgangers closely track the evolution of German fuel prices before the tax reduction up to a constant. We conclude that the parallelization of the series was successful. While actual prices consistently exceed synthetic prices before June 2022, the opposite is true after the implementation of the tax reduction. This finding suggest that the measure was at least somewhat successful in reducing fuel prices relative to the counterfactual situation without the tax reduction.

For each country and the Doppelgangers based on the country weights in Table 1, Table A.2 in the Appendix presents summary statistics for a number of structural variables related to the fuel market. In particular, we consider the (*log*) number of residents per gas

Figure 2: Real fuel prices versus Doppelganger



Notes: The blue lines show German prices for gasoline (left) and diesel (right). The red lines show the corresponding Doppelganger series based on the SDID method. The donor pool consists of European countries that did not introduce tax reductions.

station, (*log*) GDP per capita, the Russian fuel import quota and CPI energy inflation. The results in the last two columns show that the Doppelgangers for gasoline and diesel match the values for Germany quite well.

4.2 Full-sample estimates of the treatment effects

We now turn to the analysis of the impact of the tax reduction on fuel prices. To assess the magnitude of the reduction, Column (1) of Table 2 presents the estimates of the average treatment effect τ for both fuel types. For inference, we use an estimate of the asymptotic variance based on bootstrapped placebo evaluations as proposed by Arkhangelsky et al. (2021) for situations with only one treated unit. In each of the $B = 500$ bootstrap iterations, a placebo estimate of τ is calculated based on a sample drawn from the donor pool.

The estimates are significantly negative in both cases. The estimated average treatment effects (over the three months period) are 44 cents for gasoline and 20 cents for diesel. The p-value for the null hypothesis that $\tau = 0.35$ (0.17) against a one-sided alternative equals 0.99 (0.73) in case of gasoline (diesel). Given the magnitude of the estimates for both fuel types, we thus cannot reject the null hypothesis that the tax was fully passed on to consumers.[3] Relative to the findings of Montag et al. (2021) for the 2020 tax reduction on the value added tax, pass-through rates thus appear to be higher for the 2022 tax reduction.

To further gauge the plausibility of our findings, we conduct a placebo test by iteratively selecting one of the countries from the donor pool as the treated country instead of Germany. We then re-estimate the model in Eqn. (1) to obtain alternative treatment effects. If the estimates in Column (1) truly represent the impact of the German tax reduction, the alternative estimates should not be significantly different from zero. Columns (2)-(10) present the placebo estimates. Clearly, none of the estimates are significantly different from zero. In addition, the magnitude of the estimates for Germany exceeds the estimates for all other countries in absolute terms. These findings support the validity of our identification strategy.

[3]In fact, the point estimates of τ exceed the size of the tax reduction for both fuel types.

Table 2: SDID estimates of the average treatment effects

	(1) DE	(2) AT	(3) CH	(4) HR	(5) DK	(6) EE	(7) GR	(8) LV	(9) LT	(10) SK
Gasoline	-0.44^{***}	0.11	0.20	-0.20	0.23	-0.03	0.05	0.08	0.02	-0.09
	(0.03)	(0.22)	(0.21)	(0.20)	(0.20)	(0.23)	(0.22)	(0.23)	(0.24)	(0.23)
Diesel	-0.20^{***}	0.04	0.16	-0.11	0.13	-0.10	-0.08	0.08	0.04	-0.06
	(0.05)	(0.12)	(0.10)	(0.11)	(0.08)	(0.11)	(0.11)	(0.09)	(0.12)	(0.12)

Notes: Column (1) shows the SDID estimates of the average impact of the tax reduction on German fuel prices throughout the treatment period. Treatment ends in the last week of August. Columns (2)-(10) present placebo average treatment effects that we obtain by assuming that the treated unit is one of the countries from the donor pool instead of Germany. Standard errors in parentheses are based on bootstrapped placebo evaluations in which the country that was exposed to the treatment, i.e. Germany, is replaced by different untreated countries from the donor pool. '*', '**' and '***' indicate significance at the 10%, 5% and 1% critical level, respectively.

In general, pass-through rates depend on factors such as competition or price sensitivity of consumers (Weyl and Fabinger, 2013; Cabral et al., 2021; Genakos and Pagliero, 2022). Our estimates of full pass through are consistent with strong competition. This is in line with evidence in Haucap et al. (2017), who estimate a pass-through rate of changes in wholesale prices to retail prices of 90-100%, indicating a fair degree of competition in the German fuel market.

