Germany's 9-Euro-Ticket: Impacts on Disadvantaged Groups Using a Causal Inference Approach

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ABSTRACT

Free-fare policies have been proposed as a means to reduce emissions in the transport sector and promote equitable mobility. However, their potential distributional impacts on disadvantaged groups remain uncertain. Using data from Germany's 9-Euro-Ticket, we analyze the effects of nearly free transit on individuals with a low economic status, women and individuals with a disability. To offer a comprehensive evaluation we include the effects on activity participation, use of public transport and financial relief in our analysis. Relying on observational data where users self-select the treatment rather than being randomly assigned, we utilize a quasi-experimental method, Propensity Score Matching, combined with weighted regression models. This doubly robust approach enables us to identify causal effects. Our findings indicate that the 9-Euro-Ticket increased public transport use across all groups and improved activity participation, particularly among economically disadvantaged individuals. However, the program did not seem to offer targeted financial relief for economically marginalized individuals, and its benefits were less pronounced for women and people with disabilities. These results underscore the positive impact of low-fare public transport on economically marginalized individuals but also highlight its limited effectiveness in addressing barriers faced by other disadvantaged groups. The findings have important implications for policymakers and transport planners seeking to make public transport more accessible and equitable.

Keywords: Transport Equity, Propensity Score Matching, Public Transit, Fares, Policy Evaluation, 9-Euro-Ticket

INTRODUCTION

Free fare policies have been discussed as an instrument for sustainable development, seeking to promote public transit, increase ridership, reduce the negative externalities of car traffic and improve mobility for all (*1*). The 9-Euro-Ticket that was introduced by the German government between June and August 2022 allows to evaluate the effects of nearly fare-free transit for all. The ticket cost nine euros (around 10 USD) per calendar month and was valid on all local and regional buses and trains throughout Germany. It was part of a federal relief package in reaction to the war in Ukraine that negatively affected the German economy, aiming to provide financial relief. Next to the economic aspect the 9-Euro-Ticket was also meant as an incentive to switch to climate-friendly public transport and save fuels (*2*). The total of the funds for three months, amounting to 2.5 billion euros (around 2.8 billion USD), was derived from the forecast of the lost ticket revenue of the federal states. Overall, fifty-two million tickets were sold from June to August 2022. Additionally, around 10 million subscribers received the ticket automatically for the period of its availability (*3*).

While economists generally agree that optimal pricing of public transport should equal its marginal costs, this principle is only applicable if all other transport prices are also based on marginal cost pricing (*4*). Transit subsidies are furthermore typically justified on three grounds: to guarantee the provision of a public service that is often unprofitable for the operators, to secure the positive externalities of public transport and to redistribute income to specific groups (*5*). According to German Law, public transport is considered a public service that the state must provide to ensure its citizens' mobility. To fulfill this obligation, the state secures the necessary funding (*6*). In contrast to targeted fare subsidies, the 9-Euro-Ticket was available to purchase for all travel users reducing overall administrative costs for the government. However, as the ticket was a blunt policy instrument, it remains unclear whether all social groups could benefit. Decisions regarding the transportation system greatly influence people's lives by decreasing or creating access to a wide range of opportunities, impacting individuals' life chances and agency (*7*). How transport policies affect social groups with different transportation abilities and needs is thus also a question of equity (*8*). Transportation equity has been conceptualized as improving accessibility to social and economic opportunities, especially for marginalized groups (*9*). Vertical equity is used as a concept in transport planning to promote the mobility of disadvantaged groups (*10*). As most transportation interventions cause costs and benefits, it is crucial to analyze the differential social impacts of the 9-Euro-Ticket (*11*). A subsidized fare mainly addresses the price of public transit and not additional barriers faced by women, namely fear of harassment (*12–14*) and hate crimes and inaccessibility affecting individuals with a disability (*15–20*). Therefore, we expect those who are disadvantaged due to their gender or a disability to gain less mobility compared to economically marginalized persons for whom the cost of transportation is the main barrier (*21–24*).

One challenge in quantifying the social impacts of nearly fare-free transit is that few standardized methods exist, and insecurity remains which social impacts to include (*25*). In the past, most studies focused on analyzing social welfare benefits of transit subsidies (*26, 27*). While some studies found low-income households to benefit most (*28, 29*), others found most forms of subsidies catering more to higher income individuals (*30, 31*). Most previous research takes into account the taxation source of the subsidy and the distribution of public resources for different modes of transit that are used by different income groups (*32*). Different transit pricing strategies, such as flat fares, distance-based fares or mode-dependent fares are also found to cater to different income groups (*33–35*).

However, analyzing the effect of fare subsidies from a welfare perspective often only focuses on direct monetary benefits. Furthermore, aggregated metrics can conceal relevant information (*36*). In our paper we want to expand the scope to include other benefits, such as activity participation and public transport usage, taking into account the literature on transportation equity and mobility justice (*37–42*). Furthermore, we do not only analyze the distribution of benefits according to economic status but also to gender and ability. When evaluating policies, conducting randomized controlled trials to determine causal impacts is often infeasible because of ethical concerns (*43*). Randomized treatment assignment would imply in the case of the 9-Euro-Ticket, that only a randomly chosen group received the ticket. Relying on observational data, treatments are selected rather than assigned (*44*). In terms of the 9-Euro-Ticket, participants chose to buy the ticket or not. The participants will generally buy the ticket if the expected benefit is higher than the associated costs. Treatment and control groups can thus not be directly compared because we might assume that the two groups differ fundamentally in their baseline characteristics (*45*). Even in the absence of the 9-Euro-Ticket, the two groups would potentially have differing outcomes. In order to estimate causal effects in the presence of non-random treatment assignment we use a quasi-experimental approach, Propensity Score Matching. Propensity Score Matching has been used in other transportation policy contexts (*46*).

