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A new approach to evaluate long term user reactions to changes in transport costs

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A new approach to evaluate long term user reactions to changes in transport costs

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ABSTRACT
This paper presents a new application of the stated adaption survey method to analyze long term reactions to substantial changes in transport costs including different transport related energy-efficiency measures. Such long term reactions include:

- choice of car type, motorization and usage,
- choice of public transport season cards and usage (including substitution effects),
- choice of residence,
- while controlling for the influence of variables describing the residential environment and socio-demographics.

The software-based survey includes two stated adaption experiments in which the respondents are requested to state their choice and usage of mobility tools given changes of transport costs and place of residence in the second experiment on a household level. In a third experiment, the respondents had to choose between two of self-defined earlier situations.

In multi-persons households cars tend to be jointly used and also the place of residence is expected to be the result of collective decision process. Therefore, the survey considers the mobility tool ownership and its usage on a household level. The inclusion of car and public transport season card ownership is motivated by the finding of substitution between those two types of mobility tools in earlier studies.

The extensive descriptive analysis of the data shows the applicability of the approach. Not only are findings from earlier studies on the topic confirmed, but also - due to the consideration of a broader range of factors and possible reactions considered- new insights about mobility tool ownership and residence location choice are provided: people react not only by adjusting mileage but also by changing car types and choosing smaller engines or more fuel efficient engine concepts such as Hybrids or Diesel. In addition, it is shown that also substitution effects between car and season card ownership within households are important.
INTRODUCTION

Changing travel costs influence travel behavior on different levels. In the short run, individuals react by varying mileage (trip frequency, average trip length) and travel mode for certain trips. Given that individuals and households fix their marginal costs of their traveled mileage by acquiring a set of mobility tools - vehicles and public transport season and discount cards - it is clear, that mobility tool ownership is also affected by price changes. While already daily travel decisions are subject to inertia, mobility tool ownership is even more rarely reconsidered which makes it more difficult to study in a survey context.

However, the recent price shock of crude oil - doubling in between June 2005 and June 2008 - and later the economic slow-down have not only influenced daily travel decisions but might have also broken the inertia of not reconsidering mobility tool ownership as the following statistics indicate: on the one hand, individuals changed their travel behaviour in terms of mode choice, as the following statistics indicate: while the nominal income (+2.0%, BfS (1)) and population (+1.4%, BfS (2)) grew in 2008 in Switzerland at comparable rates as in the years before, analysis of the motorway traffic counts reveal a drop in the annual traffic increase from 1.2% during the years 2000-2007 to 0.65%. At the same time, however, the Swiss Federal Railways reports an increase in passenger mileage by +6.7% (Swiss Railways (3)). On the other hand, also changes in car purchase behavior became visible: market analysis both from Switzerland Auto Schweiz, Association of Swiss car importers (4) and the U.S. Autoobserver (5) reveal demand shifts towards smaller and more energy efficient cars.

Although fuel prices are currently back to the level before the price shock it is widely expected that they will start increasing again, especially when the global economy recovers. As we will see in this paper, most studies analyzing mobility tool ownership use either aggregated or disaggregated revealed preference data. As the public transport costs and fuel prices - except the fuel price shocks in 2008, 1981 and 1973 - varied only moderately, the application of such analysis is only viable for a restricted cost range. This is especially true for countries where taxes make up a substantial share of the fuel price, like Switzerland. We see therefore a lack of research examining the effects of substantial changes in transport costs on long term transport decisions such as mobility tool ownership. Last, it is still very unclear how significantly higher transport costs might affect residence location choice behavior.

Transportation is, among the industrial, commercial, residential, agriculture and waste sector, not only the sector causing the highest CO\(_2\)-emissions (32%) in Switzerland, but also the only one that shows a clearing increasing trend over the last decade (Filliger (6)). Similar applies for the United States(Conti and Sweetnam (7)). Meanwhile, most OECD countries are behind their CO\(_2\)-emission reduction targets (UNFCC (8)). Despite the observed transport related demand reactions to higher fuel prices, it is still widely accepted that further measures are needed to reach the global targets. Therefore, the need of having mobility tool ownership models that also deliver reliable forecasts the impact of substantially higher cost regimes and policy measures is obvious.

The Swiss Federal Office of Energy together with the Swiss Federal Office of the Environment commissioned the IVT with a study to analyze the long term reaction of Swiss households to substantial increases of fuel prices and different transport related energy-efficiency measures. Such long term reactions should include change in the mileage by car and public transport, changes in car ownership (including car type) and public transport season card ownership but also in residential location choice.

The remainder of the paper is structured as follows: the next section gives an overview
of methodologies when modeling of car and public transport season card ownership. In the following sections, the research methodology is specified, the questionnaire presented and data collection reported. As the project is ongoing while writing the paper, the viability of the approach is demonstrated by descriptive analysis only. However, it is expected that until the deadline for submission of revised paper, November 15, also the results of the econometric models are available.
LITERATURE

Car ownership and usage

A good overview of different car ownership models for public sector planning is provided by de Jong et al. (9). They identify nine types of car ownership models. Depending on the model purpose, the models differ from each other mainly by the level of aggregation, theoretical and methodological background, data requirement, car-type segmentation and inclusion of variables such as income, car type, sociodemographic and attitudinal variables. However, as they state that only disaggregated type choice models can fulfill the requirement of assessing the influence of cost changes on the choice of car type and mileage, only studies involving such models are presented in the following.