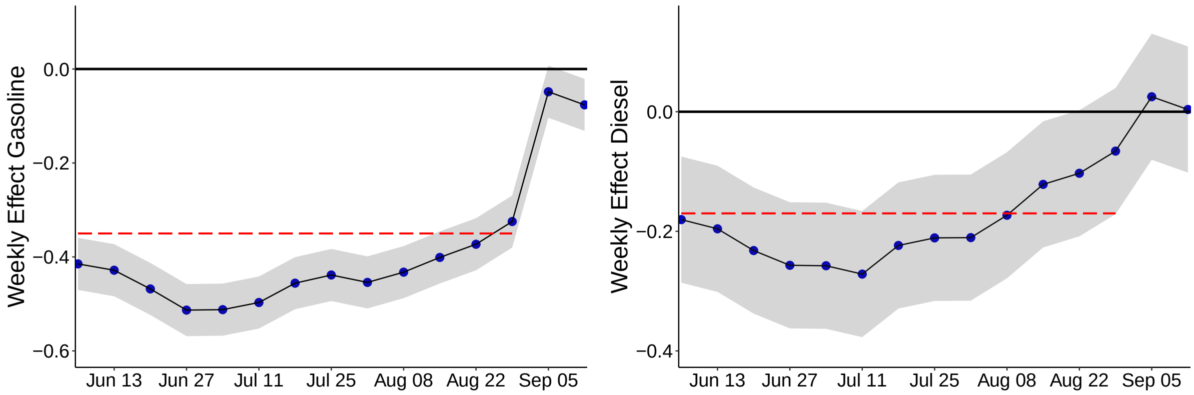
4.3 Week-by-week estimates of the treatment effects

The estimates in Table 2 are average effects for the entire treatment period. However, these estimates may mask variation in pass-through rates over time. To address this issue, we calculate week-by-week estimates of the treatment effect as follows. We first compute the weighted sum over the pre-treatment price differences in Figure 2 using the estimated time weights. For each week in the post-treatment period, we then subtract this weighted sum from the difference between actual and synthetic prices. This step is needed to remove the difference between the actual and synthetic prices in the pre-treatment period. Figure 3 presents the results. The red dashed lines show the size of the tax reduction for each fuel type.

The week-by-week estimates suggest that the tax reduction has been passed on to consumers over almost the entire three-months period. However, we observe some heterogeneity in the treatment effects across time.

Immediately after its introduction and throughout June and July, the tax reduction is passed on completely to consumers for both fuel types. The immediate pass-through is at odds with typical results in the literature showing that fuel prices tend to rise quickly but fall slowly (Verlinda, 2008). In August, pass-through rates for diesel decline considerably. By the final week of August, which is the last one fully covered by the tax reduction, the pass-through rate for diesel is reduced to approximately 50%. After the tax reduction ran out (the final two weeks of our sample), the estimates of the treatment effects are—as expected—close to zero.

Figure 3: Weekly effect of the tax reduction on fuel prices



Notes: The figures show the weekly treatment effect for gasoline (left) and diesel (right). The full-sample estimates from Table 2 are obtained by averaging over all but the last two weekly estimates.

Our finding of diminishing pass-through rates for diesel may be related to other Germany-specific factors such as the drought in Germany throughout the summer of 2022 that led to exceptional low water levels in rivers which, in turn, raised transportation costs for diesel imports and may even have increased diesel demand because transport companies were forced to shift to more fuel-intensive means of transportation.

Another potential factor that might have allowed gas stations to raise diesel prices in August is boosted demand due to front-loaded fuel purchases before the phase-out of the tax reduction. Using an event study, Coglianese et al. (2017), for instance, show how anticipatory behavior of consumers affects gasoline purchases.[4]

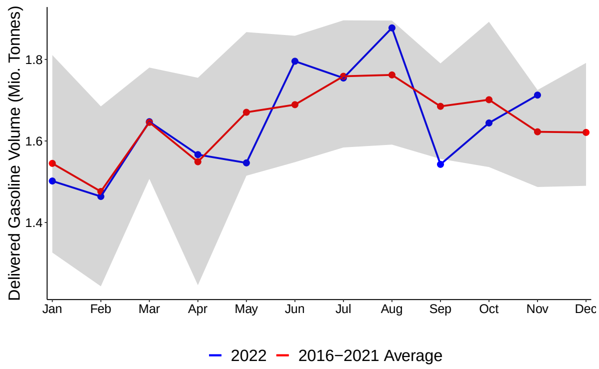
Figure 4 provides tentative evidence for front loading of fuel purchases. It presents the volume of fuel deliveries in Germany in million tonnes over each month of the year as a proxy for fuel demand.The blue line shows the series for 2022 and the red line represents the average over the preceding five years. The gray area covers the minimum and maximum values of the corresponding month for the 2016-2021 period. Fuel demand was low in May relative to previous years. This could represent a temporal shift in fuel purchases in anticipation of the tax reduction. In June, the volume increased sharply and stayed at an elevated level for the three-months period. With respect to the increase in August and the subsequent sharp drop in September, it is likely that the impending expiration of the tax reduction led consumers to front-load fuel purchases, consistent with the findings of Coglianese et al. (2017).

