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Estimating Pass-Through Rates for the 2022 Tax Reduction on Fuel Prices in Germany

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. Using the synthetic control method to compare actual 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 three months. In early June, it took approximately two weeks for the full pass-through to take effect. Moreover, pass-through rates started to decline in August while the tax reduction was still in place. We observe an upward price jump smaller than the size of the expiring tax reduction at the start of September. 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 prices (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. 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 has 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 prices for gasoline and diesel in Germany and its neighboring countries for the period January 2020 to September 2022. We use the synthetic control method of [Abadie and Gardeazabal \(2003\)](#). The synthetic control group (henceforth: ‘Doppelganger’) is constructed as a weighted average of the nine neighboring countries. The weights are chosen so that the Doppelganger as best as possible matches the dynamics of German fuel prices between January 2020 and May 2022 as well as a set of structural variables related to the fuel market. This allows for a comparison between the development of actual fuel prices in Germany and those for the Doppelganger after 1 June 2022. Given that energy taxes in the neighboring countries did not change on 1 June we are able to estimate the pass-through of the tax reduction as the price difference under the assumption that the tax reduction was the only relevant idiosyncratic change in the fuel market and that it only affected German prices but not those in the neighboring countries. 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. Our main finding is that the tax reduction was completely passed on to consumers. However, we observe incomplete pass-through rates during the first two weeks following its introduction. Similarly, pass-through rates decline in August as the end date for the tax reduction approaches. At the start of September, we observe upward price jumps for both fuel types which, however, remain below the size of the expiring tax reduction.

The price impact of the fuel tax reduction in 2022 has received little academic attention so far. An exception is [Fuest et al. \(2022\)](#) who 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) below those in France after 1 June. This comparison 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 in the first weeks of June of approximately 90% for gasoline and 100% for diesel. In a related study, [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. Relative to the findings of [Montag et al. \(2021\)](#), pass-through rates appear to be higher for the tax reduction in 2022. We contribute to the literature by relying on the synthetic control

method to estimate the pass-through rates. Thus, we move beyond the analysis of [Fuest et al. \(2022\)](#) who focus solely on France as the comparison group. In addition, we consider the effectiveness of the tax reduction over its entire three-months duration.

The synthetic control method was introduced by [Abadie and Gardeazabal \(2003\)](#). In their study, [Abadie and Gardeazabal \(2003\)](#) 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. The method has been applied in various other contexts. [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.

The remainder of this paper is organized as follows. Section 2 describes the data and the synthetic control method. Section 3 discusses the main results. Section 4 presents various robustness checks. Section 5 concludes.

2 Synthetic control method

We estimate the impact of the fuel tax reduction on retail prices using the synthetic control method (SCM) of [Abadie and Gardeazabal \(2003\)](#). Let \mathbf{x}_1 denote a (131×1) vector which consists of 126 weekly average prices for gasoline or diesel (in euros) in Germany during the pre-treatment period spanning the first calendar week of 2020 through the 21st calendar week of 2022 and five observations for structural variables related to the German fuel market. Two structural variables are the number of residents per gas station in 2020 and the average per-capita income (in euros) over the years 2020 and 2021. We take the natural logarithm of both variables. Next, we consider the average quota of German imports of oil and gas from Russia relative to total fuel imports and annualized average energy inflation based on the energy consumer price index (CPI), which covers fuel, electricity, and gasoline. The data for these two variables are again averages over the years 2020 and 2021. For inflation, we calculate the geometric average. Finally, we include the average price for the respective other fuel type (diesel for gasoline and vice versa) over the full pre-treatment period.

Next, \mathbf{X}_0 is the corresponding (131×9) matrix for the ‘donor pool’ (cf. [Abadie et al., 2010](#)), which consists of Germany’s neighboring countries, i.e., Austria (AUT), Belgium (BEL), the Czech Republic (CZE), Denmark (DNK), France (FRA), Luxembourg (LUX), the Netherlands (NLD), Poland (POL) and Switzerland (CHE).¹

Our aim is to estimate weights for each country in the donor pool such that the Doppelgänger 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),

$$(\mathbf{x}_1 - \mathbf{X}_0 \mathbf{w})' \mathbf{V} (\mathbf{x}_1 - \mathbf{X}_0 \mathbf{w}), \quad (1)$$

¹Table A.1 in the Appendix provides details on the construction of all variables. For each country, Table A.2 presents the data for the structural variables. Figure A.1 depicts the times series of fuel prices.

where \mathbf{w} is a (9×1) vector of weights with elements $w_i \geq 0$ for $i = 2, \dots, 10$ and $\sum_{i=2}^{10} w_i = 1$. The (131×131) symmetric and positive semidefinite matrix \mathbf{V} reflects the relative importance of the variables in \mathbf{x}_1 and \mathbf{X}_0 .² The optimal weights \mathbf{w}^* are those that minimize the MSE in Eqn. (1). Note that we estimate different vectors of weights for gasoline and for diesel.

The Doppelganger for a given fuel type is constructed as $\tilde{\mathbf{X}}_0 \mathbf{w}^*$, where the (146×9) matrix $\tilde{\mathbf{X}}_0 = [\mathbf{X}'_0 \mathbf{X}_0^*]'$ 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 .

