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Push and pull strategies to increase the uptake of small electric vehicles

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ABSTRACT

The demand for larger, heavier, and high range battery electric vehicles (BEVs) is growing. When relying on car utilization, smaller cars with sufficient battery range for typical daily distances could reduce greenhouse gas emissions, consumption of raw materials and pedestrian fatalities. Within our stated preference study with 844 participants, we used a combination of push and pull measures to motivate conventional car users to switch to a small BEV for everyday trips and mobility services for long-range trips. Our results suggest that up to 30% of conventional car owners would be open to switch to a small BEV in combination with mobility services. This can be increased to 41% through improved charging possibilities at home and at work. Combined with a fundamental CO_2 tax on fuel, up to 67% would switch. The results are relevant for transport planners and politicians in designing efficient strategies to increase the uptake of small BEVs.

1. Introduction

There is common agreement amongst scientists that fossil-fuel-based private car mobility is one of the main contributors to negative externalities such as CO_2 emissions, noise, lower air quality and accidents. It is thus imperative to reduce private car mobility with fossil fuels to reach a more sustainable transport system that is in line with the United Nations Development Goals and the Paris Agreement. Technological advances are among the various possibilities to increase sustainability. In particular, battery electric vehicles (BEVs) fueled with renewable electricity can lead to considerable CO_2 emission reductions (Franzò and Nasca, 2021; icct, 2021). In this context, BEVs are gaining in share of total new car registrations around the globe. Recently, Norway has been the first country to report a share of BEVs on new car registrations of over 70% (Holland, 2021) and other countries see substantial growth in BEV adoption as well (European Alternative Fuels Observatory, 2021). However, at the same time, the demand towards large cars and sport-utility-vehicles (SUVs) is increasing, and car manufacturers intensively provide electrified versions of popular SUVs. Furthermore, consumers expect BEVs to achieve ranges that are comparable to conventional cars, in order to cover also long-distance trips, e.g. for holidays, without having to repeatedly recharge the battery along the way (Kowalska-Pyzalska et al., 2022). In view of these developments, it is expected that a substantial share of large and high-range BEVs will be bought in the future.

However, simply replacing current fossil fuel cars with big, high-range BEVs bears several risks: Firstly, facing the characteristics of electric cars, CO_2 and other pollutant emissions strongly depend on the battery capacity, which increases with larger BEVs and range requirements (Ellingsen et al., 2016; Franzò and Nasca, 2021) and are predominantly due to the greenhouse-gas intensive production

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process of batteries (Xia and Li, 2022). Looking at the total lifecycle GHG emissions from cradle-to-grave, a 640 km range BEV (110kWh) has an approximately 28% higher lifecycle GHG emissions compared to a 320 km range BEV (47kWh) (Woody et al., 2022). Similarly, Hung et al. (2021) estimate the difference between a Nissan Leaf with a 62kWh battery to have 12% lower lifecycle GHG emissions compared to a VW ID.4 with a 82kWh battery. Generally, a 10kWh increase in battery capacity leads to an approximate 6% increase in lifecycle GHG emissions.

Secondly, the higher consumption of raw materials for the production of larger and high-range BEVs could lead to an increased risk of supply-chain shortages (Karabelli et al., 2020; Neidhardt et al., 2022). Third, larger and heavier cars increase fatal pedestrian crashes (Tyndall, 2021). Finally, in view of the expected population growth, road infrastructure will increasingly face capacity limits with negative effects on quality of life, particularly in cities where competition with alternative utilizations of public space is highest. Increasing congestion and car presence are likely impacts if the stock of vehicles (and particularly large vehicles) continues to increase (Henderson, 2020).

Hence, under a sustainability point of view, the electrification of car mobility must go along with more systemic innovations challenging the overall mobility culture by downsizing of vehicles and batteries. Particularly, it is important that car-owning households adopt more environmentally sound solutions, for example, switching to a smaller BEV with lower battery capacities which are compatible to the daily driving needs of most users. In Switzerland, for example, the daily average distances covered by car correspond to 24 km (BFS and ARE, 2017). Hence, the expectation of high ranges for BEVs often only have the purpose to be able to cover also very occasional long-distance trips without additional recharging while travelling. In this context, Meinrenken et al. (2020) show that matching the BEV range to drivers' typical trip distances has a high greenhouse gas emission reduction potential. Similarly, Wolfram et al. (2021) show that downsizing cars (e.g. from SUV to a small car) could reduce carbon life cycle emissions by 38%.

In the meantime, leading BEV manufactures included or announced small cars in their portfolio, e.g., Tesla, Renault, or VW. However, the adoption of small cars is exacerbated by misjudgments of customers: specifically, customers tend to overestimate their actual need for range of a car, leading to range anxiety with regard to small BEVs (Hao et al., 2020; Noel et al., 2020). Needell et al., 2016 found that a 2013 Nissan Leaf, which has an average range of 120 km, could already be sufficient to replace 87% of daily car trips in the US, without the need to recharge the BEV during the day. Also, the work by Melliger et al. (2018) show that a range of 230 km is sufficient to replace 87% of all trip legs in Switzerland and 85% of trip legs in Finland. Consequently, many small BEVs are sufficient to cover most of the daily trips already today.

1.1. *Mobility services and long-distance trips*

However, occasional long-distance trips that are not covered by the small BEV with smaller batteries, are still remaining. In order to provide sustainable and valuable solutions for these occasional long-range trips, we focus on other mobility alternatives like car-sharing, car-rental or public transport. Needell et al., 2016 suggest that the availability of carsharing services of conventional internal combustion engine vehicles or BEV with a high range could play an important role for increasing the diffusion of privately owned small BEVs, as they act as a convenient backup for the rare cases, when the range of a small BEV is not sufficient. Further, Hoerler et al. (2021) empirically show a correlation between carsharing experience and openness to buy a small to mid-sized BEV, underlining the suggestion by Needell et al., 2016. Finally, Brückmann et al. (2021) find that Swiss car owners who have a subscription to a carsharing provider are more likely to own a BEV. As such, combinations of small BEVs for everyday trips and carsharing/car-rental or public transport for the occasional long-range trips could be a more sustainable alternative to owning a private fossil fuel driven car or a big BEV with large batteries. In order to provide valuable options for occasional long-range trips, we are going to test current car users whether they accept a small BEV covering daily distances in combination with public transport or carsharing/car-rental as the next car replacement.

Furthermore, a mobility lifestyle using mobility services without owning a private car has been found to have a high greenhouse gas mitigation potential (Vita et al., 2019). As a consequence, we additionally test current car users whether they accept a flexible combination of public transport and carsharing/car-rental in the context of the discussion of car-free households (Paijmans and Pojani, 2021).

We are aware that switching from owning a private car to mobility services requires a general shift in mobility culture. Adopting a new mobility lifestyle would lead to changes in mobility behavior and daily routines, e.g., regarding the fueling/charging practice or the organization and planning of trips and journeys (Sopjani et al., 2020). Despite of its potential advantages, as presented, such a new mobility lifestyle combining the ownership of a small BEV for everyday trips and using mobility services for the occasional long-range trips, to the best of our knowledge, has only been considered through qualitative research in earlier studies (e.g. the unbundling of cars to daily use and infrequent use by Sprei and Ginnebaugh (2018)).

1.2. *Push and pull strategies*

In order to support the uptake of sustainable mobility behavior and decisions, Steg and Vlek (1997) distinguish between push measures, decreasing the benefits of conventional cars and car use, and pull measures aiming to improve alternatives to the private fossil fuel car. On the one hand, pull measures are more easily capable of creating political majorities, requiring no sacrifices by those getting "pulled" and are therefore much more likely to be accepted (Keizer et al., 2019; Steg, 2003). However, they often prove to be of limited success in initiating behavioral changes (Cools et al., 2011). On the other hand, push measures like an increase in CO_2 tax (Venturini et al., 2019) or the gradual intensification of fleet emission targets within the EU (Fekete et al., 2021) have been proven to be successful. Hoerler et al. (2020) also find through a hypothetical scenario that a gradual increase of a combination of push measures like fuel taxes, vehicle import restrictions and ban of non-electric vehicles in city centers increase the openness to change mobility behavior with regard to mobility services. Tilov and Weber (2021), for example, show that gasoline taxes could be effective in reducing vehicle kilometers travelled.

However, research also points to potential problems with such policies, since taxes and regulations increase opposition and are less accepted by persons with a right-winged ideology and those driving larger cars or reporting high annual mileage (Harring et al., 2017; Stradling et al., 2000; Wicki et al., 2019). Finally, Lilliestam et al. (2021) show that carbon pricing like emissions trading systems and carbon taxes don't currently accelerate a technological change.

Taking into account the difficulties described above, scholars suggest to combine strategies of discouragement (push) and encouragement (pull) (Rietveld and Stough, 2005; Thaller et al., 2021; Wicki et al., 2019). This way, valid alternatives are created for those who get "pushed" out of their comfort zone (Eriksson et al., 2008). The combination of push and pull measures has since been adopted by many scholars (e.g. Stoiber et al., 2019; Wang et al., 2020). We take up this discussion on push and pull measures, implementing in our survey the following pull-measures to increase acceptance of the proposed alternatives: Better Home & Charge and Work & Charge, better access to carsharing stations and additional information on Total Cost of Ownership. As a push-measure, we implement a stepwise increase of CO_2 tax on gasoline and diesel:

Better Home & Charge and Work & Charge solutions: While some scholars stress the importance to foster fast charging stations to enable BEVs owners to drive long distance trips (Haustein and Jensen, 2018), others suggest that Home & Charge and Work & Charge (HC & WC) would be important in higher BEV adoption rates (Hardman et al., 2018; Melliger et al., 2018; Patt et al., 2019), referring to the limited daily distance that car drivers cover on average. Since we propose the utilization of a small BEV to cover daily distances, the HC & WC obstacle seemed to be of higher relevance for our study. Hence, we hypothetically provide the availability HC & WC as a first pull measure.

Better access to carsharing stations: Carsharing is convenient if you have access to a carsharing station close to your place of residence. We therefore increase the comfort of carsharing by hypothetically increasing the number of carsharing stations and availability of a shared car as a second pull measure.

Information on Total Cost of Ownership: Consumers commonly misjudge the total cost of ownership (TCO) of cars underestimating or neglecting sunk and periodical costs in their cost-awareness, e.g. purchase price, maintenance, taxes, and insurance (Andor et al., 2020; Gössling et al., 2022; Lane and Potter, 2007). While studies show that BEVs could indeed lead to savings compared to owning a similar fossil fuel car, this is not yet considered by the general public (Andor et al., 2020; elementenergy, 2021). As such, awareness regarding cost advantages of BEVs as well as comparing the TCO of BEVs with similar conventional vehicles might increase its uptake. Hence, we argue, that information on TCO could be a promising third pull measure towards the uptake of the mobility alternatives.

Stepwise increase of CO_2 tax: As a push measure, we use a 4-step CO_2 tax increase on gasoline and diesel, since earlier research shows that this can be an effective and feasible policy to spur behavior change if combined with appropriate pull measures (Eriksson et al., 2008; Thaller et al., 2021; Wicki et al., 2020, 2019).

To the best of our knowledge, no study so far combined within one choice experiment different push and pull measures, enabling this way an integrated push and pull strategy in fostering the uptake of small BEVs in combination with mobility services. With our research, we fill this gap and provide practical insights for policy makers and mobility planners.

Summarizing, our study considers the following research gaps:

- Acceptance of small BEVs in combination with mobility services for occasional long-distance trips, when switching from a conventional fossil fueled car
- Acceptance of a flexible combination of mobility services for all trips, in the context of car-free households
- Potential of push and pull strategies in order to further foster such a switch.

These research gaps lead to the following research questions:

- What percentage of conventional car users are open to: i) a mobility lifestyle with ownership of a small BEV in combination with public transport, ii) ownership of a small BEV in combination with carsharing/car-rental or, iii) a flexible combination of public transport and carsharing without car ownership?
- What push and pull measures, like i) increasing levels of fuel tax, ii) better availability of charging stations, iii) increased carsharing availability and iv) information on TCO might foster such a shift?

The remainder of this paper is structured as follows: Section 2 describes the survey design, the statistical model, and the limitations of the study. This is followed by Section 3 and 4, containing the results and the discussion. Finally, Section 5 summarizes the research and provides recommendations for policy and practice.

Table 1
Experiment sample and SHEDS 2020 sample compared to the Swiss population.

Variable	Level	Experiment (n = 1175)	SHEDS 2020 (n = 5′500)	Swiss population	Difference Experiment / Swiss population
Age[1]	Average	48.44	44.52	44.2	$t(1175) = 9.32$, $p < 0.001$
Gender[2]	Male	51.3%	48.1%	49.6 %	$\chi2$ (1, N = 1175) = 1.39, $p = 0.239$
	Female	48.7%	51.9%	50.4 %	
Education[3]	Less than university	52.3%	54.9%	50.5%	$\chi2$ (1, N = 1175) = 1.45, $p = 0.229$
	University	47.7%	45.0%	49.5%	
Gross Household income[4]	<3′000 CHF	6.9%	6.9%	10′114 CHF (average)	
	3′000–4′500 CHF	10.6%	9.4%		
	4′501–6′000 CHF	16.2%	17.1%		
	6′001–9′000 CHF	29.0%	28.4%		
	9′001–12′000 CHF	20.7%	21.1%		
	More than 12′000 CHF	16.6%	17.1%		
Household car ownership[5]	No	25.6%	23.5%	22.0%	$\chi2$ (1, N = 1175) = 15.83, $p < 0.001$
	Yes	74.4%	76.5%	78.0%	
Public transport passes[5]	No	14.2%	15.2%	43.0%	$\chi2$ (1, N = 1173) = 395.93, $p < 0.001$
	Yes	85.8%	84.8%	57.0%	

[1] Swiss Federal Statistical Office (2021a), [2]Swiss Federal Statistical Office (2021b), [3]Swiss Federal Statistical Office (2021c), [4]Swiss Federal Statistical Office (2021d), [5]BFS and ARE (2017).

