A NATION-WIDE EXPERIMENT: FUEL TAX CUTS AND ALMOST FREE PUBLIC TRANSPORT FOR THREE MONTHS IN GERMANY - REPORT 5 INSIGHTS INTO FOUR MONTHS OF MOBILITY TRACKING

Abstract

In spring 2022, the German federal government agreed on a set of measures that aim at reducing households’ financial burden resulting from a recent price increase, especially in energy and mobility. These measures include among others, a nation-wide public transport ticket for 9 EUR per month and a fuel tax cut that reduces fuel prices by more than 15%. In transportation research this is an almost unprecedented behavioral experiment. It allows to study not only behavioral responses in mode choice and induced demand but also to assess the effectiveness of transport policy instruments. We observe this natural experiment with a three-wave survey and an app-based travel diary on a sample of hundreds of participants as well as an analysis of traffic counts. In this fifth report, we present first analyses of the recorded tracking data. 910 participants completed the tracking until September, 30th. First, an overview over the socio-demographic characteristics of the participants...
within our tracking sample is given. We observe an adequate representation of female and male participants, a slight over-representation of young participants, and an income distribution similar to the one known from the "Mobilität in Deutschland" survey \[1\]. Most participants of the tracking study live in Munich, Germany. General transportation statistics are derived from the data for all phases of the natural experiment – prior, during, and after the 9 EUR-Ticket – to assess potential changes in the participants’ travel behavior on an aggregated level. A significant impact of the 9 EUR-Ticket on modal shares can be seen. An analysis of the participants’ mobility behavior considering trip purposes, age, and income sheds light on how the 9 EUR-Ticket impacts different social groups and activities. We find that age, income, and trip purpose significantly influence the impact of the 9 EUR-Ticket on the observed modal split.

1 Introduction

In transportation research, it is quite unlikely to observe or even perform real-world experiments in terms of travel behavior or traffic flow. There are few notable exceptions: subway strikes suddenly make one important alternative mode not available anymore \[2,3\], a global pandemic changes travelers’ preferences for traveling at all or traveling collectively with others \[4\], or a bridge collapse forces travelers to alter their daily activities \[5\]. However, in 2022 the German federal government announced in response to a sharp increase in energy and consumer prices a set of measures that partially offset the cost increases for households. Among these are a public transport ticket at 9 EUR per month \[1\] for traveling all across Germany in public transport, except for long-distance train services (e.g., ICE, TGV, night trains), as well as a tax cut on gasoline and diesel, resulting in a cost reduction of about 15% for car drivers \[2\]. Both measures are limited to three months, namely June, July and August 2022. As of mid June, more than 16 million tickets have been sold \[3\] while it seems that the fuel tax cut did not reach consumers due to generally increased fuel prices and oil companies are accused of not forwarding the tax cuts to consumers \[4\].

For the Munich metropolitan region, Germany, we designed a study comprising three elements. The three elements are: (i) a three-wave survey before, during and after the introduction of cost-saving measures; (ii) a smartphone app based measurement of travel behavior and activities during the same period; (iii) an analysis of aggregated traffic counts and mobility indicators. We will use data from 2017 (pre-COVID-19) and data from shortly before the cost reduction measures as the control group. In addition, the three-wave survey is presented to a German representative sample. The main goal of the study is to investigate the effectiveness of the cost-saving measures with focus on the behavioral impact of the 9 EUR-Ticket on mode choice \[6\], rebound effects \[7, 8\], and induced demand \[9\]. Further details on the study design and the first results can be found in our four previous reports \[10, 11, 12, 13\].

In this fifth report, we first provide an assessment of the sociodemographics of the sample group actively using our smartphone tracking app in Section 2. In Section 3 we supply aggregated transportation statistics from the tracking data that has been recorded from beginning of the experiment to end of September 2022. Section 4 analyzes the mobility of the participants regarding their spatio-temporal activity behavior taking into account the different socio-demographic groups among our participants. The results of the exploratory data analysis presented herein, are discussed in Section 5.

