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From Highway to Rail? Germany's Public Transport Ticket Experiment

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Abstract

This paper examines the impact of Germany's nationwide *9-Euro-Ticket*, a temporary almost fare-free transport ticket, on highway passenger traffic. Using a difference-in-differences approach, we find a significant reduction of approximately 4.5%, primarily driven by decreased weekend traffic. Event study results also indicate considerable heterogeneity across time, federal states, and road types. A similar but more persistent effect is observed for the *Deutschlandticket*, the permanent successor to the *9-Euro-Ticket*. However, our findings suggest that neither ticket has resulted in a lasting shift from private cars to public transport, especially among commuters. Hence, the overall efficiency of this measure remains uncertain, particularly in view of the high direct costs and the necessary investments required to improve Germany's rail infrastructure in the near future.

Keywords: Modal Shift, 9-Euro-Ticket, Deutschlandticket, Difference-in-Differences

JEL Codes: R48, R41, L91

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1 Introduction

In 2022, the German Parliament has temporary introduced a nationwide local public transport ticket. The so-called *9-Euro-Ticket* has enabled travellers the unlimited usage of local public transport for 9€ per month between June and August 2022.[1] The direct costs for this governmental intervention have been 2.5 billion euros. Even though the *9-Euro-Ticket* was primarily intended to relieve the financial burden on citizens, the intervention at the same time greatly simplifies the existing tariff structures of the tariff and transport associations for local public transport in Germany. Moreover, another goal of the German government was to give an incentive to switch to public transport and to save fuel.[2]

The temporary *9-Euro-Ticket* means the nationwide introduction of a uniform price setting for local public transport. This could result in the absence of a price signal that previously helped capture the value of services, potentially limiting information about demand for optimal capacity planning. As a consequence, this may contribute to capacity challenges and variations in service quality (Liebensteiner et al., 2024). The same issue also holds for the long-term successor of the *9-Euro-Ticket*, the *Deutschlandticket*, which has been passed by the German Parliament in March 2023.[3] The *Deutschlandticket* has become effective in May 2023 and its concept is very similar to the *9-Euro-Ticket*, although it is only available on a subscription model

[1] See https://www.bmdv.bund.de/SharedDocs/DE/Artikel/K/9-euro-ticket-beschlossen.html.

[2] See https://www.bundestag.de/dokumente/textarchiv/2022/kw20-de-neun-euro-ticket-894660.

[3] See https://dserver.bundestag.de/btd/20/055/2005548.pdf.

and it has a higher monthly price.[4]

Governments very often intervene in the market by means of subsidies in order to keep prices at a lower level than the market would actually allow. These subsidies might be reasonable when there is 1) a positive externality of a higher public transport frequency due to lower opportunity costs for the passengers (Button, 2010; Mohring, 1972), or 2) the public subsidies internalize the negative externality of the motorized individual traffic by making the public transport traffic relatively more appealing (Basso and Silva, 2014; Parry and Small, 2009).

In this paper, we want to identify the effect of the *9-Euro-Ticket* on highway passenger traffic in Germany. We analyze whether such a type of almost fare-free nationwide public transport tickets might have an impact on the decision of individuals to shift from car to public transport. Therefore, we use a unique data set including traffic data for all German highways and employ a difference-in-differences (DiD) approach with Austria and Switzerland being our control countries. We also apply the synthetic DiD design to check the robustness of our main findings as well as to additionally analyze the effect of the *Deutschlandticket* on highway traffic in Germany.

Our results imply that the introduction of the *9-Euro-Ticket* has decreased the highway passenger traffic in Germany by approximately 4.5% on average. However, we also show that this effect is heterogeneous over time, across the 16 German federal states, between different road types as well as mainly driven by less weekend traffic. Our findings for the *Deutschlandticket*

[4] From May 2023 to December 2024 the price was 49€ and from January 2025 on 58€ per month, see `https://www.tagesschau.de/wirtschaft/verbraucher/deutschlandticket-teurer-100.html`.

are very similar, even though its effect is longer lasting and not only driven by less weekend traffic or a specific road type.

The rest of the paper is structured as follows. Section 2 presents related literature. We present our data set and descriptive statistics in Section 3. In Section 4, we explain our empirical strategy and then present the estimation results in Section 5. Our extensions and robustness checks are provided in Section 6, while we discuss our findings in Section 7. We conclude in Section 8.

2 Related Literature

There is already some empirical evidence on the effect of uniform price settings in the public transport sector from earlier policies in Germany as well as from other countries. The city of Tallinn (Estonia) has introduced a fare-free public transport (FFPT) in 2013 to improve the mobility for its residents. Several empirical studies have identified only a small effect of this policy on passenger demand. They find an improvement for the mobility of low-income residents, while transit ridership increase was lowest among working-age commuters (Cats, Reimal, and Y. Susilo, 2014; Cats, Y. O. Susilo, and Reimal, 2017; Hess, 2017). In an experimental study, Fujii and Kitamura (2003) show that offering auto drivers a temporary free bus ticket may convince them to shift to the public transport sector.

Even though there is some evidence that ticket price reductions can cause a demand increase in public transport usage (Wallimann, Blättler, and Arx, 2023), empirical evidence for a modal shift is scarce so far. Bull, Muñoz, and

Silva (2021) investigate the effect of FFPT on travel behavior by randomly assigning an unlimited travel pass to workers in Santiago (Chile). They (ibid.) find a 23% rise in the total number of trips made during off-peak, which can be attributed to an increase in subway usage among individuals living close to a station, but the authors find no evidence of mode or period substitution. Busch-Geertsema, Lanzendorf, and Klinner (2021) analyze the effect of the introduction of a FFPT in Hesse (Germany) by using survey data. Their results show a substantial increase in the use of public transport for commuting and other trip purposes, still the authors find no decrease in car use and availability.

Regarding the introduction of the *9-Euro-Ticket* in Germany in 2022, most of the available evidence comes from survey data and descriptive analyses, with two notable exceptions. First, Liebensteiner et al. (2024) also apply a differences-in-differences (DiD) approach and an event study to analyze the effect of the *9-Euro-Ticket* on mobility patterns. They (ibid.) find a limited substitution between transportation modes, a strong increase in leisure train journeys, and notable adverse effects on rail infrastructure quality. Second, Guajardo Ortega and Link (2025) use data from GPS-tracked trips and report significant inertia effects for car users, implying that they are unlikely to change their travel mode. Therefore, only a small modal shift from car to public transport is identified.

In a market research study, the Association of German Transport Companies finds that 10% of the *9-Euro-Ticket* customers waived at least one of their daily car trips.[5] The German Federal Statistical Office finds an average

[5] See https://www.vdv.de/bilanz-9-euro-ticket.aspx.

increase in the public transport demand of 44%, but only a small decrease in the motorised private transport.[6] Relying on survey data, Loder et al. (2024) find that around 20% of the *9-Euro-Ticket* customers substituted at least some private transport trips with public transport. Similarly, Andor et al. (2023) find a significant reduction in the kilometers traveled by car of approximately 10%.

Lastly, so far there are two papers analyzing the environmental effects of the *9-Euro-Ticket*. Aydin and Kürschner Rauck (2023) study the short-term effects of the *9-Euro-Ticket* on particulate matter and find a significant decrease. The authors interpret that a reduction in car usage is responsible for their findings. Gohl and Schrauth (2022) use a DiD design to estimate the effect of the *9-Euro-Ticket* on air pollution and find that this intervention reduced a benchmark air pollution index by more than six percent.

3 Data and Descriptive Statistics

3.1 Data

We rely on data from the *Federal Highway Research Institute* (*BASt*) including all motor vehicles recorded at counting stations on freeways and highways

[6]See https://www.destatis.de/DE/Presse/Pressemitteilungen/2022/09/PD22_377_12.html.

within Germany.[7] All motor vehicles are permanently counted at automatic counting points and the data is available on an hourly basis for every traffic line and direction, while up to nine vehicle types can be distinguished. In January, 2025, the counting point network on federal highways included 2,114 counting points (1,228 on highways and 886 on extra-urban federal roads). This data is collected by Autobahn GmbH des Bundes (AdB) and the federal states and transmitted to BASt on a monthly basis. The data also forms an important basis for traffic or construction decisions and measures.[8]

We incorporate traffic counting data from other European countries—Austria, Switzerland, and Finland—which serve as control groups depending on the specific econometric approach applied in this paper. Germany (D), Austria (A) and Switzerland (CH) refer to the so-called DACH region, encompassing approximately 100 million individuals who largely share similar socioeconomic conditions, despite regional variations within and across each country.[9] Hence, Austria and Switzerland should serve as appropriate countries to function as a control group for Germany.

The counting data for Austria originates from the *Motorway and Ex-*

[7] We define freeways and highways for each country, categorizing country-specific road types into these two classes. Broadly, where we adhere to the European Commission report on motorways and the Vienna Convention on Road Signs and Signals (https://road-safety.transport.ec.europa.eu/system/files/2021-07/ersosynthesis2018-motorways.pdf). Here, a freeway (such as a motorway) is a high-capacity road designed exclusively for motor traffic, featuring separate carriageways, no at-grade crossings, and controlled access. In contrast, a highway (such as a Bundesstraße in Germany) is a major road connecting cities and regions, allowing mixed traffic, including slower vehicles, and often featuring intersections. While freeways ensure uninterrupted high-speed travel, highways accommodate both regional and local traffic with varying access controls. At times, we refer to 'highway' traffic, using this term in a broader, general sense to encompass all traffic on both road types, regardless of specific classifications.

[8] See https://www.bast.de/DE/Verkehrstechnik/Fachthemen/v2-verkehrszaehlung/zaehl_node.html.

[9] See, https://www.statista.com/topics/4623/dach-countries/.

pressway Financing Joint-Stock Company (*ASFiNAG*). All motor vehicles are permanently counted at automatic counting points and the data is available on a monthly basis for every traffic line and direction, while two different vehicle types can be distinguished. The counting point network on federal highways in Austria included 270 counting points in the beginning of 2025.[10] The *Swiss Federal Roads Authority* (*ASTRA*) provides traffic counting data for Switzerland. The data set includes observations from 559 counting points on an hourly basis for up to ten vehicle types. The observations can further be distinguished between two directions and two different road types.[11]

In addition, the provider *Fintraffic* collects traffic counting data for Finland, which we use in an extension of our estimation approach. This data is available on an hourly basis for nine vehicle types. We can distinguish between two directions and all available lanes. The data set contains observations for 529 counting points on Finnish roads.[12]

Even though the German, Swiss as well as the Finnish samples allow for a differentiation between various types of motor vehicles, we limit our analysis to the four categories passenger cars, passenger cars with trailers, delivery vehicles, and motorcycles, which all fall into the category of vehicles weighing less than 3.5 tonnes. This selection is made because the anticipated impact of the *9-Euro-Ticket* is pertinent only to these vehicle types. Besides, the data from Austria is available exclusively with a distinction between vehicles

[10]See https://www.asfinag.at/verkehr-sicherheit/verkehrszaehlung/. The data set with all relevant information was available upon request.

[11]See https://www.astra.admin.ch/astra/de/home/dokumentation/daten-informationsprodukte/verkehrsdaten/daten-publikationen.html. The data set with all relevant information was available upon request.

[12]See https://tie.digitraffic.fi/api/tms/v1/stations.

below and above 3.5 tonnes.

We consolidate the traffic data from counting points on a monthly basis, as this represents the most granular level of data aggregation available published in Austria. In addition to this aggregation level, the data is balanced across multiple dimensions. We ensure that each counting point is comprehensively balanced throughout the years 2022 to 2023, resulting in precisely 24 observations per counting point. This method is crucial in minimizing the impact caused by any partial dropouts of the counting points.

We also use data on daily average gasoline (E5) and diesel consumer prices. For Germany, we rely on information on the station level provided by *Tankerkönig-API*[13], which is based on the market transparency unit for fuels (*Markttransparenzstelle für Kraftstoffe, MTS-K*)[14] hosted by the federal cartel office (*Bundeskartellamt*). The Austrian information is available on a federal level from *E-Control*.[15] In contrast, Finland and Switzerland only have national fuel prices available, sourced from the *Finnish Information Centre of Automobile Sector*[16] and the *Bundesamt für Statistik*[17], respectively.

Moreover, we use the weather variables daily mean temperatures, average wind speed, and number of ice days gathered from nearest weather stations made available by the *European Climate Assessment & Dataset* (ECA&D) project (Klein Tank et al., 2002).[18] Our goal is to account for the different

[13]See https://dev.azure.com/tankerkoenig/_git/tankerkoenig-data.

[14]See https://www.bundeskartellamt.de/EN/Tasks/markettransparencyunit_fuels/markettransparencyunit_fuels_node.html.

[15]See https://www.e-control.at/publikationen/preistransparenz-datenbank.