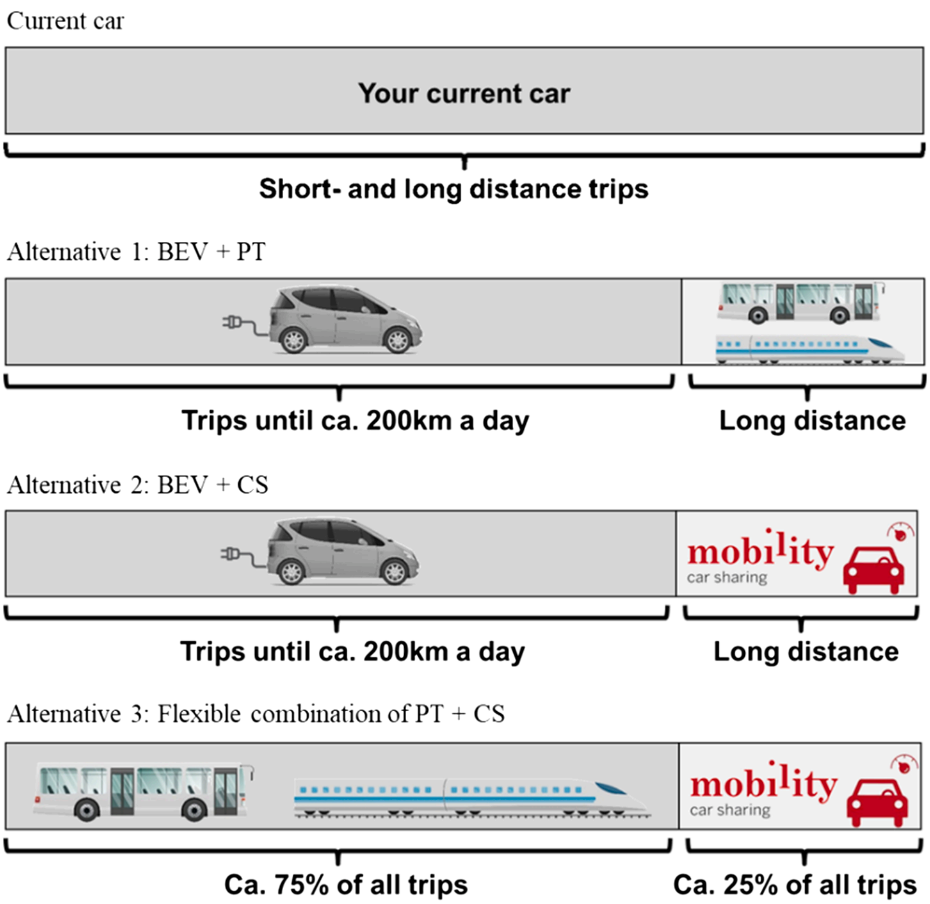

Fig. 1. Visual depiction of the three alternatives studied in this work. Mobility is the largest carsharing operator in Switzerland covering the whole country.

2. Methodology

2.1. Survey sample

We designed a multiple price list choice experiment within SHEDS 2020. SHEDS is representative for age, gender, and tenancy status for the German- and French speaking population of Switzerland. In total, 1′175 of the 5′500 SHEDS respondents were accounted to our choice experiment, from which 844 own at least one household car with a gasoline or diesel engine (including hybrids) and 15 households own a BEV. For a full description of SHEDS, see Weber et al. (2017). The following table displays the differences between the Swiss population, SHEDS 2020 and our experiment sample for a set of socio-demographic and mobility related variables (Table 1).

We have a slightly older sample and a small underrepresentation of car owning households compared to the Swiss population. Since our research only focuses on car owning households, a reweighting of the sample in the context of our study is not necessary. Gender, education, and income do not differ strongly from the overall SHEDS 2020 sample and the Swiss population. However, the experimental sample and the SHEDS survey sample have an overrepresentation of public transport pass owners compared to the Swiss population.

2.2. Definition of alternative mobility lifestyles

Our target group were Swiss households owning a fossil-fuel driven car. We asked respondents to imagine a hypothetical scenario three years in the future: After a car breakdown, they were faced with the decision of keeping their current mobility lifestyle and buying a new fossil fuel car or switching to an alternative that would replace the car and all trips conducted with that car (details are provided in Section 2.3). The alternatives were derived looking at innovative mobility scenarios currently proposed in literature (e.g. Sprei and Ginnebaugh (2018)) and discussing these in two expert workshops with the SCCER CREST network (Swiss Competence Center for Research in Energy, Society and Transition), which is composed of mobility experts, economists, psychologists and sociologists.

Fig. 1 provides an overview of the choice set, consisting of the "current car" option and three alternatives, as shown to the survey respondents. The basis of alternative 1 and alternative 2 is a small sized BEV like the Renault Zoe (52 kWh battery capacity and a range of 342 km according to WLTP) or BMW I3 (38 kWh battery capacity and a range of 310 km according to WLTP), since research shows that most trips could be covered by current small BEVs (Meinrenken et al., 2020; Melliger et al., 2018; Needell et al., 2016). Both cars are categorized as a small car but still offer up to 5 seats fulfilling the needs of an average family in Switzerland. In adverse climate conditions like during winter, the range of BEVs are, on average, reduced by 30 to 36% (Hao et al., 2020; Wei et al., 2022). Further, a reduction of up to 30–40% of driving range is expected while driving on a highway (Yuan et al., 2020). As our experiment took respondents three years into the future, new versions of the Renault Zoe and BMW I3 or similar cars are expected to deliver around 400 km WLTP (Renault Group, 2020). Hence, we used the threshold of 200 km per day, which could be easily covered by such a car even in adverse weather conditions without the need to recharge the car during the day. Trips which exceed the 200 km limit per day would be conducted by either public transport (Alternative 1) or carsharing/car-rental (Alternative 2). Elementenergy (2021) show that 67% of German car owners have 10 or fewer trips per year exceeding 200 km. Similarly, Neuenschwander (2020) finds through GPS data that Swiss car travelers exceed the overall distance of 200 km only on 3% of the days within a year. We further included a third alternative for replacing the current fossil-fuel driven car through a flexible combination of public transport and carsharing/car-rental, providing an alternative without car ownership.

We intentionally restricted the choice sets to these three alternatives, since we want to investigate the openness to a more radical mobility change. We don't consider, for example, switching from currently using a large conventional car to a similar sized BEV to be a strong change of mobility lifestyle, especially since it has lower sustainability benefits compared to the three alternatives above.

2.3. Choice experiment - survey

We structured the choice experiment survey in four parts: 1) questions about the car and car usage characteristics, 2) introduction to the multiple price list choice experiment, 3) actual choice tasks and 4) follow-up questions. Other relevant socio-demographic, mobility-related, psychological, and sociological variables were drawn from the main survey of SHEDS 2020. Fig. 2 provides an overview of the survey structure. Respondents in the HC & WC treatment group are not asked to answer the multiple price list for alternative 3 since a better charging situation is useless for this alternative consisting only of public transport and carsharing, without owning a BEV. Similarly, for the CS treatment group, alternative 1 does not include carsharing, which therefore is excluded for this treatment group. In the following, we describe each step of the survey.

1) Questions on mobility behavior

The questions on mobility behavior are used to tailor the choice experiment questions to the respondent's mobility situation in part 3. The following information of the currently owned conventional car is included:

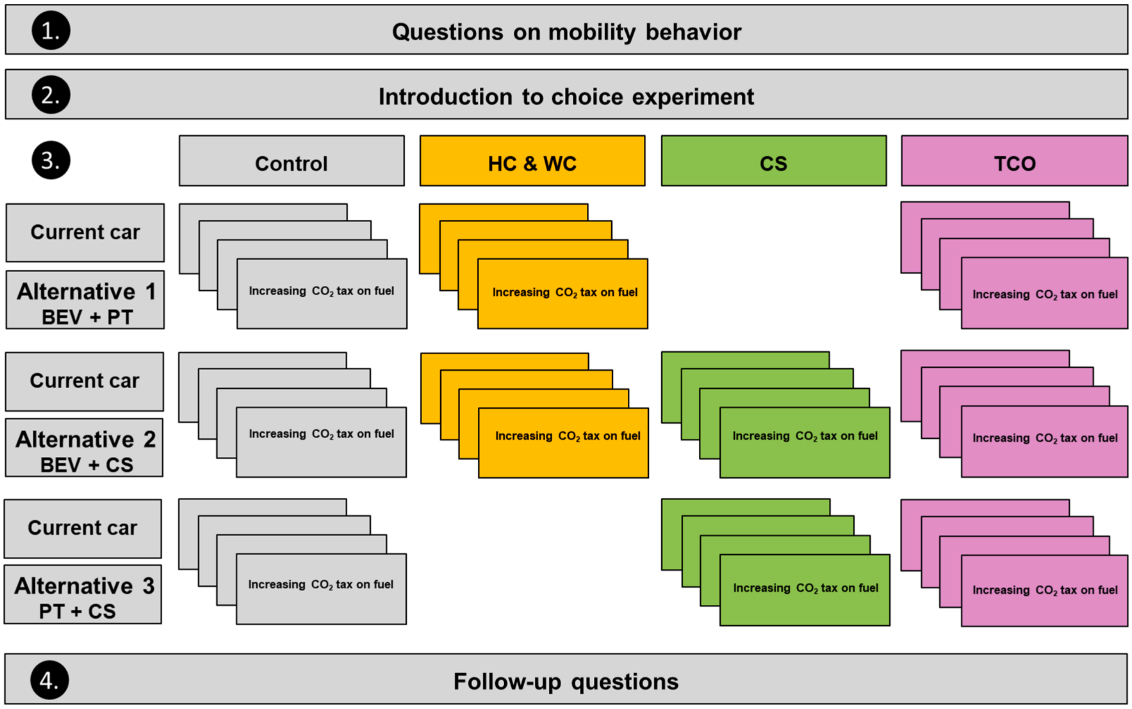

Fig. 2. Overview of survey structure, where PT stands for public transport, HC & WC for Home & Charge and Work & Charge, CS for carsharing and TCO for total cost of ownership.

- the fuel type (gasoline, diesel)
- the mode of purchase (bought new, within a leasing contract, bought as a second-hand car)
- age of the car at purchase
- the price of the car
- average kilometers driven per year
- the number of daytrips exceeding 200 km per year
- the average lengths of these daytrips exceeding 200 km
- the number of car trips exceeding 400 km with at least one overnight stay per year
- the average distance covered for these car trips with at least one overnight stay

All questions are targeted to the main household car (i.e., the car that is used most within the household). According to the average distances covered in Switzerland (see section 2.2), we assume that trips exceeding the 200 km threshold would be very rare and therefore, a large part of the population can estimate the number of the respective trips per year.

2) Introduction to choice experiment

Within this second part of the survey, the respondents were told to imagine a situation in about three years, where their main household car breaks down and cannot be repaired. In this context, they are asked to decide whether they would buy a similar car again (status quo referred to as “current car”) or switch to an alternative. The status quo and the three alternatives are then explained and visualized according to Fig. 1. A randomization process assigned each person into one of the following four treatment groups (see Fig. 2), each with a specific introduction:

- The **control** group reflects the current situation regarding infrastructure and sharing possibilities.
  This group is introduced to the next steps through the following text: “Please assume for all choices: The public charging infrastructure has slightly increased. The availability of carsharing and car-rental stations is similar to today.”
- The treatment group **HC & WC** is offered improved charging infrastructure at the respective locations and is introduced to the next steps through the following text: “Please assume for all choices: **The charging infrastructure has improved significantly.** You have easy access to a charging plug at home, and most companies provide charging at work. As such, you can easily charge your battery at home during night or at work if required.”
- The treatment group **CS** is offered an increased accessibility of carsharing stations through the following text: “Please assume for all choices: **The availability of carsharing stations and shared cars has increased significantly.** You can easily access a car by foot from your home and one-way trips are possible. In rural regions, it is common to share cars via apps.”

- The treatment group **TCO** is informed about the full overall costs of their current car use and the proposed alternatives. The treatment is introduced with the text "In each choice, you are presented the **full costs of the options according to your current mobility behavior.** These costs represent all expenses for the car (including amortization, parking, insurance, taxes, depreciation, fuel, registration, tires and repair & maintenance) and all expenses for public transport or carsharing/car-rental if applicable."

The TCO is calculated by utilizing the respondents' answers to the questions about their car and mobility behavior in part 1 of the survey, combined with fixed costs and variable costs adapted from Touring Club Switzerland (TCS, 2021). Fixed costs include depreciation, interest on capital, road tax, third-party insurance, partial casco, ancillary expenses, garage costs and vehicle maintenance. Variable costs are mileage-dependent and include depreciation, fuel costs, tire exchange and general service and repair expenses. Details of the TCO calculations can be retrieved in Hoerler and Stoiber (2021).

3) Choice experiment

After the treatment text and a message asking the respondent to carefully consider the coming decisions as if these really affected their preferences and household budget, the choice experiment starts.