While early studies (e.g. Mannering and Winston (10), Train (11)) analyzed vehicle type choice in terms of numbers of vehicles and vintage, the focus of research shifted recently: motivated by energy and environmental concerns the models were specified to examine the effectiveness of different policy measures on fuel consumption and emission reduction and thus included vehicle types and consumption. Models that combined revealed (RP) and stated preference (SP) turned out to deliver satisfactory results and were applied for example for U.K.’s car ownership model (Mattew et al. (12)). Brownstone et al. (13) and Hensher and Greene (14) combined RP and SP data to evaluate preferences of both conventional and alternative fuel/electric vehicles. Brownstone et al. (13) found that SP data is critical for obtaining information about attributes not available in the marketplace (such as new engine types), while RP data is critical for obtaining realistic body-type choice and scaling information. Since they modeled make, vintage and size categories, a key issue with RP data was the large number of vehicle type alternatives which was approached by importance sampling. Birkeland and Jordal-Jørgensen (15) developed a car type choice model for new cars to analyze different policy measures intending to obtain a more efficient car fleet. Based on a vast database that included more than 150'000 individuals and companies that bought a car in 1997 in Denmark, they were able to use detailed make and model combinations as choice set of which 49 alternatives were randomly chosen. To clarify buyers’ preferences for different types of taxes and changing fuel prices, also a SP survey of 200 car buyers was conducted. The model was validated by forecasting the 1997 car sales and did reasonably well. Concerning the effectiveness of different policy measures, their conclusion was that controlling the choice of new cars is most effective through taxation of purchase prices while fuel prices have a significantly lower impact. Similar findings can also be derived from the models of presented by Mattew et al. (12) and Brownstone et al. (13).

Müller and de Haan (16) implemented the parameter estimates of Birkeland and Jordal-Jørgensen (15) in an agent-based model of consumer choice of new cars that was successfully validated for Switzerland. Using this particular model, de Haan et al. (17) simulated the effects of different energy-efficiency feebates system and concluded that such stick and carrot schemes are very effective policy measures to decrease CO\textsubscript{2} emissions indeed.

While the above models are able modeling future fuel consumption, forecasting changes in CO\textsubscript{2}-emissions is only valid under the assumption of negligible rebound-effects. Rebound effects are commonly defined as increases of demand induced by efficiency gains (Sanders (18)), namely the increase of driven milage as a result of the less driving cost of more energy efficient car. While all of the above presented models find the effect of fuel prices on car choice are significantly lower than purchase price, only the development of discrete-continuous models made it possible to jointly model vehicle type choice and usage. Examples of the
implementation of such models to evaluate different policies can be found in Feng et al. (19) or Goldberg (20). In OECD countries a prominent number of households own more than one car. As it clear that the choice of several vehicles is interdependent, Bhat (21) extended these models to the so-called multiple discrete-continuous model which is able cover car choice and usage on a household level including several cars. Recently, such models were used to estimate the impact of fuel prices, vehicle characteristic, demographics and residential environment on household vehicle holdings and use (Bhat et al. (22), Fang (23), Bhat and Sen (24)). Hitherto, these approaches did model the effect of fuel prices indirectly by employing the different car type’s running costs. Possible non-linear effects caused by substantially higher fuel prices however were not yet examined. In addition, these models were fed only with RP data. Thus being unable to cover individual preferences such as to propensity to stick with a certain car type, cannot be identified properly.

Public transport season card ownership

Compared to the vast amount of studies analyzing car ownership, there are only few studies covering public transport season card ownership and usage. Again, literature can be separated according to the employed methodology, namely time series analysis and discrete choice models.

García-Ferrer et al. (25) use monthly data of the Madrid Transport Consortium (Consorcio de Transportes de Madrid) from the years 1987-2000 to estimate elasticities of single and 10-trip bus and metro tickets as wells as season cards. While the season card elasticity turned out to be insignificant, significant cross price elasticity with respect to 10-trip tickets were revealed. However, the authors point also to the instability of the results due to collinearity problems. More reliable result for the same study area are obtained by Matas (26) who analyzes yearly data of the number of public transport trips over the year 1979-2001. Here, significant price elasticities for both bus and metro season cards are reported. To cover mode substitution effects, the model includes significant fuel price cross elasticities.

Although it should be intuitively obvious that public transport season card can serve as a substitute good to car ownership, especially when fuel prices increase strongly, studies considering this effect by jointly modeling car and public transport season card ownership are rare. Simma and Axhausen (27) study the choice between the commitment to one or the other mode and its impacts on travel behavior as well as the temporal dimension based on Dutch and German panel data. Using structural equation modeling, a high degree of stability for both car and season card ownership was identified. Additionally, it revealed that the commitment to one mode also strongly influences mode usage which emphasizes the substitutive relationship between car and public transport season card ownership. However, the employed data does not include any information on price levels which made the estimation of any price-related influence impossible.