This paper presents three contributions. Firstly, it extends beyond considering economic status and addresses other factors in the context of transport-deprivation such as gender and ability (*22*). Secondly, instead of focusing solely on net monetary benefits, this study explores the effectiveness of subsidized fares in benefiting disadvantaged groups in a broader sense. The benefits evaluated in this study cover activity participation, public transport usage, and financial relief. Lastly, this research seeks to identify the causal effects of almost fare-free public transport using a causal inference method. The effects of the 9-Euro-Ticket are estimated using Propensity Score Matching, and weighted regression models. This doubly robust approach reduces the bias of the estimates compared with traditional models, such as Ordinary Least Squares (*44*).

The paper is organized as follows. We first describe our data and methodology. Then we present the results from the weighted regression models. Finally, we discuss our findings and give an outlook on future research. The research design is displayed in Figure 1.

DATA AND METHODOLOGY

The data used is part of the Mobilität.Leben study with a total of 2,569 participants. More information on the study design can be found in earlier publications (*47–49*). 1650 participants (64.2%) are part of a study focusing on the Munich Metropolitan Region, the rest of the sample (919, 35,8%) were recruited nationally. The non-Munich sample is representative. The Munich Metropolitan Region comprises different types of spatial structure, covering both rural and metropolitan areas to represent different mobility behavior, furthermore all genders and ages are represented (*47*). Until July 2023 there have been six survey waves. We will draw on data from the first three waves, the timing of the distribution is depicted in Figure 2. The first survey was completed by 2,141 participants and the second survey by 1,733 participants. Completion rates were higher in the national sample than in the Munich sample. 117 observations were discarded as unreliable because of implausible completion times. Table 1 describes the variables used in the analysis.

TABLE 1 : Variable Description

Variable	Role	Type	Survey Question	Answer
Person with a Disability	Covariate	Binary	Are you limited by a health problem in activities of daily living?	Yes, very limited/ Yes, somewhat limited
Ticket: Bad Idea	Covariate	Binary	Please indicate your agreement with the statement: "The 9-Euro-Ticket is a good idea!"	Completely disagree/ disagree
Ticket: Neutral	Covariate	Binary	Please indicate your agreement with the statement: "The 9-Euro-Ticket is a good idea!"	Neither agree nor disagree
Ticket: Good Idea	Covariate	Binary	Please indicate your agreement with the statement: "The 9-Euro-Ticket is a good idea!"	Completely agree/ agree
Access to Public Transport	Covariate	Continuous	What public transport options are available within a 5-minute walk of your home?	Number of selected options (bus, S-Bahn, tram, U-Bahn)
Activity Level	Covariate	Continuous	On average, how many days do you travel to different locations in a week?	Sum of answers for work, leisure, and errands
Mode of Transport: Often (May)	Covariate	Binary	How often do you use the following modes of transport in a week?	Daily/ 4-5 days a week
Mode of Transport: Sometimes (May)	Covariate	Binary	How often do you use the following modes of transport in a week?	2-3 days a week/ Once a week/ Less than once a week
Mode of Transport: Never (May)	Covariate	Binary	How often do you use the following modes of transport in a week?	Never
Economically Marginalized Person	Covariate	Binary	How does your household cope with price increases? How much does the following statement apply to you? "Because of the increased prices, I have to forgo many things in my life." Which statement about saving applies to your household in a typical month?	At least one of the following: Very bad, Completely true, The household must draw on savings or borrow money
Savings	Outcome	Binary	How strongly do you agree with the following statement? "I can spend the money saved from the 9-Euro-Ticket on more useful things."	Completely agree/ Agree
Activity Level: Leisure (Jul/Sep)	Outcome	Continuous	On average, how many days do you travel to different locations in a week?	Answer for "leisure"
Activity Level: Errand (Jul/Sep)	Outcome	Continuous	On average, how many days do you travel to different locations in a week?	Answer for "errand"
Public Transport: Often (Jul/Sep)	Outcome	Binary	How often do you use public transport in a week?	Daily/ 4-5 days a week
Public Transport: Sometimes (Jul/Sep)	Outcome	Binary	How often do you use public transport in a week?	2-3 days a week/ Once a week/ Less than once a week
Public Transport: Never (Jul/Sep)	Outcome	Binary	How often do you use public transport in a week?	Never
9-Euro-Ticket	Treatment	Binary	Did you purchase the 9-Euro-Ticket for the month of June/July?	At least once "yes"