Within the treatment groups described above, each person is presented the choice tasks utilizing vignettes with two options each: The "current car" option and one of the alternatives 1, 2 and 3 (see Fig. 1 for an overview of the choice options and Fig. 3 illustrating an exemplary choice task for the TCO treatment group). Every respondent is presented all three alternatives in random order. Within each alternative, the respondents are confronted with a multiple price list experiment of four steps, representing hypothetical and substantial increases of a CO_2 tax on fuel (the push measure according to the discussion in section 1.2). We didn't include a CO_2 tax on electricity, since the electricity mix in Switzerland is largely carbon-free and to draw the focus on the increase in fuel price. The multiple price list starts with a baseline CO_2 tax on gasoline and diesel of 15%, individually calculated according to the mobility behavior of the respondent. Afterwards, the CO_2 tax increases stepwise to 50%, 100% and 200%. The amount of the CO_2 tax is in addition to the current fuel price, including other levies (there is currently no CO_2 tax on gasoline or diesel in Switzerland). In the experiment, the respondents are informed about the new fuel price. Further, they are informed that the price includes a CO_2 tax of XX% according to the step of the multiple price list. As soon as the respondent chooses the alternative option, the process of the multiple price list is interrupted. As such, over the alternatives 1, 2 and 3, each respondent conducts a minimum of 3 (the respondent chooses the alternative every time in step 1 of the multiple price list) and a maximum of 12 (the respondent proceeds to step 4 of the multiple price list for all alternatives) choice tasks. The general idea of a multiple price list is to explore the level, at which the financial burden is so high, that a decision change to an alternative is induced. Respondents who would not switch even after introducing a 200% CO_2 tax on gasoline and diesel are thus less susceptible to financial push measures and should be addressed by other measures such as the pull measures tested with the treatments in the same survey.

Each choice task was supported by various attributes for the different choice options (see Fig. 3), including car price (tailored to the respondents' answers in part 1 of the survey), variable cost (tailored to the car size and fuel type of the respondents' car), total cost for the TCO treatment, availability of fuel and charging stations, and sharing possibilities for alternative 2 and 3. If the respondent sticks to the current car (option 1), the multiple price list starts to trigger a CO_2 tax of 50% on gasoline and diesel representing a 35% increase of

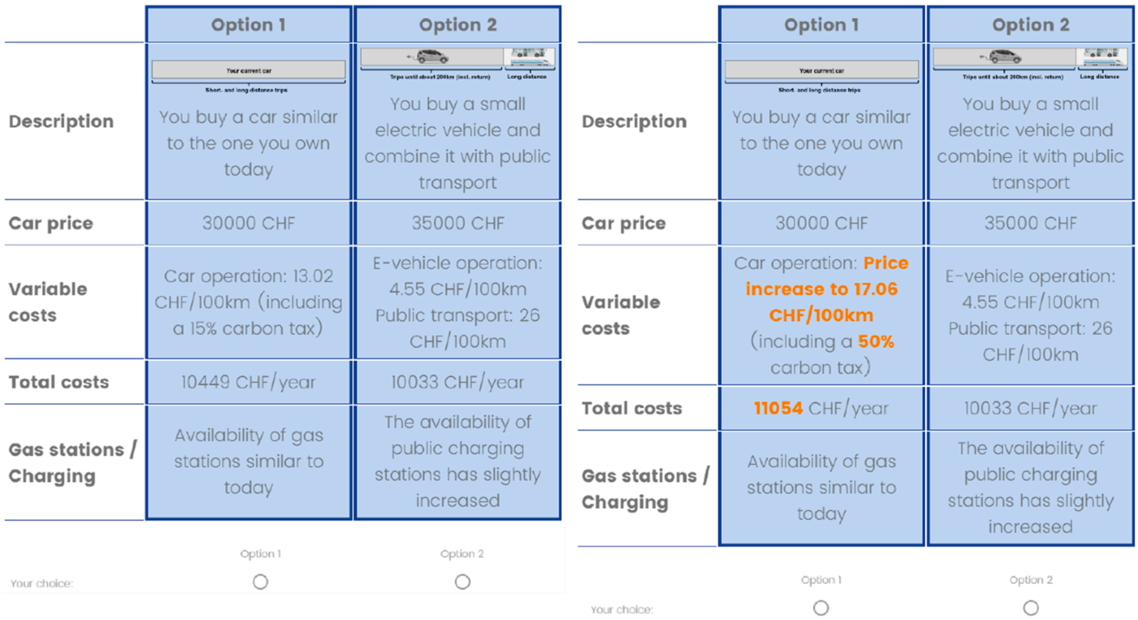

Fig. 3. Example of two consecutive pages of the multiple price list survey for the TCO treatment group. The first page representing the baseline 15% CO_2 tax scenario and the second page the 50% CO_2 tax scenario, after the respondent chose option 1 in the baseline scenario. Changes are marked in bold orange. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

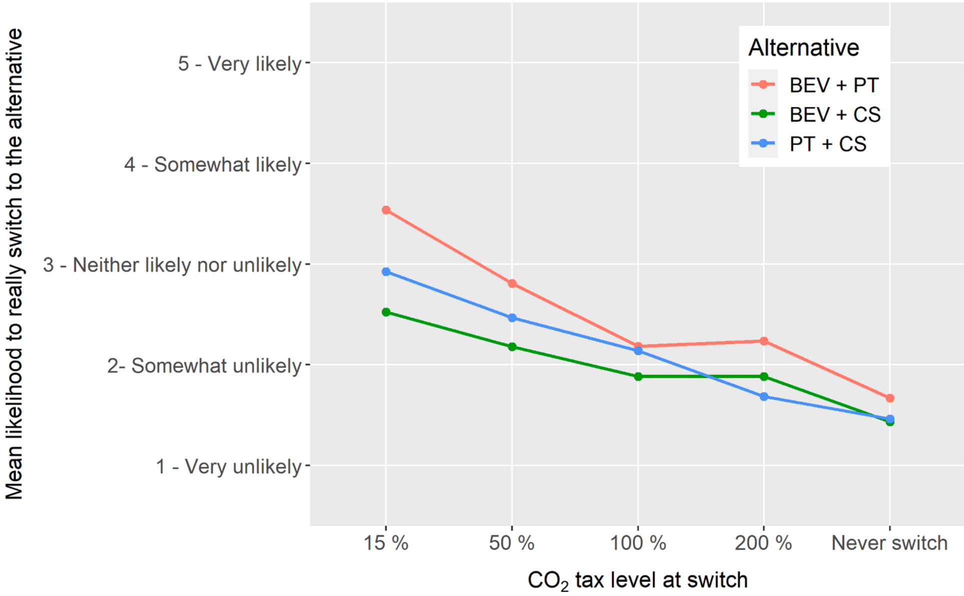

Fig. 4. Mean likelihood to really switch to the alternatives for each CO_2 tax level at switch.

gasoline and diesel cost per liter (since the baseline already includes a 15% CO_2 tax on fuel). The same is followed stepwise to a CO_2 tax of 100% and 200% if the respondent keeps choosing option 1. The stepwise increase of the CO_2 tax is represented in the "variable cost" attribute of the choice task. For the TCO treatment group, the total cost attribute is also recalculated with each increase in CO_2 tax.

4) Follow-up questions

After the choice experiment, every respondent answered a set of follow-up questions. For each alternative (BEV + PT, BEV + CS, CS + PT), we asked the likelihood to really choose the alternative if the respondent needed to replace his/her main household car within the next few years on a 5-point Likert-scale (very unlikely to very likely). If the respondent chose "very unlikely", a possibility to explain the decision within a blank text field was implemented. This allowed us to validate the choice experiment answers and get a deeper insight into potential reasons restraining from adopting the more sustainable alternatives.

Another set of questions asked about the satisfaction with the number of carsharing stations and whether the current range of small BEVs of approximately 250 km satisfies the needs for everyday trips. Last, we asked the respondents how close their place of residence is located to a carsharing or public charging station and whether they have the possibility to charge an EV at home.

2.4. Data screening

To ensure validity of our results, we conducted several consistency checks. First, we examined the average duration of filling in the choice-experiment to check whether some respondents rushed in answering the questions. With a median of 6.8 min, we expect that overall responding times below 2 min would be too short for a thorough answering of the choice experiment's questions. Since we asked the respondents to report their annual mileage driven with their main household car and how many daytrips exceeding 200 km and overnight trips exceeding 200 km one-way they conduct per year (including an indication on how long these trips exceeding the threshold of 200 km are), we could check whether they can consistently estimate their number of long-range trips. In only two cases, respondents reported long-range trips exceeding the annual mileage driven with their main household car. These cases were removed from the analysis due to inconsistency. We further checked whether respondents were consistent in answering the choice questions and the follow-up questions. For respondents who switched to one of the three alternatives in the choice experiment task, we would expect a higher average rating in the follow-up question that asked whether the respondent would really switch to such an alternative in real life on a Likert scale from 1, very unlikely to 5, very likely. Fig. 4 shows that this is the case for all three alternatives. The difference is less pronounced between the 100% and 200% CO_2 tax on fuel. This is expected since the biggest hurdle is a switch to one of the alternatives directly in the baseline condition without any CO_2 tax increase, or no switch at all.

We checked the validity of respondents' assessment whether an EV range of 250 km is sufficient for their everyday trips (a Likert scale from 1, totally disagree to 5, totally agree). This was possible, since we know their number of daytrips exceeding 200 km per year from part 1 of the experiment (see section 2.6). We found a clear trend towards lower agreement with more daytrips exceeding 200 km per year (see Fig. A1 in the appendix). We therefore assume that respondents were able to make reasonable decisions in their choice tasks. From the TCO treatment group, we deleted 15 cases with inconsistent purchase prices (e.g., no purchase price despite the car being new, or a clear mismatch between age of the car and the purchase price).

Table 2
Hurdle model with and without interactions for each alternative and treatment.

	Model 1 (Without interaction)	**Model 2 (Including interaction)**
Alternative 1 Charging	df = 13, AIC = 2016.838	df = 15, AIC = 2015.766
Alternative 1 TCO	df = 10, AIC = 1490.126	–
Alternative 2 Charging	df = 8, AIC = 1819.004	df = 12, AIC = 1791.634
Alternative 2 Sharing	df = 14, AIC = 1791.633	df = 18, AIC = 1783.980
Alternative 2 TCO	df = 9, AIC = 1000.971	–
Alternative 3 Sharing	df = 12, AIC = 1598.703	df = 14, AIC = 1592.915
Alternative 3 TCO	df = 8, AIC = 1733.83	df = 10, AIC = 1732.97

Table 3
Frequency of respondents for whom the TCO of alternative is lower or higher than their current car for each of the 3 alternatives.

	Control		TCO Treatment	
	TCO of alternative lower	TCO of alternative higher	TCO of alternative lower	TCO of alternative higher
Alternative 1: BEV + PT	166 (83%)	34 (17%)	163 (82%)	36 (18%)
Alternative 2: BEV + CS	122 (63%)	71 (37%)	121 (62%)	73 (38%)
Alternative 3: PT + CS	195 (99%)	1 (1%)	194 (98%)	4 (2%)

2.5. Statistical analysis

Since our data consists of structural zeros (respondents who never switch) and count data (switching at 15% CO_2 tax, 50% CO_2 tax, 100% CO_2 tax and 200% CO_2 tax), a hurdle model works best (Hu et al., 2011). As our multiple price list only contains 4 steps, we transformed the fuel cost of the respondents' car into count data, increasing the number of datapoints due to the differences in fuel type (gasoline and diesel) and car size to increase the interpretability of the results. Accordingly, we calculated the fuel cost of the respondents' car at the switch, which depends on the CO_2 tax levels, car size and fuel type. We checked for differences between the control and treatment groups regarding car size and fuel type through chi-square test and did not find any significant differences. The increase in fuel costs therefore depends on the CO_2 tax at the switch. Respondents who didn't switch at all received the value of 0, which denotes the hurdle in the hurdle model. The model first checks through a binomial logit link whether respondents decided to switch (fuel cost > 0) or not (fuel cost = 0). Then a count model with a negative binomial log link regression tests whether there is a significant difference in fuel cost at the switch between the control group and the treatment group. Since a switch at a higher CO_2 tax stage corresponds to higher fuel costs, people displaying larger fuel costs switched at a later stage. We rounded the fuel costs to integers and ensured that the first value starts at 1 by subtracting 9 from the lowest rounded fuel cost of 10 CHF / 100 km. Fig. A2 in the appendix provides a histogram displaying the large amount of zeros (respondents that didn't switch at all) represented in our data.

SHEDS contains many variables related to socio-demographics, mobility characteristics, attitudes, and values. Since previous research shows that mobility related decisions in stated preferences strongly depend on these variables (see e.g. (Hoerler et al., 2021; Singh et al., 2020)), we checked whether there are significant differences between our control and the treatment groups by performing independent sample t-tests for continuous variables and chi-squared tests for categorical variables. An overview of these variables is shown in Table A1 in the appendix. All variables that exhibited significant differences were included in the hurdle model to account for these differences. Since we want to measure the effect of the treatment on the probability to choose the alternative mobility lifestyle, we applied an exploratory approach to find any significant interaction of the treatment variable with the socio-demographic, mobility characteristic or attitudinal variables shown in Table A1. In doing so, we followed the principle of weak heredity in selecting interaction terms and checked the AIC of the model with and without the interaction term. Weak heredity states that at least the interaction and one of the interacting variables need to have a significant effect to be included in the model (Wu and Hamada, 2011). In total seven hurdle models are calculated, one for each treatment and alternative. Table 2 compares the models without the interaction (model 1) and including the interaction (model 2). No significant interactions were found for Alternative 1 TCO and Alternative 2 TCO.

We further checked the qqr-plot, the rootogram and AIC to ensure that a binomial logit link fits best. Figs. A3 – A5 in the appendix show the difference between a Poisson model and a binomial model with a rootogram clearly showing a visually better fit of the binomial model. Accordingly, the AIC is considerably lower for all models using a binomial logit link compared to a Poisson model.

Regarding the TCO treatment, we only want to test the effect of the TCO information treatment, if the TCO of the alternative is lower than the TCO of their current car. Hence, the control and treatment group in the TCO hurdle model only contain cases for which the TCO of the alternative is lower, leading to a separate control group for the TCO treatment. Table 3 shows the percent of respondents being better off with the alternative for each alternative including all CO_2 tax levels.

