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DECISION MODELLING ON HOUSEHOLD LEVEL FOR ENERGY, FLEET CHOICE AND EXPENDITURE

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Abstract

This thesis analyses decision modelling and behaviour on a household level regarding energy consumption in housing and transportation, fleet choice in the case of high fuel prices and household expenditures. For this research three different data sets were used: A) A data set about total energy consumption from a survey including Stated Preference experiments about long term investment decisions in energy saving technology and a Priority Evaluator experiment about total energy consumption ,conducted among home-owners in the canton of Zurich. B) A data set about fleet choice from a survey including Stated Preference experiments for high fuel prices, conducted among car owners in Switzerland. C) The Swiss National Income and Expenditure Survey reporting all incomes and expenditures for a representative sample of Swiss households for the duration of one month. This data set covers the years between 2001 and 2008.

The methodologies used were, next to standard descriptive statistics, Multinomial Logit Models (MNL) to model long term investment decisions, Multiple Discrete-Continuous Extreme Value model (MDCEV) to model total energy consumption and fleet choice and linear last square regressions to model household expenditure categories.

In addition to the modelling, the results from the MDCEV models were analysed regarding residuals and accuracy of model implementation.

Results of the analyses showed that total energy consumption was very difficult to model and produced unreliable results. Long term investments in energy saving technology as well as the change to cleaner, less fuel consuming cars, are preferred over a change in energy consuming behaviour when fuel prices are substantially higher.

Linear regression models showed that household budget expenditures are very individual and reveal very few interdependencies. The categories which are most predictable are savings and food while the least predictable are public transportation and housing rent and mortgage interest payments.

Zusammenfassung

In dieser Dissertation wird das Entscheidungsverhalten von Haushalten analysiert. Dabei werden Entscheidungen auf Haushaltsebene in Bezug auf Energieverbrauch in den Bereichen Wohnen und Verkehr, die Flottenwahl bei hohen Treibstoffpreisen und Haushaltsausgaben analysiert und modelliert. Für diese Dissertation wurden verschiedene Datensätze untersucht: A) Ein Datensatz über den Energieverbrauch von Hausbesitzern im Kanton Zürich, gewonnen aus einer Befragung mit Stated Prefernce Experimenten über Investitionen in energiesparende Infrastruktur und einem Priority Evaluator Experiment über Gesamtenergieverbrauch. B) Ein Datensatz bestehend aus Stated Preference Experimenten, in welchen Autobesitzer über die Flottenwahl im Fall hoher Treibstoffpreise befragt wurden. C) Daten der Haushalts Budget Erhebung (HABE) des Bundesamtes für Statistik, in welcher alle Einkünfte und Ausgaben einer repräsentativen Stichprobe von Schweizer Haushalten erhoben wurden. Der Datensatz umfasst die Jahre 2001 bis 2008.

Die Methoden welche bei der Analyse benutzt wurden sind, neben herkömmlicher beschreibender Statistik, A) Multinomiale Logit Modelle (MNL) um langfristige Investitionen von Haushalten in energiesparende Technologien zu modellieren, B) Multiple Discrete-Continuous Extreme Value (MDCEV) Modelle um den Gesamtenergieverbrauch von Haushalten und die Flottenwahl zu modellieren, C) Lineare Regressionen mit der Methode der kleinsten Quadrate für die Modelle zu den Haushaltsausgaben.

Zusätzlich zu den Modellen wurden MDCEV Modelle simuliert und die Residuen analysiert um die Genauigkeit der Modellimplementationen zu beurteilen.

Die Resultate zeigen, dass der Gesamtenergieverbrauch sehr schwer zu modellieren ist und instabile Resultate hervorbringt. Langfristige Investitionen in energiesparende Heizsysteme und Rennovationen sowie ein Wechsel auf effizientere Autos werden Verhaltensänderungen bevorzugt. Die linearen Regressionen zu den Haushaltsausgaben zeigen, dass die Budgets sehr individuell sind und wenige Wechselwirkungen zwischen den verschiedenen Ausgabekategorien bestehen. Die am besten vorhersagbaren

Kategorien sind Sparen und Nahrungsmittel, während die am schwersten vorauszusagenden Ausgaben diejenigen für öffentlichen Verkehr und Wohnen sind.