3 Results

This section presents our main findings. Since the Doppelgangers are weighted averages of Germany's neighboring countries, we first examine which countries are assigned nonzero weights. Table 1 shows the optimal weights for gasoline and diesel.

Table 1: Country weights

	AUT	BEL	CZE	DNK	FRA	LUX	NLD	POL	CHE
Gasoline	0.36	0.00	0.03	0.21	0.27	0.00	0.13	0.00	0.00
Diesel	0.42	0.00	0.00	0.00	0.07	0.00	0.51	0.00	0.00

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

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, France and the Netherlands, which account for 76% of the weights for gasoline and 100% for diesel. The Czech Republic and Denmark account for the remaining weights for gasoline. Belgium, Luxembourg, Poland and Switzerland receive a weight of zero.

Before analyzing the impact of the tax reduction on fuel prices, we compare the German observations for the structural variables to those of the two Doppelgangers. Table 2 presents the matching of the structural variables for Germany and the Doppelgangers in the pre-treatment period. The last column shows population-weighted averages where the highest weights are assigned to France (39%), Poland (23%) and the Netherlands (11%).

Average fuel prices, (log) GDP per capita and the Russian fuel import quota are well-matched between Germany and the Doppelgangers. We observe some deviations for (log) residents per station and CPI energy inflation, although the magnitude of the differences is modest. The results also show that the Doppelgangers perform similar to the population-weighted average. The modest matching of the structural variables in some cases is likely due to the fact that these five data points only make up a very small fraction of the observations in \mathbf{x}_1 and \mathbf{X}_0 . We address this issue in a robustness check below. Overall, however, we conclude that our method is able to match these structural features of the German fuel market relatively well.

²The 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).

Table 2: Matching of structural variables

	Germany	Doppelganger gasoline	Doppelganger diesel	Population-weighted average
Gasoline prices	1.50	—	1.55	1.46
Diesel prices	1.40	1.39	—	1.40
Residents per station (<i>log</i>)	8.66	8.25	8.26	8.43
GDP per capita (<i>log</i>)	10.94	10.98	11.02	10.67
Russian fuel import quota	0.29	0.29	0.27	0.29
CPI energy inflation	0.06	0.08	0.13	0.08

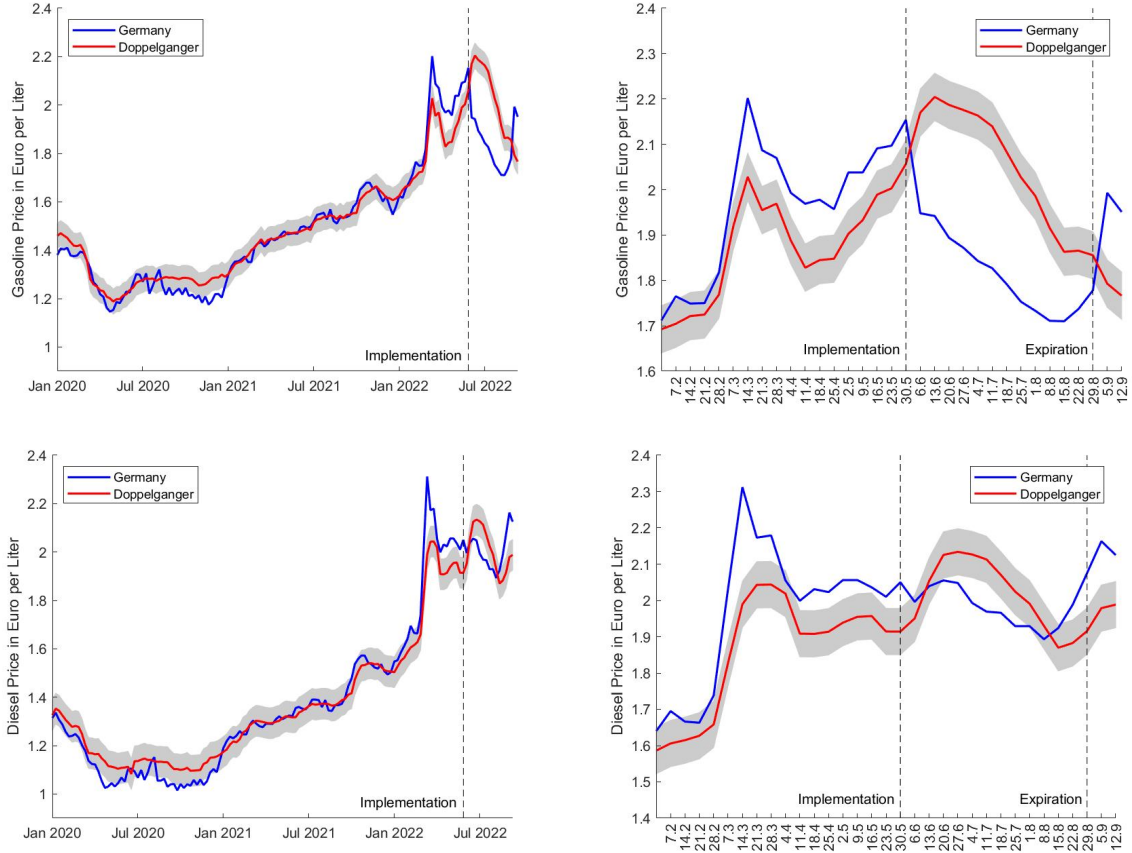
Notes: This table presents pre-treatment values of the structural variables (and pre-treatment fuel price averages) for Germany and the Doppelgangers as well as population-weighted averages.