2 Tracking Participants

This section elaborates on the socio-economic characteristics of the 910 GPS-tracked participants who took part in the study from May 24, 2022 via the “Mobilität.Leben” smartphone application available on iOS and Android devices and recorded at least one trip until September 30, 2022. All socio-economic parameters were self-reported by the participants within the survey phase of the study. For general results of this phase, the interested reader is referred to our previous report \[11\]. This evaluation especially focuses on the tracked participants, constituting a subsample of all surveyed participants.

\[https://www.bundesregierung.de/breg-de/aktuelles/9-euro-ticket-2028756\]
\[https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Schlaglichter/Entlastungen/schnelle-spuerbare-entlastungen.html\]
\[https://www.tagesschau.de/wirtschaft/unternehmen/neun-euro-ticket-135.html\]
\[https://apnews.com/article/politics-business-germany-prices-deb85a000d63cd57b76446d9c90c3e18\]
2.1 Age Distribution of Participants

Figure 1 shows the relative age distribution of male and female participants within our tracking sample. For reference, the demographic age distribution for Germany in 2022 is depicted. Comparing the age distribution of our study group with the German age distribution, the following observations can be made: for male participants between 40 to 80 years, the participant distribution aligns well with the German age distribution, whereas participants of both genders with an age between 20 and 40 are over-represented. Women between the age of 65 and 80 are under-represented in comparison to men in the same age group. Participants younger than 18 do not occur as a minimum age of 18 is required to participate in the study. Due to the general availability of data within all relevant age groups, we conclude that with appropriate sample weights we can make our tracking sample representative from an age and gender perspective in future analyses. Since this report is focused on a descriptive analysis of the recorded data, we leave an extrapolation using such weights to later research.

Figure 1: Age distribution of tracked participants vs. age distribution for Germany in 2022

2.2 Gender Distribution of Participants

We asked participants to report their gender as one of three categories: male, female, and diverse. The sample contains approximately equal numbers of female and male participants (422 female, 484 male and 4 diverse), as shown in Figure 2.

Figure 2: Gender distribution of tracked participants
2.3 Income of Participants

We evaluated participants’ income levels using threshold definitions already known from the Mobilität in Deutschland (MiD) study, as shown in Figure 3. The evaluation shows that with a share of 35.5% most households have a net income of more than 5,500 € per month, followed by two groups of 21.2% each, of households with incomes between 4,000 € and 5,500 € and between 2,500 € and 4,000 €, respectively. 10.5% of the sample households have between 1,500 € and 2,500 € at their monthly disposal. The number of participants in lower household income groups is significantly smaller with 9.5% living on less than 1,500 € per month. 2.2% did not disclose their income.

![Figure 3: Income of tracked participants](image)

2.4 Dwelling

Participants of the tracking experiment mainly live in the south east of Germany, where the study was first announced, as shown in Figure 4a. A majority resides in the greater Munich area and most within the city of Munich and its central and thus most interconnected public transport (PT) tariff-zone (zone M) of the local PT agency MVV. (Figure 4b). Concludingly, PT is easily available to the tracking participants.

![Figure 4: Residences of sample group](image)
3 Transport Statistics

In this section, an overview over aggregated transport statistics (traveled distances, modal split) is presented together with an update on participation rates. All analyses are performed based on tracking data recorded between May 24, 2022 and September 30, 2022. This includes the total time range from beginning of June until the end of August during which the 9 EUR-Ticket was valid in Germany. During this observation period, 910 individuals have recorded a trip with the provided smartphone application at least once. In it, a participant is considered to be active in a given week if they recorded at least one trip in that week. It can be seen that more than 700 participants have been active each week after the first week of the study. During the first week of the experiment, around 300 participants were recorded. The first week of our experiment was also the last week before the 9 EUR-Ticket was introduced. After a high increase of active participants in the second and third week participation peaked in the fourth week with around 820 active users. During the following weeks, the amount of participants slowly decreased with 700 active participants in the last week of our observation period.

A total of 670,096 trips was recorded within the observation period assessed in this report. Based on participants’ feedback via the smartphone application, 4982 trips were recorded incorrectly due to technical errors. The remaining 665,114 trips have a total length of 6,550,250 km. Of these, walking was the most prominent mode of transport with 372,430 reported trips, followed by individual transport, e.g. car, with 108,944 trips and 101,265 trips by public transport. Trips by bike were recorded in 80,088 cases and by airplane and all other forms of transport in 786 and 1601 respectively. While the share of trips conducted by plane is low, accounting for only 0.1% of all recorded trips, distances travelled by plane account for 21.2% of the recorded mileage. Due to this disbalance, we exclude air travel from the following analysis to not skew our results. We also disregard all recorded trips with non-specified forms of transport. Our used smartphone application can accept feedback from users. They can correct the detected mode of transport, mark a trip as incorrect, or merge two trips as one. These corrections were made for 36,151 trips. It is also possible to confirm the recorded trips. This has been done by our participants for 430,199 trips.