[16]See https://www.aut.fi/en/statistics/taxation_prices_of_transport_and_road_expenditure/price_development_of_gasoline_and_diesel.

[17]See https://dam-api.bfs.admin.ch/hub/api/dam/assets/33787135/master.

[18]See Figure B.4 in Appendix B for the spatial distribution of weather stations across the Germany, Austria and Switzerland (DACH) region and Finland.

weather conditions around counting point area, as these conditions influence traffic dynamics. Weather conditions can affect traffic volume, speed, and accident risk in different locations heterogeneously (Cools, Moons, and Wets, 2010).

In technical terms, we match the weather stations by the closest spatial distance with the nearest counting point, and the daily mean temperature data were subsequently averaged to a monthly level.[19]

Lastly, we include data on the total number of nights spent at a tourist accommodation establishments on a national level, e.g. nights spent at hotels, camping grounds, recreational vehicle parks and trailer parks, gathered from Eurostat[20]. This data reflects overall differences between countries in the evolution of travel behavior, e.g., general trend differences in vacations.

3.2 Descriptive Statistics

Our data set contains freeway and highway traffic data for Germany, Austria, Switzerland and Finland. Due to the previously explained monthly aggregation and further balancing schemes, our final sample contains 24,936 observations (33,984 including Finland) on counting point level for the years 2022 and 2023.

[19]If the closest station data was unavailable for a particular date, we substituted the missing value the next station with the necessary information. Specifically, we employed the (blended) daily mean temperature (TG), daily maximum temperature (TX), daily mean wind speed (FG), see https://www.ecad.eu/dailydata/predefinedseries.php. To determine frost days, the minimum temperature is employed, adhering to the definition that classifies an ice day as one in which the maximum temperature falls below 0 degrees Celsius, as stated in https://www.dwd.de/EN/ourservices/germanclimateatlas/explanations/elements/_functions/faqkarussel/eistage.html.

[20]See, Eurostat, Nights spent at tourist accommodation establishments - monthly data (online data code: tour_occ_nim, https://doi.org/10.2908/TOUR_OCC_NIM.

We present the development of the overall highway traffic of passenger cars over time for Austria (AUT), Switzerland (CHE), Germany (GER) and Finland (FIN) in Figure 1. At this, the vertical black and blue lines indicate the period of the *9-Euro-Ticket*, whereas the vertical red line signifies the launch of the *Deutschlandticket*. In general, Figure 1 shows that the development of the overall highway traffic of passenger cars exhibits seasonal fluctuations, as there is more traffic in the summer compared to the winter term in all four countries. Naturally, the overall traffic of passenger cars is much higher in Germany compared to Austria, Switzerland or Finland. Nevertheless, the development of car passenger traffic over time is very similar across the four countries in our observation period.

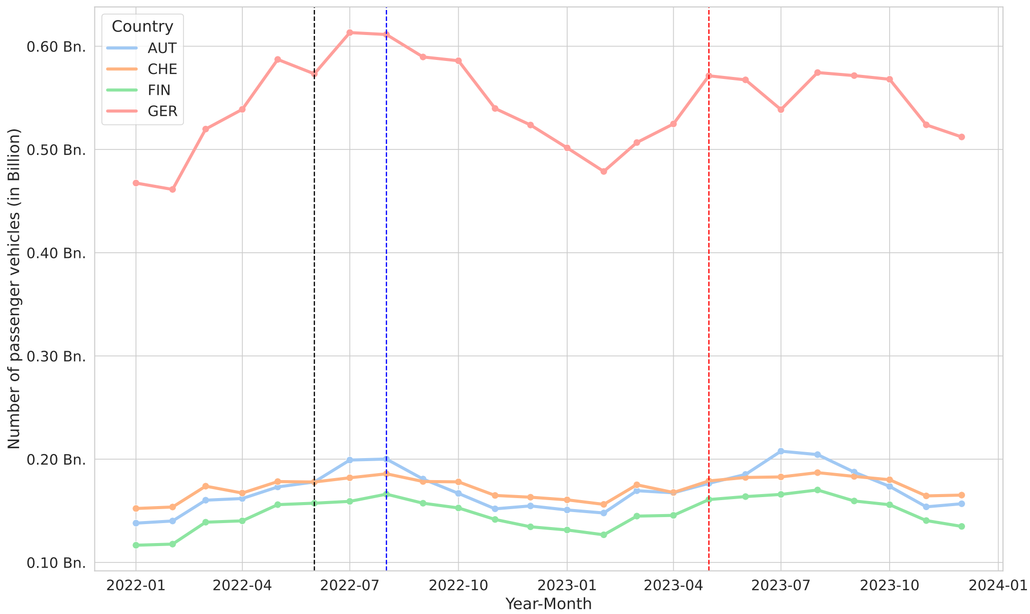

Figure 1: Development of the monthly overall highway & federal road traffic of passenger cars in Austria (AUT, blue line), Switzerland (CHE, orange line), Finland (FIN, green line) and Germany (GER, red line). The vertical black and blue lines mark the introduction and discontinuation of the *9-Euro-Ticket*, while the vertical red line marks the introduction of the *Deutschlandticket*.

Figure 1 also implies that at the introduction of the *9-Euro-Ticket* in

June 2022 a slight decrease in overall passenger car traffic has taken place. However, in the other two months of July and August 2022, traffic increased to levels above the previous May. We observe no similar pattern in our control countries at the same time. A similar pattern seems to be evident at the time of the implementation of the *Deutschlandticket* in May 2023. There is a substantial decline in July (analogous to the decrease observed in June of the preceding year), suggesting a seasonal influence potentially attributable to holiday periods.

In Figure 2, we present the normalized version of Figure 1 (May 2022 = 1). This modification is intended to underscore the similar trend evolution observable prior to the implementation of both tickets, providing an initial indication that the comparison countries might function as an appropriate control group. Moreover, this presentation on the development of highway traffic can better account for the different country sizes. For instance, the rise in highway passenger car traffic in the summer months of 2022 seems to be higher in Austria compared to Germany in normalized values.

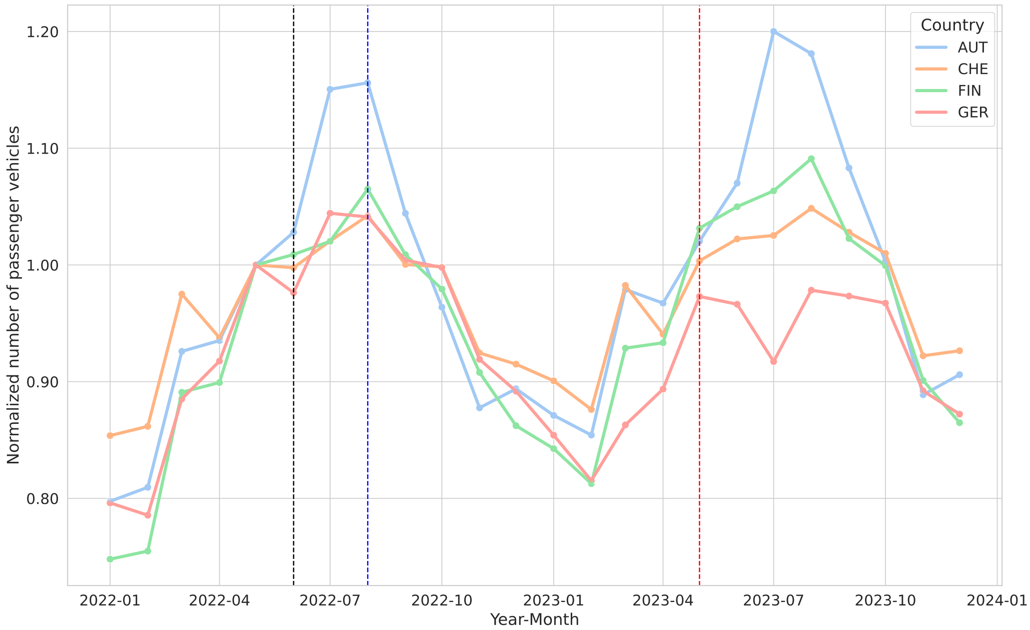

Figure 2: Development of the monthly overall highway & federal road traffic of passenger cars in Austria (AUT, blue line), Switzerland (CHE, orange line), Finland (FIN, green line) and Germany (GER, red line) normalized to the month prior to May 2023. The vertical black and blue lines mark the introduction and discontinuation of the *9-Euro-Ticket*, while the vertical red line marks the introduction of the *Deutschlandticket*.

Country	Number of Counting Points Balanced	Number of Counting Points (Observed: Balanced + Unbalanced)	Number of Counting Points Raw	Coverage Balanced-to-Observed	Coverage Observed-to-Raw
GER	736	1,767	2,093	41.65%	84.42%
FIN	377	447	524	84.34%	85.31%
CHE	173	308	486	56.17%	63.37%
AUT	130	271	291	47.97%	93.13%
All	1,416	2,793	3,394	50.70%	82.29%

Table 1: Number of unique counting points per country. *Raw* refers to counting points available in the unfiltered information from our data providers (see Table A.3), which expands from 2022 to 2023.

To highlight the coverage of the raw data of our providers, we present Table 1. Our balanced sample contains 1,416 counting points. We show the number of unique traffic counting points per country, categorized into three levels of data availability: *Balanced*, *Observed* (sum of Balanced and Unbalanced), and *Raw* (the total number of unfiltered counting points from data providers). Additionally, the table reports two coverage metrics: (i) *Balanced-to-Observed*, representing the proportion of balanced counting points relative to the observed set, and (ii) *Observed-to-Raw*, indicating the share of counting points in the raw data set.

Germany has the highest number of counting points across all categories, with 736 balanced points, 1,767 observed points, and 2,093 raw points. Finland exhibits a relatively high proportion of balanced points (84.34% of the observed set) and a similar *Observed-to-Raw* ratio (85.31%). Switzerland and Austria contain lower absolute counts, with Austria showing the highest *Observed-to-Raw* coverage at 93.13%. The table highlights the extent to which the data set has been processed and filtered, reflecting variations in data availability.[21]

[21]Related to road classes, the data set includes traffic from most freeways and highways, 29 of Austria, 260 of Germany, 47 of Switzerland and 57 of Finland (see Table A.1).

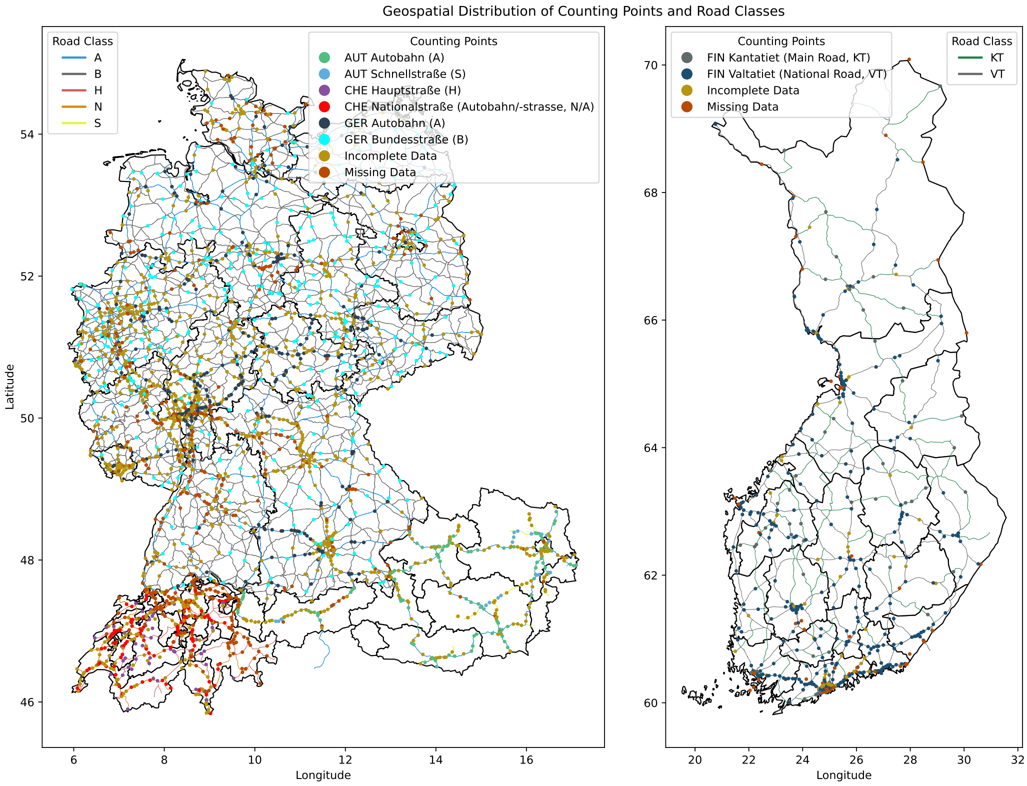

Figure 3: Spatial distribution of traffic counting points across the DACH regions) Germany, Austria, Switzerland) and Finland, differentiated by road classes. The left panel shows the classification of road networks in Germany, Austria and Finland, including Austrian Autobahn (A), Schnellstraße (S), German Autobahn (A), German Bundesstraße (B), Swiss Nationalstraße (Autobahn/-strasse, N/A) and Swiss Hauptstraße (H). The right panel illustrates the Finnish road network, categorized into Kantatiet (Main Road, KT) and Valtatiet (National Road, VT). Missing or incomplete data points are marked distinctly to highlight data coverage (see text for explanation). Sources: See Table A.3.