We now turn to the analysis of the impact of the tax reduction on fuel prices. The blue lines in Figure 1 show actual prices for gasoline (upper plots) and diesel (lower plots) in Germany. The red lines depict the series for the respective Doppelganger. The gray confidence bands correspond to plus/minus one standard deviation of the differences between actual prices and the corresponding Doppelganger in the pre-treatment period. The left panels present the series for the entire sample period, whereas the right panels zoom in on the data for the period after February 2022. The SCM 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.

The Doppelgangers closely track the evolution of German fuel prices before the tax reduction. In particular, the synthetic control groups strongly outperform population-weighted averages (not shown). In the period following the invasion of Ukraine, we observe a decoupling of the series, which may be evidence of the relatively strong importance of Russian energy supply for especially Eastern Germany. An alternative potential explanation is that fuel retailers moderately raised their prices in anticipation of the tax reduction that ‘forced’ them to lower prices. In particular, we find that fuel prices have increased by 10 (14) cents for gasoline (diesel) relative to the comparison group in the 21st calendar week (represented by the dashed lines). To estimate the full effect of the tax reduction on retail prices, we add these price differences to the estimated post-treatment price differences.

Broadly speaking, Figure 1 shows that the tax reduction has been passed on to consumers. However, we observe considerable heterogeneity in the treatment effects across both time and fuel types. For both gasoline and diesel, we observe a short delay before prices fully reflected the tax reduction. For gasoline, we find that German prices are 22 cents below the Doppelganger price in the first week of June. By the second week of June, the difference is equal to 26 cents. The change in the difference relative to the last week of May is even larger at 32 (36) cents. Relative to the tax reduction of 35 cents, this implies a short-term pass-through rate for gasoline of 91%, respectively 103%. Over the same period, diesel prices decreased by 9 (15) cents compared to its Doppelganger relative to the last week of May. Considering that the tax reduction for diesel was 17 cents, our findings suggest pass-through rates of 53%, respectively 88% in the first two weeks. Over

Figure 1: Real fuel prices versus Doppelgänger



Notes: The blue lines show German prices for gasoline (left panel) and diesel (right panel). The red lines show the corresponding Doppelgänger series based on the SCM. The width of the gray confidence bands is equal to one standard deviation of the differences between both pre-treatment fuel prices series.

the next seven weeks, pass-through rates for both fuel types are essentially constant at (more than) 100%.

In contrast, pass-through rates decline considerably throughout August. By the final calendar week that is fully covered by the tax reduction, the pass-through rate for gasoline is reduced to 50% while the actual diesel price even *exceeds* the synthetic price even when accounting for the pre-treatment difference of 14 cents. After the tax reduction ran out before the final two weeks covered by our sample, we observe further increases of actual fuel prices relative to those suggested by the Doppelgängers. For diesel, the difference between actual and synthetic prices are close to 17 cents, i.e., the size of the tax reduction, but only if the pre-treatment difference is ignored. For gasoline, the differences remain below 35 cents.

In summary, our results suggest that the tax reduction has been passed on to consumers after the first few weeks of June. While we observe constant price reductions in July, these effect slowly vanish throughout August. This is particularly the case for diesel. Finally, we observe a considerable price jump at the start of September, which, however, remains below the size of the expiring tax reduction.

Our findings suggest that the overall goal of relieving households in the face of rising energy prices has been achieved, but not for the entire implementation period. The reasons behind the low initial pass-through rates for diesel relative to gasoline are unclear. The General German Automobile Club (*Allgemeiner Deutscher Automobil-Club*) reported in the spring of 2022 that rising diesel prices are related to an unusually high demand for fuel oil for that time of year. If this effect continued into May and June, for example because households increased their oil stocks out of fear of continuously rising prices, it may help explain the incomplete initial price reduction for diesel. The overall impression in the German public discussion that petroleum companies only partially pass on the tax reduction is likely related to an increase of fuel prices in Europe at the beginning of June against the background of an overall increase in the price of crude oil. As a result, the price reduction in Germany remained below the tax reduction in absolute terms. This highlights the importance of comparisons to a proper counter-factual scenario rather than comparisons of actual prices to their pre-treatment levels.

Our finding of diminishing pass-through rates in particular for diesel in August 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.

4 Robustness

We confirm the validity of our results in several robustness checks. For brevity, we do not report the detailed findings from these robustness checks here but in the appendix.

