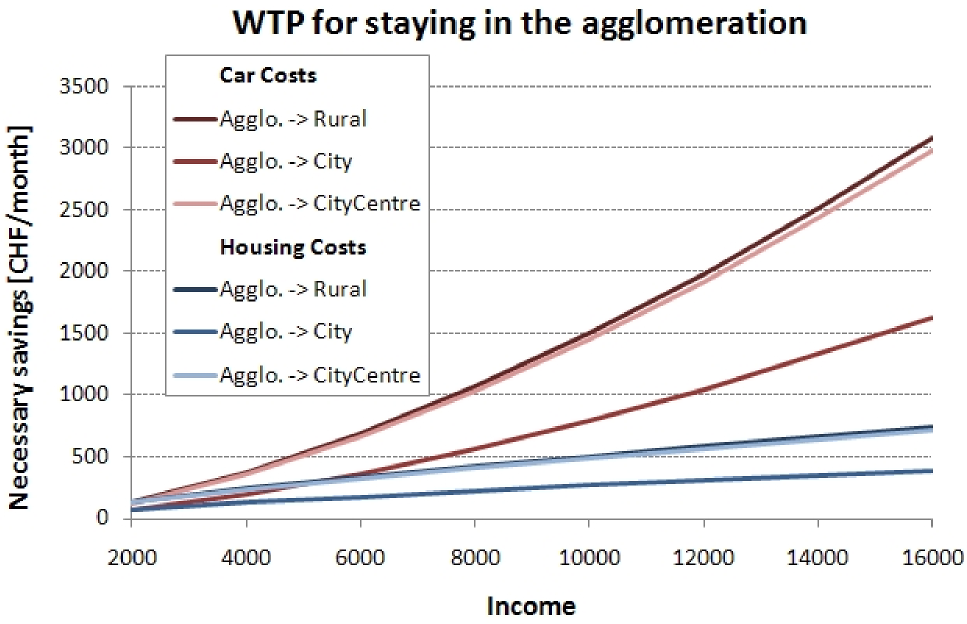

Mobility Costs and Residence Location Choice

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Abstract

This paper analyzes how residence location choice is influenced by substantial changes in transport costs in Switzerland. Given different price regimes, a stated preference experiment combined two residence location situations and corresponding mobility tools as selected by the respondent in a prior stated adaption experiment.

Overall, the results suggest a high averseness against moving away from the current type of residence location. The willingness to pay before moving to a more central place that causes less car costs ranges for an average income lies between 463 CHF/month in the case of a residential location change from the agglomeration to the urban area and 2040 CHF/month in the case of moving from the rural area to the city centre. In addition, differences in the valuation of housing, car and public transport costs are identified whereas car cost are generally the least negatively valued. The perception of these costs is also income dependent: the higher the household's income, the lower the valuation of costs.

Keywords

Mobility tool ownership, car ownership, season card ownership, residence location choice

1 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 the marginal costs of the 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. Lastly, in response to substantially higher travel costs, individuals might also adjust their residential location and move to more central places that involve less travel costs. While daily travel decisions are subject to substantive inertia, mobility tool ownership and residential location especially are even more rarely reconsidered which makes them more difficult to study.

However, the recent crude oil price shock - 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: while the nominal income (+2.0%, BfS (2009a)) and population (+1.4%, BfS (2009b)) 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 (2009)). On the other hand, also changes in car purchase behavior became visible: market analysis both from Switzerland Auto Schweiz, Association of Swiss car importers (2009) and the U.S. Autoobserver (2008) reveal demand shifts towards smaller and more energy efficient cars. However, up to now no fuel price related changes in residence location choice were reported.

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 clearly increasing trend over the last decade (Filliger (2009)) . Similar applies for the United States(Conti and Sweetnam (2008)). Meanwhile, most OECD countries are behind their CO_2-emission reduction targets (UNFCC (2008)). 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 and residence location choice models that also deliver reliable forecasts of 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 changes of the mileage traveled by car and public transport, changes in car ownership (including differentiation between car type and motorization) and public transport season card ownership but also in residence location choice.

The remainder of the paper that focuses on the residence location choice is structured as follows[1]: the next section gives an overview of methodologies when modeling the impact of mobility costs on residence location choice. In the following sections, the research methodology is specified, the questionnaire presented and data collection reported. Finally, the modeling approach and the model results are presented and interpreted in the conclusion.

[1] In this paper only results of the residence location choice experiment are reported. However, preliminary results of the mobility tool ownership experiments are presented in an other paper (Erath and Axhausen (2009a)).