5 Robustness

We confirm the validity of our results in several robustness checks. First and in light of potential anticipation effects, we analyze the effect of using other treatment dates. Second, we assess whether our results change if the donor pool consists only of neighboring

[4]A potential explanation for the fact that a decline in pass-through rates is only visible for diesel is that price elasticities for diesel and gasoline demand differ (Montag et al., 2021; Haucap et al., 2017).

Figure 4: Delivered Gasoline Volume



Notes: The blue line shows the delivered gasoline volume in million tonnes for Germany. The red line shows the corresponding five-year average for the same time series. The gray area represents the minimum and maximum value of the corresponding month over the last five years.

countries of Germany. Third, we consider whether our findings still hold if we use the synthetic control method instead of the SDID estimator.

5.1 Alternative treatment dates

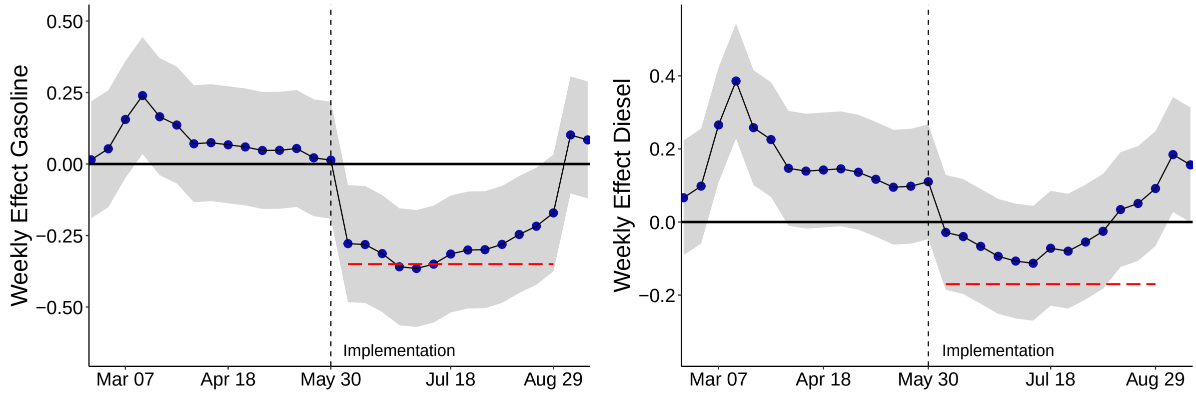
Figure 1 shows that German fuel prices exceed those of the donor pool for a brief period following the outbreak of the war in Ukraine. Similarly, Figure 2 shows that the difference between actual and synthetic fuel prices increases during this period. A potential explanation is that fuel retailers moderately raised their prices in anticipation of the tax reduction that 'forced' them to lower prices. If this is the case, it may threaten the parallelization of time trends in the pre-treatment period. To assess whether this is an issue for our results, we re-estimate equation (1) but exclude the period between the Russian invasion and the implementation of the tax reduction from the pre-treatment period. This effectively means that the week in which the Russian invasion took place ($t = 112$) is selected as the new starting date of the treatment period.

Table A.3 in the Appendix presents the new country weights. The weights are relatively similar to those in Table 1. The main difference is that Croatia and Slovakia now also receive positive weights. The time weights change more strongly. In the original specification, non-zero weight is assigned to gasoline prices in three weeks in March and April 2022. For diesel, one week in May 2020 and four weeks in March/April 2022 receive positive weight. In the alternative specification, almost all periods with positive weights in the baseline specification are now part of the treatment period. As a result, the major part of non-zero weights shifts to November 2021 for both, gasoline and diesel. Figure A.1 shows the Doppelganger series based on the new weights. While the Doppelganger series for gasoline looks very similar to the one derived in our main specification, the series for diesel is noticeably different.

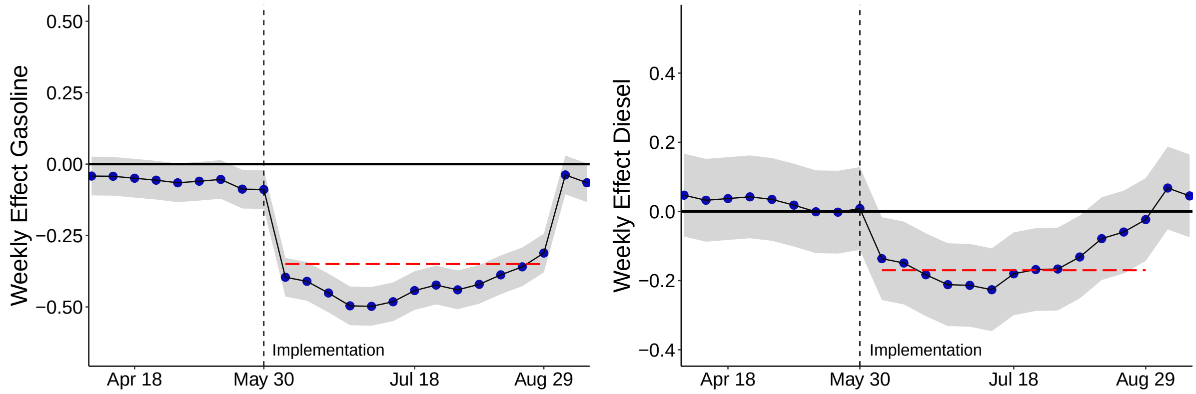
The upper part of Figure 5 presents the new week-by-week estimates of the treatment effects. German fuel prices clearly increased sharply in March 2022 relative to what the Doppelganger dynamics suggest. Importantly for our analysis, the estimates of τ are close to zero throughout April and May. This suggests that fuel retailers did not increase prices in the run-up to the tax reduction. After the implementation of the tax reduction, the