One concern with our approach could be the modest matching for the structural variables in Table 2. We have speculated above that this may be due to these five observations only making up a very small fraction of the rows in \mathbf{x}_1 and \mathbf{X}_0 . We address this hypothesis in two ways: First, we omit the weekly 2020 fuel prices from the construction of the Doppelgangers, thereby increasing the relative importance of the structural variables (Appendix B). Second, we retain the 2020 fuel prices but instead exclude the structural variables from \mathbf{x}_1 and \mathbf{X}_0 (Appendix C). Both approaches produce different sets of optimal weights, although Austria, the Czech Republic, Denmark, France and the Netherlands remain the only countries with nonzero weight. As expected, the matching of the structural variables improves if we reduce the number of observations for the weekly fuel prices in the construction of the optimal weights, although the population-weighted average remains competitive. In contrast, the matching of the structural variables deteriorates relative to the main specification if we exclude those variables from \mathbf{x}_1 and \mathbf{X}_0 . Reassuringly, the estimated effects of the tax reduction are nearly identical to those in Figure 1.

As an alternative to the SCM, we use the synthetic difference-in-differences (SDID) estimator of Arkhangelsky et al. (2021) (Appendix D). This estimator combines the construction of a synthetic control group with a difference-in-differences estimation of the treatment effect in one step. While the SCM and SDID approaches are conceptually similar, there are differences in the construction of the synthetic control group. Whereas the SCM aims to match the pre-treatment behavior of the treatment and control groups 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. In addition, the SDID estimator tends to display a lower concentration of the 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. When using the SDID estimator, nonzero weights are assigned to every country except for Poland. None of the country weights exceed 19%. The matching of fuel prices and structural variables is similar to that of the SCM. With respect to the estimated effects of the tax reduction, we again find a delayed initial adjustment of approximately two weeks, pass-through rates close to 100% in July and decreasing rates throughout August. The estimated average treatment effects (over the three months period) are about 35 cents for gasoline and 15 cents for diesel, which translates to average pass-through rates of 100% and 88%. We prefer the SCM because the SDID estimator does not allow for the inclusion of time-invariant control variables such as our choice of structural variables for the fuel market.

5 Conclusion

Despite the impression in the public debate in early June 2022 that petroleum companies did not pass the tax reduction on to consumers, we find that the temporary reduction of fuel taxes was indeed passed on to consumers. 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, we document a delay of approximately two weeks for the complete pass-through to take effect. Moreover, the effect on fuel prices gradually decreased throughout August while the tax reduction was officially still in place. Finally, fuel prices jumped upwards by less than the size of the expiring tax reduction at the start of September.

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Appendix

A Data description

Table A.1: Variable description

Variable	Description and data sources
Fuel prices	Weekly average prices for gasoline and diesel in euros per liter for the period from the first calendar week of 2020 to the 36th calendar week of 2022. All time series are taken from globalpetrolprices.com.
Residents per station (<i>log</i>)	Natural logarithm of the number of residents divided by the number of gas stations in the year 2020. The data are taken from statista.com.
GDP per capita (<i>log</i>)	Natural logarithm of the average across the annual observations for GDP per capita in the years 2020 and 2021 in euros. All series are taken from data.worldbank.org.
Russian fuel import quota	Average across the monthly observations for the share of oil and gas imports from Russia relative to total imports of oil and gas in the years 2020 and 2021. All data are taken from Eurostat.
CPI energy inflation	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. The series are retrieved from OECD.

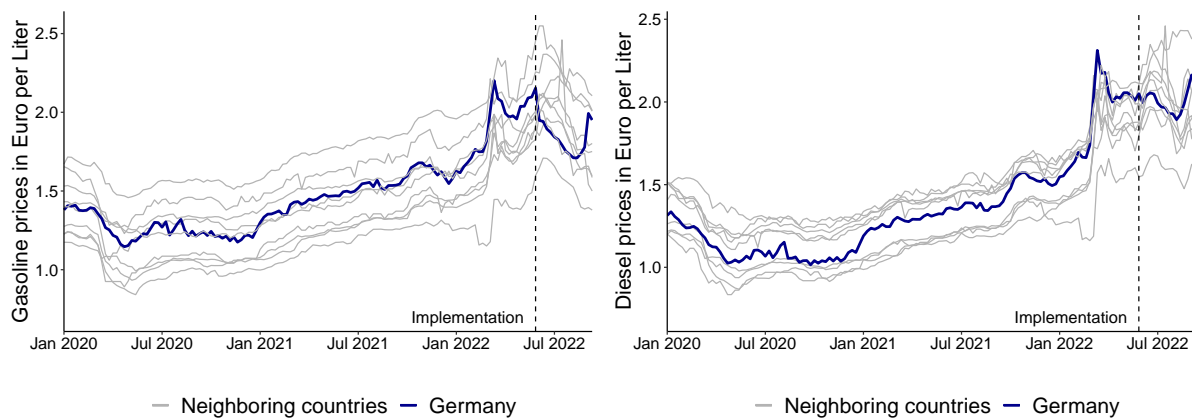
Notes: This table describes the construction and sources of the variables used in the empirical analysis. For each variable, we collect data for Germany and its neighboring countries, i.e., Austria, Belgium, the Czech Republic, Denmark, France, Luxembourg, the Netherlands, Poland and Switzerland.