2 Literature

2.1 Residence location choice and travel costs

In contrast to the extensive literature discussing travel cost reactions on mode choice, mobility tool ownership and usage, the influence on residence location choice has received only limited attention. However, residence location choice itself is a widely studied topic: Depending on the type of the employed data, the residence location choice literature can be subdivided into three different methods, namely longitudinal , revealed and stated preference data. In addition, there is a bulk of research focussing on the influence of one's lifestyle on the residence location choice.

2.1.1 Longitudinal data

Since residence locations choice decisions are taken usually relatively seldom but dependent of the stage in one's life, the idea to analyze longitudinal data describing the life course is obvious. Beige (2008) found a strong relationship between residence locations choice and mobility tool ownership during the life course. Interestingly, alteration in residence, education and employment occur noticeably more frequently than changes of mobility tool ownership. Persons between the ages of 15 and 35 years are most mobile, i.e., moving and changing occupation as well as varying the ownership of mobility tools most frequently. Afterwards, they become relatively established.

However, due to data constraints, the influence of travel cost on residence location choice decisions can usually not be included in the analysis when modeling longitudinal data.

2.1.2 Revealed preference data

The literature review of earlier studies (Zondag and Pieters (2005)) already stated that the number of empirical studies of transport impacts on land use is quite limited. This is especially so when compared with the large body of empirical studies on the reverse impact of land use on transport.

Generally, in revealed preference studies the mobility costs cannot directly be included in the analysis: when analyzing revealed preference data, non-chosen alternatives usually have to be sampled to estimate the models. Thereby, the indication of one household's mobility costs is related to many uncertainties. Therefore, when analyzing mobility aspects of residence location using reveal preference data, not the mobility costs itself but the mobility offer is described:

Usually, this is done by employing accessibility measures. Since places with high accessibility tend to cause lower mobility costs (more opportunities reachable in less distance), it can be considered as a proxy for mobility costs.

In a early study, Weisbrod *et al.* (1978) emphasized that transportation level-of-service has only marginal influence on residential preferences. Factors beyond the scope of public policy at that time (e.g. mobility costs and quality of public transport), such as the desire for single-family, detached homes among families with children and reduced moving rates for older persons and families with several children, all affect mobility and location patterns more than other factors related to public expenditures. Bürgle (2006) found that from all tested mobility-related variables only those directly related to the individual, such as travel time to work, have strong influence on residence location choice, while other mobility related variables, such travel time to city centre, are less important or, as in the case of overall accessibility, even insignificant.

Löchl (2007) analyzed not the demand but the supply side of the residence choice market by estimating property and rent prices applying the hedonic pricing method. Interestingly, of all accessibility measures, the variable describing the travel time to the city centre showed the best explanation power. However, also the proximity of the next rail station influences positively the price level.

2.1.3 Stated preference data

There are several constraints when analyzing revealed preference data to study residence location choice. Besides data issues (effective sampling strategies, multi-collinearity, high data requirements), the main constraint is that no impact of new measures and policies such as road pricing or substantially higher mobility cost can only hardly be evaluated. To overcome these constraints several researches used stated preference techniques to analyze residence location choice.

Hunt (2001) concluded, based on a stated preference survey with respondents from Edmonton, Canada, that dramatic improvements in travel times to work would be required to compensate the typical household for a move into higher-density dwelling forms. A stated preference study for six cases in Belgium and the Netherlands, Molin and Timmermans (2003) confirmed these findings. They concluded that, regardless the study area and the model specification, accessibility attributes are significantly less important than attributes describing the housing and the neighborhood. Axhausen (2003) analyzed the supply side of the residence choice market and suggested that transport changes appear to have relatively modest impacts on house prices.

2.1.4 Residence location choice as a lifestyle decision

It is widely accepted, that the place of residence is chosen to fulfill the needs of the household members best and reflects therefore the household's lifestyle (see e.g. Kitamura *et al.* (1997), Krizek and Waddell (2003), Schwanen and Mokhtarian (2005)). Results of stated preference data collected in the Portland metropolitan area (Oregon) presented by Walker and Li (2007) suggests the presence of three household lifestyle segment: suburban and car orientated, suburban and transit orientated as well as urban an car orientated. However, Cao *et al.* (2006) have also noted that policies aimed to influence behavior may be of limited impact because of the large proportion of households who have strong preferences towards car oriented lifestyles.

3 Survey design

3.1 Survey implementation

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.