To illustrate the spatial distribution of freeways and highways and of the traffic counting stations in Austria, Germany, Switzerland and Finland, we present Figure 3. This figure is divided into two sections: the left panel highlights the DACH region, while the right panel focuses on Finland. Counting points are represented by colored dots, including those that are missing (refers to *Raw* from Table A.1) or incomplete due to balancing processes. Generally, the major segments of each country's freeway and highway networks are covered, implying that the findings can be interpreted broadly, notably for the entirety of Germany.

As outlined in Section 3, we also use data on fuel prices, overnight accommodations, and weather conditions. The (lagged) price of gasoline is incorporated as a control variable in our methodological framework for two reasons. First, the current gasoline price might affect the choice of the transport mode (at least for price-elastic consumers) so that we have to take into account this variable when analyzing car passenger traffic. Second, the German government has additionally introduced an energy tax reduction (*Tankrabatt*) in June 2022 which we have to control for (Dovern et al., 2023; Fuest, Neumeier, and Stöhlker, 2022; Drolsbach, Gail, and Klotz, 2023).

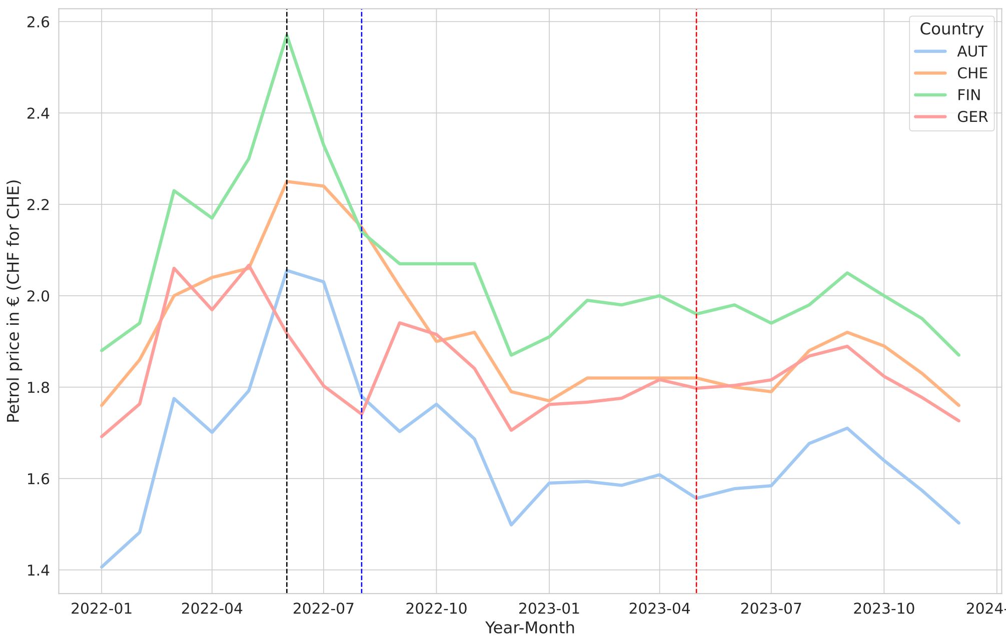

Figure 4: Development of the gasoline prices (monthly average) in Germany and Austria. The vertical black and blue lines reflect the introduction and discontinuation of the *Tankrabatt* (as well as the *9-Euro-Ticket*) in Germany, while the vertical red line marks the introduction of the *Deutschlandticket*.

Figure 4 shows the development of the monthly gasoline (E5) prices in the four countries. The black and blue vertical lines reflect the period of the *Tankrabatt* in Germany. Here, the discount on energy taxes is obviously passed on to the consumers to a larger extent, as there is a decreasing trend between June and August 2022 followed by a sharp rise in September. However, also the gasoline prices in the other three countries exhibit a decreasing trend without any similar government intervention. In general, the gasoline prices show a similar trend over time, mainly driven by the global oil prices.

We also include data on national overnight stays spent in a tourist accommodation as a proxy variable to account for intra-country variations that arise from vacations or holidays. Figure 5 illustrates these overnight stays, revealing a noticeable seasonal rise in the summer months of July and August. Additionally, in Austria and Switzerland, there is another peak occurring in winter driven by ski tourism.

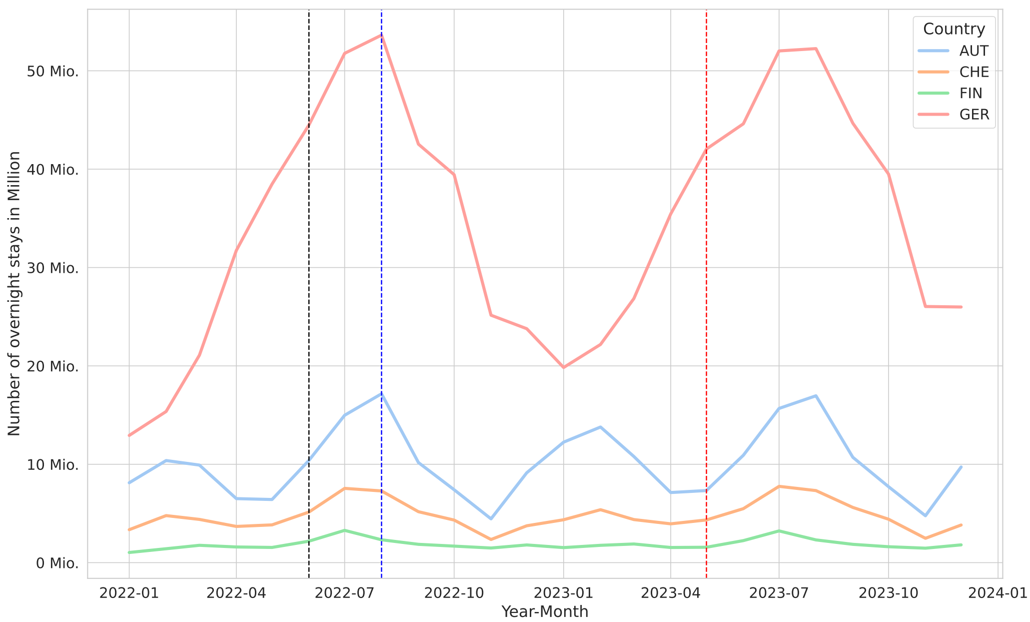

Figure 5: Development of the monthly number of overnight stays in Austria (AUT, blue line), Switzerland (CHE, orange line), Finland (FIN, green line) and Germany (GER, red line). The vertical black and blue lines mark the introduction and discontinuation of the *9-Euro-Ticket*, while the vertical red line marks the introduction of the *Deutschlandticket*.

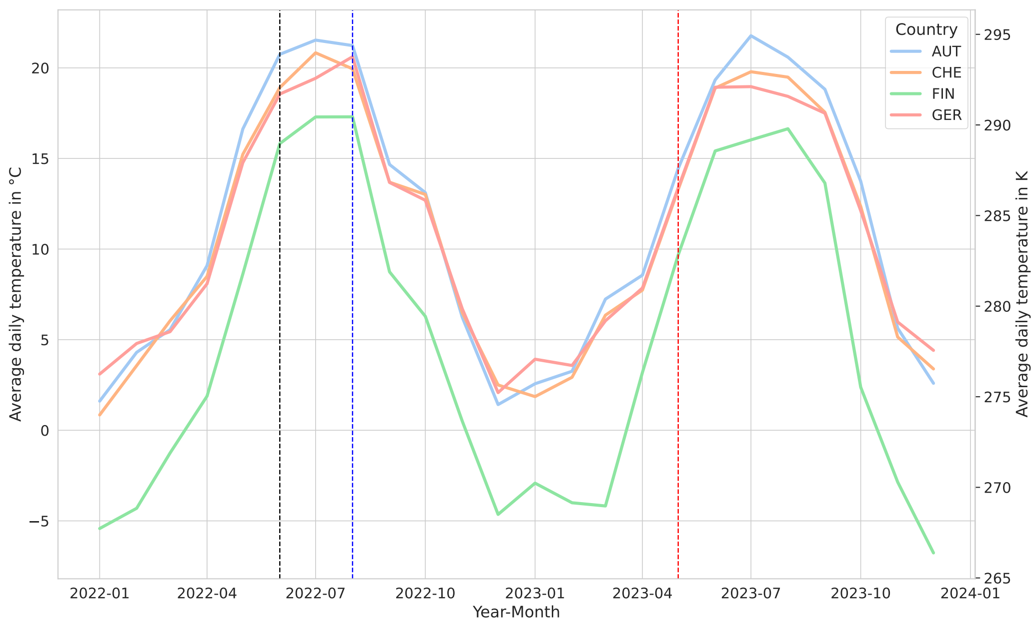

Figure 6: Development of daily average temperature (monthly average) in Austria (AUT, blue line), Switzerland (CHE, orange line), Finland (FIN, green line) and Germany (GER, red line). The vertical black and blue lines mark the introduction and discontinuation of the *9-Euro-Ticket*, while the vertical red line marks the introduction of the *Deutschlandticket*.

The previously introduced weather variables are also a part of our estimation strategy to rule out specific weather conditions at a certain counting point for a given month. Figure 6 visualizes the mean temperature on a country-month level. Temperature is presented in both Celsius (left ordinate) and Kelvin (right ordinate). Celsius is generally considered more intuitive in the social sciences. However, we posit that temperature may exert a non-linear influence on traffic patterns. This non-linearity could be incorporated into our model via a logarithmic transformation, which, however, is unsuitable for variables with negative values. In contrast, Kelvin is an absolute temperature scale with zero as the minimum value, and it can be derived from Celsius by subtracting 273.15.[22] As such, Kelvin maintains the incre-

[22] See, https://energyeducation.ca/encyclopedia/Temperature#:~:text=Celsius%20vs%20Kelvin,thermometer%20will%20read%20273.15%20K..

mental nature of the scale and can be further transformed logarithmically.

Figure 6 generally indicates that the four countries exhibit comparable cyclical patterns on a monthly average. Nevertheless, Finland's distinctly colder winter temperatures stand out in contrast to the three countries in Central Europe. This difference is further highlighted by the presence of ice days (see Figure B.1 in Appendix B).[23]

4 Methodology

In order to evaluate whether the introduction of the *9-Euro-Ticket* had a significant effect on highway passenger traffic in Germany, we apply a DiD approach. The DiD design is a quasi-experimental identification strategy for estimating causal effects and is extremely popular in applied work in economics (Angrist and Pischke, 2009). We rely on Austria and Switzerland as our control groups since both countries have very similar socio-economic conditions, a similar database, and no similar introduction of a very low-cost nationwide public transport ticket during our observation period.[24]

Throughout our analysis, we impose the stable unit treatment value assumption (SUTVA). This assumption implies that the potential outcome of a unit is not affected by the treatment of other units (Rubin, 1980). As the introduction of the *9-Euro-Ticket* should only affect the mobility behavior of German commuters, this policy should not have an impact on commuters in our control countries. Potential spillover effects could occur if individuals

[23]For a depiction of the country-wide average changes in wind speed, please see Figure B.2 in Appendix B.

[24]Finland will be utilized as a control group for robustness checks. See Section 6.4 for further details.

from the treatment country also adapt their travel behavior in the control countries due to the introduction of the *9-Euro-Ticket*. In order to control for any spillover effect of this policy, we use a proxy variable for holiday trips and the (lagged) fuel prices as covariates (see below). Furthermore, we impose the following identifying assumptions: conditional parallel trends under non-treatment, no-anticipation, and common support (Lechner et al., 2011).

First, the conditional parallel trends assumption states that in the absence of the treatment exposure, the mean potential outcome under non-treatment would be the same in the treatment and control groups, conditional on the covariates. In our analysis, this assumption implies that the traffic in Germany would have followed the same time trend as the traffic in Austria and Switzerland. Even though this assumption is not testable directly, we present some empirical support by presenting an event study below.