Table A.2: Structural variables for Germany and the neighboring countries

	AUT	BEL	CZE	DNK	FRA	DEU	LUX	NLD	POL	CHE
Gasoline prices	1.25	1.50	1.31	1.69	1.55	1.50	1.32	1.80	1.17	1.50
Diesel prices	1.22	1.53	1.29	1.50	1.49	1.40	1.25	1.49	1.18	1.58
Residents per station (<i>log</i>)	8.09	8.23	7.89	7.95	8.70	8.66	7.87	8.34	8.50	7.85
GDP per capita (<i>log</i>)	10.99	10.94	10.27	11.22	10.81	10.94	11.90	11.07	9.88	11.56
Russian fuel import quota	0.37	0.21	0.32	0.38	0.15	0.29	0.00	0.20	0.62	0.00
CPI energy inflation	0.08	0.14	-0.01	0.08	0.05	0.06	0.10	0.18	0.10	0.03

Notes: This table presents pre-treatment values of the structural variables (and pre-treatment fuel price averages) for Austria (AUT), Belgium (BEL), the Czech Republic (CZE), Denmark (DNK), France (FRA), Germany (DEU), Luxembourg (LUX), the Netherlands (NLD), Poland (POL) and Switzerland (CHE).

Figure A.1: Fuel prices in Germany and the neighboring states



Notes: The blue lines show German prices for gasoline (left panel) and diesel (right panel). The gray lines show the corresponding prices for the neighboring countries.

B SCM excluding 2020 fuel prices

To address the moderate matching for the structural variables, we re-estimate the optimal weights if we exclude the weekly 2020 fuel prices from the construction of the Doppelgangers (leaving the definitions of the structural variables unchanged). By reducing the time series of fuel prices, the relative importance of the structural variables increases. This should lead to an improved matching for these variables. Table B.1 presents the optimal weights for the new scenario.

Table B.1: Country weights

	AUT	BEL	CZE	DNK	FRA	LUX	NLD	POL	CHE
Gasoline	0.24	0.00	0.00	0.28	0.43	0.00	0.04	0.00	0.00
Diesel	0.26	0.00	0.00	0.00	0.33	0.00	0.41	0.00	0.00

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

The weights are relatively similar to those in Table 1. However, a notable difference is that the relative importance of France increases, while the weights for Austria, the Czech Republic, Denmark and the Netherlands decrease.

Table B.2 presents the matching of the structural variables for Germany and the Doppelgangers based on the weights in Table B.1.

Table B.2: Matching of structural variables

	Germany	Doppelganger gasoline	Doppelganger diesel	Population-weighted average
Gasoline prices	1.50	–	1.57	1.46
Diesel prices	1.40	1.43	–	1.40
Residents per station (<i>log</i>)	8.66	8.32	8.40	8.43
GDP per capita (<i>log</i>)	10.94	10.98	10.96	10.67
Russian fuel import quota	0.29	0.27	0.23	0.29
CPI energy inflation	0.06	0.07	0.11	0.08

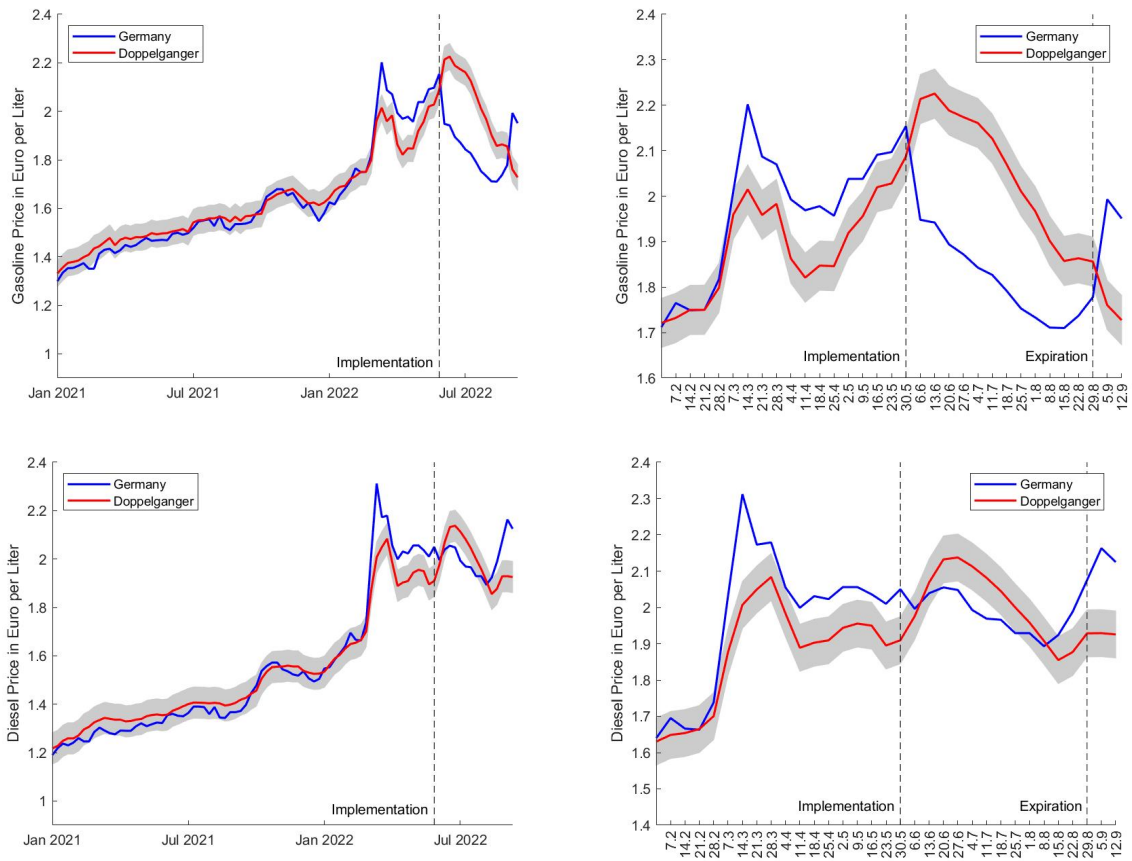
Notes: This table presents pre-treatment values of the structural variables (and pre-treatment fuel price averages) for Germany and the Doppelgangers as well as population-weighted averages.