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To assess the impact of the 9 EUR-Ticket on the general travel behavior of our sample we divided the reported data into three parts: the first part includes all trips recorded before the 9 EUR-Ticket was introduced on June 1, 2022. The second part contains all recorded trips between June 1, 2022 and August 31, 2022. In this time period the 9 EUR-Ticket was valid. The last and third part includes all trips between September 1 and September 30, 2022 and represents the time period directly after the 9 EUR-Ticket. Figure 6 reveals the modal share of our sample group in terms of traveled distances. Herein, modal shares are depicted for all phases of the experiment. For reference, modal shares for
A comparison of the 2017 modal shares from the MiD study to our data reveals principle differences between the data sets. While MiD reports 32.4% public transport, 5.4% bicycle, and 59.5% car use while indicating 2.7% of walking, we observe a higher use of public transport and a lower car use within all phases of the experiment. Setting the modal shares in the three phases of our experiment side by side, it can be seen that the introduction of the 9 EUR-Ticket had no clear impact on the share of distance covered by bicycle. This remained almost constant at 6.7% percent and 7.2% percent. After the 9 EUR-Ticket program ended, the share decreased to 5.9%, most likely due to decreasing temperatures (the mean temperature in Munich was 20.2°C in the time range before and during the 9 EUR-Ticket and decreased to 14.2°C afterwards). In contrast, the recorded share of walking clearly decreased from 5.4% of the total recorded mileage before to 4.7% during the 9 EUR-Ticket albeit almost constant weather conditions. This could indicate that the hurdle to use public transport for smaller distances diminished for our sample group with the cheap ticket.

The observed share of individual transport and public transport usage behaves the other way around: before the 9 EUR-Ticket was introduced, the share of individual transport was 49.4%. It then decreased by 6.6% during the time the ticket was valid. In the observed time-frame after the 9 EUR-Ticket the distance share of individual transport increased by 6.2% to a total share of 49.0%; slightly less than before the 9 EUR-Ticket. Initially, our sample group used public transport for 38.5% of the recorded distance. This share increased by 6.8% to 45.3% with the 9 EUR-Ticket before it decreased to 40.0% when the 9 EUR-Ticket program ended.

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5 Calculated based on the public available LMU weather data for Munich [https://www.meteo.physik.uni-muenchen.de/DokuWiki/doku.php?id=wetter:stadt:messung](https://www.meteo.physik.uni-muenchen.de/DokuWiki/doku.php?id=wetter:stadt:messung)
4 Mobility Behavior Analysis

In the subsequent section of this report, we investigate the mobility behavior of the sample group. Thereby, we focus on the effects the 9 EUR-Ticket on the modal shares of different demographic groups, described by age and income, as well as varying trip purposes. In contrast to previous sections, we do not analyze the period before the introduction of the 9 EUR-Ticket in this section. This is due to the further subdivision of trips within the phases, e.g. by trip purposes, which results in significant differences in remaining total trip quantities and finally would lead to very small sample sizes for certain segments within the phase before the 9 EUR-Ticket. Instead, we use the MiD\cite{1} as a reference and compare the results of our sample group to the national average for German metropolises. We do only consider trips conducted within the geographic borders of Germany.

In our analyses of the modal splits, we calculate the respective shares based on traveled distance by respective modes. We apply the concept of main trip purposes (Hauptwegezwecke) from MiD, which allocates the complete distance of an intermodal trip to the means of transport with the highest share of the total trip length. In order to facilitate concise graphic representations of the results, we aggregate trip purposes available in the smartphone application in the following way:

- **home**: home
- **work/education**: study, work
- **leisure**: sport, eat, family and friends, leisure
- **errand**: assistance, medical visit, errand
- **shopping**: shopping
- **unknown**: unknown, other

For the same reason, we aggregate means of transport in the manner described in Section\[3\]. Due to the relatively small share of walking trips in respect to the total distance and for the sake of clarity and simplicity, this mode is not considered in the subsequent analyses. Values are normalized to the total distance covered with the remaining three means of transport. In order to account for the known differences in mobility behavior between working and non-working days\[14\], we strictly distinguish between said working days and weekends and public holidays (once more grouped as non-working days).