With the primary objective of understanding moving behaviour, the German Mobiplan project (Beckmann et al. (28)) included an internet-based stated preference survey (König and Axhausen (29)) with respondents that recently moved at that time. The experiment was formulated as an open stated-response survey: given information on accommodation (type and price), travel time both to work and shopping by car and public transport as well as the public transport service frequency at the next stop and its distance to home, the respondents had to state choice and usage of mobility tools. The survey software recalculated in real time the costs associated with the current choice. Scott and Axhausen (30) modeled the collected data using bivariate
ordered probit models, designed to capture interaction effects between alternatives, namely car and season card ownership. The correlation parameter capturing substitution effects being indeed significant it is argued that the neglect of such interaction may produce biased results both for car and public transport season card ownership models. However, having no monetary variables included in the analysis except of income no conclusion about price elasticities could be derived.

In a study examining possible effects of the introduction of mobility pricing in Switzerland, a stated adaption experiment similar to the one of Mobiplan was conducted in Switzerland to evaluate possible long-term effects, namely changes of mobility tool ownership (Vrtic et al. (31)). The results revealed significant fuel price elasticity of car ownership, but no significant influence of public transport cost on any type of season card was recognized. As car ownership was modeled on an aggregate level, no conclusion on changes between car types could be derived.

Conclusions of literature analysis
While there is a significant amount of research analyzing car purchase behavior on a individuals level, only little research is found that analyzes it on a household level and even less combine car choice and car usage. In addition, most studies cover only a rather restricted range of fuel prices leaving the expected consumer reaction to high fuel prices unclear. The neglect of the substitution effect of public transport season cards might not only cause bias when modeling car and season car ownership but might bias the estimation of CO$_2$-effect of different policy measures: mode shifts from car to public transport usually only reduce but not eliminate emissions.
SURVEY DESIGN

The objective of the survey is to gain insight about long term reactions of transport cost changes.

Three types of reactions are expected and need therefore to be covered by the survey:

- Adaptation of the yearly mileage on two levels: changes of overall driven mileage and its modal split,
- Adaptation of mobility tools ownership: Type of car and motorization, type of public transport season card
- Adaption of the place of residence.

Due to the multitude of the expected demand reactions and the complexity of the decision process, the survey is designed as a stated adaptation experiment (Lee-Gosselin (32)) carried out in a face-to-face interview. In order to give the respondent a direct feedback about the costs associated to the envisaged mobility tool bundle, the survey needs to be software based.

In multi-persons households cars tend to be jointly used and also the place of residence is expected to be the result of collective decision process. Therefore, the survey considers the mobility tool ownership and its usage on a household level. Due to organizational constraints, however, only the interviewee states the preferences for all household members. This approach was already satisfactorily implemented in similar experiments (Beckmann et al. (28), Vrtic et al. (31)).

The survey consists of four parts: In the socio-demographic part, the respondent has to provide information on all household members, the place of residence and the present choice of mobility tools. This is followed by two stated adaption experiments in which the interviewee has to chose the preferred bundle of mobility tools and indicate its usage (mileage). Whereas in the 1st experiment (SP1) only the price regime differs from the present state, the second also contains an alternation of residential location. In the third experiment, the respondent has to choose between two of the earlier self-adapted alternatives. For brevity, the next section is kept as short as possible. A more detailed description can be found in Erath and Axhausen (33).

Description of household and mobility tool ownership

Socio-demographic variables

The first part of the survey is a socio-demographic questionnaire: While certain variables are needed to construct the adaptive stated preference experiment, others are to be used in a later stadium when analyzing the data and to control the representativeness of the sample.

Along with the address, the respondents also had to specify the number of persons living in the same household, the type of housing, the rent, the spatial type of the residence area (city centre/urban area/agglomeration/rural area), the availability of parking facilities and associated costs as well as the distance and travel time to the most frequently visited shopping center. In addition, information on the public transport offer was surveyed (distance to the next bus and rail station plus service frequency).

For every person of the household above the age of 18 the following inquiries of both personal and mobility related information were being made: age, sex, education level, employment status, type of employment, travel time by car and public transport to work/education and the availability of parking there.
The income was inquired on a separate screen to give the interviewee the possibility to indicate its monthly gross household income in privacy.

Present mobility tool ownership and usage

From earlier studies, it became apparent that respondents usually encounter problems when specifying motorization, consumption and type (body) of their car(s). Since for the construction of the stated adaption experiment, but also for later analysis of the data, reliable information on this variable is of importance, the indication of make, model, engine type and choice of vintage is supported by the Swiss version of Glass’s Guide car database. This database comprises a comprehensive array of information to every car type that was available for sale in Switzerland over the last few decades. The inquiry of the yearly milage of each car was supported by a calculation tool which estimated the milage based on to the information of frequency, average distance of typical trips to work, shopping, leisure and holidays.

In addition, for every person the availability and type of public transport season card was surveyed. The usage of public transport was again specified supported by the mileage calculation tool. All car using persons needed also to indicate the yearly mileage as a driver and to name the car they use most.

Finally, it was asked whether the purchase of a new car was being considered in the next three years and what car type and motorization is envisaged.

Indication of car costs

From experience, people are only vaguely aware of the fixed and variable costs of their car(s). Since these variable costs are crucial in the stated adaption experiments, it was decided to give them an opportunity to verify the assumptions that are employed when constructing the alternative sets (choice of car types) of the experiments. For one car (the first reported), the different components of the fixed and variable cost were presented, based on the respondents indication of purchase price and mileage.