Second, the no-anticipation assumption imposes that the average causal effect of the *9-Euro-Ticket* must be zero in the baseline period, conditional on the covariates. In our case, the no-anticipation assumption states that German commuters should not adjust their mobility behavior in anticipation of the *9-Euro-Ticket* before the treatment is actually implemented. We can presume that this assumption holds since the introduction of the *9-Euro-Ticket* was approved by the German Parliament on May 19, 2022, only twelve days prior to its introduction.[25] We will further check this assumption in our event study and by assigning placebo treatments. And third, the common support assumption requires that Germany and the control countries are

[25]See https://www.bundestag.de/dokumente/textarchiv/2022/kw20-de-neun-euro-ticket-894660.

sufficiently comparable in terms of their covariates distributions, that is, there are comparable control units for every treated unit.

Under these assumptions, our baseline estimation approach is the following two-way fixed effects (TWFE) regression:

$$ln(T_{ijt}) = X'\beta + \tau \cdot Ticket_{jt} + \eta_{ij} + \lambda_t + \epsilon_{ijt}. \quad (1)$$

In equation (1), T_{ijt} denotes the highway passenger traffic of counting point i in country j at month t. The dummy variable $Ticket_{jt}$ is equal to one for the temporary introduction of the *9-Euro-Ticket* in Germany and 0 otherwise, so that τ gives the average treatment effect of the treated (ATT) for the introduction of the nationwide ticket (condtitional on covariates X).

The vector X' contains the covariates for the lagged gasoline prices (in logs), the mean daily temperature (in logs), the daily average wind speed (in logs) and the number of ice days of the nearest weather station as well as the number of nights spent at tourist accommodation (in logs), and the introduction of the long-term *Deutschlandticket* in May 2023[26]. The variable η_{ij} corresponds to country-counting point fixed effects to control for any time-invariant differences between counting points[27] and λ_t gives the time fixed effects to control for traffic seasonality. The model in equation (1) is estimated using standard errors that are clustered at the highway level.

We control for different weather conditions because these factors may impact traffic patterns in ways that are unrelated to the treatment. Ice days,

[26]See https://www.dw.com/en/germany-launches-49-monthly-public-transport-ticket/a-65225055.

[27]Each counting point is unique, regardless of the country in which it is located.

for instance, may lead to a reduction in traffic due to hazardous driving conditions, while extreme temperatures, whether hot or cold, can alter travel behavior by affecting people's decisions to drive, use public transportation, or avoid travel altogether. By accounting for spatial and temporal variations, we aim to ensure that changes in traffic volumes are not confounded by weather-related factors, which could otherwise bias the estimated effect of the *9-Euro-Ticket* or *Deutschlandticket*.

Moreover, we also apply an event study approach (dynamic DiD) to assess the effect of the *9-Euro-Ticket* on free- and highway traffic. This allows us to analyze the effect on car traffic dynamically over time and to check the key identification assumption of parallel trends in the absence of the *9-Euro-Ticket* introduction. The event study design is a frequently applied tool to evaluate policy treatments (see, e.g., Cunningham (2021), ch. 9.4). Hence, we include a set of interaction terms comprised of an indicator for whether the country is Germany and indicators for some months before and after the introduction of the *9-Euro-Ticket*. Let $\kappa \in \{\kappa_{-5}, ..., \kappa_{18}\}$ denote the months relative to the introduction of the *9-Euro-Ticket* in June 2022 (which is κ_0). We choose the month before the introduction of the ticket (κ_{-1}) as the omitted group, yielding the following equation:

$$ln(T_{ijt}) = X'\beta + \eta_{ij} + \lambda_t + \sum_{\kappa \neq \kappa_{-1}} \tau_\kappa \cdot D_{j,t\in\kappa} + \epsilon_{ijt}. \qquad (2)$$

Again, our dependent variable T_{ijt} denotes the highway passenger traffic of counting point i in country j at month t and the vector X' contains the same covariates as presented above. The variable η_{ij} corresponds to country-counting point fixed effects to control for any time-invariant differences between all country-counting points and λ_t gives the time fixed effects to control for traffic seasonality. The indicator variable $D_{j,t\in\kappa}$ is one if counting point i is in Germany and the month is κ. Thus, the coefficients τ_κ measure the estimated change in highway passenger traffic relative to May 2022 (κ_{-1}), the month before the *9-Euro-Ticket* introduction. Estimates of τ_κ close to zero in the pre-introduction months ($\kappa \in \{\kappa_{-2}, ..., \kappa_{-5}\}$) provide some evidence against concerning pre-trends.

In our analysis, we can also identify several heterogeneous effects of the *9-Euro-Ticket*. First, we can analyze day of the week effects to differentiate between commuter and tourist traffic. Thus, we will present four different estimation results for the equations (1) and (2) including different days of the week in our sub-samples. (see Section 5). Second, while we present the estimation results for all road classes in Section 5, we can also differentiate between freeways (e.g. *Autobahnen* in Germany) and highways (e.g. *Bundesstraßen* in Germany) in our data set. The corresponding heterogeneous estimation results for the individual road classes are presented in Section 6.1.

Third, we can differentiate among various federal states in Germany, such as Hesse and Bavaria. The outcomes of this analysis are detailed in Section 6.2. An additional analysis applies the synthetic differences-in-differences (SDiD) method, which combines the concepts of synthetic control (SC) and DiD to more robustly evaluate treatment effects, serving as an extension of our primary findings in Section 6.3. In this section, we will also provide some evidence for the introduction of the *Deutschlandticket*. At last, Section 6.4

will outline results including Finland as a control group.

5 Main Results

The results of our TWFE from equation (1) are outlined in Table 2. We estimate four different specifications including different days of the week in these sub-samples. The dependent variable in all four regressions is the logarithm of highway passenger traffic at counting point i in country j at month t. In the first specification (column (1)), we use the sub-sample including all days of the week so that we do not drop any counting data. We find a significant and negative treatment effect of 4.5% ($100 \cdot (e^{-0.0460} - 1) = 4.5\%$) on highway passenger traffic in Germany ($p < 0.05$). The *Deutschlandticket* seems to have a larger negative average impact on traffic, although this should not be interpreted as a causal effect here (see Section 6.3).

The *9-Euro-Ticket* effect remains relatively robust for the three other specifications the columns (2)-(4) in Table 2, in which we use sub-sampling to include specific days of the week. Nevertheless, the negative effect seems to be slightly larger on weekends (column (4)) compared to weekdays (columns (2) and (3)), giving some empirical support that this ticket has especially decreased tourist car traffic. Interestingly, this is completely different for the *Deutschlandticket*, which we will discuss in more detail in Section 6.3.

Furthermore, the estimators of our covariates X' presented in Table 2 are relatively similar across the four distinct specifications. The mean temperature has a positive effect on highway passenger traffic, which might be driven by more leisure activities due to warmer weather or a shift in transportation modes as the car might be more pleasant to use than public transport for high temperatures (cf. Section 3.1). The other two weather variables, wind speed and the number of frost days, have no statistically significant effect on highway passenger traffic.

As anticipated, there exists a positive correlation between the frequency of hotel overnight stays and passenger car traffic. This correlation is particularly pronounced during weekends (see column (4)). Finally, the lagged mean gasoline price seems to have a positive correlation with highway passenger traffic over time, which might be counterintuitive at first glance. However, we actually observe a simultaneous increase of gasoline prices and highway traffic over time in all countries included in our analysis. This observation might be supported by several empirical studies finding a relatively low price elasticity of gasoline for car drivers (Brons et al., 2008; Fridstrøm and Østli, 2021).

	Dependent variable: Traffic (1)	Dependent variable: Traffic (2)	Dependent variable: Traffic (3)	Dependent variable: Traffic (4)
9-Euro Ticket	−0.0460**	−0.0404**	−0.0411**	−0.0479*
	(0.0222)	(0.0193)	(0.0200)	(0.0248)
Deutschlandticket	−0.0816***	−0.0859***	−0.0830***	−0.0721***
	(0.0142)	(0.0129)	(0.0131)	(0.0157)
log Average Daily Mean Temperature in K	4.0675***	3.6159***	3.8118***	4.4275***
	(0.9130)	(0.7684)	(0.8027)	(1.1113)
log WindSpeed in m/s	0.0153	0.0152	0.0183	0.0160
	(0.0205)	(0.0185)	(0.0191)	(0.0236)
Number of Ice Days	−0.0006	−0.0014	−0.0012	0.0007
	(0.0021)	(0.0018)	(0.0019)	(0.0023)
log Super price (t-1)	0.2340***	0.2483***	0.2378***	0.2091***
	(0.0659)	(0.0580)	(0.0609)	(0.0804)
log Number of Nights Spend at Tourist Accommodation	0.0792***	0.0430***	0.0475***	0.1311***
	(0.0106)	(0.0083)	(0.0087)	(0.0146)
Observations	24936	24936	24936	24936
Adj. R2	0.9758	0.9749	0.9758	0.9745
FE: Year-Month	X	X	X	X
FE: Counting point	X	X	X	X
Weekdays	All	Tu to Thur	Mo to Fr	Fr to Su
Data Intervall	2022 and 2023	2022 and 2023	2022 and 2023	2022 and 2023

Standard errors (in parenthesis) are clustered at the highway level.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Difference-in-Differences estimation with log car traffic as dependent variable.

Figure 7: Event Study results based on Equation (2). The dependent variable is the logged car traffic on highways (using 95% confidence intervals). The vertical black and blue lines mark the introduction and discontinuation of the *9-Euro-Ticket*, while the vertical red line marks the introduction of the *Deutschlandticket*.

The regression results from our event study design in equation (2) are presented in Figure 7. The point estimators and their 95% confidence intervals are plotted and the estimated effects are relative to the month before the introduction of the *9-Euro-Ticket* in Germany (May 2022). The black and blue dashed vertical lines denote the start and expire date of the *9-Euro-Ticket* respectively, while the red dashed vertical line displays the start of the *Deutschlandticket*. The different colors of the point estimators and confidence intervals depict the results for the different weekday sub-samples (see Table 2).

The pre-treatment indicator dummies in Figure 7 are mostly close to the zero line and statistically insignificant, providing some empirical support for the necessary identification assumption of parallel trends in the absence of the *9-Euro-Ticket* introduction. For June 2022, the first month of the *9-*

Euro-Ticket, we find a significant total effect (red color) of this policy on highway passenger traffic in Germany, which seems to be rather driven by weekend (green) than weekday (yellow) effects. This again implies that the ticket was rather used by tourists than by commuters. Moreover, in the other two months of the policy, July and August 2022, the effect on highway passenger traffic becomes statistically insignificant for all four specifications, showing that the ticket only had a very temporary impact on modal shift in Germany.

After the *9-Euro-Ticket* has expired, the estimators are remaining close to zero and mostly insignificant until the follow-up ticket, the *Deutschlandticket*, has been introduced in May 2023 (red dashed vertical line). In the following months, this policy seems to reduce highway passenger traffic (still compared to May 2022) more stronger than the *9-Euro-Ticket*. However, also the *Deutschlandticket* seems to have no long-lasting effect as the estimators become insignificantly again from November 2023 on. This finding is further supported by Figure B.3 (Appendix B), in which we adjust the observation period to Jan. – Dec. 2023 and use April 2023 as base month to analyze the *Deutschlandticket* in an event study design.[28]

[28] We will further analyze the effect of the *Deutschlandticket* in a synthetic DiD design (see Section 6.3).

6 Extensions

6.1 Road Type

Subsequently, we proceed to assess the heterogeneous effects of the *9-Euro-Ticket* concerning the two road types freeway and highway. Based on our database, we can also classify the counting points into different road types. However, there is no clear definition of road classes that is valid in all countries. The German data includes traffic observations from freeways (*Bundesautobahn* (A)) and highways (*Bundesstraße* (B)). Since in Germany roads are classified mainly by the area of responsibility, the group of highways is very heterogeneous. Austrian traffic observations are grouped into *Autobahn* (A) and *Schnellstraße* (S), while observations in Switzerland can be distinguished into *Autobahn/-strasse* (A) and *Hauptstraße* (H).[29] The road classes covered in the Finnish data set that we use are *Valtatie* (VT) and *Kantatie* (KT). For the purpose of estimating possible heterogeneous effects, we match foreign road types with the German classification[30].

The TWFE regression results only including freeways are shown in Table 3. Obviously, the *9-Euro-Ticket* has no significant effect on freeway traffic individually for all four specifications. In contrast, the *Deutschlandticket* has a significant (negative) effect on freeway traffic, which is more pronounced on weekdays than on weekends.

[29]Swiss *Autobahn/-Autostrasse* form a segment of the *Nationalroad* category and are also identified with the label (N), `https://vignetteswitzerland.com/swiss-motorways/`.

[30]See Table A.2 for road class matches.