An overview over the general mobility behavior of the tracking group is supplied in Figures\[8a\] and \[8b\]. The purpose was either automatically inferred by the smartphone application based on e.g. points of interest or manually assigned by participants. As only around 5\% of all recorded trips and activities are manually adjusted\[11\], unknown locations make up a large number of tracked trips. When looking at subsequent statistics on trip purposes, note that roughly half of all trips recorded were assigned the label unknown. Figure\[8a\] shows the distributions of distances of trips with different purposes. Trips with purpose work/education exhibit both the longest distance and the largest dispersion, with the 3rd quartile extending up to 40 km. Trip types errand and shopping show similar distributions in regard to trip lengths. Both are relatively short with medians around 4 km and smaller dispersion compared to the other purposes. A second cluster with similar distance characteristics consists of purposes home, leisure, and unknown. Their medians are located around 6 km. The 3rd quartile whisker reaches 30 km.

A kernel density estimation of the start times of trips with different purposes is depicted in Figure\[8b\]. Following Scott’s rule\[15\], the kernel density estimation uses a Gaussian kernel with bandwith $1.8 \cdot n^{-1/6}$ for $n$ samples. With regard to the temporal distribution of trip start times, a large peak for trip type work/education occurs in the morning around 8 o’clock as to be expected. In contrast, home-trips accumulate in the late afternoons and evenings. Trip types errand and shopping occur in two peaks each, in the morning and the afternoon with a slight dip in between. Trip type shopping is shifted approximately one hour towards the evening. Trips with purpose leisure increase continuously throughout
the day and peak at 17 o’clock. Trips that were assigned to type unknown do not show clear similarities to one of the aforementioned types and can thus not be reassigned on these grounds.

4.1 Modal Split for Trip Purposes

With questioning prevailing mobility habits and routines being named one of the greatest opportunities of the 9 EUR-Ticket, we examine the change in modal shares of PT, bicycle, and car for different trip purposes in Figures 9a and 9b. It can generally be stated that PT usage is higher on working days than on non-working days with differences of 5% to 10% for respective purposes. The modal splits of our sample group are approximately similar to the one obtained from MiD on non-working days (with exceptions, especially errands) but significantly higher on working days. Trips of purpose errands yield a substantially smaller share of PT and a larger share of car respectively, compared to the other purposes both for working and non-working days. For all but one purpose, the share of PT significantly increased during the 9 EUR-Ticket period. Purpose work/education during the week is the only group where no clear increase in PT is evident. The decreases in PT ridership range from single digits to 10%. The share of cycling is mostly constant, meaning most trips not conducted with PT after the 9 EUR-Ticket period were replaced by car. The largest drop in PT ridership can be observed for trip purpose leisure on working days. On non-working days, type shopping’s PT ridership dropped the most.

https://www.bundesregierung.de/breg-de/themen/deutsche-einheit/faq-9-euro-ticket-2028756
4.2 Modal split by income group

The second major goal of the 9 EUR-Ticket was to relieve the burden on households whose cost of living had risen sharply as a result of current price developments, which especially impacts households with lower incomes. We therefore investigate the impact of the ticket on different income groups in Figures 10a and 10b. For all income groups, PT usage is higher during the week than on weekends and generally exceed the one from MiD. The results of our sample group illustrate how PT ridership generally decreases inversely proportional to income. Furthermore, the desired effect of the 9 EUR-Ticket (increased PT ridership) on working days likewise relates inversely proportional to income. On non-working days, the picture is different. The largest drop in PT usage of approximately 20% is to be observed for the group with the lowest income while the other groups show similar absolute decreases, although from different starting points. The trips were entirely replaced by motorized individual transport. The share of cycling is lowest for income group 0 - 1500€, especially on working days. With one exception, PT ridership increased on all occasions during the period of the 9 EUR-Ticket. This exception is posed by the income group more than 5,500€, where the level stayed constant. While the share of cycling did not change significantly between phases, income group 1,500€ - 2,500€ increased their share of cycling on working days after the end of the 9 EUR-Ticket and replaced a significant amount of trips conducted with PT before.