2.6. Limitations

Firstly, an important general limitation is the nature of a stated choice experiment since we didn't observe actual behavior, often referred to as hypothetical bias. We accounted for this bias by using methods such as "cheap talk", budget reminders, referencing and follow-up questions, allowing a consistency check (Haghani et al., 2021). Still, investigating how people would behave in reality needs to be addressed by a revealed preference study. Furthermore, there are potential limitations due to the narrow system borders of our survey:

- Our survey follows mostly a price sensitive approach that does not consider habits, routines, and practices, that lead to a continuity of mobility decisions and lifestyles and might overestimate the acceptance of the proposed alternatives in our survey. We tried to manage this potential error focusing on a typical strategic long-term mobility decision (car purchase after a breakdown).
- We use a stepwise increase of CO_2 tax on diesel and gasoline as a financial incentive to switch to the proposed mobility options. This opens the discussion of what instrument to take when pricing CO_2. Whereas levies show positive distribution effects, taxes are more unpopular, generating a potential resistance among respondents to choose the proposed alternatives.
- Our survey has been undertaken in Switzerland. Average distances and the alternatives proposed are adapted to the Swiss transport system, which offers relatively high-quality public transport in the whole country and carsharing possibilities in lot of regions already today. For other countries, our survey would have to be adapted. Furthermore, the data of the survey has been collected in 2020 in the midst of the first wave of the Corona pandemic, which generally led to a stronger orientation towards the car in Switzerland. This might have influenced the choices conducted in the survey, overestimating the "current car" alternative.

Furthermore, there are some potential errors referring to the specific conceptualization of our choice experiment:

- Investigating the answers to the open-stated questions as to why the respondents would not switch to the alternative in real life (shown if respondent has a score of 1 from 1, very unlikely to 5, very likely), we see that some respondents misinterpreted alternative 2 (combination of BEV and carsharing/car-rental) as they assumed their own car would be shared instead of using a carsharing service. While it was only a small fraction of respondents (roughly 6% of those who rated 1 on the Likert scale), we don't know whether respondents who did not answer the open-ended question interpreted alternative 2 correctly. We compared the results with and without the 6% who probably misunderstood alternative 2 finding no significant differences. Still, we assume that alternative 2 could be valued higher than represented in our experiment.
- Self reporting of car size could lead to different interpretations of the same car type. We checked this by examining the car model reported in SHEDS 2020 (e.g., VW Tiguan), which could then be compared to the official classification used by TCS. Only few respondents reported to own a small car, when in fact it was officially classified as a small-medium car. Differences were on maximum between two neighboring size classes, so, in general, the difference between small and large cars stays valid.
- Self-reporting of the number of trips per year exceeding 200 km could be over- or underestimated. We compared our average of 9.53 trips per year exceeding the 200 km threshold with Neuenschwander (2020), who used GPS-based data in Switzerland to estimate the number of trips for different range categories. With an average of 10.7 trips exceeding 199 km per year, the GPS-based data is very similar to our self-estimated data. Likewise, Plötz et al. (2017) investigated the number of days per year a daytrip exceeds 200 km in Sweden using GPS measurements. They find very similar results with 11.9 days per year on average, and a median of 3.8 days per year. Hence, we argue that the respondents made accurate choices regarding their number of daytrips exceeding 200 km per year. With respect to the sample of our study, Fig. 5 provides an overview of the number of daytrips exceeding the 200 km threshold per year and the number of overnight trips exceeding the 400 km threshold per year. We see that

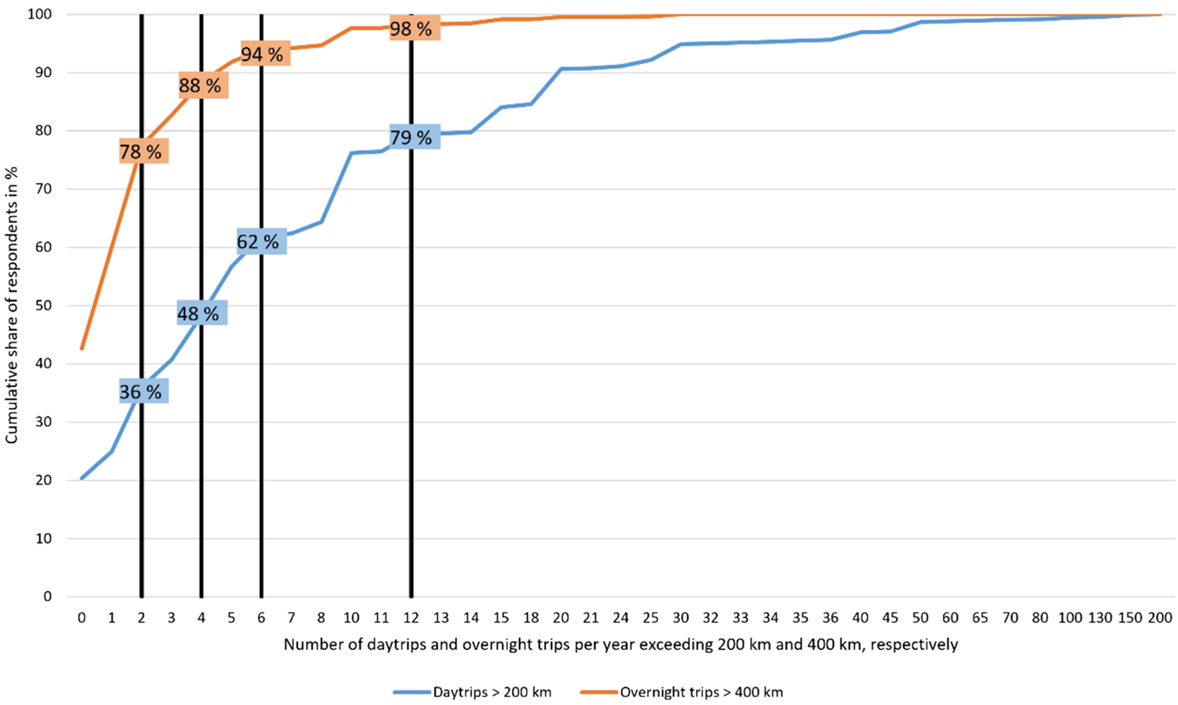

Fig. 5. Number of days per year respondents exceed the threshold of 200 km for daytrips and 400 km for overnight trips. Vertical lines highlight 2, 4, 6 and 12 days per year the threshold is exceeded.

these trips are relatively rare. Almost 80% of respondents do have 12 or fewer daytrips per year exceeding 200 km. Therefore, 80% of car owners would need to switch to a long-distance alternative at most once a month. Nearly 80% of respondents have 2 or fewer overnight trips per year that exceed the 400 km limit.

- We only compared the cost for trips driven with the main household car. This implies that for a respondent who currently also uses public transport, the alternatives 1 and 3 would come along with even greater financial benefits. To be accurate, the current public transport costs would have to be added to the TCO of the respondents' car use. We therefore assume that our estimations are rather conservative and that in reality, the potential financial benefit of switching to alternative 1 or 3 would be even higher.
- While the focus of our study is on the acceptance of small BEVs or a car-free lifestyle, we do not know whether respondents who did not indicate a switch to one of the proposed alternatives would opt for something different like a larger BEV. Since consumers usually prefer the "status quo" in choice experiments if they are uncertain what to choose (Dhar, 1997), we expect that customers who might intend to buy a BEV model that corresponds more to their current car or not want to buy a car at all, but are not open for other mobility lifestyles proposed by the alternatives, would go for the "current car" option in the choice set since it represent a "status quo" option. Consequently, we are confident that the choice set offered in the experiment corresponds to the research questions presented in section 1.

3. Results

3.1. Descriptive overview

Firstly, we provide an overview of the frequency of switches differentiated according to the levels of CO_2 tax for each alternative and treatment group. Fig. 6 summarizes the descriptive results of the choice experiment in one graph.

Alternative 1 (combination of BEV and public transport): Already 30% of the respondents would switch to this alternative at a CO_2 tax of 15% (baseline condition) and without any additional pull measures. A further 27% could be motivated to switch to

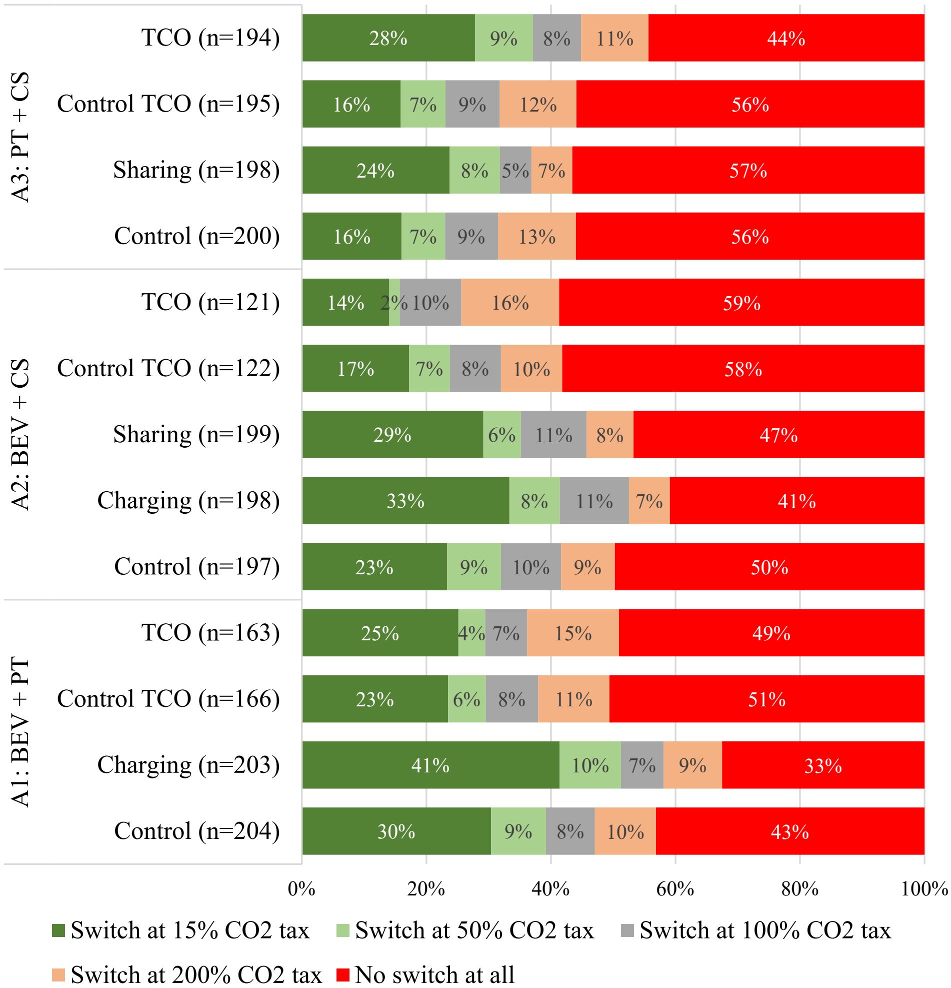

Fig. 6. Descriptive overview of the percent of respondents switching in each CO_2 tax level and each alternative and treatment group.

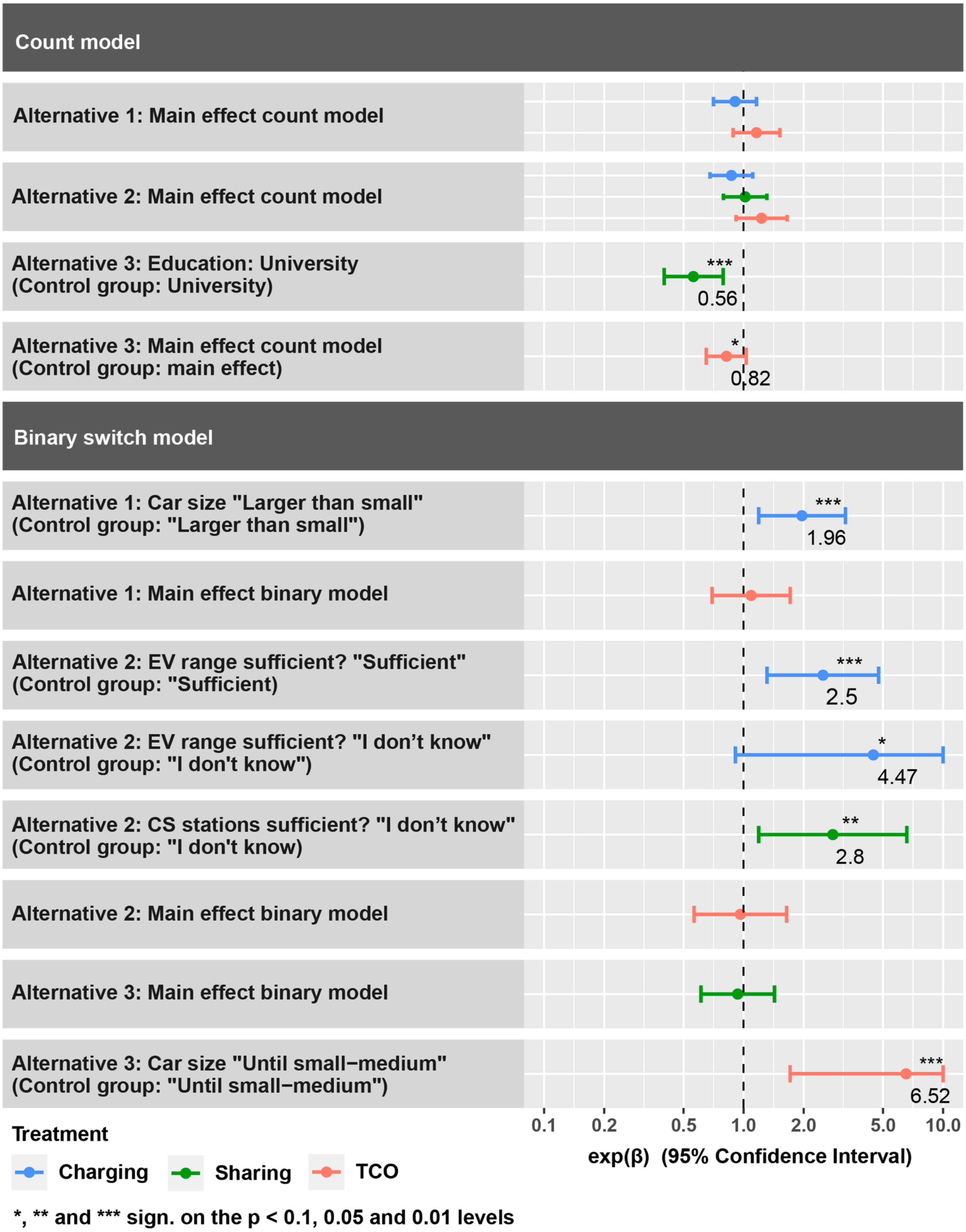

Fig. 7. Summary of hurdle model results depicting odds ratios for each alternative and treatment.