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.* (2002), Vrtic *et al.* (2007)).

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 (SP2) also contains a change in of residential location. In the third experiment, which is designed as a stated choice question, the respondent has to choose between two of the earlier self-adapted alternatives.

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 (1995)) 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 this paper, only SP3 data is analyzed. For brevity only the design of the SP3 experiment is presented. However, a detailed description of the design of the SP1 and SP2 experiment can be found in Erath and Axhausen (2009b) and Erath and Axhausen (2009a).

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

The residence location choice experiment 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 the experiments SP1 and SP2, but 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 usage and travel times to work and shopping. In three situations both alternatives were taken from SP2, where the residence locations of both alternatives differ from the reported location. In the other three situations one alternative is taken from SP1 and hence consistent with today's residence location.

Depending on the respondents mobility tool choice and indicated usage, the alternatives are described by the following variables:

- Place of residence (City centre, urban area, agglomeration, rural area)
- Housing costs per month
- Costs of all public transport tickets in the household per month
- Fixed and running costs of all cars used in the household per month
- Travel times per car and public transport to work
- Travel times per car and public transport to a shopping centre (weekly shopping)

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.

4 Data collection

4.1 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.

4.2 Recruiting

The realization of the recruiting and fieldwork was commissioned to "Interdata Forschung", a market research institute specialized in 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 number

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.

4.3 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 survey period 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.

4.4 Data Validation

Each of the three SP-experiments contained a set of six decision situations. Before modeling, the data was validated and checked for consistency. In total, 76 situation need to be excluded due to apparent data issues caused by typing errors.

5 Descriptive data analysis

An important issue of any stated preference design is the inclusion of sufficient variance in the data set. Thus, approaches that maximize variance in the data set such as orthogonal design or bayesian efficient design have become good practice. However, due to the survey design, only the choice variables residence location, housing costs and travel times to work and shopping by car and public transport could have been predefined using orthogonal design. The configuration of mobility tools and its corresponding cost, in contrast, depend directly on the respondents choice of the stated adaption experiments SP1 and SP2. Therefore, it is important to verify that the data set provides enough variance and that the individual variables are not correlated.

5.1 Variance

In logit models, the choice probability of each alternative is given by the utility difference between the alternatives. Table 1 lists the distribution characteristics of the difference between the two alternatives for monthly car, public transport and housing costs, namely the variables that could not have been controlled but are given by the respondents indications in SP1/SP2.

Table 1: Descriptive characteristics of SP3 choice variables differences

Variable	Mean difference (abs)	Std. Deviation
Housing costs [per month]	73.86	519.82
Public transport costs [per month]	4.39	83.05
Car costs [per month]	31.17	239.84

The difference between the the choice alternatives shows sufficient variance for all tested variables.

5.2 Correlation

Whereas in the design process the correlation of the travel time describing variables could be actively controlled, this only partly applies for the variables of monthly car, public transport and housing costs: One's mobility needs and housing standard can only partly be influenced by the residence location. Hence, correlations between monthly car, public transport and housing costs cannot be completely avoided. In fact, there is a trade-off between considering one's preference of mobility tools given a certain residence location choice and constructing statistically efficient survey designs. In this survey, the emphasis lies clearly on the first point wherefor correlations have to be accepted.

Table 2: Correlation of SP3 choice variables

	PT cost 1	PT cost 2	Car cost 1	Car cost 2	Hous. cost 1	Hous. cost 2
PT cost 1	1.000			.		
PT cost 2	.277**	1.000				
Car cost 1	.036	.011	1.000			
Car cost 2	.014	-.027	.898**	1.000		
House. cost 1	.044*	.173**	.363**	.407**	1.000	
House. cost 2	.039	.167**	.367**	.353**	.886**	1.000

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

As expected, the correlations listed in Table 2 are significant. However, as the effective values of most correlations are reasonable and given the sample size, the estimation of significant parameters should be possible as the sample size is large enough.

5.3 Range of mobility tools

In SP1 and SP2 the respondents had to state the number of cars and mobility tools given a certain price regime. As mentioned above, sufficient difference between the variables of all choice alternative is needed in order to estimate reliable results. Parameters estimates on these variables are only reliable if there is enough difference.