Figure 5: Weekly effect of the tax reduction on fuel prices – alternative treatment dates

Panel A – Treatment: February 21



Panel B – Treatment: April 04



Notes: The figures show the weekly treatment effect for gasoline (left) and diesel (right). The treatment date in the plots in the upper row is the week of the Russian invasion. For the plots in the lower row, the treatment period starts in the first week of April.

treatment effects are again negative. For gasoline, the estimates are close to the size of the tax reduction. This is also true for diesel, once one focuses on the change between the average estimates for the weeks before the implementation of the tax reduction to the estimates afterwards.

The bottom row presents the weekly estimates that we obtain if we shift the treatment date to the first week of April ($t = 118$). In doing so, we exclude the outliers observed in March 2022 from the treatment period. This alternative approach leads to treatment effects close to zero before the implementation of the tax reduction and again strong evidence for complete pass-through afterwards.

5.2 Neighboring countries only

In another robustness check, we restrict the sample of donor countries to the neighboring countries of Germany, i.e., Austria, Switzerland and Denmark. A strong argument for doing this is that the neighboring countries likely resemble the structure of the German fuel market more closely and are affected by the same factors (such as, e.g., similar supply chains) than more distant countries such as Greece.

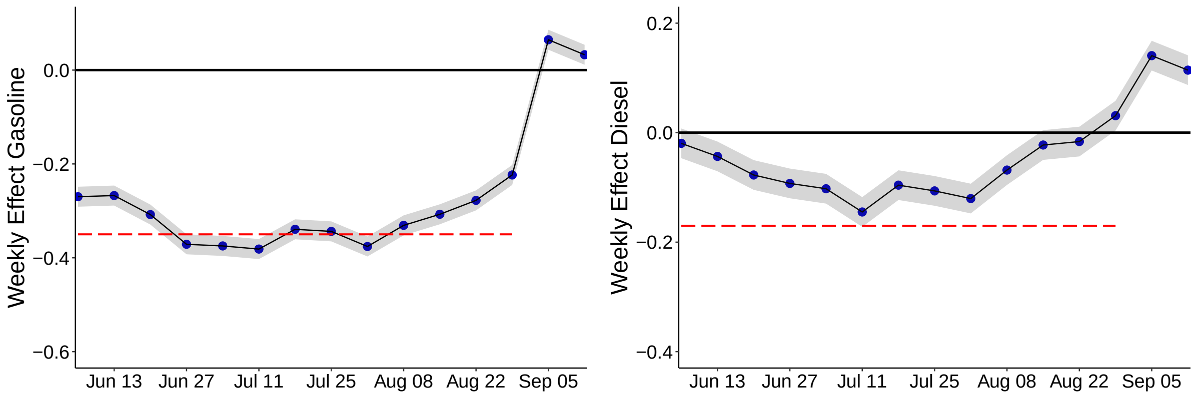
Table 3: SDID estimates of the average treatment effect

	Gasoline	Diesel
Average treatment effect (SDID)	-0.328^{***}	-0.083^{***}
	(0.011)	(0.014)

Notes: SDID estimates of the average effect of the tax reduction on German fuel prices throughout the treatment period. Treatment ends in the last week of August. The control group is based on all neighboring countries that did not introduce a tax reduction in the sample period. Standard errors in parentheses. Asterisks '*', '**' and '***' indicate significance at the 10%, 5% and 1% critical level, respectively.

Table A.4 in the Appendix presents the weights that are obtained when only the neighboring countries are used to construct the Doppelganger. As before, the distribution of weights across the three countries is relatively even with no country receiving more than 39%. Figure A.2 shows the new Doppelganger series. While the Doppelganger series for gasoline is very similar to the one in our primary specification, the series for diesel differs considerably (and more closely resembles the one we derived in the previous subsection).