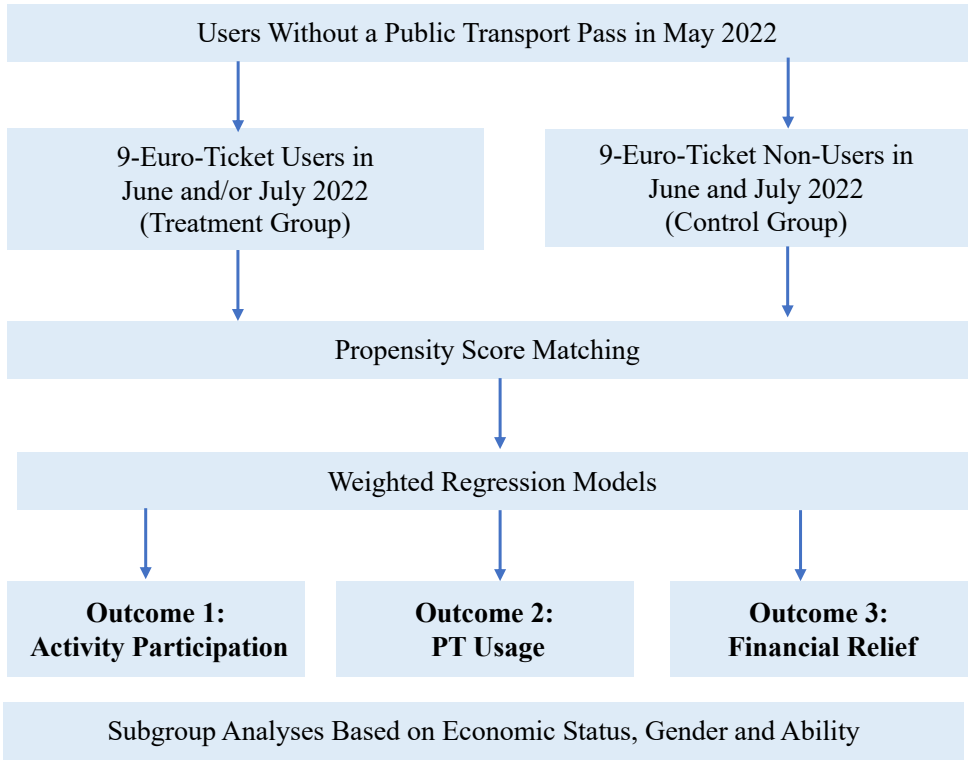

FIGURE 1 : Research Design

Research Design

To estimate the effects of the 9-Euro-Ticket, the treatment and the relevant population must be defined. The results of the second survey wave that was distributed at the end of July are used to compute the effects. Therefore, the treatment is defined as *purchasing the 9-Euro-Ticket at least once in June and/or July*. Participants who only bought the 9-Euro-Ticket in August were therefore not included in the treatment group. Furthermore, it must be considered that 543 participants (33.7 %) had already owned a transport subscription in May. While the 9-Euro-Ticket will lead to a cost reduction for this group, their habitual travel behavior will plausibly remain unaffected (*50*). Nearly all participants with a previous public transport subscription (96.3 %) received or bought the 9-Euro-Ticket. In terms of experimental designs, this group is pre-treated as they had already been subject to the treatment of having a public transport subscription. This is also in line with the policy objective of the 9-Euro-Ticket to cater primarily to new public transport users. Hence, the treatment effects are estimated for those without a public transport pass in May 2023 (N = 1,067). All further statements will apply to this subset of the data. We conducted moderation analyses using subgroups based on economic status, gender, and ability. Economic status was determined by identifying individuals experiencing economic pressure, with the specific survey questions provided in table 1. Disability was defined broadly as limitations in activities of daily living due to health issues, in line with previous research (*51*). One participant with a diverse gender was included in the analysis and categorized under the female participants.

Propensity Score Matching

When estimating the effects of an intervention, one is interested in the different outcomes of an individual under each treatment state. However, researchers can only ever observe one outcome per individual, the other (potential) outcome remains counterfactual and exists only in theory. Therefore, causal effects cannot be estimated for individual units (*44*). Thus, experimental research designs are used to estimate treatment effects: Participants are randomly assigned to the treatment or the control group. As policies are usually directed at certain parts of the population, the Average Treatment Effect on the Treated (ATT) is of special interest.

However, randomized controlled trials are often infeasible for policy evaluation because of ethical concerns (*43*). In the case of the 9-Euro-Ticket, it was not randomly assigned but participants decided whether to purchase it taking into account the expected benefits and the associated costs. Therefore, treatment and control groups can not be directly compared because we might assume that the two groups differ fundamentally in their baseline characteristics (*45*). Even in the absence of the 9-Euro-Ticket, the two groups would potentially have differing outcomes. One possible approach for observational data is conditioning the sample on a set of variables (X) that predict treatment assignment. This implies that the potential outcomes of treatment and control group are independent of the treatment assignment (D) given their observed characteristics (X) (*52*).

$$Y^0, Y^1 \perp\!\!\!\perp D|X \tag{1}$$

If this assumption holds, a robust ATT estimate can be calculated in the presence of a non-randomly assigned treatment.

$$E[\delta|D=1] = E[Y^1|D=1,X] - E[Y^0|D=1,X] \tag{2}$$

Conditional on X, there are no systematic differences between treatment and control group. X is thus a straightforward balancing score b(x) that is specified so that the conditional distribution of X given b(x) does not differ between the treatment and the control group (*45*). However, due to the "curse of dimensionality", it is oftentimes not feasible to match units from treatment and control group on all covariates contained in X. Rosenbaum showed that the propensity score can be used as a balancing score (*45*). The propensity score is the estimated probability of taking the treatment, modeled as a function of covariates predicting the treatment assignment. The true form of the propensity score is unknown when working with observational data. Therefore, propensity score estimations are used (*44*).