Stated preference experiments

SP1: Effect of price changes on mobility tool ownership

The first of three stated preference experiments is designed as a stated adaption experiment. Given today’s residence, but under a new regime of mobility costs, the respondent has to indicate the respective choice and usage of mobility tools for all household members. Each respondent is confronted with six such situations, which are predefined by an experimental design. The experimental design is constructed by orthogonal design and combines three variables with different levels as presented in table I.
TABLE 1 Characteristics of the stated preference experiments

<table>
<thead>
<tr>
<th>SP</th>
<th>Variable</th>
<th>Definition</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1</td>
<td>Var.car costs</td>
<td>Fuel price</td>
<td>1.5, 2, 3, 4, 5 [CHF/l]</td>
</tr>
<tr>
<td></td>
<td>Fixed car costs</td>
<td>Depending on car type/engine size [CHF/month]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Public transport costs</td>
<td>Price level in relation of today’s prices</td>
<td>-10%, +20%, +50%</td>
</tr>
<tr>
<td></td>
<td>Incentives</td>
<td>Car tax surcharge [2]</td>
<td>+/-432, +/-864</td>
</tr>
<tr>
<td></td>
<td>(One out of three options)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Buyer’s premium [3]</td>
<td>1500, 3000 [CHF]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO2-tax on fuel</td>
<td>0.2, 0.5 [CHF/l]</td>
</tr>
<tr>
<td>SP2</td>
<td>Includes the same variable and levels as SP1 plus:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spatial type of residence</td>
<td>One of: City centre/Urban area</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Travel times by car</td>
<td>To work and Depending on the spatial type of the new residence</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and public transport shopping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP3</td>
<td>Choice between two in SP1 and SP2 self-defined situations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note that the respondents were told to imagine a stable price regime and their long-term reaction, including regular car replacement.

Car choice In the case of car choice, the respondents had to specify their car choice by the three variables type, engine size and engine type as stated in table 2. In addition to cars owned by the household, the respondent could also select the option "Mobility" which stands for a membership in Switzerland’s biggest car sharing association.

TABLE 2 SP1: Car choice characteristics

<table>
<thead>
<tr>
<th>Car type</th>
<th>Price</th>
<th>Capacity</th>
<th>Engine type and consumption factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro</td>
<td>18’000 CHF</td>
<td>&lt; 1500ccm</td>
<td>Fuel 1.0</td>
</tr>
<tr>
<td>Subcompact</td>
<td>25’000 CHF</td>
<td>&lt; 2000ccm</td>
<td>Diesel 0.75</td>
</tr>
<tr>
<td>Compact</td>
<td>30’000 CHF</td>
<td>&lt; 2500ccm</td>
<td>Hybrid/Gas 0.9</td>
</tr>
<tr>
<td>Mini MPV</td>
<td>35’000 CHF</td>
<td>&lt; 3000ccm</td>
<td>Elektro 0.7</td>
</tr>
<tr>
<td>Mid-size Car</td>
<td>45’000 CHF</td>
<td>&gt; 3000ccm</td>
<td></td>
</tr>
<tr>
<td>MPV</td>
<td>50’000 CHF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-size Car</td>
<td>70’000 CHF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUV/Luxury vehicle</td>
<td>90’000 CHF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sports car</td>
<td>75’000 CHF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobility</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To give the respondent direct feedback of his choice, the software is programmed to indicate the costs associated to any combination of mobility tools and mileage. Thereto, fixed and variable costs for all offered combinations of cars type and motorization needed to be predefined. These costs were derived from the cost manual of the Swiss Touring Club Touring Club Schweiz [34], Switzerland’s largest car drivers association. To get realistic assumptions on purchase prices and consumption, data of all new cars available in Switzerland provided...
by Swiss Federal Office of Energy (SFOE) was analysed. Combinations of car types and engine sizes that are not available in the market were also excluded as choice options in the experiment.

Additionally, the respondent had to indicate whether the chosen car is purchased as new or used car, which defines the eligibility of the buyer’s premium incentive, the depreciation rate but also consumption.

For every chosen car, the respondent has to indicate its supposed the mileage under the new price regime. To obtain reliable information the respondent was urged to use the yearly mileage calculation tool.

The software features a function to import the present car fleet, whose usage was highly recommended to the respondents to provide them first an idea of the expenses they face under the new cost regime.

Public transport season card choice In Switzerland three types of public transport season card are available: The Half-Fare card allows to purchase rail, tram and bus tickets at half fare. Local and regional transport network offer monthly and yearly passes which allow to use public transport on their networks without any additional charge. Lastly, the owner of a General Abonnement (GA) enjoys unlimited travel on nearly the entire public transport network in Switzerland. To capture the effective prices of all season card offers as accurately as possible, several subtypes (e.g. travel classes, reduction for seniors, monthly/yearly payment etc.) were considered in the survey.

While the yearly costs of the General Abonnement solely consists of fixed costs, for all other options available also variable cost components need to be considered. The unit costs [CHF/km] of the variable component again depend on the usage, since short trips in the local network tend to be more expensive than in the interregional network. To keep the cost calculation as realistic as possible, fixed and variable costs for eight distance categories were predefined.