Figure 6: Weekly effect of the tax reduction on fuel prices



Notes: The figures show the weekly treatment effect for gasoline (left panel) and diesel (right panel). The average of the values excluding the September values corresponds to the ATT in Table 3.

Table 3 and Figure 6 present the new estimates of τ. For both gasoline and diesel, the estimates of the average treatment effect are noticeably smaller than the baseline results above. However, the estimates are still negative and highly significant because the standard errors are also much smaller than before.[5] For gasoline, we cannot reject the null hypothesis of complete pass-through of the tax reduction. For diesel, the evidence is less clear.

[5] A donor pool of just three countries is problematic for the calculation of standard errors based on placebo evaluations of the control countries. This explains the small standard errors in this application.

5.3 Synthetic control method

As an alternative to the SDID estimator, we analyze the impact of the tax reduction on fuel prices using the SCM of Abadie and Gardeazabal (2003). Let $\mathbf{x}_1$ denote a (126×1) vector which consists of the weekly average German prices for gasoline or diesel during the pre-treatment period. Next, $\mathbf{X}_0$ is the corresponding (126×9) matrix for the donor countries.The SCM aims to estimate weights for each country in the donor pool such that the Doppelganger constructed using these weights resembles Germany as much as possible (in terms of the variables considered). The objective function is given by the mean squared error (MSE),

$$(\mathbf{x}_1 - \mathbf{X}_0\mathbf{w})'\mathbf{V}(\mathbf{x}_1 - \mathbf{X}_0\mathbf{w}), \tag{3}$$

where $\mathbf{w}$ is a (9×1) vector of non-negative weights for $i = 2, \ldots, 10$ with $\sum_{i=2}^{10} w_i = 1$. The (126×126) symmetric and positive semidefinite matrix $\mathbf{V}$ reflects the relative importance of the variables in $\mathbf{x}_1$ and $\mathbf{X}_0$.[6] The optimal weights $\mathbf{w}^\star$ are those that minimize the MSE in equation (3).

The Doppelganger for a given fuel type is constructed as $\widetilde{\mathbf{X}}_0\mathbf{w}^\star$, where the (141×9) matrix $\widetilde{\mathbf{X}}_0 = [\mathbf{X}_0' \; \mathbf{X}_0^{*\prime}]'$ includes data for the 15 weeks since the implementation of the tax reduction in the 22nd calendar week of 2022 through the first full week after the tax reduction ran out (36th calendar week) in addition to the data in $\mathbf{X}_0$.

Table 4: SCM country weights

	AT	CH	HR	DK	EE	GR	LV	LT	SK
Gasoline	0.31	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00
Diesel	0.30	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00

Notes: This table presents the optimal country weights based on the SCM for European countries without tax reduction.

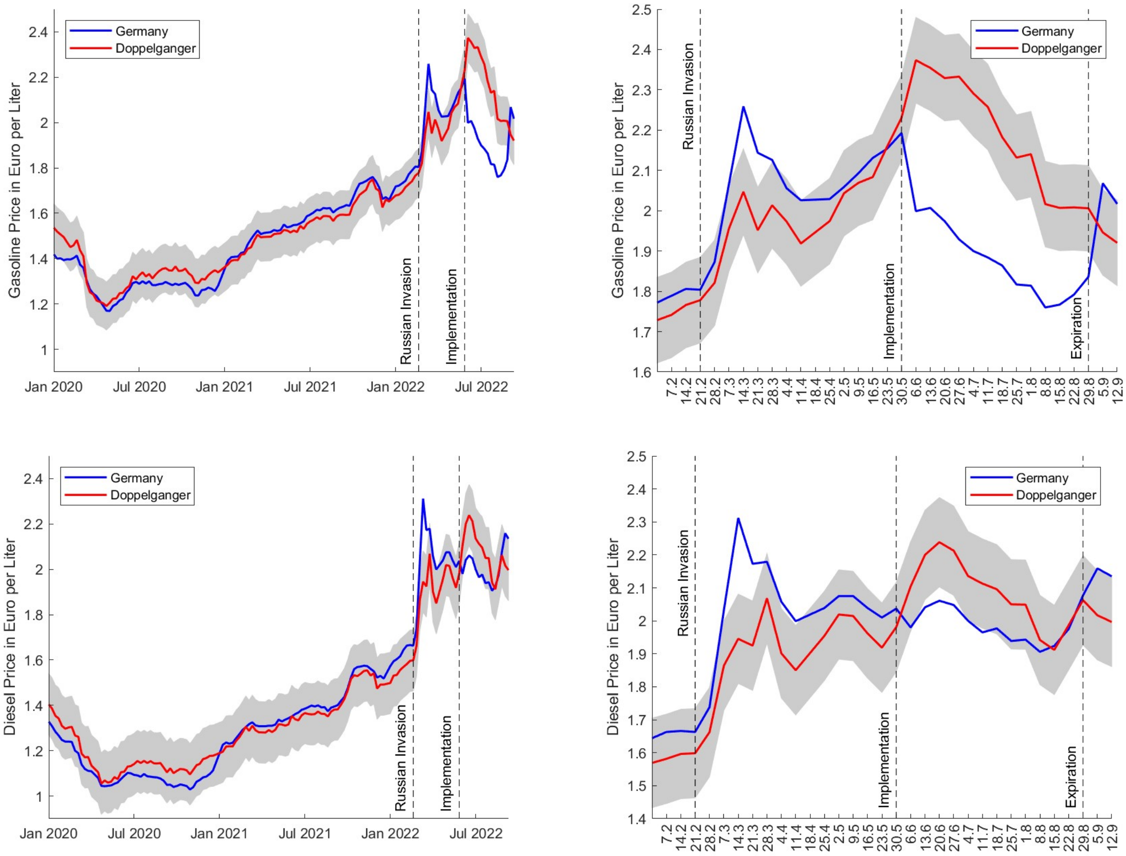
Table 4 presents the optimal country weights. The concentration of weights is much higher than in the SDID approach. The evolution of German energy prices and the structural variables prior to the introduction of the tax reduction are best mimicked as a combination of Austria and Denmark, which account for 100% of the weights for both fuel types. All other countries receive a weight of zero.