Table 3: Differences in mobility tools in SP3

		Frequency	Percent
Half-Fare	Not equal	64	2.7
	Equal	2313	97.3
GA	Not equal	36	1.5
	Equal	2341	98.5
Netpass	Not equal	95	4.0
	Equal	2282	96.0
Car	Not equal	185	7.8
	Equal	2192	92.2

The figures in Table 3 shows clearly that the number of mobility tools own by one given household does not alter much between two alternatives in the experiment. Hence, the modeling of these variables is omitted.

6 The Multinominal Logit Model

6.1 Model form

The stated choice experiment is modeled as an Multinominal Logit Model (MNL) and estimated using the Software Biogeme (Bierlaire (2008).

In the Logit-Model, the utility of the discrete choice alternatives is described by a systematic, deterministic and a random (error term) component. The utility U of alternative j for a person q can then be expressed as:

$$U_{jq} = V_{jq} + \varepsilon_{jq} \tag{1}$$

with:

V_{jq}	systematic, measurable component
ε_{jq}	non-systematic, non-measurable component to capture unobservered, individual idiosyncrasies and errors in measurement

The utiltity functions of V_{iq} are user-defined combinations of alternative- and person-specific attributes. The chosen alternative j is then the one that exhibits the highest utility for person q:

$$\begin{aligned} &U_{jq} \geq U_{iq}, \forall i \neq j \\ &V_{jq} - V_{iq} \geq \varepsilon_{iq} - \varepsilon_{jq}, \forall i \neq j \end{aligned} \tag{2}$$

Since the value of $\varepsilon_{iq} - \varepsilon_{jq}$ is unknown, only an estimation of the choice probability of one alternative can be described. Hence, the choice probability of alternative j is given by

$$\begin{aligned} &P_{jq} = P(\varepsilon_{iq} \leq \varepsilon_{jq} + V_{jq} - V_{iq}), \forall i \neq j \\ &P_{jq} = \int f(\varepsilon) d\varepsilon, \end{aligned} \tag{3}$$

whereas $f(\varepsilon)$ stands for the density function of the mutual error term. For the multinominal logit model, the error terms are expected to be independent and Gumbel-distributed with an average value of 0 and equal standard deviation. Then, the choice probability of alternative j is given by:

$$P_j = \frac{e^{V_j}}{\sum_i e^{V_i}} \tag{4}$$

6.2 Elasticities

Based on the the parameter estimates, elasticities can be calculated. In the context of of discrete choice models, a direct elasticity measures the percentage change in the probability of choosing a particular alternative in the choice set with respect to a given percentage change in an attribute of the same alternative.

Hence, direct point elasticities in the MNL-model are defined as follows:

$$E^{P_{iq}}_{X_{ikq}} = \frac{\partial P_{iq}}{\partial X_{ikq}} * \frac{X_{ikq}}{P_{iq}}, \tag{5}$$

with

$E^{P_{iq}}_{X_{ikq}}$	the elasticity of choosing alternative i with respect to changes of variable k for person q,
P_{iq}	the probability of choosing alternative i for person q,
X_{ikq}	the value of variable k of alternative i for person q

In the case of linear formulations of the utility term the partial derivatives equal the β-parameters and the equation collapses to:

$$E^{P_{iq}}_{X_{ikq}} = \beta_{ik} X_{ikq}(1 - P_{iq}), \tag{6}$$

for the direct point elasticity.

For non-scalar variables (e.g. dummy variables such as used for the preference of residence location choice) only arc elasticities can be calculated:

$$E^{P_{iq}}_{X_{ikq}} = \frac{(P^1_{iq} - P_{iq})/(X^1_{ikq} - X_{ikq})}{(P^1_{iq} + P_{iq})/(X^1_{ikq} + X_{ikq})} \tag{7}$$

Elasticities are relative to the absolute value of the variables and the choice probability of one given alternative. Therefore, the correct indication of an average elasticity requires sample enumeration: For all situations in the sample, an individual elasticity is calculated and later aggregated to an average elasticity.

7 Modeling and Results

7.1 Modeling approach

The modeling started by only employing the actual choice variables, namely costs of housing, cars and public transport, travel times and the type of residence location, which are coded as dummy variables.

The model was then extended by the inclusion of socio-demographic (e.g. income) and inertia (e.g. actual place of residence) variables. Thereby, the key objectives have been explanatory power, number of significant variables and the ability of the model to answer the key question, namely the willingness to accept higher mobility costs before changing the residential location.

Several dozen of different utility specifications were tested during the modeling process. Of all estimated modes the one presented in the next section fulfilled the above stated objectives best.