As expected, the matching of the structural variables improves in case the 2020 fuel prices are omitted from the construction of the synthetic control group. The matching improves in particular for the (*log*) number of residents per station. However, the population-weighted average remains competitive.

Finally, Figure B.1 compares actual fuel prices in Germany with those for the new Doppelgangers. The blue lines are identical to those in Figure 1. As before, we observe a divergence of actual and synthetic prices in the build-up to the implementation.

The impact of the tax reduction on fuel prices is very similar to our main results. We find a delay of approximately two weeks in the pass-through of the tax reduction for gasoline and diesel prices. Afterwards, we find consistent pass-through rates of 100% (or more) throughout July and decreasing rates in August.

Figure B.1: Real fuel prices versus Doppelgänger



Notes: The blue lines show German prices for gasoline (left panel) and diesel (right panel). The red lines show the corresponding Doppelgänger series based on the SCM. The width of the gray confidence bands is equal to one standard deviation of the differences between both pre-treatment fuel prices series.

C SCM excluding structural variables

This section provides results for the SCM if we exclude the structural variables from \mathbf{x}_1 and \mathbf{X}_0 . Table C.1 presents the optimal weights we obtain after minimizing Eqn. (1).

Table C.1: Country weights

	AUT	BEL	CZE	DNK	FRA	LUX	NLD	POL	CHE
Gasoline	0.39	0.00	0.09	0.41	0.00	0.00	0.12	0.00	0.00
Diesel	0.20	0.00	0.00	0.30	0.00	0.18	0.31	0.00	0.00

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

The weights are similar to those in Table 1 in the sense that Austria, Denmark and the Netherlands receive a large weight in the construction of both Doppelgangers. Notably, however, France receives a weight of zero in the new setting, which suggests that in our main specification France is primarily needed to fit the structural variables.

Table C.2 shows the matching of the structural variables for Germany and the Doppelgangers based on the new weights.

Table C.2: Matching of structural variables

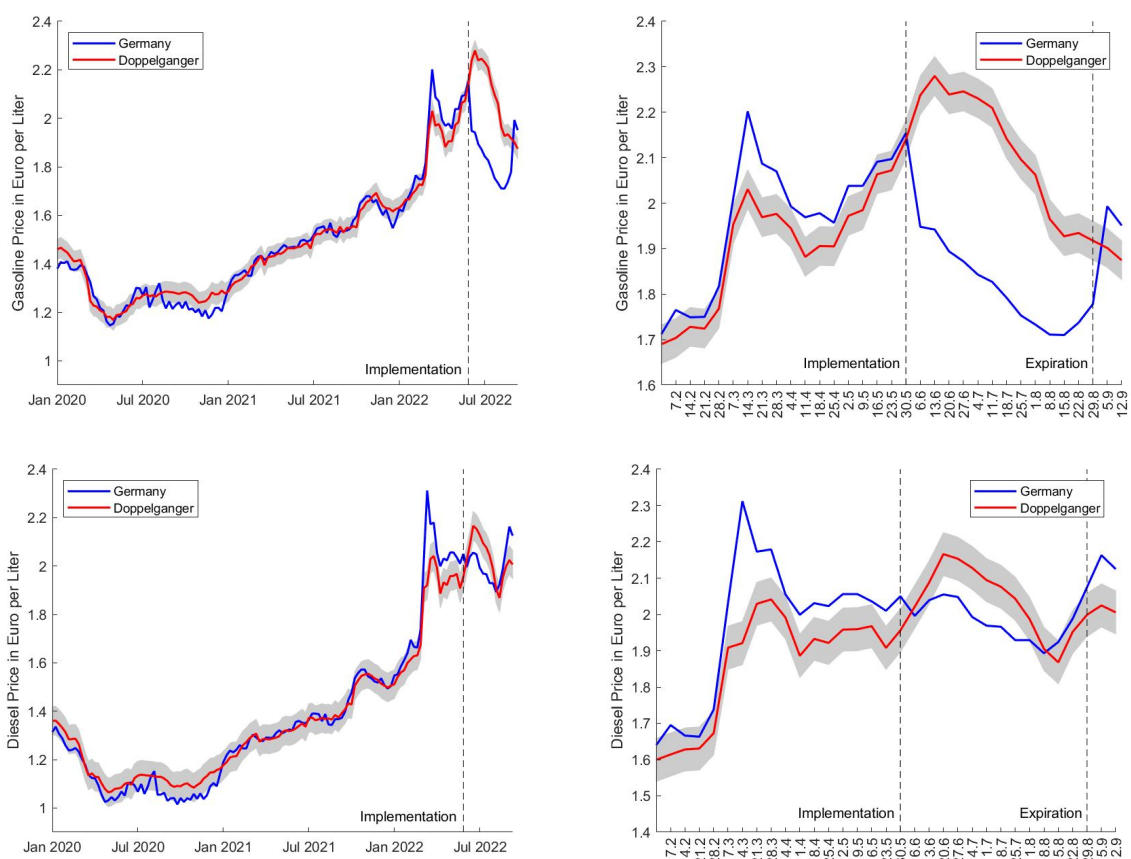
	Germany	Doppelganger gasoline	Doppelganger diesel	Population-weighted average
Gasoline prices	1.50	–	1.57	1.46
Diesel prices	1.40	1.37	–	1.40
Residents per station (<i>log</i>)	8.66	8.04	8.09	8.43
GDP per capita (<i>log</i>)	10.94	11.03	11.25	10.67
Russian fuel import quota	0.29	0.35	0.25	0.29
CPI energy inflation	0.06	0.08	0.11	0.08