	Dependent variable: Traffic (1)	Dependent variable: Traffic (2)	Dependent variable: Traffic (3)	Dependent variable: Traffic (4)
9-Euro Ticket	−0.0077	−0.0074	−0.0074	−0.0052
	(0.0233)	(0.0199)	(0.0208)	(0.0264)
Deutschlandticket	−0.0761***	−0.0838***	−0.0827***	−0.0609***
	(0.0166)	(0.0157)	(0.0155)	(0.0179)
log Average Daily Mean Temperature in K	4.8853***	4.2502***	4.3987***	5.5591***
	(1.2982)	(1.0845)	(1.1293)	(1.5865)
log WindSpeed in m/s	0.0270	0.0262	0.0286	0.0291
	(0.0278)	(0.0251)	(0.0258)	(0.0317)
Number of Ice Days	0.0005	−0.0002	−0.0000	0.0016
	(0.0024)	(0.0020)	(0.0022)	(0.0028)
log Super price (t-1)	0.1442*	0.1534**	0.1554**	0.1214
	(0.0815)	(0.0714)	(0.0750)	(0.1002)
log Number of Nights Spend at Tourist Accommodation	0.0963***	0.0670***	0.0729***	0.1347***
	(0.0131)	(0.0102)	(0.0106)	(0.0185)
Observations	14232	14232	14232	14232
Adj. R2	0.9438	0.9475	0.9474	0.9352
FE: Year-Month	X	X	X	X
FE: Counting point	X	X	X	X
Weekdays	All	Tu to Thur	Mo to Fr	Fr to Su
Data Intervall	2022 and 2023	2022 and 2023	2022 and 2023	2022 and 2023

Standard errors (in parenthesis) are clustered at the highway level.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: DiD results with log car traffic as dependent variable, AUT and CHE as controls and only road type freeways (A).

Thus, the significant effect of the *9-Euro-Ticket* in our main estimations (see Section 5) seems to be rather driven by less traffic on German highways, which is confirmed by the TWFE results for this road type in Table 4. For highway traffic, the effect of the *9-Euro-Ticket* is significant in all four specifications, and even more pronounced than the *Deutschlandticket* effect. Besides, the effect of the *9-Euro-Ticket* on highway traffic is stronger on weekends than on weekdays. This again suggests that this ticket was frequently used by tourists for weekend trips in the summer of 2022, which has significantly reduced highway (but not freeway) traffic. This is completely different for the *Deutschlandticket* as it has a negative effect on both, highway and freeway traffic, while the effect is even slightly larger for weekdays compared to the weekend.

	Dependent variable: Traffic (1)	Dependent variable: Traffic (2)	Dependent variable: Traffic (3)	Dependent variable: Traffic (4)
9-Euro Ticket	−0.1360**	−0.1193**	−0.1191**	−0.1529**
	(0.0644)	(0.0575)	(0.0585)	(0.0700)
Deutschlandticket	−0.1122***	−0.1120***	−0.1069***	−0.1100***
	(0.0387)	(0.0360)	(0.0360)	(0.0410)
log Average Daily Mean Temperature in K	2.7201***	3.0142***	3.0269***	2.3434**
	(0.9767)	(0.9279)	(0.9446)	(1.0719)
log WindSpeed in m/s	−0.0050	0.0018	0.0014	−0.0123
	(0.0278)	(0.0285)	(0.0281)	(0.0284)
Number of Ice Days	−0.0019	−0.0022	−0.0023	−0.0009
	(0.0034)	(0.0031)	(0.0031)	(0.0037)
log Super price (t-1)	0.2752**	0.3577***	0.3015**	0.1753
	(0.1238)	(0.1291)	(0.1237)	(0.1184)
log Number of Nights Spend at Tourist Accommodation	0.0850***	0.0290	0.0355*	0.1645***
	(0.0281)	(0.0186)	(0.0201)	(0.0407)
Observations	10704	10704	10704	10704
Adj. R2	0.9492	0.9508	0.9512	0.9434
FE: Year-Month	X	X	X	X
FE: Counting point	X	X	X	X
Weekdays	All	Tu to Thur	Mo to Fr	Fr to Su
Data Intervall	2022 and 2023	2022 and 2023	2022 and 2023	2022 and 2023

Standard errors (in parenthesis) are clustered at the highway level.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: DiD results with log car traffic as dependent variable, AUT and CHE as controls and only road type highways (B).

We also present event study results separated for freeway (Figure 8) and highway (Figure 9) traffic. Figure 8 indicates that the *9-Euro-Ticket* only has a significant effect on freeway traffic in June 2022, while the effect is not significant in July and August at all. Moreover, the total effect (red color) in June is only driven by less freeway traffic on weekends (green), as the estimator is insignificant even in June for weekday freeway traffic (yellow and blue). In contrast, the *Deutschlandticket* seems to have a negative effect on freeway traffic at least in the first five months after its implementation.

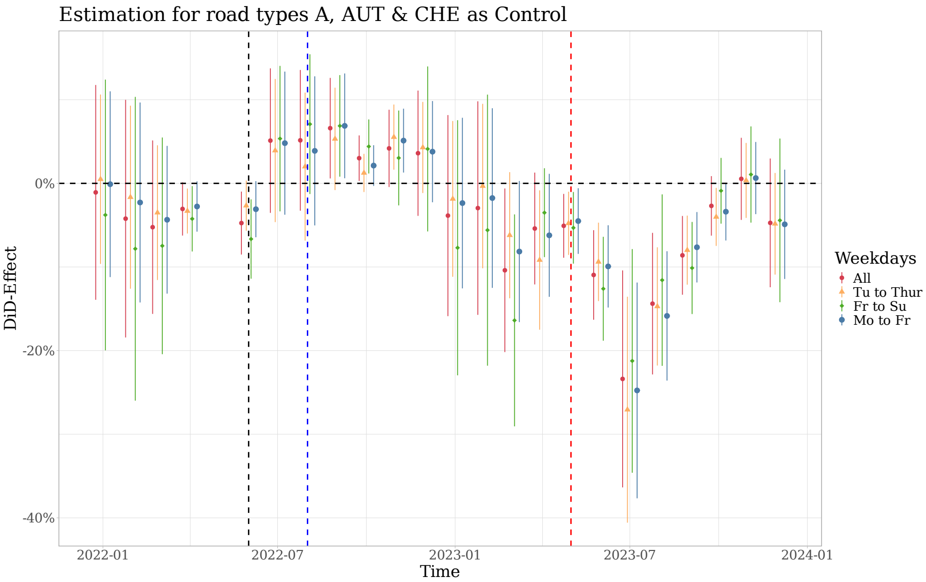

Figure 8: Event Study results based on Equation (2). The dependent variable is the logged car traffic on freeways (using 95% confidence intervals). The vertical black lines indicate the duration of the *9-Euro-Ticket*.

In Figure 9, we show the event study for highway traffic, which looks slightly different. First, the *9-Euro-Ticket* has a significant negative total effect in June and August 2022 on highway traffic, which again seems to be mostly driven by less weekend traffic. However, its worth mentioning that the parallel trends assumption does not hold individually for weekend highway traffic (see pre-trends in green in Figure 9), while this assumption holds again for the three other specifications. Once more, the *Deutschlandticket* has a longer lasting negative effect on highway traffic, even though there is no significant effect in the month of its implementation (May 2023), now.

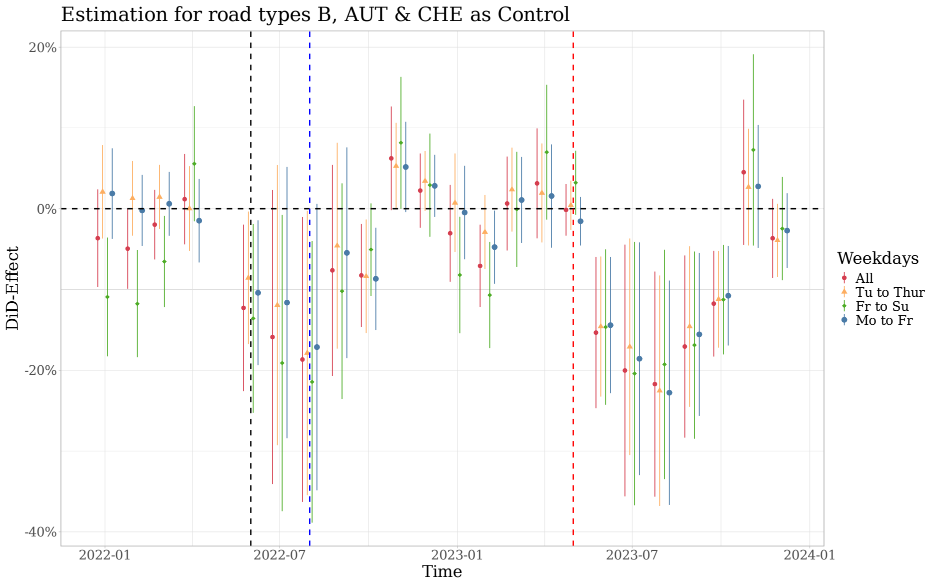

Figure 9: Event Study results based on Equation (2). The dependent variable is the logged car traffic on highways (using 95% confidence intervals). The vertical black lines indicate the duration of the *9-Euro-Ticket*.

6.2 Heterogeneity by Federal States

As an extension of our main event study approach in Section 5, we can also estimate heterogeneous treatment effects for the 16 German federal states individually. Therefore, we estimate equation (2) individually for any federal state. We present the corresponding event studies in Figure 10 including all days of the week as well as all road classes and using Austria and Switzerland as control countries again. The numbers next to the federal state acronyms in Figure 10 indicate the number of the respective counting points in this state.

As a first insight of Figure 10, for 8 of the 16 federal states we have considerably less than 100 counting points in our data set[31], hardly allowing us to interpret their estimation results at this geographic level, which are mainly insignificant anyway. For the eight remaining federal states, the parallel trends assumption seems to be fulfilled individually as the pre-trends are very close to zero and mostly insignificant. However, the significant treatment effect of the *9-Euro-Ticket* in Figure 7 for June 2022 (see Section 5) seems to be mainly driven by only four federal states: Baden-Wuerttemberg (BW), Hesse (HE), North Rhine-Westphalia (NW), and Thuringia (TH). The *9-Euro-Ticket* has no significant effect on highway passenger traffic at all in Bavaria (BY), Lower Saxony (NI), Rhineland-Palatinate (RP), and Saxony-Anhalt (ST).

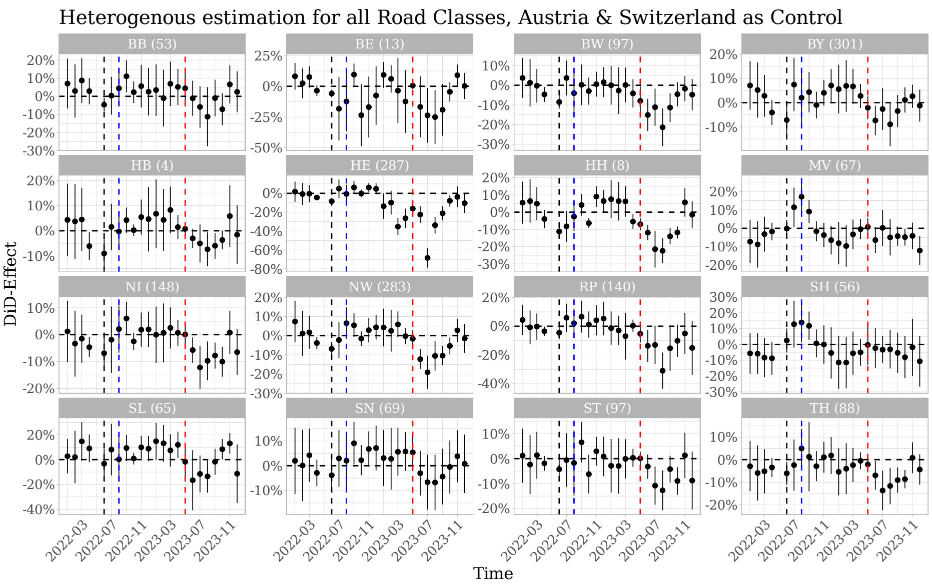

Figure 10: Event Study results based on Equation (2) for Austrian & Swiss counting points as control units. The dependent variable is the logged car traffic on highways per month (using 95% confidence intervals). The vertical black and blue lines mark the introduction and discontinuation of the *9-Euro-Ticket*, while the vertical red line marks the introduction of the *Deutschlandticket*.

[31]These are Brandenburg (BB), Berlin (BE), Bremen (HB), Hamburg (HH), Mecklenburg-Western Pomerania (MV), Schleswig-Holstein (SH), Saarland (SL), and Saxony (SN).

In the months between the end of the *9-Euro-Ticket* and the introduction of the *Deutschlandticket* in May 2023, there are almost no significant changes in highway passenger traffic in all federal states. Then, the *Deutschlandticket* again temporary reduces highway traffic in Germany in most of the eight federal states with more than 80 counting points, even though the values of the point estimator differ across the individual states. A special case is the Southern federal state Bavaria, for which rather the *9-Euro-Ticket* nor the *Deutschlandticket* seem to cause a significant effect in highway passenger traffic.[32] Overall, the results in this section again indicate the heterogeneity in the impact of very cheap public transport tickets on highway traffic.