4.3 Modal Split of Age Groups

Concluding the analysis of the 9 EUR-Ticket’s impact on demographic groups, we explore the effects on the modal splits of different age groups in Figures 11a and 11b. The data of our sample group reveals a general trend of decreasing/increasing PT/car ridership, respectively, proportionally to age. This trend is stronger on working days, while the modal split of age groups between 40 and 70 years on non-working days is approximately similar. Another finding valid for all age groups is a higher PT usage on working days than on non-working days. Compared to MiD, the share of PT is higher except age groups above 40 years on non-working days. Distances traveled by bicycle are comparable, although the youngest age group distinctively exhibits the smallest relative share of active mobility on both kinds of days. On working days, the age groups 30-39 and 40-49 both yield higher shares of PT usage after the 9 EUR-Ticket although the absolute increase is small. The opposite is true for all other age groups on working days. On non-workingdays, the only group showing a higher PT usage after the period of the 9 EUR-Ticket is the one below 20 years of age. The largest drop of PT usage is to be found for the 20 to 29 year old participants on non-working days. Further comparably large decreases are evident for the oldest two age groups above 60 years, on working as well as non-working days, although a large share of participants is likely to be retired.
5 Discussion and Conclusion

This report presents first analyses of the data collected within the first four months of the tracking experiment of the “Mobilität.Leben” study. As a baseline for the understanding and interpretation of all subsequent analyses, it assesses age, gender, income, and dwellings of the tracking participants. Subsequently, general transport statistics, as well as disaggregated statistics on activities and the usage of different means of transport are presented with a special focus on modal splits. This section discusses our findings and the limitations of both the study and the employed methodology. A first limitation of the study is constituted by the size of our sample group as well as the available time-frame for the assessment of pre-9 EUR-Ticket behaviors. While participation rates have shown to be constantly high throughout the reported time-frame, only one week of data before the introduction of the 9 EUR-Ticket exists. In addition, due to the successive start-up phase, far fewer participants submitted data during this first week than in later phases of the experiment. Seasonal effects may also be present during all phases of the experiment since all data was recorded in less than a year’s time. This lack of data, especially in the first phase of our experiment, motivated the decision to leave out any data recorded before the start of the 9 EUR-Ticket for more disaggregated analyses. In consequence for purpose- or subgroup-specific statistics, there is no direct reference from before the 9 EUR-Ticket from within the study group. When analyzing the impact of the 9 EUR-Ticket by e.g. a comparison of modal splits during and after its introduction, potential backlashes from re-increased pricing or other compensatory mechanisms may also influence mode choice without any indication in the presented data. Although the MiD survey can serve as an alternative reference for pre-9 EUR-Ticket behaviors to some extent, large differences between MiD and our surveys can be observed especially for modal splits. These differences appear to be in the same order of magnitude as the observed influences of the 9 EUR-Ticket indicating that no clear baseline of mobility behavior prior to the 9 EUR-Ticket can be established. Considering the differences in survey methodology of MiD and “Mobilität.Leben” supports this argument. Apart from the particularities concerning the first phase of the experiment, it should be noted that all the results presented in this report are initially only representative of the group of participants observed. This group is – as shown in Section 2 – relatively wealthy, a little younger than the German population, and includes more male than female participants. Whether and to which extent observations regarding this study group can be extrapolated onto larger populations in and outside of Germany remains unclear. Another point worthy of discussion is the way trip purposes and means of transport are labeled, which are – for the best part – not surveyed directly, but inferred from raw GPS trajectories supplied by the participants. This is done based on the algorithms employed by the MOTIONTAG smartphone app. While tracking participants have the option to correct any labeling manually and thereby directly reveal activity types and mode choice, only around 5% of all recorded trips and activities are manually adjusted [11]. Approximately half of all recorded activities retain an unknown label. Despite all limitations and reservations due to sample size, quality, and sample group composition, a clear positive effect of the 9 EUR-Ticket on the aggregated modal share on PT usage is revealed by our experiment for both working days and non-working days. The disaggregated modal splits shown in Section 4 have revealed significant influences of trip purpose, income, and age on the modal split and PT utilization respectively. Most notably, work and education trips during workdays were hardly affected by the 9 EUR-Ticket. In contrast, errands, leisure, and shopping activities were preceded by PT trips more
often during the 9 EUR-Ticket program than afterwards. Independent of the experiment phase, increasing household incomes correlate with decreasing PT usage and increased car usage in our sample. Additionally, the availability of a reduced ticket price for PT appears to affect low-income households significantly stronger than their high-income counterparts especially on non-working days. Similarly, age presents to have an adverse effect on PT usage in our sample. Nevertheless, the relative reduction of PT utilization after the end of the 9 EUR-Ticket is especially large for participants under 30 and over 60 years of age.

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