Acknowledgments

In 2009, after two years of designing bridges and tunnels made of reinforced concrete, I was given the opportunity to switch from practice into academia and from structural engineering to transportation planning. I would like to thank Prof. Kay W. Axhausen for making it possible by offering me a position as a research assistant at IVT and for giving me time, space, ideas and feedback to pursue my research. I learned a lot from him and he always supported me, no matter which country or continent I was living on.

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Chapter 1

Introduction

1.1 Background and Motivation

As more complex transportation models are developed in various places around the world, and the range of topics of interest is widening among public and private decision makers in the transportation world, more research areas are opened up.

Firstly, limits to global resources and ecological challenges, like climate change, raise interest, not only in the development, but also in the distribution and promotion of cleaner and resource friendlier technologies. Practitioners and politicians in urban and transport planning all over the world are working to lower the environmental impact through the promotion of slow modes, such as cycling and walking, the strengthening of efficient public transport modes, and the anticipation and adaptation of cleaner motorized vehicles like natural gas, hybrid or electric cars.

Secondly, the shape and size of overall travel demand in industrialized countries is changing as a result of different working patterns (flexible workspace, home office), new communication devices, changing social networks and needs, as well as increasing demand for leisure and recreational activities. According to the Swiss Travel Microcensus of 2010 (Swiss Federal Statistical Office (BFS), 2012), leisure was the largest share of trips with 47.3 % of average travel time, compared to 18.5 % for work.

Thirdly, the new generation of transportation models are often activity based multi agent simulations, such as MATSim (Multi Agent Transport Simulation), an open source tool that is currently being developed at the Institute of Transport Planing and Systems (IVT) at ETH Zürich and at Technical University Berlin (MATSim, 2014). These agent based transport simulations assume an activity plan for every simulated agent, which are typically derived from travel diaries, from census data or from travel surveys. To apply these models for the purpose of forecasting, transportation patterns in the distant future, travel demand and activity chains must be modelled.

All of the above mentioned reasons show the need of understanding and modelling a person's decision whether (travel demand generation), where (destination choice) and how (mode choice) to make a trip. Understanding the motivations behind people's decisions allows the planner to model aspects of transportation like energy demand, fleet composition, travel demand, changes in destination patterns and so on, for the long term.

While undoubtedly many of these decisions depend on personal preferences, they are very often made not by a single individual, but by the whole household. Many transport modes, like season tickets or private cars offer synergies and mutual benefits within a household. The decision about the location of residence is generally taken by the household as a whole and has a major impact on travel demand and mode choice. And last but not least, financial matters are very often household decisions, sometimes implicitly in the case of room-mates helping each others out, sometimes legally mandated as in the case of marriage.

This thesis investigates the decision making process on the household level, regarding energy consumption, trip generation, mode choice and expenditure allocation.

1.2 Research Areas

The research of decisions on household level was conducted on different topics. In a first study, we looked at total household energy consumption of home-owners and their decision whether to reduce energy consumption in housing or in transportation.

This study investigates trade-off patterns and interdependencies between energy consumption in housing and in transportation, using Multinomial Logit models (MNL) and Multiple Discrete-Continuous Extreme Value models (MDCEV).

A second study analysed household decisions on how to react to a very substantial surge in fuel prices, by looking at travel distance elasticities and the effects on fleet choice, again using MDCEV models.

The MDCEV methodology used in the previously mentioned studies and in others as well was analysed regarding goodness of fit by an examination of the model's residuals.

A forth research area discussed in the thesis is how household expenditure categories can be modelled and whether, and to what extent, interdependencies exist among expenditure categories, with a special focus on expenditure on private and public transportation.

1.3 Thesis Structure

The structure of the thesis is as follows: In chapter two, the different data sets used for modelling are introduced and described. There, a special focus is laid on the survey conducted among homeowners in the canton of Zürich, which concluded a set of questions describing the household, a Stated Preference experiment on long term investments to save energy and an interactive, on-line implementation of a Priority Evaluator style experiment (Hoinville, 1977) capturing the measures a household would take, if it were forced to reduce its energy consumption.

In the third chapter, a long term investment decision MNL-model for home-owners is estimated to investigate decisions of how households that own their own home as well as at least one car would invest in energy saving technology in the case of high energy prices.

The forth chapter describes the results of the MDCEV model, using the data from the Priority Evaluator that estimates parameters influencing a households decision on what measures to use to lower energy consumption and how much energy to save with the chosen measure, if forced to do so in the short term.