Figure A.1 shows the Doppelgangers analogously to Figure 2. The SCM method estimates the effect of the tax reduction as the difference between actual prices and those for the Doppelgangers in the post-treatment period, i.e., the weeks following the implementation of the tax reduction. Therefore, the right panels zoom in on the data for the period after February 2022. The gray confidence bands correspond to plus/minus two standard deviations of the differences between actual prices and the corresponding Doppelganger in the pre-treatment period.

The Doppelgangers closely track the evolution of German fuel prices before the tax reduction. In the period following the invasion of Ukraine, we observe a decoupling of

[6] The MSE depends on the choice of $\mathbf{V}$. Following the standard approach, we choose a diagonal $\mathbf{V}$ matrix that minimizes the MSE (Abadie and Gardeazabal, 2003; Abadie et al., 2010; Born et al., 2019).

Figure 7: Real fuel prices versus Doppelganger



Notes: The blue lines show German prices for gasoline (upper) and diesel (lower). The red lines show the corresponding Doppelganger series based on the SCM. The donor pool consists of European countries that did not introduce tax reductions. The width of the gray confidence bands is equal to two standard deviations of the differences between both pre-treatment fuel prices series.

the series, which may be evidence of the relatively strong importance of Russian energy supply for especially Eastern Germany.

The treatment effect fluctuates around 31-40 cents for gasoline, which implies full pass-through in June and July. For diesel, the difference is equal to 11-18 cents. In line with the SDID results, we observe decreasing pass-through rates in August and price jumps at the start of September.

A disadvantage of the SCM is that it is not possible to carry out traditional inference. In order to gauge the statistical significance of our findings, Figure A.3 in the Appendix shows the estimated price gaps for Germany (black lines) and for hypothetical cases where one of the countries from the donor pool is selected as the treatment group (gray lines). The price gap for Germany is considered significant if the series represents one of the lowest quantiles of the distribution of price gaps. Clearly, this is the case.

6 Conclusion

To attenuate rising gasoline and diesel prices, the German government implemented a temporary cut of fuel taxes from June through August 2022. In contrast to the impression in the public debate in early June 2022 that petroleum companies retained part of the tax rebate, we show that the temporary reduction of fuel taxes was indeed passed on to consumers. We find full pass-through for both gasoline and diesel when comparing prices in Germany to a synthetic Doppelganger based on a sample of European countries that did not reduce taxes on fuel. Our estimates of pass-through rates largely match those of Fuest et al. (2022) and Montag and Schnitzer (2022). The higher pass-through rates relative to earlier tax reductions (cf. Montag et al., 2021) could be related to higher public awareness and the threat of policymakers to pursue antitrust measures if companies would not comply as was expected of them. However, the effect on diesel prices gradually decreased throughout August while the tax reduction was officially still in place.

A potential caveat of our study is the relatively small donor pool because it can lead to problems with inference due to underestimation of standard errors. Many European countries are not eligible for the donor pool because they introduced similar tax cuts that (partly) overlapped with the temporary tax reduction in Germany.

The topic of our paper is likely to be policy relevant in the next years. Ongoing geopolitical tensions and the energy revolution will probably lead to further volatility of energy prices. Our analysis shows that the fuel tax reduction in Germany was effective in terms of its goal of relieving consumers. However, pass-through rates are likely to depend on local market conditions and the regulatory environment and might be different in other situations/countries. Moreover, there likely is heterogeneity across regions. In particular, regions close to national borders could be subject to spillover effects. Such heterogeneity in pass-through rates would be interesting to study in a different project based on more granular data for the German fuel market. Another question that is not addressed by our paper is whether other potential policy measures (such as direct transfers to low-income households) are more efficient under the premise that primarily particular groups of households should be supported.