Housing costs In this first experiment the residence location is not altered. Since the share of fossil heating energy in Switzerland amounts to 70% (Swiss Federal Statistical Office) it must be assumed that with higher fuel prices also heating costs increase. In addition it is widely argued that budget effects need to be represented when modeling mobility tool ownership. Therefore, heating costs were coupled with fuel costs assuming that the product prices (price of fuel less taxes and distribution costs) remain equal. The respondent could vary his choices until he was satisfied.

SP2: Effect of price and residence place changes on mobility tool ownership

The analysis of census data suggests that the spatial type of residence affects both mileage and car type shares. In turn, this means that the cost of mobility are influenced by the place of residence. Therefore, the survey design of SP2 asks respondents to indicate their envisaged set of mobility tools given the change of residence: in addition to the cost variation, in the second series of the six stated adaption situation also the place of residence and hence travel times to work and major shopping centers are varied.
Travel times  Depending on the newly defined residence location, different ranges of travel time were considered. When defining these ranges, special attention was payed so that the travel times where both realistic but also broad enough to get situations with sufficient variation.

Mileage  As in SP1, besides the mobility tools also the respective yearly mileage can be adapted by the respondent. It is clear that the respondents would find it very hard to freely indicate reliable information on the yearly travel demand given a new place of residence. Therefore it was decided to indicate the estimated yearly travel demand based on statistical data derived from the most recent Swiss travel survey Swiss Federal Statistical Office (37).

Housing costs  Depending on the new place of residence, the housing costs are adapted based on the Swiss’ most comprehensive rent survey Wüest & Partner AG (38). To represent the quality standard of the respondents apartment, an additional factor is employed which is given by dividing the actual rent by the rent that would be expected given the above assumptions. The heating costs depend again on the fuel price level and is implemented in the same way as in SP1.

Travel costs  Fuel and public transport prices are altered in the same range as in SP1. However, in SP2 the travel cost regime needs to be equal for two corresponding situations to match SP3’s experimental design.

SP3: Choice between two residence location with optimized sets of mobility tools

The last series of six choice situations is formulated as a stated choice experiment and is designed to evaluate the respondents propensity to move to more central locations due to travel cost increases. Each situation combines two alternatives from SP1 and SP2 experiments, whereas only alternatives with the same cost regime but different residence locations were combined. Thereby, trade offs between the following variables result: Residence location and costs, sets of mobility tools and travel times. For the first three situations both alternatives were taken from SP2, where all residence locations differ from the reported location. For the remaining three three situations one alternative is taken from SP1 and hence consistent with today’s residence location.

All stated preference experimental designs were once changed during the survey to cover a broader spectrum of combinations of travel costs and changes of residence locations.
DATA COLLECTION

Software

The survey software is programmed as a Java application to run on a Windows XP/Vista platform. The program flow follows the structure of the survey as presented here. The software is programmed to run in three languages since interviews were conducted in the German-, French- and Italian-speaking parts of Switzerland.

During the fieldwork no problems were encountered with the software. However, software updates, like the implementation of the 2nd stage experiment plans, as well as the data collection and monitoring of the survey caused substantial organizational efforts. For similar future projects, a web-based solution where interviewers would use mobile broadband communication devices is suggested.

Recruiting

The realization of the recruiting and fieldwork was commissioned to "Interdata Forschung", a market research institute specialized on face to face interviews based in Lucerne, Switzerland. The interviewees were directly recruited by the interviewers while strict quotas needed to be fulfilled to ensure the representativeness of the sample. Quotas were defined for a multitude of variables that may influence mobility tool ownership such as sex, age, income, household size, type of presently owned car and public transport season card, spatial structure of residence and education level. Due to the survey focus, only persons living in a household with at least one car are considered. As an incentive, each interviewee was paid 20 CHF.

Fieldwork

Before the fieldwork commenced, all interviewers attended a work shop where they were introduced to the survey and learned to handle the software. All interviews are conducted in June and July 2009. During the realization of the interviews, the interviewers were coached by the fieldwork supervisor of Interdata. The quality of the data was monitored by the research team through the analysis of interim data deliveries. In total, 409 interviews were conducted by 13 interviewers. Overall, the quotas were fulfilled satisfactorily and the sample can be considered representative for the Swiss population except of public transport season card ownership: while GA and local and regional network passes are represented according to the expected shares, too few Half-Fare owners are covered by the sample (16.1% instead of 26.5%). Therefore, reweighing might be necessary when forecasting the impact of changing travel costs.

The interviewers reported that the survey was well understood. However, it was reported that some respondents found it very unlikely to change their place of residence and had therefore problems to imagine their mobility needs in SP2.
DISCUSSION OF DESCRIPTIVE DATA ANALYSIS

In this section the response of changing transport costs is presented. Emphasis is placed upon the change of behavior when respondents are confronted with different options of behavior change. No results from econometric models, namely of multiple discrete-continuous models can be presented yet. However, it is argued that also descriptive analysis sufficiently demonstrates the applicability of our approach and indicates the trends to be expected by matching policies.

To cancel out possible effects resulting from changes of residence area occurring in the SP2 experiment, in the following analysis of respondents reaction to cost variations only data of the SP1 is considered. SP2 and SP3 data is considered when analyzing substitute effects and the influences of residence location choice. Basis of the analysis are 409 interviews resulting in 7,362 choice situations or 2,454 in each case of SP1, SP2 and SP3.