Notes: This table presents pre-treatment values of the structural variables (and pre-treatment fuel price averages) for Germany and the Doppelgangers as well as population-weighted averages.

As expected, the matching of all structural variables (except for CPI energy inflation) is slightly worse if those variables are excluded from the minimization problem in Eqn. (1). Nonetheless, the differences between the observations and Germany are relatively small in most cases.

Figure C.1 shows actual fuel prices for Germany and the new Doppelganger series. As in Appendix B, the impact of the tax reduction on fuel prices is almost identical to our main findings. As in Figure 1, we observe a delay of approximately two weeks in the pass-through of the tax reduction for gasoline and diesel prices, consistent pass-through rates of 100% in July and decreasing pass-through rates in August.

Figure C.1: Real fuel prices versus Doppelgänger



Notes: The blue lines show German prices for gasoline (left panel) and diesel (right panel). The red lines show the corresponding Doppelgänger series based on the SCM. The width of the gray confidence bands is equal to one standard deviation of the differences between both pre-treatment fuel prices series.

D Synthetic difference-in-differences estimator

We use the SDID estimator of [Arkhangelsky et al. \(2021\)](#) as an alternative to the SCM. This approach combines the construction of the synthetic control group with the estimation of the average treatment effect via the following two-way fixed effects regression:

$$\arg \min_{\tau, \mu, \alpha, \beta} \left\{ \sum_{i=1}^{10} \sum_{t=1}^{141} (X_{it} - \mu - \alpha_i - \beta_t - D_{it}\tau)^2 w_i \lambda_t \right\}, \quad (2)$$

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 the weekly average price for gasoline or diesel in country $i = 1, \dots, 10$ and week $t = 1, \dots, 139$. We exclude the final two weeks in our sample from the estimation because they cover the period after the tax reduction expired. Germany represents the first country ($i = 1$) and the tax reduction was implemented in week $t = 127$. Thus, the treatment indicator is defined as

$$D_{it} = \begin{cases} 1 & \text{if } i = 1 \text{ and } t \geq 127 \\ 0 & \text{else.} \end{cases} \quad (3)$$

The parameter τ represents the impact of the tax reduction on fuel prices in Germany.

Eqn. (2) is weighted using 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 in Eqn. (2). 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. After computing w_i and λ_t , a difference-in-differences regression analysis is applied to the reweighted panel as described in Eqn (2).

Table D.2 presents the country weights.

Table D.1: Country weights

	AUT	BEL	CZE	DNK	FRA	LUX	NLD	POL	CHE
Gasoline	0.17	0.06	0.17	0.18	0.04	0.14	0.11	0.00	0.13
Diesel	0.16	0.07	0.15	0.16	0.04	0.19	0.16	0.00	0.07

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

The procedure assigns nonzero weight to all countries in the donor pool except for Poland. As expected, the concentration of weights is much smaller than for the SCM.

Table D.2 shows average values for the structural variables in the pre-treatment period.