The Propensity Score Model

When selecting the covariates to be included in the matching process, the goal is to satisfy the assumption of "strong ignorability", which means that conditional on the observed covariates, there are no unobserved differences between the control and treatment group. There is little cost in including unnecessary variables, i.e. variables that are unrelated to the treatment assignment. They may slightly increase the variance of the model (*53*). In contrast, omitting relevant confounding variables will significantly increase bias. It is therefore advisable to include all variables that could influence treatment assignment and/or outcome (*53*). This is also true for the 9-Euro-Ticket, where several factors influence the decision to purchase the 9-Euro-Ticket and the outcomes. Table 1 shows the relevant dependent variables (outcome and treatment) when choosing which variables to include in the propensity score model.

Vincent Kaufmann's concept of motility provides a framework for considering the space in which mobility decisions are situated (*54*). The categories provided in the motility framework are taken into account when selecting the variables for matching. Table 2 presents an overview of the categories and their corresponding variables in the propensity score model. It should be noted that the categories are interdependent and therefore variables could potentially fit into different categories. For example, the socioeconomic variables included may affect all three categories. Because the data can only be matched on observed characteristics, some variables such as "knowledge of PT" or "preference" are proxied by past behavior.

TABLE 2 : Motility and Variables used for PSM

Motility Categories	Variables Included in the Propensity Score	Variable Name in the Model
Access		
• Options (Transportation, Services) • Conditions (Costs, Logistics, Constraints)	• Public Transport Access, Regiostar Classification (German Classification of Regional Type) • Other Socio-Economic Variables (Age, Gender, Economic Status, Employment, Household Size, Children)	• PTAccess, RegiostarClassification • Age, Gender, EconomicStatus, Employment, HouseholdSize, Children
Competence		
• Physical Ability • Acquired Skills • Organizational Skills	• Disability • Driving License • Knowledge about PT (e.g., About Schedules; Proxied by Experience Through Past Use)	• Disability • License • ModeUsage
Appropriation		
• Needs • Plans • Aspirations • Understandings	• Attitude towards Climate Change, Political Attitudes, Attitude towards the 9-Euro-Ticket • Preference (Proxied by Previous Activity Participation and Mode Use)	• AttitudeClimateChange, PoliticalAttitude, AttitudeTicket • ActivityLevel

The propensity score b(x) is specified in the following way:

$$b(x) = Pr[D = 1|X] = \tag{3}$$
$$\beta_0 + \beta_1 \text{PTAccess}_i + \beta_2 \text{RegiostarClassification}_i + \beta_3 \text{Age}_i + \beta_4 \text{Gender}_i + \beta_5 \text{EconomicStatus}_i$$
$$+ \beta_6 \text{Employment}_i + \beta_7 \text{HouseholdSize}_i + \beta_8 \text{Children}_i + \beta_9 \text{Disability}_i + \beta_{10} \text{License}_i$$
$$+ \beta_{11} \text{ModeUsage}_i + \beta_{12} \text{AttitudeClimateChange}_i + \beta_{13} \text{PoliticalAttitude}_i + \beta_{14} \text{AttitudeTicket}_i$$
$$+ \beta_{15} \text{ActivityLevel}_i + \varepsilon_i$$

Figure 2 shows the propensity score distribution depending on ticket purchase, a logit model was used. The "common support" assumption implies that the treatment and control groups overlap substantially in their propensity score distribution. The density of the distribution may differ (*53*). As shown in Figure 2, the range of propensity scores is similar between the two groups. In the group without the ticket, lower propensity scores are estimated; in the group with the 9-Euro-Ticket, more propensity score estimates are closer to one. No estimates are exactly 0 or 1, allowing the propensity score to be used for matching.