Annual mileage

Adjustment of the yearly mileage is probably the most likely demand reaction as only the usage of the currently owned car(s) is affected. As presented in table 3 the respondents reacted on fuel price changes by adjusting their mileage. While the impact for higher income classes is less distinct, in lower income classes the average mileage decreases up to 22%. Neglecting other possible influences, namely price changes of public transport and different incentive regimes, an average fuel price elasticity of -0.12 can be derived from the data. This value is in line with other studies using robust and proven methodologies that analyze RP-data such as time series analysis (e.g. Baranzini et al. (39)). This finding emphasizes the applicability of the approach of letting respondents state their yearly mileage to evaluate fuel price elasticity.

### TABLE 3 Influence of fuel price on annual car mileage in SP1

<table>
<thead>
<tr>
<th>Price Gaz [CHF/l]</th>
<th>Monthly household Income CHF/a</th>
<th>&lt;2000</th>
<th>&lt;4000</th>
<th>&lt;6000</th>
<th>&lt;8000</th>
<th>&lt;10000</th>
<th>&lt;13000</th>
<th>&lt;16000</th>
<th>&gt;16000</th>
<th>n.a.</th>
<th>Average</th>
<th>Total share</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td></td>
<td>7750</td>
<td>8686</td>
<td>10046</td>
<td>10595</td>
<td>12741</td>
<td>10669</td>
<td>12643</td>
<td>11371</td>
<td>15869</td>
<td>11193</td>
<td>16.6%</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>7731</td>
<td>8454</td>
<td>9690</td>
<td>10460</td>
<td>12326</td>
<td>9962</td>
<td>12583</td>
<td>10609</td>
<td>15815</td>
<td>10854</td>
<td>21.8%</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>6533</td>
<td>7132</td>
<td>9457</td>
<td>9843</td>
<td>11871</td>
<td>9775</td>
<td>11010</td>
<td>11488</td>
<td>16173</td>
<td>10499</td>
<td>22.4%</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>6433</td>
<td>6722</td>
<td>8884</td>
<td>8843</td>
<td>11408</td>
<td>9758</td>
<td>10977</td>
<td>11467</td>
<td>14070</td>
<td>9854</td>
<td>20.8%</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>6657</td>
<td>6989</td>
<td>8613</td>
<td>8762</td>
<td>10989</td>
<td>10571</td>
<td>11229</td>
<td>9878</td>
<td>14287</td>
<td>9782</td>
<td>18.3%</td>
</tr>
<tr>
<td>Total share</td>
<td></td>
<td>2.0%</td>
<td>9.5%</td>
<td>21.0%</td>
<td>17.5%</td>
<td>16.1%</td>
<td>13.2%</td>
<td>6.5%</td>
<td>6.5%</td>
<td>7.8%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Car type

Given the increasing fuel costs in the experiment, one can also expect that people prefer owning smaller, more fuel efficient car types. Figure 1 shows how the respondents adjusted their actual car types in the experiment including all offered levels of fuel cost.

While only the car types "Micro" and "Subcompact" become more popular, the shares of all other types are decreasing. Interestingly, the intensity of the relative drop within each of these categories is quite stable, ranging from -16% for compact cars to -25% for full size cars - only sport cars owners tend to stick more with their actual car types (-13%). Also the relative gain for the two categories with increasing market shares are very similar: +37% for micro cars and +35% for subcompact cars.
The bars and the respective values in figure 1 indicate the interrelation of car type changes. As expected, respondents currently owning micro or subcompact cars still tend prefer those types, but also show the strongest inclination to get rid of their cars. When reconsidering car type, owners of compact, mid-sized cars and mini MPV prefer subcompacts while full-size car owners would largely change to mid-sized cars. Sports and SUV/luxury vehicle owners exhibit a less clear switching pattern. In addition, those people have also a smaller propensity to change the car type at all. This is an interesting finding, especially because the running costs of those cars are not only the most affected by fuel price increases but also the highest average mileage is reported for these two types. A possible explanation for this might be that people owning such cars tend also to have higher income than all others (10,630 CHF/month vs 8,112 CHF/month). Additionally, they might have higher expectations of car comfort as they spend more time in their cars (higher mileage).

When analyzing the influence of the different incentive schemes on the propensity of (not) choosing those cars types affected by those schemes, no clear pattern could be recognized. However, only the results of the envisaged statistical models can provide definitive insight on the significance of such influence.

Motorization

Table 4 summarizes the respondents reaction in terms of adjusting motorization. While still in most situations the engine size was kept constant, it is also obvious that higher fuel prices lead to a higher propensity of acquiring smaller engined cars. When it was decided to chose a smaller engine, usually the engine size was reduced by only one category (-500ccm).
TABLE 4 Changes of engine size in SP1