6.3 Synthetic DiD Approach

To check the robustness of our main estimation results, we further apply the SDiD approach as suggested by Arkhangelsky et al. (2021). The SDiD differs from the so far applied DiD design by means of an additional weighting of control units and time periods. In the SDiD design, there is a greater emphasis on control units that are similar to treated units, as well as time periods that are similar to treated periods. The average causal effect of the *9-Euro-Ticket* is estimated as follows:

[32]Notably, Bavaria is among the German federal states with the lowest rail network density (in km of track per $\mathbf{km^2}$; see Figure B.5 in Appendix B). This underscores the importance of a dense rail network in facilitating a substantial modal shift. A focus on low ticket prices in public transport seems not to be sufficient, given the German rail infrastructure.

$$
(\hat{\tau}^{sdid}, \hat{\mu}, \hat{\alpha}, \hat{\beta}) = \\
\arg\min_{\tau,\mu,\alpha,\beta} \left\{ \sum_{i=1}^{N} \sum_{j=1}^{J} \sum_{t=1}^{T} (T_{ijt} - \mu - \alpha_i - \beta_t - X'_{ijt}\gamma - Ticket_{jt}\tau)^2 \hat{\omega}_i^{sdid} \hat{\lambda}_t^{sdid} \right\}. \tag{3}
$$

Including counting points from Austria and Switzerland, we obtain a balanced panel with $N = 1,039$ counting points, $J = 3$ countries and $T = 8$ months (Jan.-Aug. 2022). Since the approach is only designed for a persistent treatment, we cannot use observations after August 2022. As before, the variable T_{ijt} in equation (3) gives the traffic volume for counting point i in country j and month t (in logs), while the variables α_i and β_t denote counting point and time fixed effects, respectively, and μ is an intercept. The binary variable $Ticket_{jt}$ indicates the introduction of the ticket. The ATT is then given by τ. Moreover, the weights $\hat{\omega}_i^{sdid}$ and $\hat{\lambda}_t^{sdid}$ denote unit and time weights, respectively. The unit weights $\hat{\omega}_i^{sdid}$ are chosen in a way that the trend for traffic volumes of control units aligns with that of treated units in the pre-treament period. Similarly, the time weights $\hat{\lambda}_t^{sdid}$ are calculated to emphasize pre-treatment periods that are similar to treatment periods for units that are never treated.

	9-Euro-Ticket (1)		Deutschlandticket (2)	
	SDiD (no controls)	SDiD (with controls)	SDiD (no controls)	SDiD (with controls)
ATT	-0.1263	-0.0835	-0.0524	-0.0506
standard error	0.0149	0.0145	0.0079	0.0076

Table 5: Results SDiD including countries from the DACH-region. Standard errors have been bootstrapped with 100 iterations.

Column (1) in Table 5 summarizes the estimation output for the effect of the *9-Euro-Ticket* on traffic volumes with and without the inclusion of covariates.[33] We find an average effect of -0.0835 (with controls), implying that the *9-Euro-Ticket* significantly reduced traffic volumes by 8.01%.[34] The unit weights $\hat{\omega}_i^{sdid}$ used in the estimation are summarized in Table 6. Since the number of unique counting points in our data set is large, the weight assigned to any specific station is smaller than 1%. Therefore, we summarize the distribution of the 100 counting points with the greatest allocation of weights. Noticeably, these 100 units make up roughly 38% of total weights. Relying on the estimation that includes covariates, Austrian counting points cover 62% of the 100 greatest unit weights, while Swiss counting points make up 38%.

	no controls		with controls	
Country	weights	n	weights	n
AUT	0.2397	62	0.0744	20
CHE	0.1556	38	0.3083	80
Total	0.3953	100	0.3826	100

Table 6: Distribution of the 100 greatest unit weights $\hat{\omega}_i^{sdid}$ in SDiD estimation for the *9-Euro-Ticket* across the DACH region countries.

Figure 11 summarizes the result of our SDiD estimation graphically. As explained above, using unit weights puts a greater emphasis on control units that develop similarly compared to treated units, therefore having the parallel trends assumption hold. Together with the time weights displayed by the

[33]As in the previous estimations, the set of covariates includes average daily temperature, wind speed, the number of ice days, gasoline prices of the previous month (in logs) and the number of nights stayed at tourist accommodations (in logs).

[34]The exact effect size is calculated as follows: $100 \times (e^{-0.0835} - 1) = -8.01\%$.

red area below the black line, the causal effect is calculated as presented in equation (3). It is indicated by the black arrow in Figure 11.

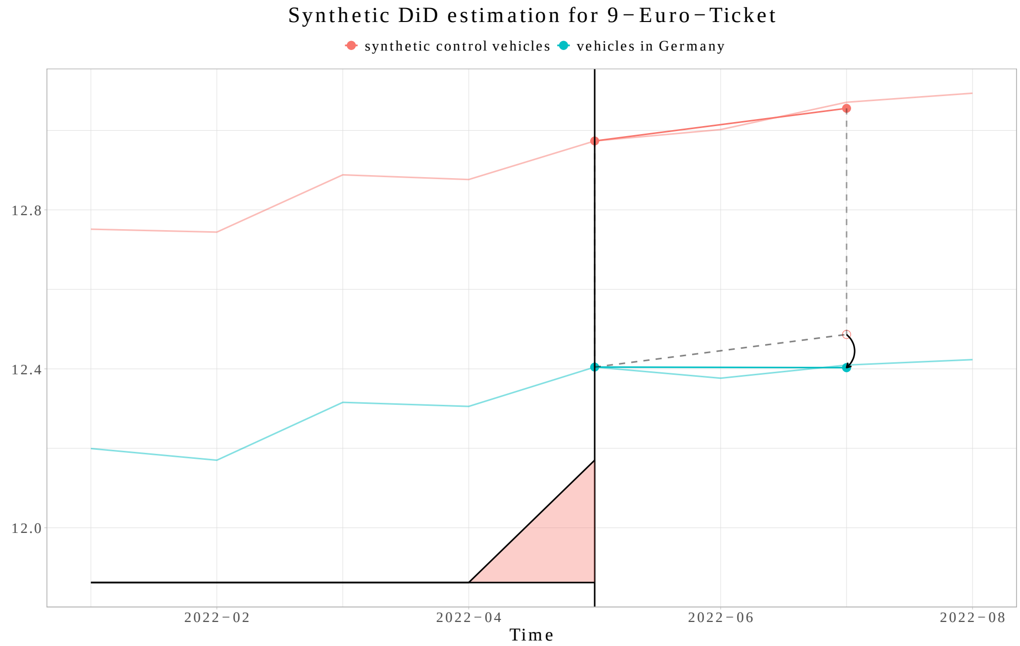

Figure 11: Results of the SDiD estimation. The red area displayed at the bottom shows the time weights $\hat{\lambda}_t^{sdid}$.

In a second step, we employ the same approach as above to estimate the average treatment effect of the treated (ATT) of the *Deutschlandticket*, which has been introduced in May 2023 and is still in place to date. Table 5 shows the corresponding estimation results in column (2). Regardless of the inclusion of covariates, the introduction the *Deutschlandticket* causes a significant reduction in highway traffic of approx. 5%.

The difference in the size of our estimations results using the SDiD approach compared to the DiD design displayed in Section 5 can be explained as follows. One obvious difference can be traced back to the weighting on control units and time periods. Especially, the focus on time periods that omit the winter months entirely (particularly large time weights for April and May 2022, as shown in Figure 11 for the *9-Euro-Ticket*) marks an important difference compared to our (dynamic) DiD in Section 5.[35]

6.4 Alternative Control Group

Our database allows to use Finland as an alternative control country to employ a further extension of our empirical approach. Even though Finland is less similar to Germany compared to Austria or Switzerland in terms of socio-economic aspects, one major advantage is that we do not expect spillover effects between Germany and Finland. This means that the SUTVA should not be violated and we might assume that traffic in Finland is not influenced by the introduction of the *9-Euro-Ticket* at all (cf. Section 4).

As above, we estimate the TWFE regression given in equation (1). Using only Finland as the control group, we obtain a panel data set of 26,712 observations from January 2022 to December 2023. Table 7 summarizes the estimation results for our four sub-samples. The results obtained in this estimation range from 3.98% to 5.77%. They are of similar effect size compared to our main estimation, although the effect is now mainly driven by a reduction of traffic during weekdays while we cannot observe a significant effect on weekends.[36]

[35]An analogous scenario is given for the *Deutschlandticket*, as illustrated in Figure B.6.

[36]Regarding the covariates, the estimated effects are of similar magnitude as in the main estimation for both mean temperature and gasoline price. The other weather-related covariates (wind speed and the number of ice days) now have a statistically significant effect on traffic volumes, which might be explained by the larger variation in these variables in both countries (see Figure B.1).

	Dependent variable: Traffic (1)	Dependent variable: Traffic (2)	Dependent variable: Traffic (3)	Dependent variable: Traffic (4)
9-Euro Ticket	−0.0406***	−0.0594***	−0.0442***	−0.0123
	(0.0110)	(0.0117)	(0.0109)	(0.0117)
Deutschlandticket	−0.0879***	−0.1086***	−0.0993***	−0.0677***
	(0.0094)	(0.0105)	(0.0100)	(0.0092)
log Average Daily Mean Temperature in K	2.5041***	2.9162***	2.7259***	1.9989***
	(0.4979)	(0.4970)	(0.4868)	(0.5425)
log WindSpeed in m/s	−0.0524***	−0.0569***	−0.0477***	−0.0469***
	(0.0114)	(0.0125)	(0.0121)	(0.0112)
Number of Ice Days	−0.0050***	−0.0065***	−0.0059***	−0.0031***
	(0.0011)	(0.0011)	(0.0010)	(0.0011)
log Super price (t-1)	0.1800**	0.1781**	0.2213***	0.2092***
	(0.0716)	(0.0694)	(0.0682)	(0.0772)
log Number of Nights Spend at Tourist Accommodation	0.0780**	0.1020***	0.0832***	0.0579
	(0.0334)	(0.0303)	(0.0297)	(0.0390)
Observations	26712	26712	26712	26712
Adj. R2	0.9823	0.9814	0.9823	0.9808
FE: Year-Month	X	X	X	X
FE: Counting point	X	X	X	X
Weekdays	All	Tu to Thur	Mo to Fr	Fr to Su
Data Intervall	2022 and 2023	2022 and 2023	2022 and 2023	2022 and 2023

Standard errors (in parenthesis) are clustered at the highway level.
* p < 0.1, ** p < 0.05, *** p < 0.01

Table 7: Estimation results of the TWFE regression using only Finnish counting points as control units.

In a next step, we apply the SDiD approach to our extended sample using Austrian, Swiss and Finnish counting points as possible control units. Including all observations from these countries, we obtain a balanced panel with $N = 1,416$ counting points, $J = 4$ countries and $T = 8$ (for the *9-Euro-Ticket*) or $T = 16$ (for the *Deutschlandticket*) months (see equation (3) in Section 6.3). Table 8 summarizes the estimated effects with column (1) representing the results for the *9-Euro-Ticket* and column (2) displaying the estimates for the longer lasting *Deutschlandticket*. Compared to our SDiD estimation in Section 6.3, we obtain a similar effect size for the *Deutschlandticket*. However, the ATT of -10.99%[37] for the *9-Euro-Ticket* is larger in this approach.

Again, these differences can arise due to the different weighting scheme applied in the SDiD approach compared to the (dynamic) DiD design. Especially the weighting of time periods, which in this case agains emphasizes the months April and May, can affect the estimation results. Second, adding Finnish traffic data to our pool of possible control units, we find a greater

[37] See also Figure B.7 in Appendix B.

weighting of highways due to the fact that there are only few roads that classify as freeways in Finland (see Table 9 for a summary of the weights). The larger ATT in Table 8 is mainly driven by the road type highway. This can be further analyzed by subsampling the data for the different road types and employing the SDiD as above (see Tables A.4 and A.5 for the corresponding results).

	9-Euro Ticket (1)		Deutschlandicket (2)	
	SDiD (no controls)	SDiD (with controls)	SDiD (no controls)	SDiD (with controls)
ATT	-0.1022	-0.1164	-0.0559	-0.0581
standard error	0.0109	0.0120	0.0070	0.0068

Table 8: Results SDiD including countries from the DACH region and Finland.

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	no controls		with controls	
Country	weights	n	weights	n
AUT	0.0462	24	0.0292	13
CHE	0.1075	51	0.0466	21
FIN	0.0520	25	0.1320	66
Total	0.2058	100	0.2078	100

Table 9: Distribution of the 100 greatest unit weights $\hat{\omega}_i^{sdid}$ in SDiD estimation for the *9-Euro-Ticket* across countries.