alternative 1 with increasing monetary push measures (50%, 100%, and 200% CO_2 tax on fuel), while 43% of respondents do not switch to alternative 1 even after including a 200% CO_2 tax on gasoline and diesel, indicated by the red bar in Fig. 6. This latter group seem to reflect respondents that cannot be motivated to switch at all, even after strong financial measures. The percent of respondents who switch already at the 15% CO_2 tax level increases from 30% to 41% for the charging treatment group. This group is offered a significantly better charging situation at home and at work. The share of respondents who could further be motivated through the increasing CO_2 tax levels is 26% and very similar to the control group. Lastly, we see a reduction of respondents who never switch from

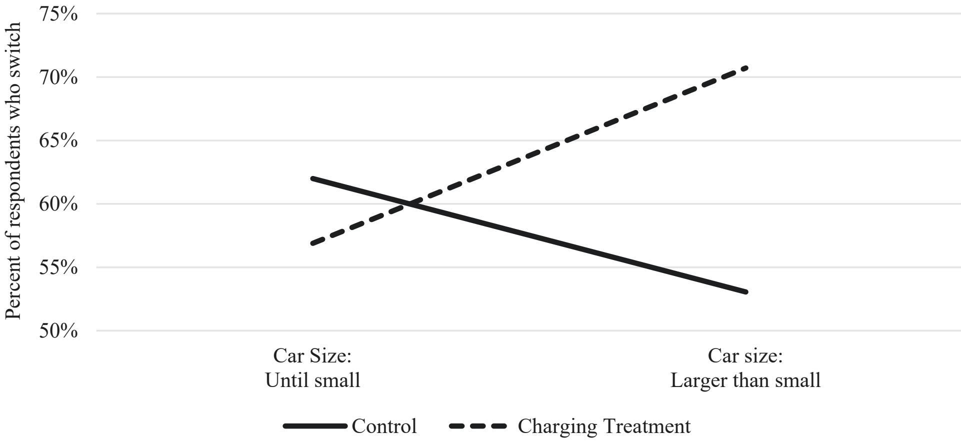

Fig. 8. Interaction plot between car size and charging treatment.

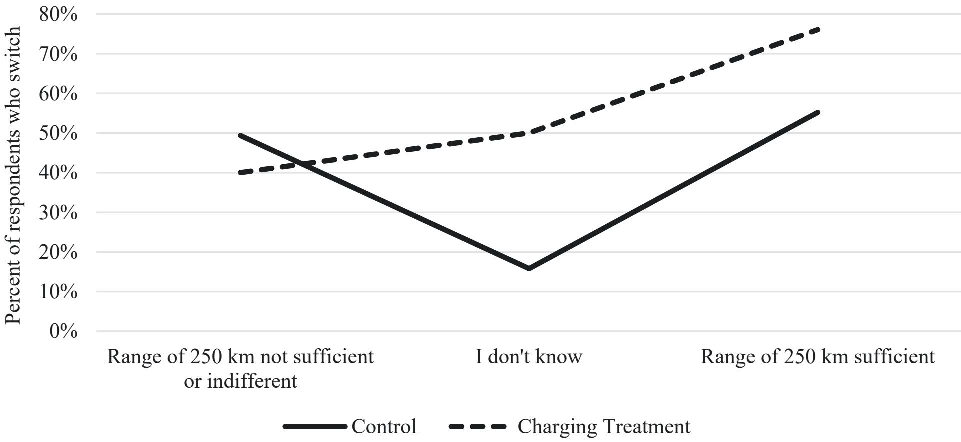

Fig. 9. Interaction plot between BEV range sufficiency and charging treatment.

previously 43% to 33%. Regarding the TCO treatment, which includes additional information on the total cost of car ownership and of the utilization of mobility services, we see no observable effects.

Alternative 2 (combination of BEV and carsharing/car-rental): Fewer respondents switch already at the 15% CO_2 tax level, compared to alternative 1 (23% compared to 30%). The share of respondents who could be motivated to switch through increasing CO_2 tax levels is similar to alternative 1 (28% compared to 27%) and accordingly, the share who never switch is 7 percentage points higher compared to alternative 1. Similarly to alternative 1, the charging treatment increases the switch at the baseline condition (15% CO_2 tax) by 10% and reduces the percent of respondents who never switch by 9%. The sharing treatment has a smaller effect, increasing the switch at the baseline condition by 6 percentage points compared to the control group and reduces the percent of respondents who never switch by 3%. Comparing the TCO control group with the TCO treatment group, we don't see a strong difference regarding the switch at the baseline condition and regarding respondents who never switch.

Alternative 3 (combination of public transport and carsharing/car-rental): This alternative is the least preferred option, as only 16% of respondents switch directly at the 15% CO_2 tax level (compared to 23% for alternative 2 and 30% for alternative 1). Twenty-nine percent could be further motivated to switch by an increase in CO_2 tax on fuel and 56% of respondents never switch to alternative 3 in the control condition. In the case of alternative 3, the sharing treatment increases the share of respondents who switch at the baseline condition (24% compared to 16%) but doesn't decrease the number of respondents who never switch to alternative 3 (57% compared to 56%). Finally, the TCO treatment increases the share of respondents who switch to alternative 3 at the baseline condition by 12% and decreases the share of respondents who never switch to alternative 3 by 12%.

3.2. Results of the Hurdle model

The results of the hurdle model are divided in two parts; 1) the binary switch model (or zero-inflated model) testing whether a participant decided to switch or not and 2) the count model testing a difference in fuel cost (representing the level of CO_2 tax) at the

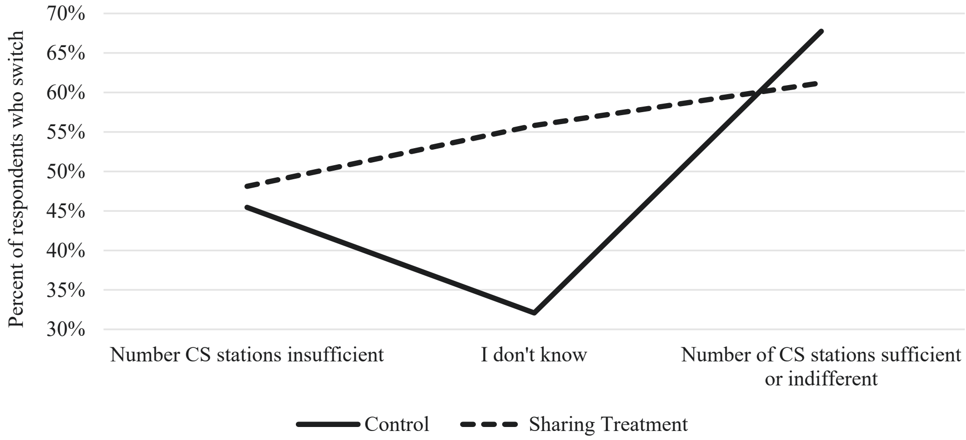

Fig. 10. Interaction plot between sufficiency of carsharing stations and sharing treatment.

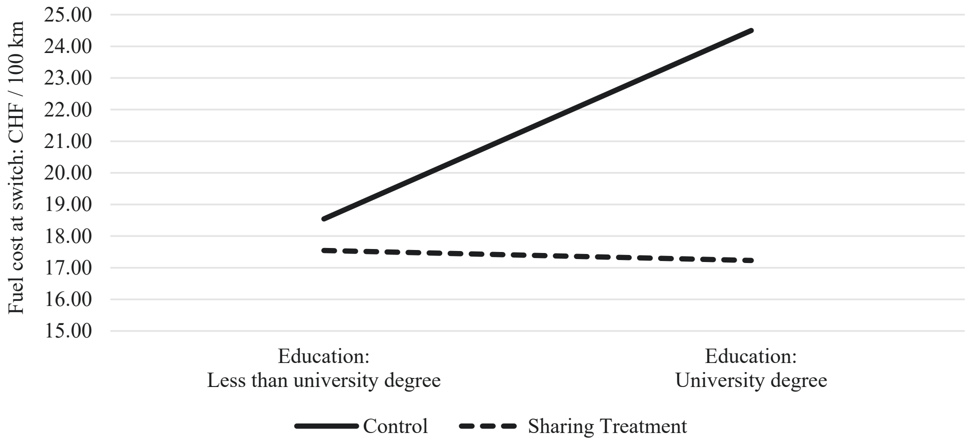

Fig. 11. Interaction plot between education and sharing treatment (count model).

switch. Fig. 7 provides an overview off all results. The reference group is provided in parentheses. The specific result tables containing the exponentiated beta coefficients exp(β) (odds ratio), the 95% confidence interval of exp(β) and the significance levels are shown in Tables A2 – A8 in the appendix. Where significant interaction effects are present, we provide a line plot for better visual interpretation.

Model results alternative 1: Battery electric vehicle & public transport.

Within the binary switch model, we see a significant interaction between the **charging treatment** and car size of the current main household car. As shown in Fig. 8, respondents owning a car that is larger than the small category (refer to Table A1 in the appendix) and received the charging treatment are almost two times (1.96) more likely to switch from their current car to alternative 1 (BEV + PT). Yet, respondents owning micro or small cars (until small) do not differ significantly between the treatment and control group.

We find no significant interaction nor a significant effect of the **TCO treatment** regarding the switch to alternative 1. Moreover, we don't find a significant effect for the count model, indicating that the amount of CO_2 tax needed to further push the respondents to switch to the alternative is the same for the control group and the charging or TCO treatment group.

Model results alternative 2: Battery electric vehicle & Carsharing/car-rental.

In the binary switch model, we see a significant interaction between the **charging treatment** and the indication, whether a BEV range of 250 km is sufficient for the respondents' everyday trips. Again, we visualize the interaction with a line plot in Fig. 9.

Respondents who received the charging treatment and stated that a BEV range of 250 km would be sufficient for their everyday trips are 2.5 times more likely to switch to alternative 2 (BEV + CS) compared to respondents who did not receive the treatment, indicating that even though an EV range of 250 km would be sufficient for everyday trips, increasing the possibility for home & charge and work & charge (charging treatment) could significantly increase the odds to switch to such an alternative. A smaller but still significant difference on the $p < 0.1$ level could be found for people indicating that they don't know if 250 km range for a BEV is sufficient for their everyday trips. Here they are more than 4 times more likely to switch, which however has a large CI due to fewer cases. Last, no difference regarding the probability to switch to alternative 2 (BEV + CS) could be found for people stating that they find a BEV range of 250 km to be insufficient for everyday trips. Further, we find no significant effects in the count model.

Regarding the **sharing treatment**, we find a significant interaction with the indication, whether the carsharing station abundancy

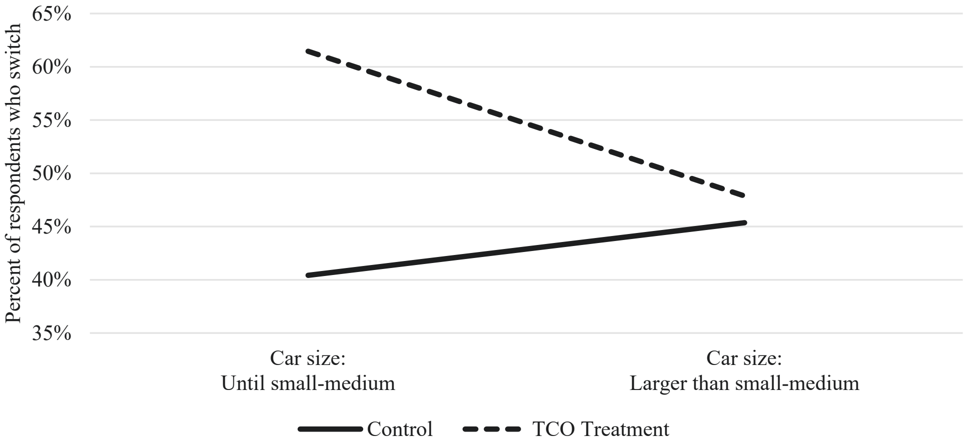

Fig. 12. Interaction plot between car size and TCO treatment.

is sufficient to motivate the respondent to try and use carsharing in the binary switch model. Together with Fig. 10 we see that respondents who received the sharing treatment (easy access to carsharing in walking distance from place of residence) and don't know whether the number of carsharing stations are sufficient in motivating them to use carsharing (more often), are 2.8 times more likely to switch to alternative 2 compared to the control group.

Respondents who received the **TCO treatment** are not significantly more likely to switch to alternative 2. We don't find any significant effects for sharing nor the TCO treatment group in the count model.

Model results alternative 3: Public transport & Carsharing/car-rental.