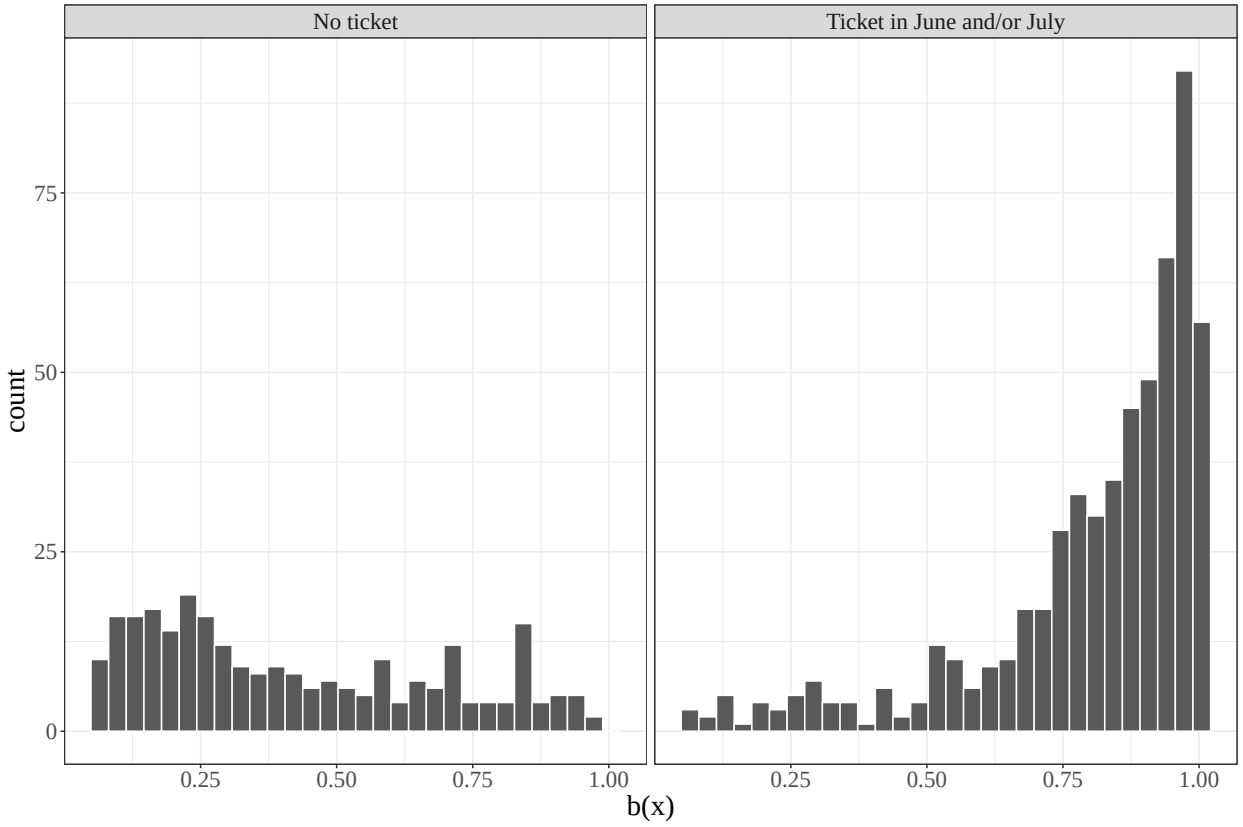

FIGURE 2 : Distribution of the Propensity Score b(x)

Matching

Testing various matching methods, a combined propensity score with exact matching on economic status, ability and gender (*55*) using optimal full matching resulted in the most balanced matched sample. The R *matchIt* package was used for matching (*56*). Figure 3 shows the effectiveness of

PSM in reducing covariate imbalance between the control and treatment group. The commonly used threshold for the standardized mean difference of 0.1 is displayed. For almost all variables, matching reduced the standardized mean difference between treatment and control group, although perfect balance was not achieved. The sample size after matching is 567 in the treatment group (ESS: 69.66) and 260 in the control group. Since full matching was used no observations were discarded. As logistic regression requires complete observations, the sample available for matching decreases in size compared to the original sample.

Weighted Regression Models

Propensity Score Matching does not estimate effects by itself, but must be combined with other models such as linear regression (*53*). Regression after matching can further reduce bias due to remaining imbalances in the matched data (*44*). Weighted regression models provide less biased estimates by accounting for individual-level heterogeneity between the treatment and control group. The weights used are propensity score estimates (*44*). Because the weighted regression estimates condition on the covariates twice (both in the matching process and in the regression), the results are said to be doubly robust (*44*). All treatment effects were estimated using g-computation and cluster-robust standard errors with the *marginaleffects* R package (*57*). The following model specifications were used to estimate the ATT in weighted regression models using linear models.

$$\begin{aligned}&\text{Outcome} = \\ &\beta_0 + \beta_1 \text{Treatment} + \beta_2 \text{PropensityScore} + \beta_3 \text{Covariates} + \beta_4 (\text{Treatment} \times \text{Covariates}) + \\ &\beta_5 (\text{Treatment} \times \text{PropensityScore}) + \varepsilon_i\end{aligned} \tag{4}$$

The propensity score was added to the regression model to increase robustness (*58*). In addition, to minimize the impact of any remaining imbalances in the matched data, all covariates used for matching were included as controls in the model, including the interaction effects with the treatment variable. Subgroup effects were estimated based on gender, economic status, and ability. Some survey questions were only addressed to those who purchased a ticket. For these outcome variables, logistic regression models were fitted to the subset of the treatment group, including all covariates used for matching as controls.

RESULTS

In this section, we will present our results using weighted regression models to estimate the ATT and logistic regression models for outcomes concerning only the ticket users.

Activity Participation

Two models were estimated with the average number of days per week participants participated in leisure activities and ran errands as outcomes. The results are presented in Table 3. The results indicate a significant positive effect of the 9-Euro-Ticket on participation in leisure and errand activities for the entire sample. The moderation analysis shows that the effect varied across subgroups depending on the activity. The 9-Euro-Ticket had a significant positive effect on leisure activities for men, those not economically marginalized, and those without disabilities with effect sizes up to 0.54. This indicates, that the 9-Euro-Ticket led some groups to participate in leisure activities on one additional day every two weeks. No significant effects were observed for the other groups. Women, the economically marginalized and those without disabilities experienced an increase in the number of days running errands. The results suggest no increase in activity participation for