The fifth chapter contains a MDCEV model about household fleet choice in the case of very high fuel prices, showing how energy prices influence the amount of annual miles travelled and the willingness, or need, to change car or engine type.

The sixth chapter is an analysis of residuals of the MDCEV models applied in chapters four and five as well as in other studies. It analyses the accuracy of the predictions of the model when simulated, and how size and distribution of residuals are influenced.

Chapter seven presents a set of linear regression models for different household expenditure categories. The regressions were estimated using both the original households , as well as a pseudo panel. The pseudo panel was constructed by aggregating all households of the same type for every month between 2001 and 2008.

Chapter eight then offers a discussion on the general importance of the presented work, as well as insights found regarding decision modelling on the household level, data used and methodologies.

Chapter 2

Data Sets

This chapter contains a description and analysis of the data sets used in this thesis. The first section is about the data, that was gathered as part of this thesis, with a survey about energy consumption and trade-offs between energy in housing and transportation. As survey design and data collection were part of this work and because it introduces a rarely used survey tool called the Priority Evaluator, this data set is described in more detail.

The second data set was collected as part of a study for the Swiss Federal Office for the Environment about fuel price elasticities in car fleet and residential location choice (Erath and Axhausen, 2010). The data was collected using a survey including socio-economic information and a 3-staged Stated Preference experiment. The parts of survey and data set relevant to the model presented in chapter 5, are described here.

The third data set presented in this chapter is part of the Swiss Income and Expenditure Survey for the years 2001 to 2008 (Swiss Federal Statistical Office (BFS), 2008). The data is the base for the models of expenditure interdependencies presented in chapter 7. Section 2.3 of this chapter gives an introduction and a descriptive analysis of this data set.

2.1 Total Household Energy Consumption Data Set

The content of this section was first published in Jäggi and Axhausen (2010).

2.1.1 Introduction

In Switzerland the two main sectors of private energy consumption are housing and transport. According to the "Gesamtenergiestatistik" (Swiss Federal Office of Energy (SFOE), 2009), transportation and household use 34.5% and 28%, respectively, of the energy consumed. The biggest potential household energy savings lie in these two sectors, in contrast to "grey energy" in nutrition and consumer goods, which cannot really be influenced by households.

This data set was created specifically to find out how home-owners would behave if they were forced (legally or financially) to reduce energy consumption and how they would trade-off between the two major consuming sectors, housing and transport.

Exploring these questions, two different data collection approaches applied; the two alternatives are: first, multivariate open choice experiments - such as stated preference experiments - consisting of several alternatives with different financial incentives and second, constraint choice experiments in the form of a Priority Evaluator in which a budget of carbon output has to be met and behaviour adjusted. The survey investigating these questions uses a sample of 500 home-owners, (owner-occupier), from the canton of Zurich, out of a total canton population of 100.000 (Statistical Office of the Canton Zurich, 2010). All home-owners participating in the study must own at least one car, so that the differences in energy use per sector can be determined. The information gathered in the survey will be used to estimate long-term energy efficiency investment decisions made by home- and car-owners.

2.1.2 Data Collection Methodologies

2.1.2.1 Stated Preference

To design the second part of the study, a stated preference methodology is used. Instead of collecting real data, the respondents are asked hypothetical questions. This is necessary if the information needed is about choices that have not been made yet, but are expected to happen in the future and therefore interesting for research. Other reasons to use this method, and a good description, are given by Louviere et al. (2000) and Train (2003). The respondents are asked to imagine a hypothetical (market-) situation and then to choose from a set of alternatives, called the choice set. The alternatives are designed in advance and defined by several specifically chosen variables. By selecting from alternatives, the respondent reveals his intentions and preferences. One major advantage of this method: if information on specific variables is needed, they can be built into the experiments' design in a statistically appropriate and efficient way.

2.1.2.2 Priority Evaluator

The principle of the Priority Evaluator method is to let the respondents make trade-offs within a restricted budget in a controlled test environment. The action that we try to reproduce is similar to putting together a grocery basket using a given budget. The respondents have to make decisions about what attributes (e.g. products) they want and what part of the budget they want to use for it.