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Appendix

Table A.1: Overview of tax reductions in European countries

Country	Period of tax reduction	Donor pool	
		All countries	Neighbors
Hungary	Nov. 2021 – Dec. 2022	–	–
Poland	Feb. 2022 – Oct. 2022	–	–
Belgium	Mar. 2022 – Jul. 2022	–	–
Portugal	May 2022 – Dec. 2022	–	–
Netherlands	Apr. 2022 – Jun. 2023	–	–
Spain	Apr. 2022 – Jun. 2022	–	–
France	Apr. 2022 – Dec. 2022	–	–
Sweden	May 2022 – Sep. 2022	–	–
Czech Republic	Jun. 2022 – Sep. 2022	–	–
Germany	Jun. 2022 – Aug. 2022	–	–
Bulgaria	Jul. 2022 – Dec. 2022	–	–
Romania	Jul. 2022 – Dec. 2022	–	–
Finland	Apr. 2022 – Dec. 2022	–	–
Cyprus	Mar. 2022 – Aug. 2022	–	–
Ireland	Mar. 2022 – Dec. 2022	–	–
Luxembourg	Apr. 2022 – Aug. 2022	–	–
Italy	Mar. 2022 – Sep. 2022	–	–
Slovenia	Mar. 2022 – Apr. 2022	–	–
Austria	None	✓	✓
Switzerland	None	✓	✓
Denmark	None	✓	✓
Croatia	None	✓	–
Estonia	None	✓	–
Greece	None	✓	–
Latvia	None	✓	–
Lithuania	None	✓	–
Slovakia	None	✓	–
Malta	None	–	–

Notes: This table provides an overview about tax reductions in EU countries in 2022. Malta is excluded from any donor pool due to fixed prices over the given periods.

Table A.2: Structural variables for Germany and the donor pool

	DE	AT	CH	HR	DK	EE	GR	LV	LT	SK	DG1	DG2
Residents per station (*log*)	**8.66**	8.09	7.87	8.38	7.96	7.88	7.50	8.05	8.27	8.59	7.80	8.02
GDP per capita (*log*)	**10.65**	10.70	11.25	9.53	10.92	10.01	9.70	9.74	9.85	9.78	10.19	10.38
Russian fuel import quota	**0.29**	0.05	0.00	0.08	0.16	0.39	0.23	0.20	0.72	0.78	0.20	0.26
CPI energy inflation	**0.06**	0.08	0.03	-	0.08	0.20	0.10	0.08	0.11	0.01	0.09	0.09

Notes: This table presents pre-treatment values of the structural variables for Germany (DE), Austria (AT), Switzerland (CH), Croatia (HR), Denmark (DK), Estonia (EE), Greece (GR), Latvia (LV), Lithuania (LT) and Slovakia (SK). DG1 (DG2) describes the pre-treatment time series averages for the Doppelganger gasoline (diesel) based on the optimal country weights that are displayed in Table 1. Residents per station shows the natural logarithm of the number of residents divided by the number of gas stations in the year 2021. GDP per capita describes the natural logarithm of the average across the annual observations for GDP per capita in the years 2020 and 2021 in euros. The Russian fuel import quota is constructed as the average across the monthly observations for the share of oil and petroleum imports from Russia relative to total imports of oil and petroleum in the years 2020 and 2021. CPI enegy inflation is calculated as the annualized geometric average over the monthly energy-based CPI inflation rates for the years 2020 and 2021. The month-on-month inflation rates are defined as the growth rate in a given month relative to the previous month.

Table A.3: Country weights (alternative treatment date)

	AT	CH	HR	DK	EE	GR	LV	LT	SK
Gasoline	0.13	0.07	0.10	0.28	0.03	0.12	0.08	0.08	0.10
Diesel	0.17	0.03	0.14	0.24	0.00	0.12	0.05	0.17	0.08

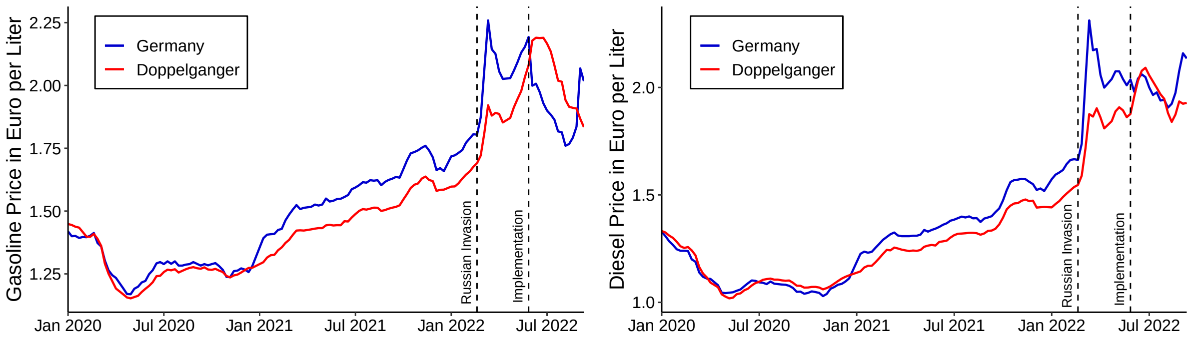
Notes: This table presents the optimal country weights based on the SDID method for European countries that did not introduce tax reductions. The treatment date is the week of the Russian invasion.