<table>
<thead>
<tr>
<th>Price Gaz [CHF/l]</th>
<th>Car sharing</th>
<th>No car</th>
<th>&lt;-500 cmm</th>
<th>&gt;-500 cmm</th>
<th>equal</th>
<th>&lt;+500 cmm</th>
<th>&gt;+500 cmm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>.7%</td>
<td>1.3%</td>
<td>5.2%</td>
<td>89.2%</td>
<td>2.2%</td>
<td>1.3%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.0%</td>
<td>1.7%</td>
<td>7.4%</td>
<td>87.4%</td>
<td>1.8%</td>
<td>.7%</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.1%</td>
<td>1.7%</td>
<td>10.4%</td>
<td>84.2%</td>
<td>1.4%</td>
<td>.3%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>.1%</td>
<td>4.6%</td>
<td>3.9%</td>
<td>16.0%</td>
<td>73.9%</td>
<td>1.2%</td>
<td>.3%</td>
</tr>
<tr>
<td>5</td>
<td>.3%</td>
<td>7.4%</td>
<td>3.4%</td>
<td>17.9%</td>
<td>70.7%</td>
<td>.3%</td>
<td></td>
</tr>
<tr>
<td>Total Share</td>
<td>.1%</td>
<td>3.1%</td>
<td>2.4%</td>
<td>11.4%</td>
<td>81.1%</td>
<td>1.4%</td>
<td>.5%</td>
</tr>
</tbody>
</table>

When separated according to car types, people owning compact, mid-sized, full-sized cars and mini MPVs are about twice as likely (in about 22% of the cases) to downsize their engines than SUV/luxury and sports car owners. Since hardly any engine of the currently owned micro and subcompact cars does not belong to the smallest engine category, not much potential is left here.

Adjustments are also made concerning the engine type: While the percentage of Diesel engined cars in the sample is 14.8%, in the SP experiment the share increases depending on the fuel price level to 23.1% (1.5 CHF/l) up to 31.6%. Although on a lower level, the same trend applies also for hybrids (2.0-11.0%) and natural gas powered cars (1.1-3.1%). Electric cars however do not get beyond a share of 1.7% which might be caused by the unfamiliarity of the respondents with the concept or concerns about the rather restricted range of such cars.

Season card ownership

Table 5 lists the shares of the different types of public transport season cards according to the different price levels of public transport and fuel. Whereas prices changes of public transport seem to have only little influence, higher fuel prices tend to boost at least the sale of transport network passes.

TABLE 5 Influence of price variations on season card ownership in SP1

<table>
<thead>
<tr>
<th>Price Level public transport</th>
<th>GA</th>
<th>Half-Fare Card</th>
<th>Network pass</th>
<th>No seasoncard</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10%</td>
<td>3.1%</td>
<td>16.4%</td>
<td>12.5%</td>
<td>68.0%</td>
</tr>
<tr>
<td>+20%</td>
<td>3.1%</td>
<td>15.9%</td>
<td>10.6%</td>
<td>70.4%</td>
</tr>
<tr>
<td>+50%</td>
<td>3.0%</td>
<td>16.1%</td>
<td>11.7%</td>
<td>69.2%</td>
</tr>
<tr>
<td>Total share</td>
<td>3.1%</td>
<td>16.1%</td>
<td>11.6%</td>
<td>69.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel prices [CHF/l]</th>
<th>1.5</th>
<th>2.5%</th>
<th>15.6%</th>
<th>10.8%</th>
<th>70.7%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>2.5%</td>
<td>14.7%</td>
<td>11.1%</td>
<td>71.6%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.6%</td>
<td>16.8%</td>
<td>11.9%</td>
<td>67.7%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2.9%</td>
<td>15.3%</td>
<td>11.6%</td>
<td>70.2%</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>3.5%</td>
<td>18.5%</td>
<td>12.6%</td>
<td>65.4%</td>
</tr>
<tr>
<td>Total</td>
<td>3.1%</td>
<td>16.1%</td>
<td>11.6%</td>
<td>69.2%</td>
<td></td>
</tr>
</tbody>
</table>
Overall, the impacts of changing costs are much less distinctive for public transport season card than for car ownership. Besides the effective inertia of season card ownership, this result might also have been caused by the given fact that the survey sample and screen design emphasized car ownership. However, definitive conclusion about the impact of both car and public transport costs on season card ownership can only be provided by the envisaged econometric models.

Rebound effects

One argument when promoting policies towards a higher car fuel efficiency is often a possible neglect or at least unappropriate consideration of rebound effects. Given the option of adjusting car type, engine size and mileage, the hypothesis would be that respondents scaling down car type and engine size used the efficiency/monetary gains to increase their mileage. It is assumed that fuel consumption increases with car size. The segmentation of relative changes in car size applied in this analysis follows the order of car size as given in table [2]. For example, if in one situation a respondent changed from a compact to a micro car, this observation would belong to the category "-2".

<table>
<thead>
<tr>
<th>Price Gaz [CHF/l]</th>
<th>Change Car type (sizes)</th>
<th>-4</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>Car sharing</th>
<th>no Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td></td>
<td>-833</td>
<td>-588</td>
<td>-971</td>
<td>-326</td>
<td>417</td>
<td></td>
<td></td>
<td>-2000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>-286</td>
<td>-867</td>
<td>-313</td>
<td>-724</td>
<td>-382</td>
<td>500</td>
<td></td>
<td>-3214</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>-613</td>
<td>-1902</td>
<td>-1070</td>
<td>-1216</td>
<td>1111</td>
<td></td>
<td></td>
<td>-4000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>-2130</td>
<td>-1605</td>
<td>-1566</td>
<td>-1451</td>
<td>-1918</td>
<td>250</td>
<td>833</td>
<td>-4000</td>
<td>-2194</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>-667</td>
<td>-3032</td>
<td>-1367</td>
<td>-1820</td>
<td>-1975</td>
<td>111</td>
<td>-167</td>
<td>-4000</td>
<td>-2193</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2.3%</td>
<td>3.7%</td>
<td>6.4%</td>
<td>10.4%</td>
<td>70.1%</td>
<td>1.5%</td>
<td>2.5%</td>
<td>0.1%</td>
<td>3.1%</td>
</tr>
</tbody>
</table>