7 Discussion

The results of our paper indicate a significant reduction in highway traffic of approximately 4.5% during the period of the *9-Euro-Ticket*. We find that this effect is very heterogeneous over time, with respect to the day of the week, across the 16 German federal states, and by road types. We find similar results for the follow-up ticket, the *Deutschlandticket*, even though its effect is longer lasting and is not primarily driven by less weekend traffic or a specific road type.

The observed reduction in highway traffic can most plausibly be attributed to an increased substitution of private car journeys with public transport, as evidenced by earlier studies (Liebensteiner et al., 2024; Loder et al., 2024). However, our findings imply that there is no long-term modal shift triggered by both ticket types. In our dynamic analysis, we only find a significant effect on highway traffic for the first month of the intervention (June 2022), which is mainly driven by four German federal states. Moreover, the negative average treatment effect of the *9-Euro-Ticket* is mainly driven by less holiday traffic on weekends on highways (*Bundesstraßen*) rather than German freeways (*Autobahnen*). Hence, this temporary intervention does not appear to be sufficient to achieve a lasting modal shift from the car to public transport for commuter trips, which is in line with Ortega and Link (2025).

Our findings suggest that the *9-Euro-Ticket* as a temporary intervention has only initiated a *follow-the-crowd effect* by many consumers in the first month of its intervention, followed by decreasing demand in July and August 2022.[38] This might be explained by the theory of information cascades, in which individuals make the same decisions regardless of their private information (Anderson and Holt, 1997). In summer 2022, the media coverage of this intervention and, thus, the topic salience has been quite large in Germany.[39] Even though the modal shift effect of the *Deutschlandticket* is lasting for

[38] See https://mcc-berlin-ariadne.shinyapps.io/dticket-tracker/.

[39] See, e.g., https://www.nytimes.com/2022/08/15/world/europe/germanys-trains-9euro-pass.html.

a few months in 2023, our event study results suggest that also this ticket successor causes no long-term modal shift.

In general, our results imply that it is questionable whether the German government has reached its environmental goal of providing an incentive to switch from the car to public transport. Evaluations from survey data indicate that only 10% of the ticket users have not used public transport before the intervention anyway.[40] Moreover, the missing price signal from the demand side has caused a lower service quality during the *9-Euro-Ticket* period due to capacity issues and train delays, as shown by Liebensteiner et al. (2024).

Lastly, also the fiscal policy perspective of both, the *9-Euro-Ticket* and the *Deutschlandticket* remains, skeptical. While the one-time costs of the former has been 2.5 billion euros for the government, the German tax payers spend 3 billion euros per year for the Deutschlandticket.[41] At the same time, the transport companies and municipalities lack money to improve the rail infrastructure due to the reduced revenues. Krebs and Steitz (2021) calculate that a total of 50 billion euros is required for the expansion and digitization of the German rail network from the German government alone until 2030. Hence, also in light of the findings of this paper, it may be economically more meaningful to allocate these funds toward supply-side investments in the public transport sector.

[40]See https://de.statista.com/infografik/30102/derzeitiger-anteil-deutschlandticket-nutzer_innen-nach-vorheriger-oepnv-nutzung/.

[41]The direct costs are split between the German government and the 16 federal states (see https://www.blog-bpoe.com/2024/10/28/wege-aus-der-krise-innovation-wohnungsbau-und-arbeitsanreize/).

8 Conclusion

In this paper, we find that the introduction of the *9-Euro-Ticket* in Germany led to an approximately 4.5% reduction in highway passenger traffic, primarily due to a shift to public transport on weekends. This effect is very heterogeneous over time and across the 16 German federal states. Our results imply a similar effect for the *Deutschlandticket*, even though this effect seems to be longer lasting and not mainly driven by less weekend traffic or a specific road type. These findings are also robust in a synthetic DiD design for both ticket types.

The results of our study might have important implications for policy formulation in the fields of transportation and climate policies. First, they imply that almost fare-free transport tickets can effectively stimulate modal shift from private cars to public transport, at least temporarily. Simplified tariff structures in the public transport sector can encourage usage and facilitate decision-making for a certain group of travelers. However, the results of our event studies imply that there is no longer lasting modal shift caused by both ticket types. In particular, such an intervention does not seem to be sufficient to reach a long-term modal shift from car to public transport for commuters (given the traffic infrastructure in Germany). Especially, the ticket does not seem to be a real alternative for commuters in rural areas, where public transport is insufficiently developed in Germany.[42]

Hence, the efficiency of this governmental intervention as a whole remains questionable, not least through its high direct costs. Given the necessary in-

[42] See https://www.vdv.de/evaluationsbericht-deutschland-ticket-2023.pdfx?forced=true, p.7.

vestments to improve the German rail infrastructure in the near future, it might be more meaningful to spend these tax revenues for long-term and supply-side investments into the public transport sector. Furthermore, the absence of a price signal from the demand side has contributed to a decrease in service quality throughout the *9-Euro-Ticket* period, attributable to capacity constraints and train delays during peak hours.(Liebensteiner et al., 2024).

A limitation of our study is the lack of individual-level travel data, which prevents a more granular analysis of user behavior across different demographics. Future research could investigate long-term behavioral changes induced by, e.g., the *Deutschlandticket* and explore how similar policies affect rural versus urban mobility. Moving forward, policymakers should carefully monitor the long-term sustainability and financial implications of such temporary initiatives and also take into account the effect of such a ticket on the price mechanism in this market. Evidence-based policy is essential for a functioning transport sector and a sustainable economic policy in general.

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A Appendix: Additional Tables

Country	Road Class	Number of Unique Road Classes: Balanced	(Observed: Balanced + Unbalanced)	Raw	Coverage: Balanced-to-Observed	Observed-to-Raw
AUT	A	20	22	25	90.91%	80.00%
	S	9	13	14	69.23%	64.29%
CHE	A	16	17	30	94.12%	53.33%
	H	31	40	56	77.50%	55.36%
FIN	KT	29	32	43	90.62%	67.44%
	VT	28	28	28	100.00%	100.00%
GER	A	69	102	121	67.65%	57.02%
	B	191	264	439	72.35%	43.51%
All		393	518	756	75.87%	51.98%

Table A.1: Number of unique road classes per country. *Raw* refers to counting points available in the unfiltered information from our data providers A.3.

Country	Road Class	Road Class (Matched)	N	Mean	Percent
AUT	A	A	2664		7.84
	S	A	456		1.34
CHE	A	A	2904		8.55
	H	B	1248		3.67
FIN	KT/A	A	360		1.06
	KT/B	B	1224		3.6
	VT/A	A	3864		11.4
	VT/B	B	3600		10.6
GER	A	A	8208		24.2
	B	B	9456		27.8
		All	33984		100

Table A.2: To determine the number of counting points for each country and road category, divide N by 24 (representing the number of months).

Country	Data Type	Source
Germany	Counting points	*BASt*
	Borders	https://www.suche-postleitzahl.org/downloads
	Borders	https://github.com/plzTeam/web-snippets/blob/master/plz-suche/data/zuordnung_plz_ort.csv
	Roads	https://www.bast.de/DE/Verkehrstechnik/Fachthemen/Daten/Daten-BISStra.html?nn=1817946
Austria	Counting points	*ASFiNAG*
	Borders	https://www.data.gv.at/katalog/dataset/51bdc6dc-25ae-41de-b8f3-938f9056af62#resources
	Roads	https://hub.arcgis.com/datasets/SynerGIS::gip-autobahnen/about
Switzerland	Counting points	*ASTRA*
	Borders	https://www.swisstopo.admin.ch/de/landschaftsmodell-swissboundaries3d#swissBOUNDARIES3D---Download
	Roads	https://data.geo.admin.ch/browser/index.html#/collections/ch.astra.nationalstrassenachsen/items/nationalstrassenachsen?.asset=asset-nationalstrassenachsen_2056.gdb.zip
Finland	Counting points	Fintraffic: https://tie.digitraffic.fi/api/tms/v1/stations
	Borders	https://simplemaps.com/gis/country/fi
	Roads	https://vayla.fi/en/transport-network/data/open-data/transport-network-data

Table A.3: Sources for the data used in the spatial distribution of traffic counting points.

	9-Euro Ticket (1)		Deutschlandticket (2)	
	SDiD (no controls)	SDiD (with controls)	SDiD (no controls)	SDiD (with controls)
ATT	-0.0671	-0.0402	-0.0576	-0.0519
standard error	0.0128	0.0117	0.0086	0.0087

Table A.4: Results for SDiD including all countries, but only freeways (A).

	9-Euro Ticket (1)		Deutschlandticket (2)	
	SDiD (no controls)	SDiD (with controls)	SDiD (no controls)	SDiD (with controls)
ATT	-0.1718	-0.1885	-0.0458	-0.0684
standard error	0.0202	0.2882	0.0108	0.0095

Table A.5: Results SDiD including all countries, but only highways (B). Note: Our data does not contain B-roads for Austria.

B Appendix: Additional Figures

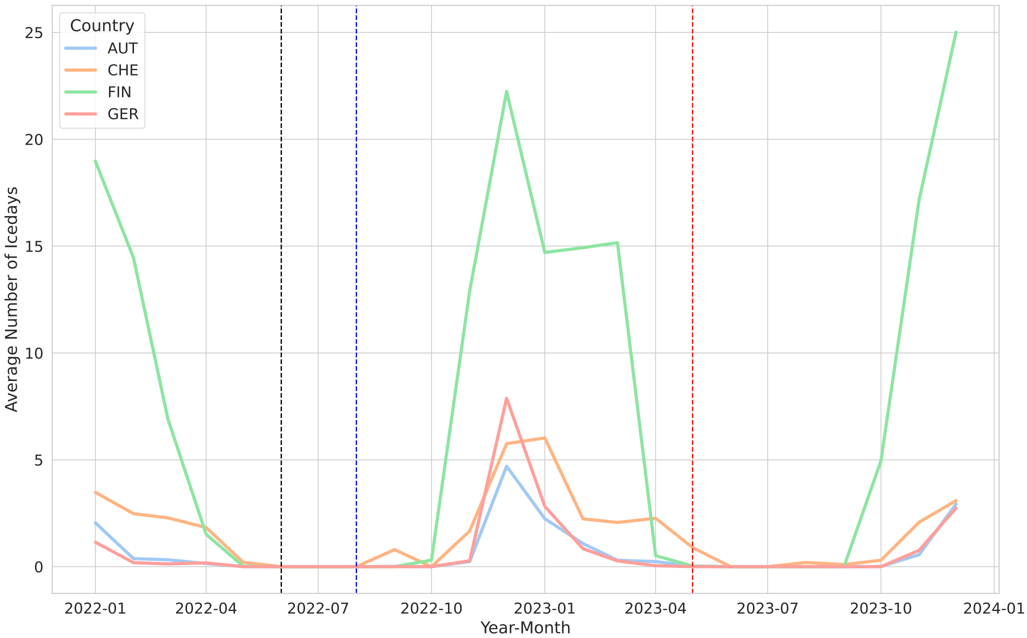

Figure B.1: Development of the number of ice days (monthly average) in Austria (AUT, blue line), Switzerland (CHE, orange line), Finland (FIN, green line) and Germany (GER, red line). The vertical black and blue lines mark the introduction and discontinuation of the *9-Euro-Ticket*, while the vertical red line marks the introduction of the *Deutschlandticket*.

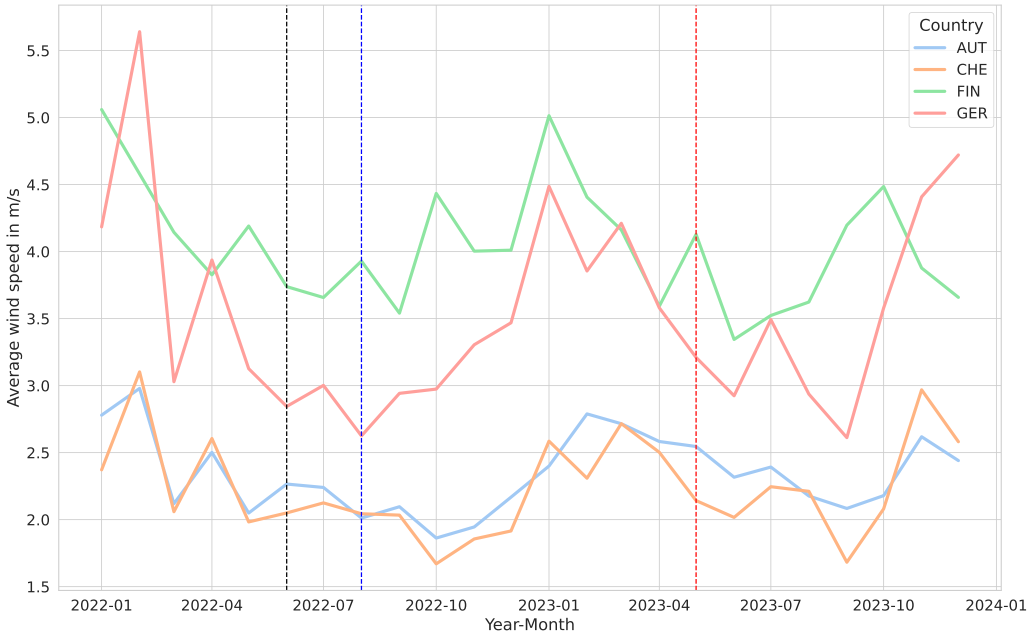

Figure B.2: Development of the wind speed (monthly average) in Austria (AUT, blue line), Switzerland (CHE, orange line), Finland (FIN, green line) and Germany (GER, red line). The vertical black and blue lines mark the introduction and discontinuation of the *9-Euro-Ticket*, while the vertical red line marks the introduction of the *Deutschlandticket*.