7.2 Utility function

The final model considers four key elements:

- Perception of car, public transport and housing costs
- Influence of income on cost perception
- Preference of residence area depending on today's place of residence
- Influence of travel time characteristics

According to economic theory, people with higher income should have a lower cost sensitivity. Therefore, the model includes non-linear interaction terms that describe the income-dependency of the cost perception. The general form of such interaction terms is given by:

$$f(y,x) = \beta_x * \left(\frac{y}{\bar{y}}\right)^{\lambda_{y,x}} * x, \qquad (8)$$

with:

x	observed variable, e.g. travel time, travel cost,
β_x	linear utility parameters of the observed variable x

y	observed value of the interacting variable, e.g. income, trip distance
$\overline{y}$	reference value of the variable y
$\lambda_{y,x}$	elasticity of the utility depending on the value of variable y

A negative value of the λ-parameter indicates that higher income leads to an alleviated cost sensitivity: Given an individual's income that is for example 50% higher than the average income, the fraction $\frac{Inc}{\overline{Inc}}$ equals 1.5. Given for example a λ-parameter of -2.0, the sensitivity term equals 0.44 meaning that individuals with an income 50% above average perceive the respective costs 66% less than the average. Similar modeling approaches were already successfully used in research practice as e.g. the examples of Mackie *et al.* (2003) and Hess *et al.* (2008) show. In addition, the cost perception term is interacted with the variable describing the percentage of mobility costs that is paid by a third party such as the employer.

As mentioned above, residence location choice is strongly influenced by the household's lifestyle. Instead segmenting households by lifestyle describing variables such socio-demographics (age, number of children, etc.) or attitudes, the suggested model includes the respondent's present residence location choice. To cover the inertia of residence location change, an interaction term describes for every type of present residence location the utility loss caused by moving from that residence location type to one of the three other types. This has the advantage of low data requirements when applying the model to scenario analysis: only the spatial distribution of household residence but no information on attitudes or other socio-demographic variables would be needed.

It is assumed that the indication of travel times for public transport is only of limited importance to captive car drivers and vice versa. Therefore, the terms covering the perception of travel times are interacted with variables describing modal usage within the choice alternatives.

The utility function of the suggested model takes the following form:

$$
\begin{aligned}
V_{i,j} =& C_i + \beta_{\text{HouseCost}} \left(\frac{\text{Inc}_j}{\overline{\text{Inc}}}\right)^{\lambda_{HouseInc}} \text{HouseCost}_i + \\
& \beta_{\text{PTCost}} \left(\frac{\text{Inc}_j}{\overline{\text{Inc}}}\right)^{\lambda_{PTInc}} \text{PTCost}_i * (1 - \text{PercentPTPaid}_j) + \\
& \beta_{\text{CarCost}} \left(\frac{\text{Inc}_j}{\overline{\text{Inc}}}\right)^{\lambda_{CarInc}} \text{CarCost}_i * (1 - \text{PercentCarPaid}_j) + \\
& \text{ActCityCentre}_j * (\beta_{\text{CityCentre\_Urban}} * D_{i,\text{Urban}} + \beta_{\text{CityCentre\_Agglo}} * D_{i,\text{Agglo}} + \beta_{\text{CityCentre\_Rural}} * D_{i,\text{Rural}}) + \\
& \text{ActUrban}_j * (\beta_{\text{Urban\_CityCentre}} * D_{i,\text{CityCentre}} + \beta_{\text{Urban\_Agglo}} * D_{i,\text{Agglo}} + \beta_{\text{Urban\_Rural}} * D_{i,\text{Rural}}) + \\
& \text{ActAgglo}_j * (\beta_{\text{Agglo\_CityCentre}} * D_{i,\text{CityCentre}} + \beta_{\text{Agglo\_Urban}} * D_{\text{i,Urban}} + \beta_{\text{Agglo\_Rural}} * D_{i,\text{Rural}}) + \\
& \text{Rural}_j * (\beta_{\text{Rural\_CityCentre}} * D_{i,\text{CityCentre}} + \beta_{\text{Rural\_Urban}} * D_{i,\text{Urban}} + \beta_{\text{Rural\_Agglo}} * D_{i,\text{Agglo}}) + \\
& \text{PercCarMil}_j * (\beta_{\text{TT\_CarJob}} * \text{TT\_CarJob}_i + \beta_{\text{TT\_CarShop}} * \text{TT\_CarShop}_i) + \\
& \text{PercPTMil}_j * (\beta_{\text{TT\_PTJob}} * \text{TT\_PTJob}_i + \beta_{\text{TT\_PTShop}} * \text{TT\_PTShop}_i) + \\
& \beta_{\text{MaxCommute}} * D_{\text{i,MaxCommute}}
\end{aligned}
\tag{9}
$$

with:

$V_{i,j}$	utility of alternative i for household j,
Inc	monthly income of household
$\overline{\text{Inc}}$	average monthly household income in the sample
HouseCost	monthly housing cost of alternative i
PTCost	monthly cost of public transport usage
PercentPTPaid	percentage of public transport paid by a third party (e.g. employer)
CarCost	monthly cost of car usage
PercentCarPaid	percentage of car cost paid by a third party (e.g. employer)
ActCityCentre	1, if the respondent's actual residence location is city centre, else 0,
ActUrban	1, if the respondent's actual residence location is urban area, else 0,
ActAgglo	1, if the respondent's actual residence location is agglomeration, else 0,
ActRural	1, if the respondent's actual residence location is rural area, else 0,
$D_{\text{CityCentre}}$	1, if the residence location in alternative i is city centre, else 0,
D_{Urban}	1, if the residence location in alternative i is urban area, else 0,
D_{Agglo}	1, if the residence location in alternative i is agglomeration, else 0,
D_{Rural}	1, if the residence location in alternative i is rural area, else 0,
$D_{\text{PercCarMil}}$	car share of the total indicated mileage in alternative i,
$D_{\text{PercPTMil}}$	public transport share of the total indicated mileage in alternative i,
TT_CarJob	travel time by car to the work place,
TT_PTJob	travel time by public transport to the work place,
TT_CarShop	travel time per car to the shopping center,
TT_PTShop	travel time per public transport to the shopping center,

$D_{\text{MaxCommute}}$ 1, if the travel time to work with the preferred mean of transport exceeds the acceptable travel time, else 0,

7.3 Results

The estimated parameters which fit the data best according to the specified utility function are summarized in table 4.

All cost parameters are negative and statistically significant indicating that costs have a negative influence on the utility and hence to choice probability of one alternative. Most negatively perceived are housing costs. Against it, public transport costs are around 30% and car costs even 50% lesser valued. In addition, all income sensitivity parameters are also negative and statistically significant. Hence, people with higher income perceive costs less. This relation is most prominent for the perception of public transport expenses followed by car and housing costs. For example, a household with an income of 9'000 CHF/month perceives public transport costs 60%, car costs 47% and housing costs 28% less than a household with an income of 6'000 CHF/month.

Concerning the residence location, the preferences are also clear: Nearly all inertia parameters are negative and highly significant showing a strong objection of changing the spatial type of residence location. Only the two parameters associated to a change of residence from the city centre to the surrounding urban area or to the agglomeration are not significant. The main reason for this, however, is arguably the small number of city centre based households in the sample (only 36 persons representing 203 or 8.5% of all evaluated choice situations). The strongest inertia is found for households actually living in the rural area, whereas the urban centre is most unfavored followed by urban area and agglomeration. Agglomeration households also dislike other types of residence location. However, the overall inertia is lower and the urban area is less undesirable than the city centre or the rural area. People actually living in the urban area are about as unlikely to move to the city centre or to the agglomeration while the rural are is the most disliked.

Table 4: MNL estimation results

Parameter	Value	Robust Std err	Robust t-test	
C_1	0.038	0.088	0.44	
C_2	0.00	fixed		
β_{CarCost}	-0.0015	0.00033	-4.45	**
$\beta_{\text{HouseCost}}$	-0.0035	0.00089	-3.97	**
β_{PTCost}	-0.0024	0.00093	-2.56	*
$\beta_{\text{TT\_CarJob}}$	-0.009	0.006	-1.33	
$\beta_{\text{TT\_PTJob}}$	0.024	0.008	2.83	**
$\beta_{\text{TT\_CarShop}}$	0.006	0.011	0.57	
$\beta_{\text{TT\_PTShop}}$	-0.003	0.013	-0.26	
$\beta_{\text{Agglo\_City}}$	-0.74	0.20	-3.76	**
$\beta_{\text{Agglo\_Urban}}$	-1.36	0.24	-5.75	**
$\beta_{\text{Agglo\_Rural}}$	-1.41	0.28	-5.08	**
$\beta_{\text{CityCentre\_Agglo}}$	-0.42	0.27	-1.54	
$\beta_{\text{CityCentre\_Urban}}$	0.28	0.31	0.90	
$\beta_{\text{CityCentre\_Rural}}$	-1.09	0.41	-2.65	**
$\beta_{\text{Urban\_Agglo}}$	-1.13	0.24	-4.64	**
$\beta_{\text{Urban\_CityCentre}}$	-0.97	0.19	-5.22	**
$\beta_{\text{Urban\_Rural}}$	-4.12	0.66	-6.24	**
$\beta_{\text{Rural\_Agglo}}$	-1.29	0.28	-4.61	**
$\beta_{\text{Rural\_City}}$	-2.47	0.29	-8.65	**
$\beta_{\text{Rural\_CityCentre}}$	-3.28	0.28	-11.77	**
$\beta_{\text{MaxCommute}}$	-0.38	0.16	-2.38	*
λ_{CarInc}	-1.53	0.18	-8.52	**
$\lambda_{HouseInc}$	-0.81	0.24	-3.34	**
λ_{PTInc}	-2.20	0.31	-7.00	**