The binary switch model does not show any significant effects for the **sharing treatment**. However, we find a significant interaction between education and the sharing treatment within the count model. The interaction is visualized as a line plot in Fig. 11. Respondents who have a university degree and received the sharing treatment have, on average, a 1.79 (1/0.56) times lower fuel cost at the CO_2 tax level of their switch to the alternative, compared to the control group. Hence, respondents with a university degree seem to react earlier to increasing CO_2 taxes when combined with better carsharing availability than their counterparts. However, no differences could be found for respondents who have not a university degree.

We further find a significant interaction effect for **TCO treatment** in the binary switch model (Fig. 12). Here, respondents who own a micro, small or small-medium car (summarized as "until small-medium") were 6.52 times more likely to switch to alternative 3 if they received the TCO treatment compared to the control group. On the other hand, respondents who own larger cars (mid-sized, large and SUV) did not significantly differ between the treatment and control group regarding the switch to alternative 3.

In the count model, the TCO treatment has a significant, although weak, effect on switching earlier (lower CO_2 tax needed) to alternative 3. On average, respondents who received the TCO treatment have a 1.22 (1/0.82) times lower fuel cost compared to the control group.

4. Discussion

In general, our results show that even with a low CO_2 tax level and no additional pull measures, a considerable share of respondents would be open to switch from their current fossil fuel car to the alternatives proposed in our choice experiment. For alternative 1, a small BEV in combination with public transport, we observed a share of 30% at a CO_2 tax level of 15%. An additional 9%, 17% and 27% could be motivated to switch to alternative 1 by a further increase of CO_2 tax on fuel to 50%, 100% $CO_{2,}$ and 200%, respectively. Alternative 2, in contrast, seems to be less popular, achieving a share of 23% at a CO_2 tax level of 15%. The results of a further increase of CO_2 tax are very similar to alternative 1. Furthermore, the comparison between the binary switch model (switch to an alternative, independent from the CO_2 tax level) and the count model (CO_2 tax level at the switch to the alternative) in Fig. 7 shows that the latter provides less significant effects than the former. Hence, the monetary push measure yields its effect irrespective of the combination with one of the three pull measures tested in the experiment, and irrespective of the actual amount of the CO_2 tax. However, despite of its effectiveness in our experiment, the reality has proven that it is difficult to win a political majority for an introduction of a CO_2 tax. In 2021, the Swiss population dismissed a CO_2 law, which included a potential rise of fuel prices by less than 10%, among other measures (Swissinfo, 2021). Hence, such a far-reaching policy would hardly be accepted by the Swiss population without any accompanying measures.

Our experiment results show that the pull measures can significantly reduce the CO_2 tax level required to reach the same number of respondents who would switch to one of the alternatives. As an example, by enabling HC & WC, 41% of the respondents could be motivated to switch to alternative 1 at a 15% level of CO_2 tax (step 1 of the multiple price list experiment). This is more effective than a 50% CO_2 (step 2 of the multiple price list experiment) tax on fuel in the control condition, with a share of 39% of respondents opting for the alternative. Combining the charging treatment with the 50% CO_2 tax scenario could increase the share of respondents willing to switch to 51%. These results are in line with previous research finding that the combination of push and pull measures can increase the

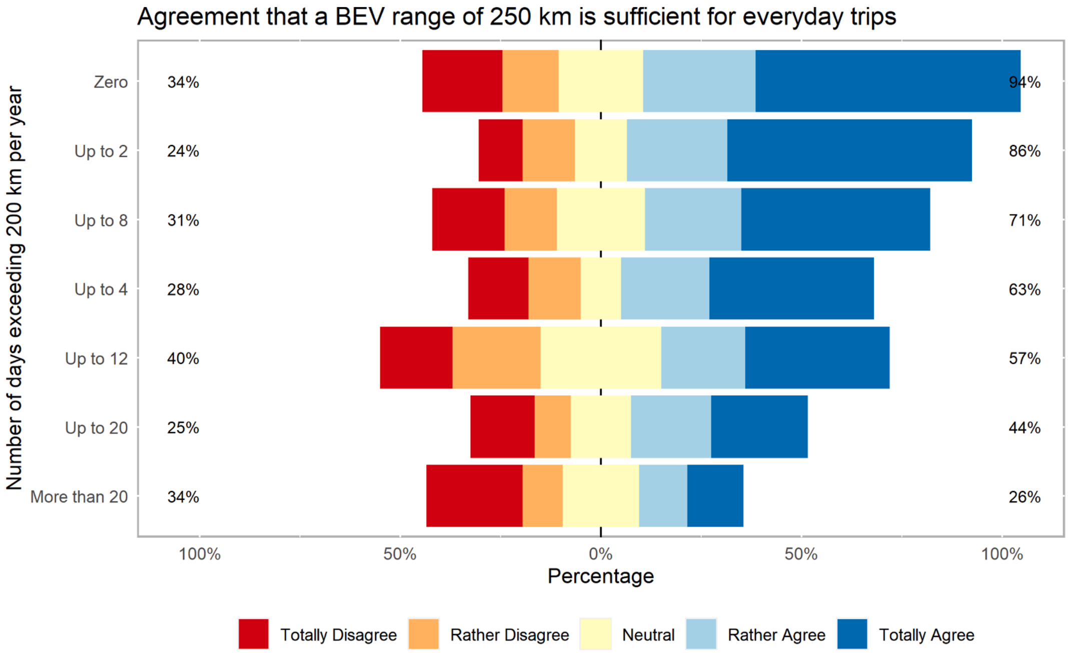

Fig. A1. Agreement with BEV range sufficiency for the number of days exceeding 200 km per year.

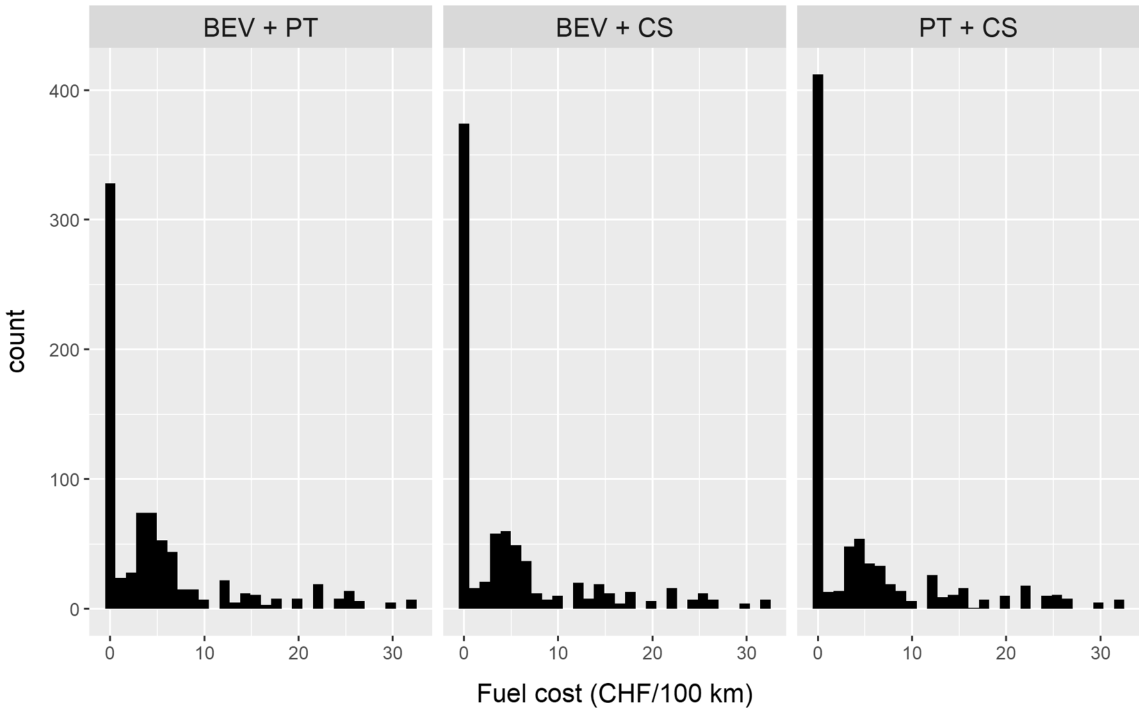

Fig. A2. Histogram of fuel cost for each alternative. A fuel cost of zero represents “no switch”.

efficiency of push measures (Thaller et al., 2021; Wicki et al., 2020). Shaffer et al. (2021) also argue that it may be difficult to incentivize the purchase of smaller BEVs without complementary measures such as a weight tax or a tax on annual mileage.

Referring specifically to the charging treatment, our results show that improved charging possibilities at home and at the workplace significantly increase the odds to switch from a fossil fuel car to a sustainable alternative, like the combination of a small BEV for everyday trips and public transport (alternative 1) or carsharing/car-rental (alternative 2) for long-range trips. This is in line with the

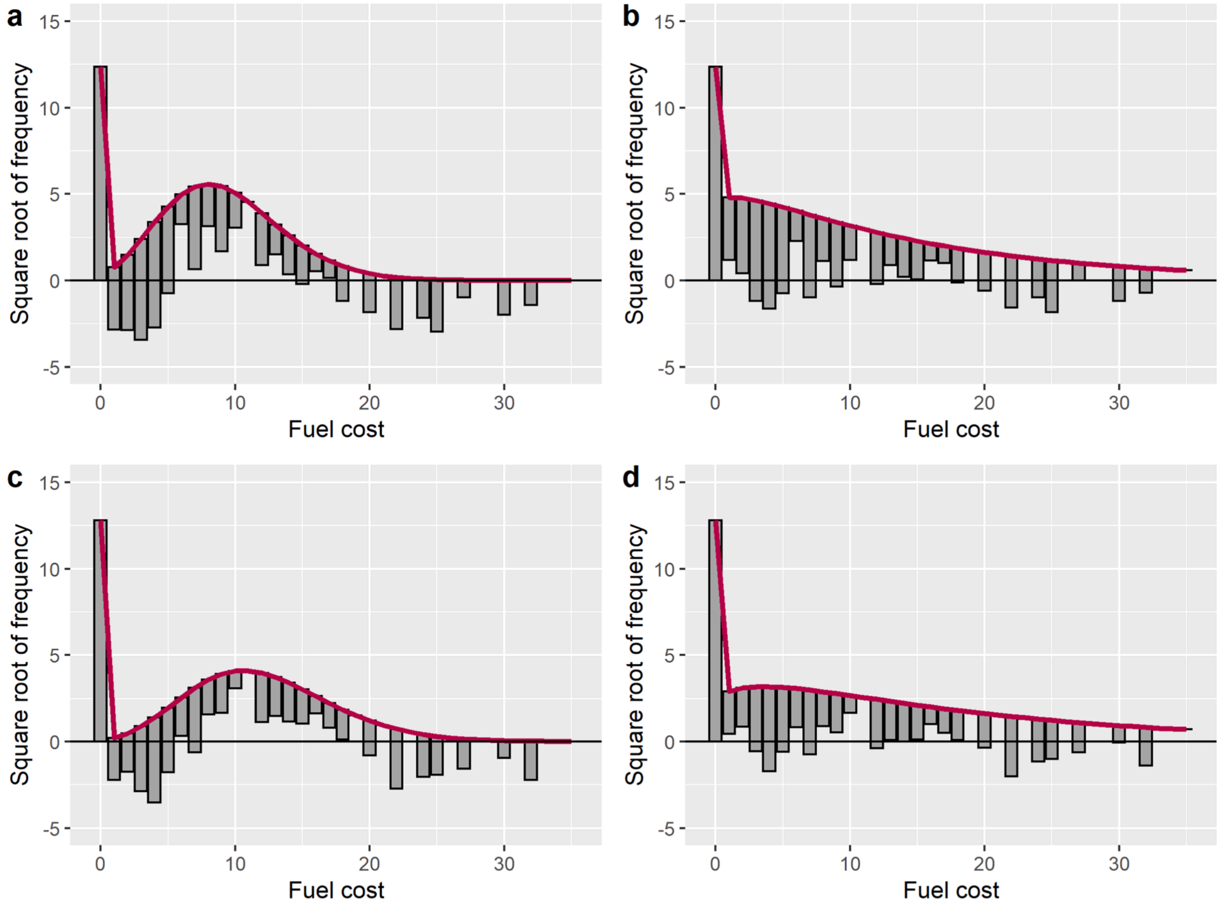

Fig. A3. Rootogram for alternative 1 (BEV + PT). a) Charging treatment with poisson model b) Charging treatment with binomial model c) TCO treatment with poisson model d) TCO treatment with binomial model.

findings from Wang et al. (2020) who show that improving the service quality of mobility services is important in individual's willingness to shift. Since small BEVs with a lower battery capacity would need to be charged more often compared to larger BEVs, the security that one can charge the car overnight at home or the reassurance that one may be able to recharge the vehicle at work, seems especially relevant for adopting small BEVs. Moreover, our choice-experiment indicates that fostering HC & WC further motivates people currently owning mid-sized to large cars to switch to a small BEV, which could be an important measure in cities and agglomerations, where space is scarce and the benefits of switching to a small BEV are most noticeable due to their lower noise and zero exhaust gas emissions. Patt et al. (2019) show that people for whom private charging access is unproblematic are much more likely to indicate a high willingness to purchase an EV as those who park their car on the street or at a shared garage, underlining the need to foster HC & WC. Hence, we strongly recommend improving charging opportunities at home for tenants, as charging access is typically less problematic for homeowners. Since respondents who currently own micro or small cars reacted less to the charging treatment, we argue that improving HC & WC possibilities could be specifically targeted to large car owners.