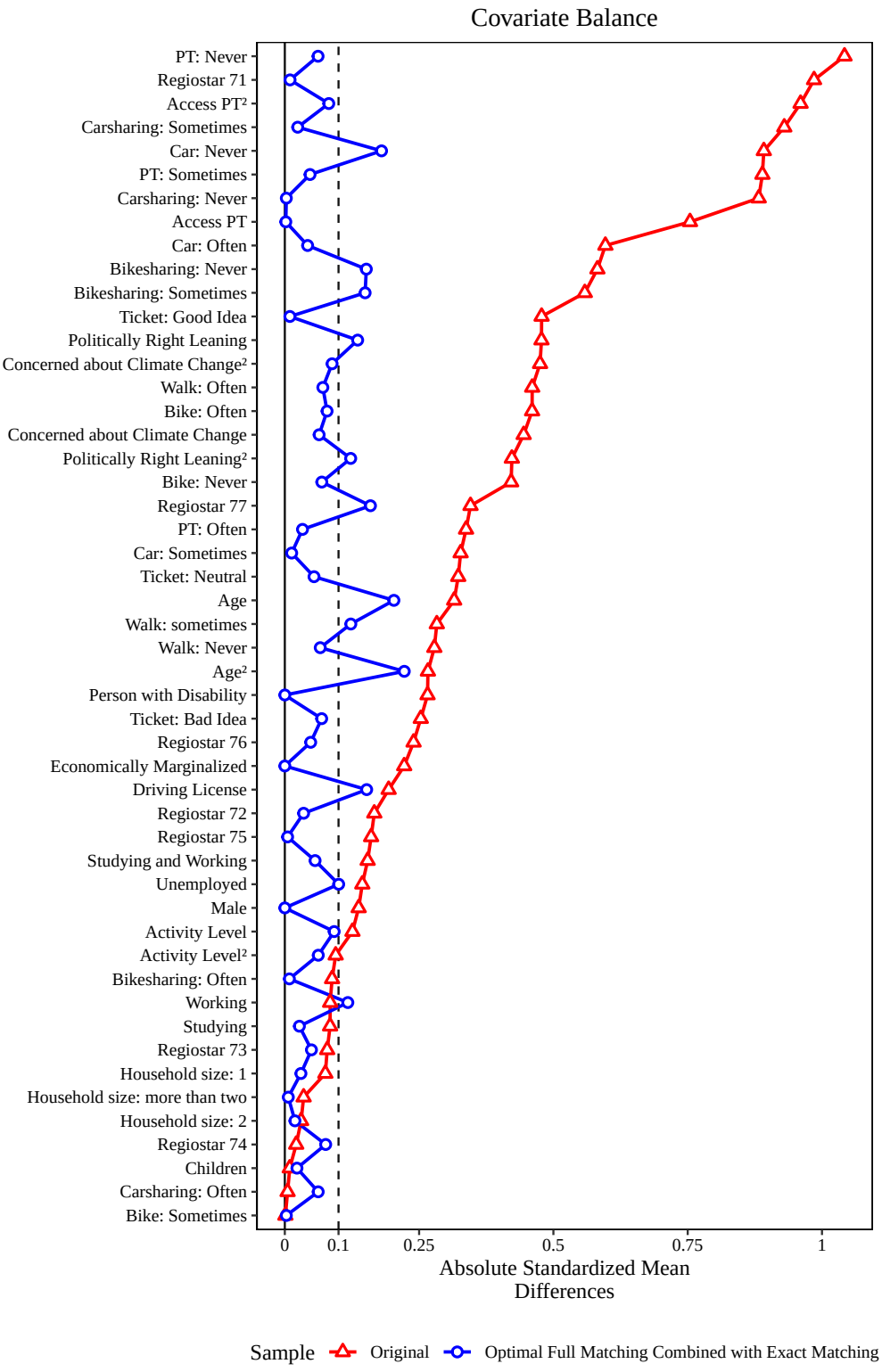

FIGURE 3 : Covariate Balance in the Original Sample and the Matched Sample.

people with disabilities in any category.

TABLE 3 : Effect of the 9-Euro-Ticket on Activity Participation

	ATT: Avg. Days with Leisure Activities	ATT: Avg. Days with Errand Activities
All	0.34**	0.30*
	(0.14)	(0.16)
Female	0.20	0.84***
	(0.25)	(0.27)
Male	0.44***	−0.03
	(0.17)	(0.20)
Economically Marginalized	−0.35	0.99***
	(0.40)	(0.33)
Not Economically Marginalized	0.52***	0.13
	(0.15)	(0.18)
Person with a Disability	−0.31	−0.53
	(0.34)	(0.32)
Person without a Disability	0.54***	0.56***
	(0.15)	(0.18)

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The difference in leisure activity participation is not significant between the genders.

The difference in leisure activity participation is significant between (non) economically marginalized persons on the 0.05 level.

The difference in leisure activity participation is significant between persons with a disability and those without on the 0.05 level.

The difference in errand activity participation is significant between the genders on the 0.01 level.

The difference in errand activity participation between (non) economically marginalized persons is significant on the 0.05 level.

The difference in errand activity participation is significant between persons with a disability and those without on the 0.01 level.

In addition, the survey asked participants whether they participated in more activities because of the 9-Euro-Ticket. Since this question is only relevant for the ticket holders, a logistic regression model was fitted to the subset of the treatment group. Table 4 shows the significant results of the analysis. Economic status was the only identity marker influencing the binary outcome, with economically marginalized individuals more likely to report increased activity participation.

Use of Public Transport

The results displayed in table 5 suggest that the 9-Euro-Ticket had a positive effect on the probability of using public transport often and led to a decrease in the probability of never using public transport, both for the entire sample and for all subgroups. The ticket seemed to be most effective in reducing the probability of never using public transport, with the treatment effect being a reduction of 49 percentage points for the whole treated sample. However, the effect size varied across subgroups, with people with disabilities experiencing a significantly smaller reduction than those without disabilities. Furthermore, the 9-Euro-Ticket impacted the use of public transport after its validity period for certain subgroups. Men, economically marginalized people and people without disabilities were more likely to use public transport often in September if they had bought the 9-Euro-Ticket. However, the effect size was small and no effects were found for the other groups.