As shown in table [6], this hypothesis is not confirmed in our data. The respondents who scale down car type rather tend to drive less. While this effect is more distinct for high fuel price levels, even for the fuel price levels of 1.5 and 2 CHF/l it does not disappear. The same applies if instead of changes of car types, the adjustment of engine size is considered.

Substitution effects

Scott and Axhausen [30] found the inclusion of substitution effects crucial when modeling mobility tool ownership in regions with viable public transport systems. Given the increasing fuel prices in the SP experiment, the joint modeling of car and public transport season card ownership might be even more important. To check the propensity of the respondents to acquire a public transport season card in substitution of a car, table [7] compares the relative number of newly acquired (or not renewed) season cards based on the change of the vehicle number in a given household. Since substitution effects can be either motivated by changes of transport cost and residence location, this analysis includes data from SP1 and SP2.
First, it has to be highlighted that in only about 8% of the cases the respondents reduced the number of cars in the household, while in about 3.7% of the cases the level of season card ownership was adjusted. However, when a household decides to get rid of a car season card ownership is clearly influenced. For example, in 11.1% and 4.3% of the cases the abolishment of a car is compensated by the acquisition of one, respectively two transport network season passes. Summarized over all types of season card, in 25.1% and 7.6% of the cases the given-away car is substituted by one, respectively two season cards. This finding stresses the need that the later employed econometric model is designed to represent substitution effects.

### Place of residence

As it is unclear whether the reconsideration of mileage and car characteristics does not over-strain the respondents abilities, the viability of the responses needs to be checked by analyzing possible differences between the adjusted mileage and car choice indicated in the SP2 with data describing the present situation.

The reported mileage within the sample differs from the pattern in the representative census: People that reported to live in the city center traveled more and people in the rural less than expected. Most likely, this is caused by erroneous indication of the present spatial type of residence. While this divergence in mileage pattern remained constant in SP1, in SP2 it disappeared. This suggests that the respondents might have been too much influenced by the software-generated mileage indication.

The comparison of the car type distribution, separated for the different spatial types of residence as reported for the present situation, with the distribution as stated in SP2 (supposing a new place of residence) shows also clear differences. When the data is analyzed on the disaggregated household level, it becomes obvious that households tend to stick with their preferred type of car. However, RP panel data from earlier studies is suggesting that people also adjust their mobility tools when moving between different spatial types. Two reasons for this discrepancy seem to be possible: People have actually difficulties to foreseen changing needs when moving between different spatial types which would question the way the experiment is formulated. However, it could also be that people decide to change the spatial type of residence because of reason that might also influence mobility tool ownership. For example, a young urban couple expecting birth of a child is both likely to purchase a (larger) car and to move in towards more rural areas. Such life course related effects are obviously not covered within this experiment.
Hence, the viability of the data in terms of the influence of residence location changes is dubious. However, similar effects of mobility cost changes as given by SP1 data could still have been determined in SP2 data, too.

The analysis of SP3 reveal strong inertia effects concerning the place of residence. In 74.3% of the situations where one of the alternatives featured unchanged place of residence, this situation was preferred. When both situations featured different places of residence, the one more similar to the actual residence situation is preferred. However, how the variables of mobility costs and place of residence jointly influenced the decisions can will only be revealed by the envisaged discrete choice modeling.
CONCLUSION

In this paper we presented a new approach how to evaluate possible long term effects of substantial increases of transport costs involving especially fuel price increases up to the level of 5 CHF/l.

It is shown that people react not only by adjusting mileage but also by changing car types and choosing smaller engines or more fuel efficient engine concepts such as Hybrids or Diesel. In addition, substitution effects between car and season card ownership within households were discovered, strengthening the argument raised in recent research to jointly model mobility tool ownership.

However, when the respondents had to imagine to move their residence to another place of different spatial type, the results are less concise. In addition, the impact of different incentive types could at least not have been satisfactorily described by the descriptive analysis. It can be argued, that the respondents, given the vast amount of possible combinations of car types engine types and sizes, might have had problems finding out for which cars the incentives were applicable. Both problems might be addressed using strategies to pre-sample relevant choice alternatives. For example, the types of car that a respondent effectively envisages or his propensity to move could be surveyed in preliminary question. The alternatives for SP-experiment would then be generated based on the responses to these questions. However, this would come at the expense of a priori exclusion of new, not considered alternatives that might by valuable anyway.

Although not yet evaluated by econometric models, the observed user reactions are in line with earlier research which highlights the applicability of the approach. In a next step, the data will be analyzed using multiple discrete-continuous extreme value models. The results of those models will not only allow to forecast long term effects of substantial changes of transport costs but also allow to evaluate different policies intended to regulate mobility tool ownership.
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REFERENCES