We tested interaction effects of our treatment variables with other attributes of the respondents, like socio-demographics, mobility characteristics, or attitudes and values. An interesting interaction has been observed for the charging treatment: Respondents who did not believe that a current BEV range of 250 km is sufficient for their everyday trips, could not be further motivated by the charging treatment to switch to a small BEV in combination with carsharing/car-rental (alternative 2). Instead, respondents who state that the range of 250 km is already sufficient significantly increased the intention to switch to this alternative in the treatment condition despite, technically, not having to heavily rely on the extra charging opportunity. This suggests that people who feel that their daily mobility needs will be covered by a small BEV can further be motivated by the reassurance of charging availability at home or at the workplace, while people who feel that small BEVs will not be enough for their daily needs cannot be motivated through increased charging possibilities at home or at the workplace. In this context, however, it should be noted that the analysis of our data shows that for the majority of people, a small BEV would indeed meet their daily mobility needs. This further indicates that informing people about their actual daily range needs might increase the uptake of small BEV, which is in line with the work of Herberz et al. (2021) who find that information about compatibility of EV range with one's own mobility needs increases likelihood to buy an EV.

The sharing treatment (increasing the number of carsharing stations and possibility of peer-to-peer carsharing close to the place of

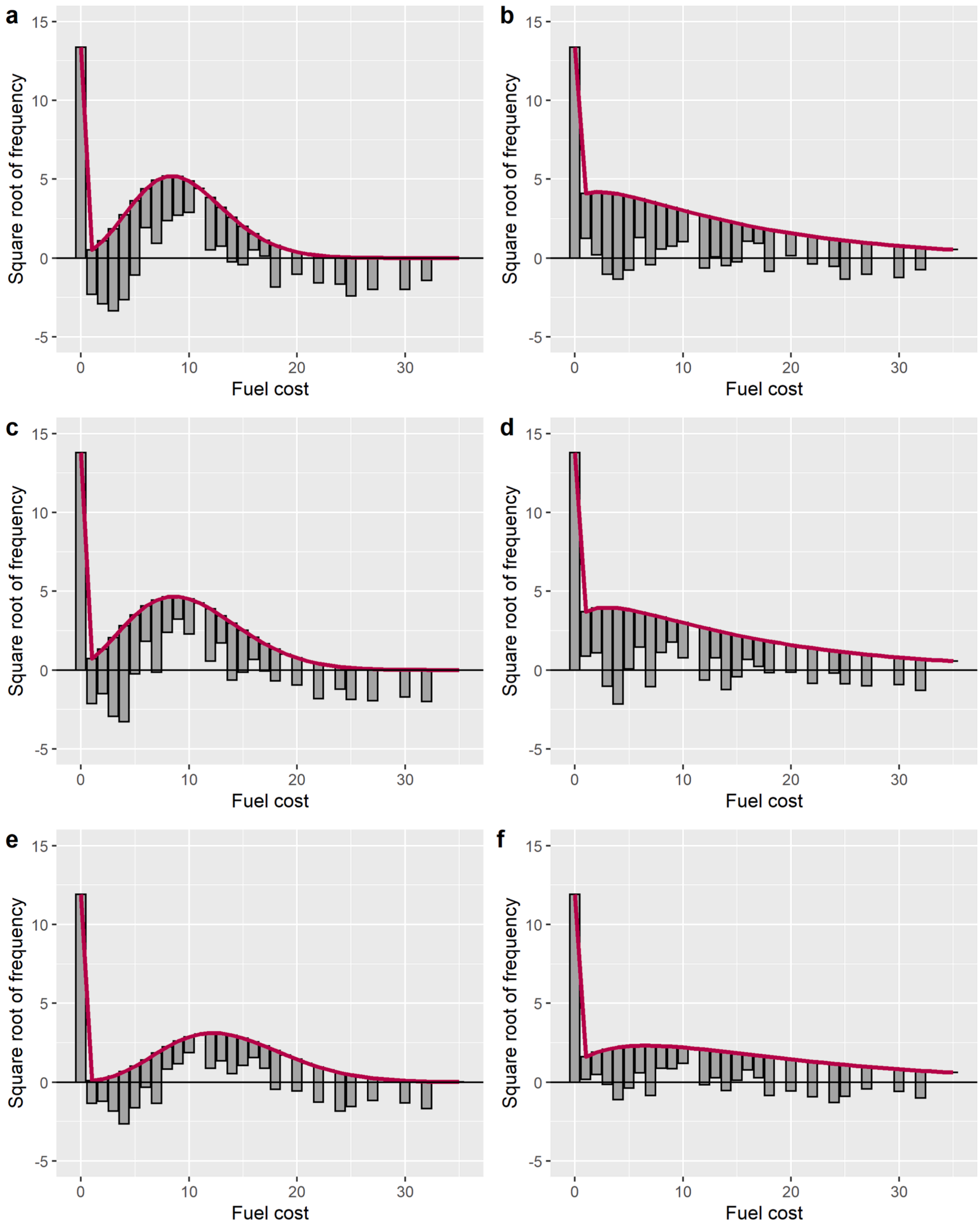

Fig. A4. Rootogram for alternative 2 (BEV + CS). a) Charging treatment with poisson model b) Charging treatment with binomial model c) Sharing treatment with poisson model d) Sharing treatment with binomial model e) TCO treatment with poisson model f) TCO treatment with binomial model.

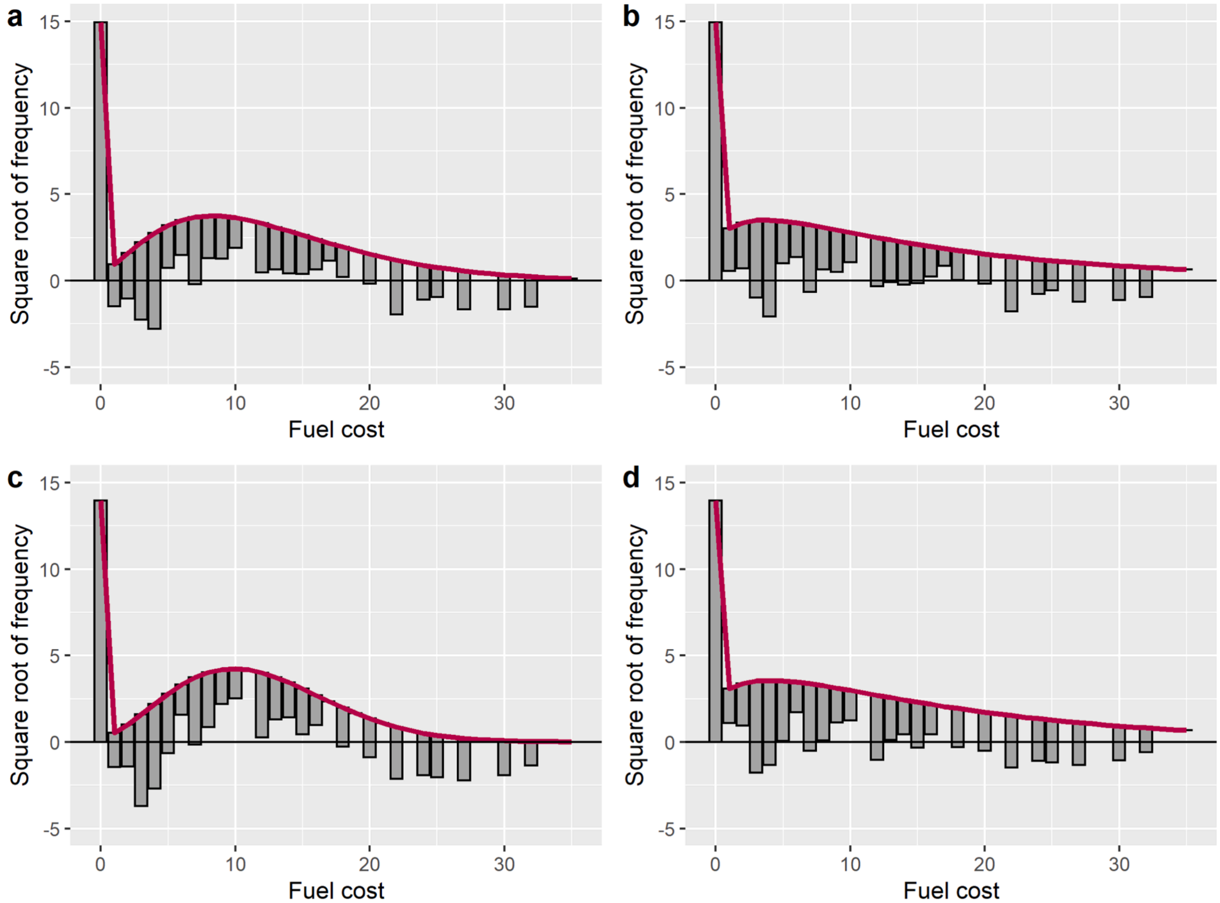

Fig. A5. Rootogram for alternative 3 (PT + CS). a) Sharing treatment with poisson model b) Sharing treatment with binomial model c) TCO treatment with poisson model d) TCO treatment with binomial model.

residence) significantly increases the odds to switch to alternative 2 (BEV + CS) for people who don't know whether the current number of carsharing stations are sufficient to motivate them to use carsharing. As such, providing people the certainty that carsharing is available close to their place of residence could be a potential lever to switch to a sustainable alternative to the private fossil fuelled car. Furthermore, the sharing treatment reduces the necessary monetary push measures (CO_2 tax level on fuel) to motivate highly educated people (university degree) to switch from previously owning a fossil fuel car to a combination of public transport and carsharing/car-rental without car ownership. This suggests that people who have at least a university degree see a benefit in increasing the carsharing stations and availability of peer-to-peer carsharing in motivating them to switch to such an alternative earlier (i.e., with lower CO_2 tax on fuel). Similar to the result regarding charging stations, informing households about the proximity to carsharing stations could increase the attractiveness of such offers, especially since 27% of the respondents did not know whether the current number of carsharing stations was sufficient to motivate them to use carsharing, and 31% of the respondents did not know how far the nearest carsharing station was from their home. Respondents who didn't know whether the number of carsharing stations was sufficient for them and received the carsharing treatment significantly increased the odds to switch to alternative 2 compared to the control group.

Regarding the TCO treatment (information about total cost of ownership of the current car and the alternatives), we found no significant effects for alternative 1 and alternative 2. However, respondents who received the TCO treatment and own a smaller car (size class until small-medium) were 6 times more likely to indicate a switch to alternative 3 compared to the control group. These results imply that people who own large cars seem to care more about convenience than money, whereas people who own smaller cars are likely to be more financially aware and thus react to the TCO treatment.

5. Conclusion and recommendations

Through a multiple price list choice-experiment with 844 Swiss households, we tested push and pull measures in motivating the respondents to switch from their current fossil fuel car to a sustainable mobility alternative. These include a small BEV for everyday trips and public transport (alternative 1) or carsharing/car-rental (alternative 2) for long-range trips, as well as a flexible combination

Table A1
Survey variables included in the study.

Variable	Level	Frequency	Percentage	Mean (Standard Deviation)
Socio-demographics				
Age	18–34	168	20	–
	35–54	359	42	–
	55+	317	38	–
Gender	Male	451	53	–
	Female	393	47	–
Education	Less than university degree	448	53	–
	University degree	396	47	–
Type of living area	City	337	40	–
	Agglomeration	280	33	–
	Countryside	227	27	–
Gross HH income	Until 4′500	94	11	–
	4,501–6,000	76	9	–
	6,001–9,000	206	24	–
	9,001–12,000	190	22	–
	More than 12,000	138	16	–
	Prefer not to say	140	17	–
HH structure	Single person HH	178	21	–
	Couple without children	276	33	–
	HH with children	353	42	–
	Non-family shared HH	37	4	–
HH size	Mean	844	–	2.50 (1.25)
Mobility characteristics				
Carsharing experience	No carsharing experience	818	97	–
	Some carsharing experience	26	3	–
Number of carsharing stations sufficient?	Number CS stations insufficient	376	45	–
	I don’t know	220	26	–
	Number of CS stations sufficient or indifferent	248	29	–
Public transport passes	None	152	18	–
	General abonnement (GA)	144	17	–
	Half-fare	595	59	–
	Other	51	6	–
Number of cars in HH	1 car	537	64	–
	2 or more cars	307	36	–
Dominant mode choice: commuting	Private car	282	34	–
	Public transport	196	23	–
	Soft modes	120	14	–
	Other	246	29	–
Dominant mode choice: leisure	Private car	510	61	–
	Public transport	121	14	–
	Soft modes	171	20	–
	Other	42	5	–
Car size of primary car	Micro	15	2	–
	Small	207	25	–
	Small-medium	195	23	–
	Mid-size	195	23	–
	Large	50	6	–
	SUV	182	21	–
Range of small BEV sufficient for everyday trips?	Range of 250 km not sufficient or indifferent	343	40	–
	I don’t know	72	8	–
	Range of 250 km sufficient	429	51	–
Number of daytrips with the main car exceeding 200 km per year	Until 6 trips per year	517	61	–
	More than 6 trips per year	327	39	–
Number of overnight trips per year with the main car exceeding 200 km oneway	Until 2 trips per year	654	78	–
	More than 2 trips per year	190	22	–
Attitudes and values				
Importance of safety	Not at all important (1)	2	0	4.30 (0.70)
	Not important (2)	6	1	
	Indifferent (3)	87	10	
	Important (4)	390	46	
	Very Important (5)	358	43	
Importance of being comfortable	Not at all important (1)	6	1	3.84 (0.78)
	Not important (2)	25	3	
	Indifferent (3)	227	27	
	Important (4)	428	51	

(*continued on next page*)

Table A1 (*continued*)

Variable	Level	Frequency	Percentage	Mean (Standard Deviation)
	Very Important (5)	158	19	
Importance of privacy	Not at all important (1)	3	0	4.32 (0.70)
	Not important (2)	8	1	
	Indifferent (3)	74	9	
	Important (4)	388	46	
	Very Important (5)	371	44	
Importance of having nice possessions	Not at all important (1)	59	7	3.06 (0.99)
	Not important (2)	163	19	
	Indifferent (3)	349	41	
	Important (4)	218	26	
	Very Important (5)	55	7	
Importance of owning a car	Not at all important (1)	58	7	3.68 (1.19)
	Not important (2)	88	10	
	Indifferent (3)	162	19	
	Important (4)	296	35	
	Very Important (5)	240	29	
Values (Likert scale from 1 (lowest) to 5 (highest))	Hedonic	859	–	3.71 (0.73)
	Egoistic	859	–	2.75 (0.73)
	Altruistic	859	–	3.93 (0.68)
	Biospheric	859	–	3.96 (0.72)

HH = household, GA = General Abonnement, a public transport pass with unlimited travel in Switzerland of most railways and other public transport.