** significant at the 0.01 level

* significant at the 0.05 level

$Adj.\rho^2$=0.3

In similar experiments, travel time parameters regularly turned out to influence the choice behavior (e.g. Vrtic *et al.* (2007), Beckmann *et al.* (2002)). The respective parameters in the present model, however, are not significant or have, like in the case of travel time to shopping by car, a counterintuitive sign. It is argued that this is partly due to correlation issues: Although the experiment design included several travel time levels for each residence location type, there is still substantial correlation between the variables describing travel time and residence location. In models estimated for test purposes that excluded residence location variables, the travel times parameters were all significant with the expected negative sign. This finding leads to the assumption that the respondent payed more attention to the indicated place of residence than the travel times. This research highlights the trade-off between place of residence and mobility costs. Therefore, models including the inertia of residence location are favored. For future studies, however, it is recommended to improve the experiment design by considering more extensive decoupling of travel times and residence location and/or more choice situation with both alternatives of the same residence location type.

Although suggested by earlier research (e.g. Walker and Li (2007)) no influence of the presence and number of kids in the household or the average age influence the propensity of changing the residence location. All respective parameters proved to be non-significant regardless whether discrete (with dummy variables) or continuous formulations were employed.

7.4 Value of staying at present residence location

The indication of the willingness to pay for staying at the present residence location is straightforward and given by the ratio of the parameter value of the aversion of changing the residence and the parameter value of cost perception. Given the model formulation, this value is dependent on the current and expected place of residence and the income.

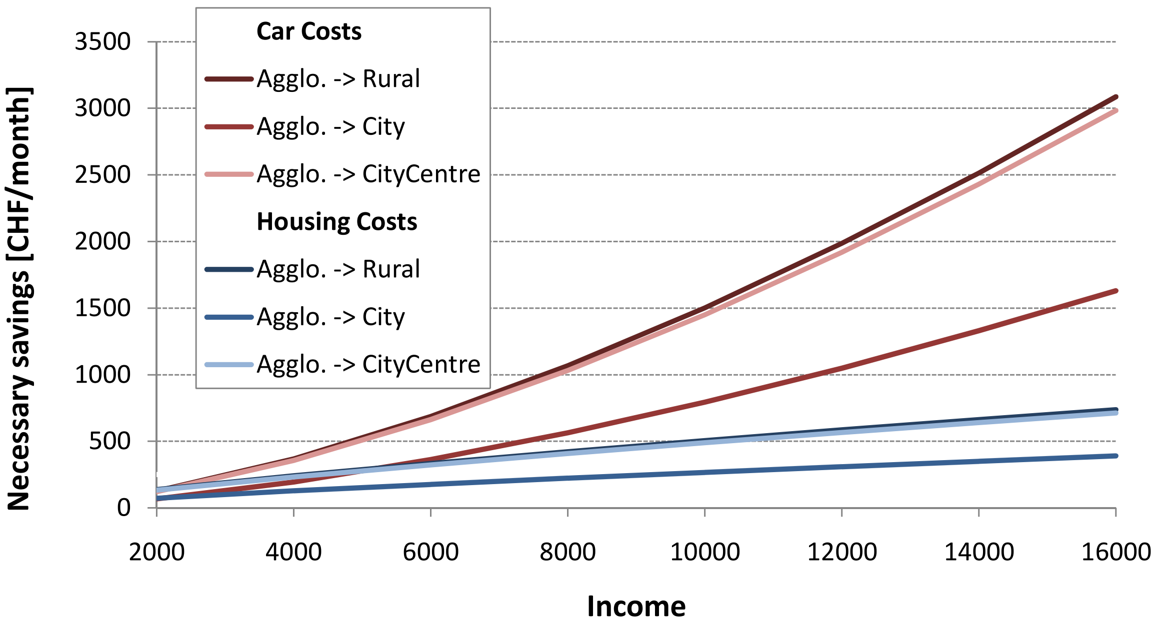
$$WTP_{R_1,R_2,C_{Type,Inc}} = \frac{\beta_{R_1,R_2}}{\beta_{C_{Type,Inc}} \left(\frac{\text{Inc}_j}{\overline{\text{Inc}}}\right)^{\lambda_{Type,Inc}}}, \tag{10}$$