Table A.4: Country weights (neighboring countries)

	AT	CH	DK
Gasoline	0.35	0.38	0.27
Diesel	0.39	0.36	0.25

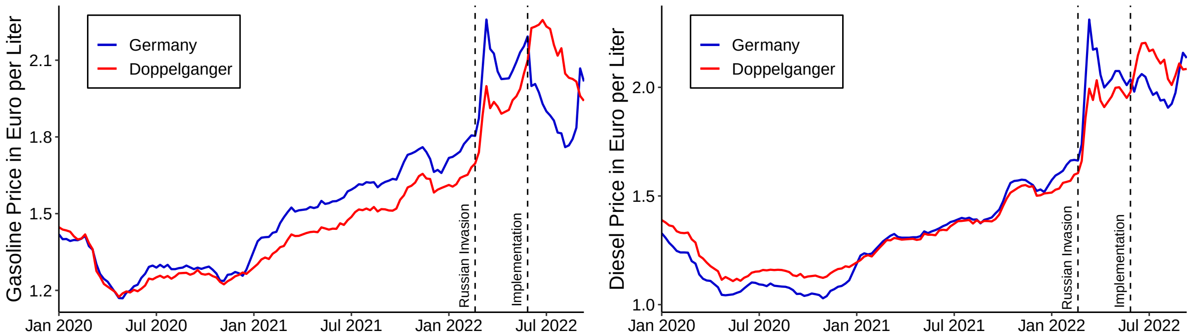
Notes: This table presents the optimal country weights based on the SDID method for neighboring countries that did not introduce tax reductions.

Figure A.1: Real fuel prices versus Doppelganger (alternative treatment date)



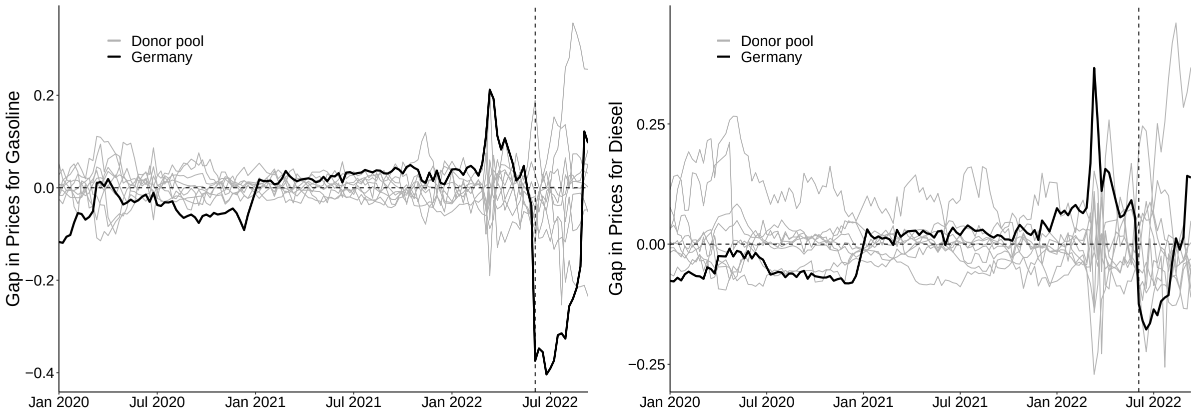
Notes: The blue lines show German prices for gasoline (left) and diesel (right). The red lines show the corresponding Doppelganger series based on the SDID method. The donor pool consists of European countries that did not introduce tax reductions. The treatment date is the week of the Russian invasion.

Figure A.2: Real fuel prices versus Doppelganger (neighboring countries)



Notes: The blue lines show German prices for gasoline (left) and diesel (right). The red lines show the corresponding Doppelganger series based on the SDID method. The donor pool consists of neighboring countries that did not introduce tax reductions (Austria, Denmark, Switzerland).

Figure A.3: SCM fuel price gaps in Germany and placebo gaps in 9 control states



Notes: The black line shows the estimated price difference between Germany and its Doppelganger for gasoline (left) and diesel (right). Gray lines show the corresponding price differences when using the countries from the donor pool in placebo tests.