TABLE 4 : Logistic Regression: More Activities Because of the 9-Euro-Ticket (Excerpt)

	Dependent variable:
	More Activities
Working	-0.47^{*}
	(0.27)
Ticket: Good Idea	0.91^{**}
	(0.36)
Male	0.02
	(0.19)
Economically Marginalized	0.66^{**}
	(0.31)
Person with a Disability	-0.14
	(0.29)
Constant	-1.09
	(2.32)
Observations	566
Log Likelihood	-359.83
Akaike Inf. Crit.	791.65
McFadden's Pseudo-R^2	0.06
Note:	*p<0.1; **p<0.05; ***p<0.01

The 9-Euro-Ticket also reduced the probability of never using public transport after its validity period for all groups except the economically marginalized. Overall, the results indicate that the 9-Euro-Ticket had a limited effect on public transport usage after its validity period.

Financial Relief

The effect of the 9-Euro-Ticket on financial relief was also studied using two models. The first model estimated the treatment effect on participants' agreement with the statement "I can spend the money saved by the 9-Euro-Ticket on more useful things". This statement was presented alongside other hypothetical statements for participants to indicate their agreement. Table 6 shows the results, which indicate that the ticket had a positive effect on the agreement rates for most of the treated subgroups. However, no significant effect was observed among economically marginalized individuals who purchased the ticket, significantly differing from the estimate for individuals with a higher economic status.

The survey also included a question asking participants whether they could benefit financially from the 9-Euro-Ticket. To analyze this question, a logistic model was fitted to the treatment

TABLE 5 : Effect of the 9-Euro-Ticket on Public Transport Usage

	ATT: Public Transport Often (During)	ATT: Public Transport Never (During)	ATT: Public Transport Often (After)	ATT: Public Transport Never (After)
All	0.10***	−0.49***	0.02***	−0.25***
	(0.02)	(0.05)	(0.01)	(0.04)
Female	0.08***	−0.56***	0.01	−0.25***
	(0.03)	(0.06)	(0.02)	(0.06)
Male	0.11***	−0.44***	0.04***	−0.24***
	(0.03)	(0.06)	(0.01)	(0.06)
Economically Marginalized	0.15***	−0.30**	0.08***	−0.04
	(0.04)	(0.12)	(0.02)	(0.10)
Not Economically Marginalized	0.09***	−0.54***	0.01	−0.30***
	(0.02)	(0.05)	(0.01)	(0.05)
Person with a Disability	0.10***	−0.31***	0.00	−0.35***
	(0.04)	(0.11)	(0.03)	(0.08)
Person without a Disability	0.10***	−0.55***	0.03***	−0.21***
	(0.02)	(0.06)	(0.01)	(0.05)

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In the first column, there are no significant differences in the subgroup effects.

In the second column, the difference in effect estimates is significant between persons with a disability and those without on the 0.10 level; the difference in effect estimates between economic status is significant on the 0.10 level.

In the third column, the difference in effect estimates is significant between (not) economically marginalized persons on the 0.01 level; the difference in effect estimates between the genders is significant on the 0.05 level.

In the fourth column, the difference in effect estimates is significant between (not) economically marginalized persons on the 0.05 level.

TABLE 6 : Effect of the 9-Euro-Ticket on Agreement to the Statement: "I can spend the money saved by the 9-Euro-Ticket on more useful things"

	ATT: Agreement to the Statement
All	0.13^{***}
	(0.05)
Female	0.18^{**}
	(0.07)
Male	0.10^{*}
	(0.06)
Economically Marginalized	-0.16
	(0.10)
Not Economically Marginalized	0.20^{***}
	(0.05)
Person with a Disability	0.09
	(0.12)
Person without a Disability	0.14^{***}
	(0.05)

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
The difference in effect estimates between (not) economically marginalized persons is significant on the 0.01 level. For the other groups, there are no significant differences.

group subset, including all covariates used for matching. Table 7 summarizes the regression results, displaying the significant variables and the subgroup characteristics. The results suggest that gender, economic status, and disability did not significantly influence the outcome.

DISCUSSION

Overall, our results suggest that the effect of the 9-Euro-Ticket varied across indicators and subgroups. Our main findings include:

- increased public transport use for all groups during the ticket's validity period
- an increase in activity participation especially for economically marginalized individuals
- no targeted financial relief for economically marginalized individuals
- less benefits for women and individuals with a disability

Economic Status

A logistic regression showed that the economic status is a significant factor in explaining whether 9-Euro-Ticket users could participate in more activities because of the 9-Euro-Ticket. This finding supports that the cost of mobility presents a major barrier for economically marginalized individuals and that a discounted price can improve their mobility. The effects on transport use after the

TABLE 7 : Logistic Regression: Financial Benefit Because of the 9-Euro-Ticket (Excerpt)

	Dependent variable:
	Financial Benefit
Age	-0.02^{*}
	(0.01)
Regiostar 72	-0.70^{*}
	(0.43)
Driving License	1.19^{**}
	(0.51)
Concerned about Climate Change	0.12^{*}
	(0.06)
Car: Sometimes	0.77^{***}
	(0.29)
Car: Never	1.18^{***}
	(0.46)
Male	-0.11
	(0.23)
Economically Marginalized	-0.46
	(0.36)
Person with a Disability	-0.19
	(0.33)
Constant	13.32
	(613.79)
Observations	566
Log Likelihood	-271.59
Akaike Inf. Crit.	615.17
McFadden's Pseudo-R^2	0.10
Note:	*p<0.1; **p<0.05; ***p<0.01

validity period support this interpretation. While all other groups reduced the probability of never using public transport after the intervention, there was no significant effect for the economically marginalized. At the same time, the probability of using public transport often after the 9-Euro-Ticket increased. This suggests that some economically marginalized people may have continued to use public transport because it has allowed them to participate in activities they could not before. However, a certain proportion of this group could only afford to use public transport at a reduced fare and has become restricted again in their mobility. The data suggest that economically marginalized individuals used the ticket primarily for errands. For this group, the new mobility offered by the 9-Euro-Ticket may have been used mainly for essential daily tasks before increasing leisure activities (*59*). Leisure activities may also be less accessible for economically marginalized individuals due to the additional costs associated with them, such as entrance or participation fees.