Table A2
Hurdle model of alternative 1 for the charging treatment including control variables.

Hurdle model Alternative 1: Charging treatment			
Predictors	*OR*	*95% CI of OR*	*p*
Count model			
(Intercept)	6.34	4.07–9.86	<0.001
Charging treatment (control group)	**0.91**	**0.71–1.16**	**0.434**
Public transport pass: GA (no public transport pass)	0.82	0.60–1.12	0.211
Importance of owning a car	1.08	0.97–1.20	0.158
Dominant mode choice commuting: Public transport (private car)	1.17	0.88–1.55	0.287
Log(theta)			0.0558
Binary switch model (Zero-inflated model)			
(Intercept)	4.91	1.14–21.12	0.032
Charging treatment (control group)	**0.24**	**0.05–1.29**	**0.096**
Education: University (less than university)	1.34	0.87–2.08	0.184
Gross HH income: 4′501-6′000 CHF (more than 12′000 CHF)	1.6	0.74–3.46	0.231
Gross HH Income: 9′001-12′000 CHF (more than 12′000 CHF)	1.25	0.75–2.10	0.396
Public transport pass: GA (no public transport pass)	1.22	0.73–2.02	0.448
Importance of owning a car	0.79	0.65–0.96	0.015
Car size of primary car: Larger than small (micro or small)	0.67	0.34–1.31	0.244
Interaction: Charging treatment * Car size of primary car: Larger than small	**2.84**	**1.11–7.24**	**0.029**
Observations	394		
R^2 / R^2 adjusted	0.418 / 0.411		

of public transport and carsharing/car-rental without car ownership (alternative 3). As push measures, we utilized a four-step increase of CO_2 tax on fossil fuels. As pull measures, several treatments increasing the comfort and convenience of the alternatives (improved home & charge and work & charge (HC & WC) possibilities, better availability of carsharing stations (CS) and informing about total cost of ownership (TCO)) were implemented in the experiment.

The push measure tested in this paper yields consistent results regardless of whether it is combined with pull measures or used as the sole measure without any pull measures (control group). However, the pull measures of HC & WC and CS motivate additional respondents to switch before the next level of CO_2 tax on fuel is triggered. Thus, push&pull measures are able to attract a higher share of respondents to the proposed alternatives than the push measure taken alone. The information treatment about TCO only increases the odds of choosing alternative 3. Accordingly, the information about TCO seems to be especially relevant when fostering mobility lifestyles that are not bound to car ownership, which seems to be still associated with status, and other values besides money (Zhao and Zhao, 2020).

Roughly 50% of respondents can't be motivated to switch despite the strong push and pull measures implemented in the experiment. Even a stepwise increase of the CO_2 tax on fuel to 200% is consequently ignored by a significant share of our sample. At first glance, this seems surprising for such a far-reaching measure. Yet, other scholars confirm that aspects like believes, convenience and habits are hindering the switch to more sustainable alternatives (Mattauch et al., 2016; Tobler et al., 2012; Wang et al., 2020).

Table A3
Hurdle model of alternative 1 for the TCO treatment including control variables.

Hurdle model Alternative 1: TCO treatment			
Predictors	*OR*	*95% CI of OR*	*p*
Count model			
(Intercept)	10.69	8.31–13.75	<0.001
Treatment TCO (TCO control group)	**1.16**	**0.89–1.52**	**0.282**
Number of cars in HH: 2 or more cars (0 cars)	1.15	0.87–1.52	0.328
Range EV sufficient? Range of 250 km sufficient (range of 250 km not sufficient)	0.79	0.60–1.05	0.104
Log(theta)			0.00224
Binary switch model (Zero-inflated model)			
(Intercept)	3.85	0.80–18.44	0.092
Treatment TCO (TCO control group)	**1.09**	**0.70–1.71**	**0.705**
Number of cars in HH: 2 or more cars (0 cars)	0.91	0.56–1.48	0.713
HH size	1.13	0.93–1.36	0.213
Observations	320		
R^2 / R^2 adjusted	0.456 / 0.449		

Table A4
Hurdle model of alternative 2 for the charging treatment including control variables.

Hurdle model Alternative 2: Charging treatment			
Predictors	*OR*	*95% CI of OR*	*p*
Count model			
(Intercept)	9.06	7.54–10.89	<0.001
Charging treatment (control group)	**0.87**	**0.68–1.11**	**0.264**
Log(theta)			0.0107
Binary switch model (Zero-inflated model)			
(Intercept)	3.76	1.57–9.06	0.003
Charging treatment (control group)	**2.5**	**1.31–4.75**	**0.005**
Gross HH Income: 9′001-12′000 CHF (more than 12′000 CHF)	1.04	0.63–1.71	0.884
Dominant mode choice commuting: Public transport (private car)	1.1	0.66–1.83	0.725
Importance of owning a car	0.74	0.60–0.90	0.003
Range EV sufficient? Range of 250 km not sufficient (range of 250 km sufficient)	0.83	0.44–1.55	0.558
Range EV sufficient? I don't know (range of 250 km sufficient)	0.15	0.04–0.56	0.005
Interaction: Charging treatment * Range EV sufficient? Range of 250 km not sufficient	**0.25**	**0.10–0.61**	**0.003**
Interaction: Charging treatment * Range EV sufficient? I don't know	**1.79**	**0.32–9.95**	**0.507**
Observations	385		
R^2 / R^2 adjusted	0.681 / 0.679		

Table A5
Hurdle model of alternative 2 for the sharing treatment including control variables.

Hurdle model Alternative 1: Sharing treatment			
Predictors	*OR*	*95% CI of OR*	*p*
Count model			
(Intercept)	4.98	2.99–8.29	<0.001
Sharing treatment (control group)	**1.02**	**0.79–1.31**	**0.888**
Dominant mode choice leisure: Public transport (private car)	0.89	0.63–1.25	0.498
Number of cars in HH: 2 or more cars (0 cars)	1	0.78–1.30	0.987
Importance of owning a car	1.19	1.06–1.33	0.004
Public transport passes: Half-fare (no public transport pass)	0.98	0.76–1.26	0.872
Number of carsharing stations sufficient? Sufficient or indifferent (not sufficient)	0.98	0.75–1.27	0.853
Log(theta)			<0.001
Binary switch model (Zero-inflated model)			
(Intercept)	0.82	0.21–3.18	0.769
Sharing treatment (control group)	**2.8**	**1.19–6.58**	**0.018**
Dominant mode choice leisure: Public transport (private car)	1.51	0.77–2.97	0.231
Number of cars in HH: 2 or more cars (0 cars)	0.99	0.63–1.55	0.958
Importance of owning a car	0.75	0.61–0.92	0.006
Number of carsharing stations sufficient? Insufficient (I don't know)	1.95	0.92–4.12	0.08
Number of carsharing stations sufficient? Sufficient or indifferent (I don't know)	4.33	1.95–9.63	<0.001
Interaction: Sharing treatment * Number of carsharing stations sufficient? Insufficient	**0.34**	**0.12–0.96**	**0.041**
Interaction: Sharing treatment * Number of carsharing stations sufficient? Sufficient or indifferent	**0.21**	**0.07–0.69**	**0.01**
Observations	388		
R^2 / R^2 adjusted	0.466 / 0.456		

Table A6
Hurdle model of alternative 2 for the TCO treatment including control variables.

Hurdle model Alternative 2: TCO treatment			
Predictors	*OR*	*95% CI of OR*	*p*
Count model			
(Intercept)	10.87	5.66–20.87	<0.001
TCO treatment (TCO control group)	**1.23**	**0.92–1.65**	**0.169**
Number of cars in HH: 2 or more cars (0 cars)	1.15	0.85–1.54	0.371
Log(theta)			<0.001
Binary switch model (Zero-inflated model)			
(Intercept)	2.53	0.49–13.12	0.27
TCO treatment (TCO control group)	**0.96**	**0.56–1.64**	**0.891**
Number of cars in HH: 2 or more cars (0 cars)	1.58	0.91–2.74	0.101
Observations	239		
R^2 / R^2 adjusted	0.612 / 0.607		

Table A7
Hurdle model of alternative 3 for the sharing treatment including control variables.

Hurdle model Alternative 3: Sharing treatment			
Predictors	*OR*	*95% CI of OR*	*p*
Count model			
(Intercept)	4.26	2.14–8.48	<0.001
Sharing treatment (control group)	**1.1**	**0.79–1.52**	**0.584**
Dominant mode choice leisure: Public transport (private car)	0.7	0.51–0.96	0.026
Public transport passes: Half-fare (no public transport pass)	0.79	0.62–1.01	0.063
Hedonic value	1.05	0.90–1.23	0.521
Importance of owning a car	1.22	1.10–1.36	<0.001
Education: University (less than university)	1.63	1.18–2.24	0.003
Interaction: Sharing treatment * Education: University	**0.51**	**0.32–0.82**	**0.006**
Log(theta)			<0.001
Binary switch model (Zero-inflated model)			
(Intercept)	6.29	1.78–22.21	0.004
Sharing treatment (control group)	**0.93**	**0.61–1.43**	**0.754**
Number of cars in HH: 2 or more cars (0 cars)	0.78	0.50–1.23	0.290
Importance of owning a car	0.68	0.56–0.82	<0.001
Observations	391		
R^2 / R^2 adjusted	0.646 / 0.638		

Table A8
Hurdle model of alternative 3 for the TCO treatment including control variables.

Hurdle model Alternative 3: TCO treatment			
Predictors	*OR*	*95% CI of OR*	*p*
Count model			
(Intercept)	6.4	4.32–9.48	<0.001
TCO treatment (TCO control group)	**0.82**	**0.65–1.03**	**0.086**
Importance of owning a car	1.18	1.07–1.29	0.001
Log(theta)			<0.001
Binary switch model (Zero-inflated model)			
(Intercept)	2.78	1.22–6.37	0.015
TCO treatment (TCO control group)	**2.62**	**1.43–4.78**	**0.002**
Car size of primary car: Larger than small-medium (small-medium or smaller)	1.41	0.78–2.55	0.253
Number of cars in HH: 2 or more cars (0 cars)	0.69	0.44–1.08	0.106
Importance of owning a car	0.7	0.57–0.85	<0.001
Interaction: Treatment TCO * Car size of primary car: Larger than small-medium	**0.4**	**0.17–0.93**	**0.033**
Observations	381		
R^2 / R^2 adjusted	0.377 / 0.373		

Experiencing new mobility products and services could help breaking the routines and thus increase the willingness to change mobility habits regarding vehicle choice and the use of mobility services (Hoerler et al., 2021, 2020; Schlüter and Weyer, 2019). Brückmann and Bernauer (2020) further find through a representative sample of Swiss residents that there is considerable room for more ambitious pull measures to increase the adoption of BEVs. Accordingly, we recommend implementing structural pull measures (like increased charging infrastructure at home and at the workplace or increased carsharing stations), soft pull measures (like information about TCO specifically targeted to small car owners or information about carsharing possibilities close to the place of residence) and other pull measures that provide easy access to this infrastructure (e.g., free trial day for e-carsharing). The pull measures should be combined with guiding push measures. The exact formulation of these push and pull measures depend on the local context and the ideology of the targeted population and should be adapted accordingly (Ejelöv et al., 2022; Wicki et al., 2019).

Our results provide information on how to increase the adoption of small BEVs by households previously owning a fossil fuel driven car. This issue is very relevant in the short term to fulfill emission targets, but also in the long term, as small BEVs exhibit strong environmental benefits compared to larger BEVs with larger battery sizes (Ellingsen et al., 2016; Wietschel et al., 2019). Since the range of 200 km is sufficient to cover most daily distances not only in Switzerland (Melliger et al., 2018; Neuenschwander, 2020) but also elsewhere in the world like China (Hao et al., 2020), North America (Needell et al., 2016), or Norway (Figenbaum and Nordbakke, 2019), we argue that the use of mobility services like public transport, carsharing and car-rental to complement a small BEV could be, in general, a viable option in many countries.

Being representative for a large part of Switzerland, extrapolating the results of our study to other countries needs to be reflected against some key characteristics of the Swiss transport system, which hosts one of the densest public transport networks and a well-established carsharing operator covering the whole country. Further, Switzerland is a comparably small country and has a high density of public charging stations (Falchetta and Noussan, 2021).

In summary, we provide a strong basis for policy makers and mobility planners to foster sustainable and multimodal mobility lifestyles based on BEVs and mobility services by addressing a variety of push and pull measures. Switching from owning large conventional cars to a more sustainable mobility lifestyle is crucial in contributing to the mitigation of climate change and a better quality of life, especially in the growing cities.

CRediT authorship contribution statement

Raphael Hoerler: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Thomas Stoiber:** Methodology, Writing – review & editing. **Andrea Del Duce:** Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A

See Figs. A1-A5 and Tables A1-A8.

Tables A2-A8 show the hurdle model results, which are divided in two parts; 1) the binary switch model (or zero-inflated model) testing whether a participant decided to switch or not and 2) the count model testing a difference in fuel cost (representing the level of CO_2 tax) at the switch. We provide the reference group in parentheses for categorical variables and mark the treatment variables in bold.

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