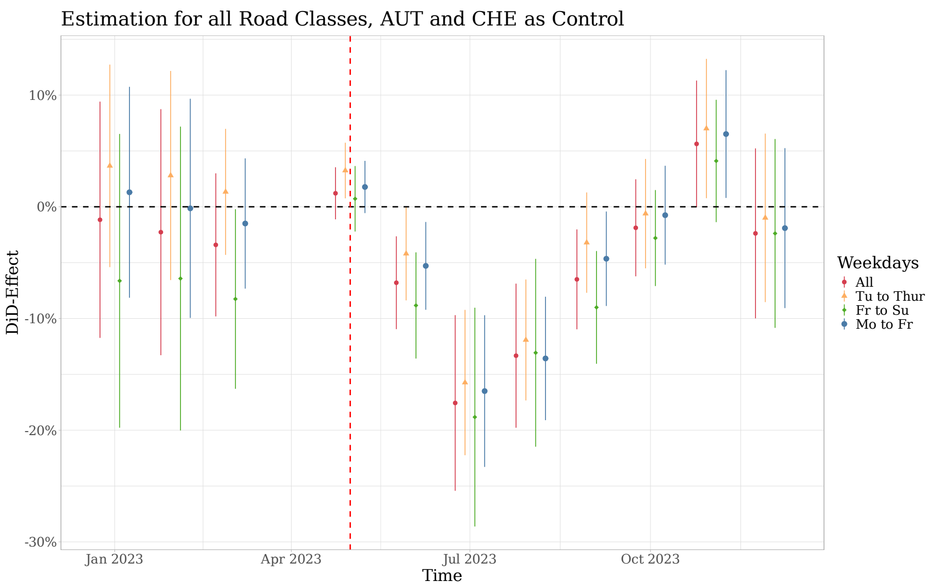

Figure B.3: Event Study results based on Equation (2). The dependent variable is the logged car traffic on freeways and highways (using 95% confidence intervals). The vertical red line marks the introduction of the *Deutschlandticket*. April 2023 serves as the reference period.

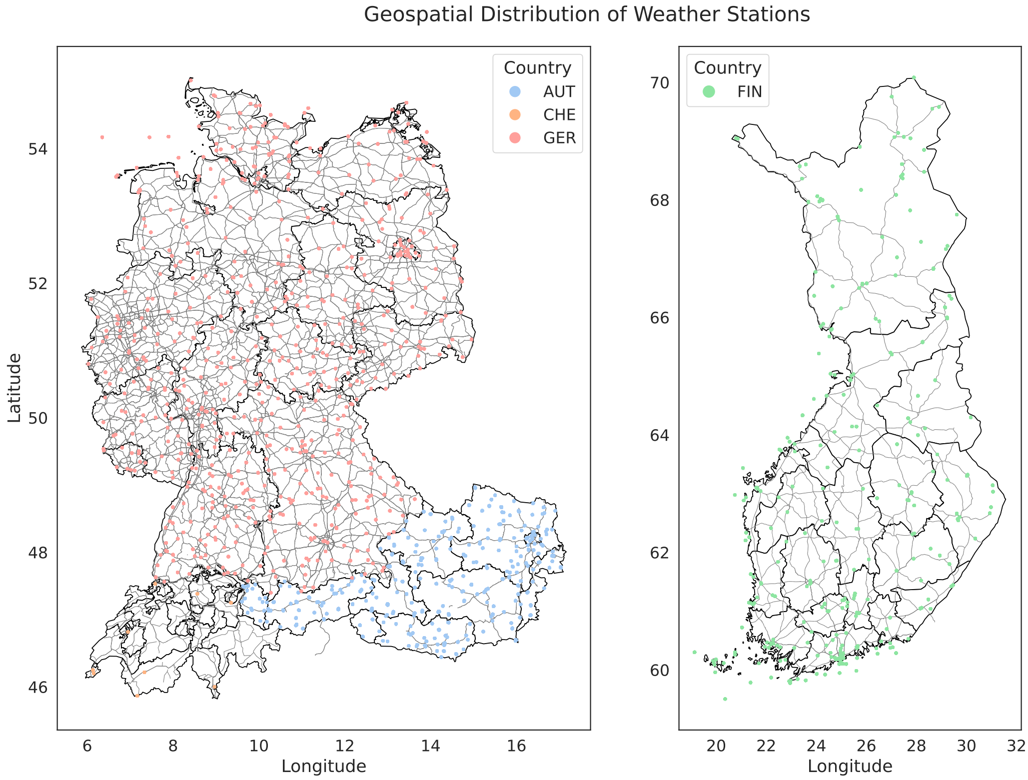

Figure B.4: Geospatial distribution of weather stations across Germany (red), Austria (blue), Switzerland (orange), and Finland (green). The maps display the locations of weather stations (colored points) overlaid on road networks, with colors distinguishing different countries.

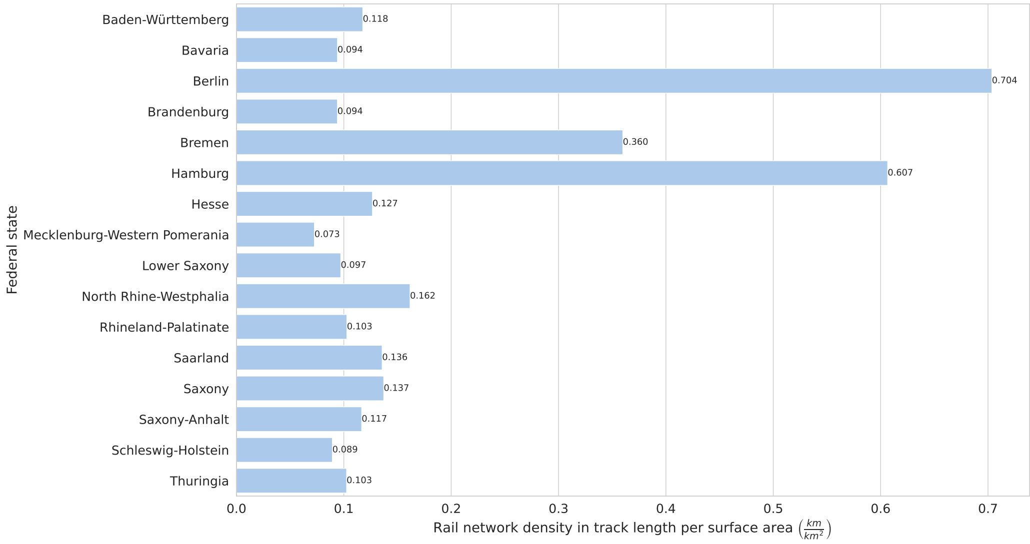

Figure B.5: Rail network density in Germany, measured as track length per surface area $\left(\frac{km}{km^2}\right)$, for each federal state. Urban states like Berlin and Hamburg exhibit the highest densities, while larger, rural states have lower values. Sources: Track lengths from 2020 (https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Transport-Verkehr/Unternehmen-Infrastruktur-Fahrzeugbestand/Tabellen/schieneninfrastruktur.html) and surface area from 2022 (https://www.statistikportal.de/de/bevoelkerung/flaeche-und-bevoelkerung).

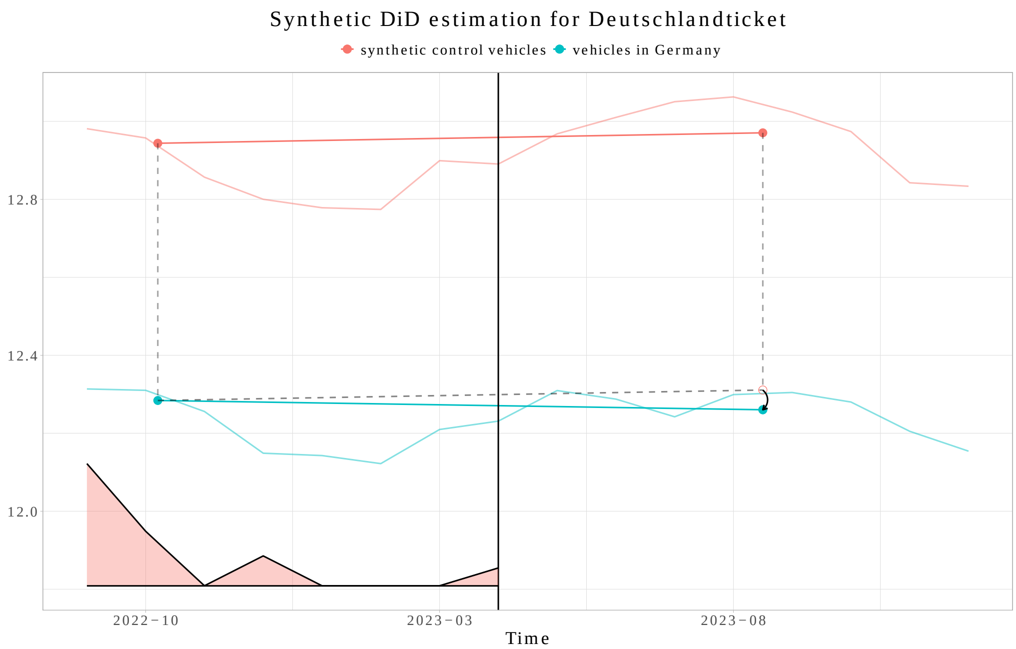

Figure B.6: Results of the SDiD estimation covering the DACH-region. The red area displayed at the bottom shows the time weights $\hat{\lambda}_t^{sdid}$.

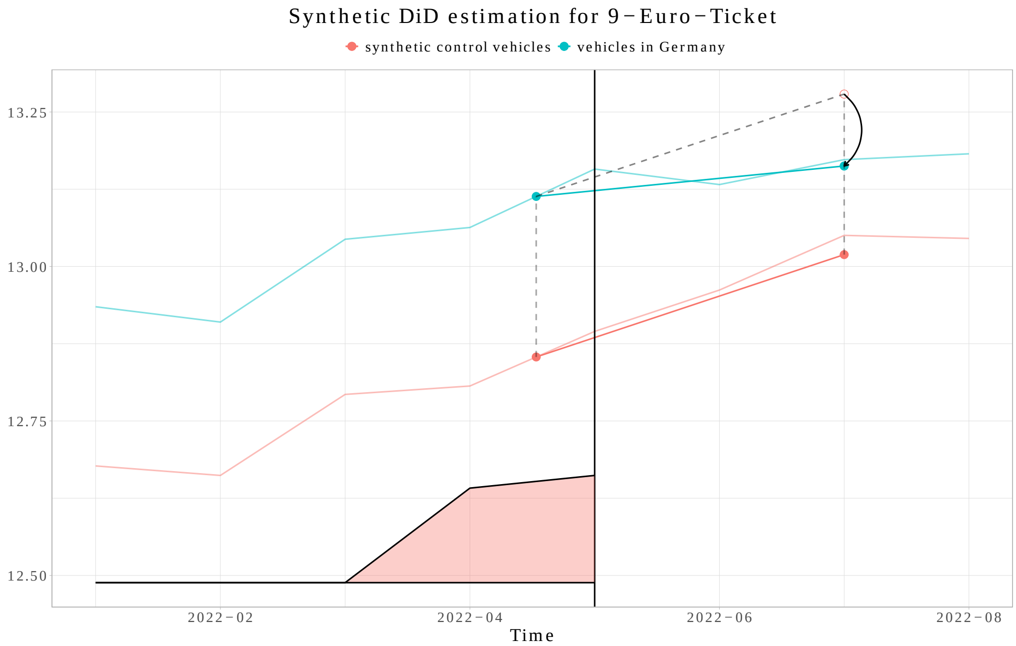

Figure B.7: Results of the SDiD estimation covering the DACH-region and Finland. The red area displayed at the bottom shows the time weights $\hat{\lambda}_t^{sdid}$.