with:

$WTP_{R_1,R_2,C_{Type,Inc}}$	the willingness to pay to stay at residence location type 1 against moving to residence location type 2,
β_{R_1,R_2}	parameter of the aversion to move to residence location type 2 when living currently at type 1,
$\beta_{C_{Type,Inc}}$	parameter of cost perception depending on the type of the costs and the income.
$\left(\frac{\text{Inc}_j}{\overline{\text{Inc}}}\right)^{\lambda_{Type,Inc}}$	influence of the income on the cost perception

In figure 1, the willingness to pay for staying in the agglomeration against increases of rent and car costs depending on the income is plotted. According to the model formulation, higher income and β_{R_1,R_2}-parameters cause also higher WTP figures. Lower β_{cost}-parameters, in contrast lead to lower WTP figures. Similar plots are also feasible for other present residence locations and also public transport costs.

Figure 1: WTP to stay in the aggglomeration



Given for example a household residing currently in the agglomeration with an monthly income of 10’000 CHF, an alternative apartment (in terms of space and comfort comparable) in the urban area must cost about 267 CHF/month less that it would be equally attractive. Alternatively, if the households expects to save 793 CHF/month of car costs when living in the urban area, both places would be equally attractive.

7.5 Elasticity

Based on the model results, costs and residence location elasticities are calculated and presented in table 5. As based on a scalar variable, the cost elasticity is calculated as a point elasticity according to equation 6. The elasticity of the residence location inertia is calculated as an arc elasticity (see equation 7 due to the nominal nature of the dummy coding. This arc elasticity figure has to be interpreted as the average increase of one alternative’s choice probability if the residence location of that alternative is consistent with the present residence location.

Table 5: Residence location choice elasticity

Variable	Elasticity
Costs: Point elasticity	
Car costs	-0.46
Pt costs	-0.13
Housing costs	-2.22
Inertia: Arc elasticity (stay at present residence location)	
City centre	0.12*
Urban area	0.39
Agglomeration	0.25
Rural area	0.46

*only the inertia of moving to the rural area is considered)

Interestingly, the elasticity of the car costs is higher than the elasticity of the public transport costs despite the values of the respective parameters: In average, car costs (e.g. 500 CHF/-month) are much higher than public transport costs (e.g. 50 CHF/month). Therefore, the impact of a relative change (e.g. 10% -> 50 CHF car costs, 5 CHF public transport costs) is higher for car costs.

The highest residential location inertia is found for individuals living in the rural area, followed by the urban area and the agglomeration. The elasticity of the inertia to stay in the city centre considers only the averseness of moving to the rural area since only this parameter is significant.

8 Conclusion

In this paper we presented how mobility and housing costs influence residential location choice behavior. People react most on housing costs while car and public transport costs are less negatively perceived. However, the averseness to leave the present residence location is substantial: Depending on the actual and the potential residence location type, the willingness to pay before moving to a more central place that causes less car costs ranges lies, assuming an average income household, between 463 CHF/month in the case of a residential location change from the agglomeration to the urban area and 2040 CHF/month in the case of rural area to city centre.

Overall, the approach of generating choice situations based on the prior stated adaption mobility tool choice experiment turned out to be successful. Based on the presented model formulation all key objectives, namely to state the averseness of changing the residence location type and the valuation of housing and mobility costs, could have been fulfilled. The only drawback is that the estimation of significant travel time parameters failed, due to correlation issues. In addition, it has to be recognized that a meaningful inclusion of variables describing the mobility tools composition was not possible since people tended to stick to their fleet of mobility tools even when considering to live in areas of different spatial type.

In future research, both issues could be addressed with simple measures: The consideration of a broader range of travel times might permit the estimation of statistically significant parameters. The collection of a larger sample might generate enough variance of mobility tools ownership but would also involve higher survey costs..

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