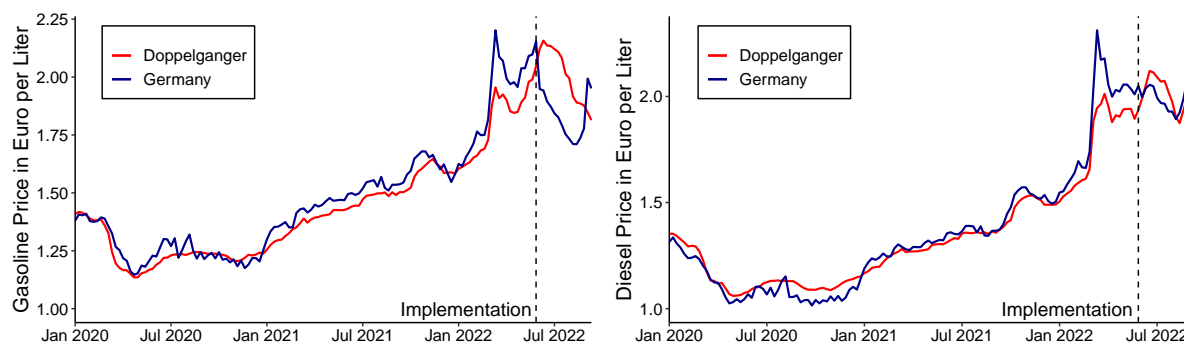
Table D.2: Matching of structural variables

	Germany	Doppelgänger gasoline	Doppelgänger diesel	Population-weighted average
Gasoline prices	1.50	—	1.48	1.46
Diesel prices	1.40	1.39	—	1.40
Residents per station (<i>log</i>)	8.66	8.03	8.06	8.43
GDP per capita (<i>log</i>)	10.94	11.12	11.13	10.67
Russian fuel import quota	0.29	0.22	0.22	0.29
CPI energy inflation	0.06	0.07	0.08	0.08

Notes: This table presents pre-treatment time series averages for the structural variables for Germany and the Doppelgängers. The last column shows population-weighted averages.

The results are broadly comparable to those we observe for the SCM. Figure D.1 shows the Doppelgängers analogously to Figure 1. We omit the confidence bands and the zoom-in plots.

Figure D.1: Real fuel prices versus Doppelgänger



Notes: The blue lines show German prices for gasoline (left panel) and diesel (right panel). The red lines show the corresponding Doppelgänger series based on the SDID.

Overall, the results in Figure D.1 are very similar to our main results. Table D.3 presents the estimates of the average treatment effect τ .

Table D.3: SDID estimates of the average treatment effect

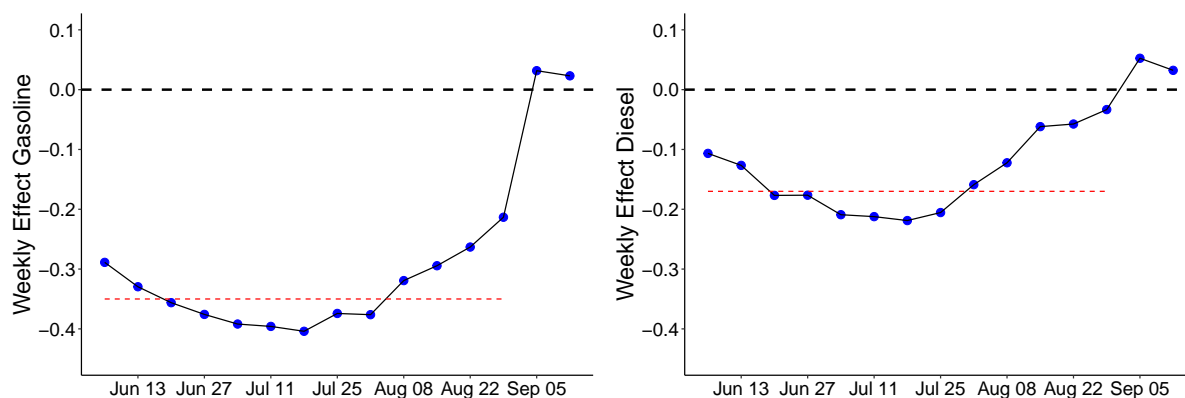
	Gasoline	Diesel
Average treatment effect	−0.351*** (0.112)	−0.146** (0.063)

Notes: SDID estimates of the average impact of the tax reduction on German fuel prices throughout the treatment period.

The estimates are significantly negative in both cases. While the treatment effects for gasoline equals the size of the tax reduction, the estimate for diesel is below 17 cents.

The estimates in Table D.3 represent average effects for the entire post-treatment sample. However, the SCM results suggest that pass-through rates vary over time. To address this issue, we calculate week-by-week estimates of the treatment effect. We first compute the weighted sum over the pre-treatment price differences in Figure D.1 by using the estimated time weights, which are non-negative for five weeks ($t = 16, 115, 121, 122$ and 123). 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 D.2 shows the results.³

Figure D.2: Week-by-week estimates of the treatment effect



Notes: Week-by-week SDID estimates of the average impact of the tax reduction on German fuel prices. The red lines represent the theoretical size of the tax reduction.

In line with the SCM results, we find that the treatment effects increase in absolute terms over the first few weeks after the implementation of the tax reduction. Afterwards, the estimates fluctuate around 35-40 cents for gasoline, which implies pass-through rates of more than 100% in July. A similar picture emerges for diesel prices. We observe decreasing pass-through rates in August and price jumps at the start of September.

³Notice that the estimates in Table D.3 are obtained by averaging over all but the last two weekly estimates in Figure D.2.