The evidence on whether economically marginalized individuals also benefited financially is mixed. The treatment effect of the 9-Euro-Ticket on agreement with the statement "I can spend the money saved by the 9-Euro-Ticket on more useful things" was not significant for this group. This may be because economically marginalized individuals had used public transport less frequently before the 9-Euro-Ticket. The ticket allowed them to be more mobile but did not lead to savings. Also, economic status was insignificant in a logistic regression predicting the financial benefit of the 9-Euro-Ticket. Collectively, these findings indicate that individuals facing economic marginalization did not receive focused financial relief.

Disability

In contrast to economically marginalized individuals, people with a disability had a significantly smaller reduction in the probability of never using public transport than people without a disability. This may suggest that additional barriers related to accessibility or fear of victimization prevented people with a disability from switching to public transport. Also, individuals with disabilities did not experience an increase in activity participation across all activity categories. Given the concept of the "accessible trip chain" (*17*), barriers may be associated with both transportation and the activity itself. Since the data show that people with disabilities were more likely to use public transportation with the 9-Euro-Ticket, this finding suggests that the challenges to participating in the activity may be due to the accessibility of the activity or other limitations. This would imply that people with disabilities used the 9-Euro-Ticket to reach their usual destinations, but did not increase their overall level of activity.

Gender

The effect of the ticket on women was also mixed. In contrast to men, they were not more likely to use public transport more often after the intervention. This finding suggests that while they may have tried to use public transport during the ticket's validity period, they were not convinced to make a more permanent switch, possibly due to other barriers they encountered when using public transport. In terms of activity participation, women used the ticket primarily for errands, while men used it more for leisure. Traditional gender roles may explain this pattern. Women typically spend more time on housework than men (*60*).

Limitations

There are several limitations of this study. The (effective) sample size is relatively small and conclusive survey weights have not yet been calculated. Therefore, it is uncertain whether the

results are representative of the entire German population. Due to the sample size, the moderation analysis was also limited to gender, ability, and economic status as monolithic categories. It is plausible that the effect might further differ, for example, between women with a disability and men with a disability, given the intersectional nature of identity categories (*61*). More subgroups based on different identity markers could be created and analyzed in a larger sample. In addition, because PSM relies on observed variables, it may be subject to omitted variable bias. Another limitation is that the dependent variables were based on self-reported behavior, which may be subject to bias. Participants may have over-reported their use of public transportation during the validity period of the 9-Euro-Ticket because they wanted to demonstrate a desired behavior or a psychological wish to justify their investment. In addition, activity participation was measured as the number of days per week that participants participated in a specific activity, which may not capture multi-purpose trips. This could particularly affect the treatment effect for women, as they are reported to use trip chaining (*62*). It is possible that the 9-Euro-Ticket led to increased participation in activities, but these activities were bundled rather than spread over several days. Trip chaining would then lead to an underestimation of the increase in activity due to the 9-Euro-Ticket.

CONCLUSION

The 9-Euro-Ticket was a German nationwide policy initiative that introduced an almost fare-free public transport system for a period of three months. Using Propensity Score Matching and weighted regression models on study participants without previous public transport subscriptions, we showed that economically marginalized people benefited most from the almost fare-free transit. In contrast, the effects on women and persons with disabilities were mixed. The results suggest that there was no targeted financial relief for the economically marginalized. Overall, therefore, the policy seemed to have been effective in addressing the most important barrier for economically marginalized persons: the cost of public transport. It also motivated some individuals to continue using public transport after the intervention. These results can be valuable for other countries that seek to increase public transport ridership and improve access for individuals with a low economic status, especially in the presence of an otherwise accessible public transport service. Despite these impressive effects, the 9-Euro-Ticket was not a cure-all. Structural barriers for marginalized groups, such as victimization or lack of accessibility, still exist. To fulfill every citizen's basic mobility needs is in line with the understanding of public transit as a public service and normative conceptions of transport equity and mobility justice. This justifies government subsidies to make public transport more accessible. Additional policy instruments are needed to implement a public transport system that enables public transport use and activity participation for all while providing targeted financial relief to economically marginalized individuals. While this research explored the effectiveness of the ticket, in the next steps we will include the costs in a comprehensive policy evaluation in the form of a cost-benefit-analysis or cost-effectiveness-analysis. Furthermore, we plan to analyze the effects of the recently introduced 49-Euro-Ticket to explore the impact of a less subsidized fare with the data we collected as part of our study.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Isabella Waldorf, Allister Loder, Stefan Wurster, Klaus Bogenberger; data collection: Allister Loder; analysis and interpretation of results: Isabella Waldorf, Allister Loder; draft manuscript preparation: Isabella Waldorf. All authors reviewed the results and approved the final version of the manuscript.

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