Hoinville (1977) gives a complete and detailed description of the Priority Evaluator approach. He conducted several studies in the UK to test the method and its variations. In a survey about location choice, people were asked to make the trade off between indoor space, outdoor space and location of their house. In another survey, respondents had to "purchase" characteristics of a commuting journey, such as: crowds, waiting time, reliability, walking time, interchanges and seating for either an underground, train or bus journey. In these surveys, respondents first assess their existing situation by giving points to the different attributes. The total amount of points given then provides the budget. In a second step, points then can be reallocated within the budget. He also mentioned the possibility of increasing the points budget by trading it off against financial sacrifice: e.g., accepting a higher rent than that reported by the respondents. Another example was given by Permain (1989) who used the Priority Evaluator to explore preferences of the British railway passenger for railway station features by letting respondents design railway stations within a budget constraint. Every variable had three to five categories and every one had a price. Hoinville (1977) stated that the best pricing scheme methodology is to use abstract points, so that there is no confusion with possible monetary attributes (e.g. ticket fares in travel surveys) or individual income situations.

In our case, the principle of the Priority Evaluator presented by Hoinville (1977) is inverted. Instead of using a continuous budget to buy positive attributes, the respondents must fill a given budget by picking negative attributes. In our study, the budget to fill is the reduction in CO_2 output and the negative attributes are different energy efficiency measures. In early experiments, the variables were mainly one-dimensional and simple (e.g. apartment size-, categorized as small, middle, big, very big; ticket fare: c 10, 15, 20, 25). In this survey, the attributes are two- or three-dimensional: the first dimension is the change in lifestyle or refurbishment, indicated by attribute name (e.g. replace car with a more efficient one). The second dimension is an associated price, always a lump sum, in Swiss francs (CHF) showing respondents the attributes' financial effect. The third dimension consists of associated running costs (or savings) in CHF / year for the same purposes. Note that not all attributes have both kinds of prices. These costs represent actual and realistic costs and do not have to be optimized within the rigorous, closed and predefined budget of the Priority Evaluator (in our case, the reduction of CO_2 output). However, the respondents must still consider costs to remain within their individual actual monetary household budgets. In this survey, we also collect information about the household income level so that we can analyze both aspects of the trade-off (lifestyle and monetary aspects) within the closed frame of the CO_2 output reduction budget. Previous studies did not use statistical models to examine priority evaluator data, but only used descriptive statistics to identify preferences.

2.1.3 Survey Protocol

The survey is divided into three parts: first, general questions about household members, cars, house, financial situation and attitude are asked. Second, the participants are confronted with nine hypothetical scenarios of gasoline and heating oil prices, each with four alternatives to reduce energy expenses. Third, the participants are asked to reduce their carbon output to a pre-set level by choosing among given options.

2.1.3.1 Sample Size

To get a heterogeneous sample, participants are recruited among people living in the 112,644 single-family homes of the canton of Zurich. A canton is an administrative district similar to a state (US), or Bundesland (Germany). As a base for participant recruitment, a list of 5.000 addresses for people living in a single-family home was acquired. The addresses have been randomly drawn; by going through the list from the top down, we obtain a random sample.

2.1.3.2 Participants

The participants of the study must own the house they live in, as well as at least one car. They must be able to make decisions about the refurbishment of the house or the replacement of the heating system. It is important to exclude people who do not have to bear the costs of potential renovations to prevent bias. Also excluded are home-owners already using a heat pump as a heating system, because one of the major issues of the study is the willingness to pay for, and the acceptance of, heat pumps.

2.1.3.3 Protocol

In the first step, an announcement letter was sent to people from the list with a very short introduction to the survey topic and an announcement that the survey team would call during the next few days to ask questions about current energy consumption of the house and car. This letter ensures that most people do not get called unexpectedly and have, in the form of the letter, a formal document with the ETH logo; people being called then usually know that the caller is from a widely known and respected institution. They also can prepare their consumption data to make the recruitment process more efficient.

2.1.3.4 Recruitment

In the second step, an interviewer calls the numbers on the list. If we cannot reach the person after five tries on different days, the address is marked as 'not reached'. Calling time is between 5 and 8 pm, allowing access to working/commuting people as well as residents usually at home all day. People reached by phone are asked the following questions:

1. 'Are you interested in participating in the study?'
2. 'Do you own the house you live in?'
3. 'Do you own a car?'
4. 'Is your house equipped with a heat pump?'

The people answering the first three questions with 'yes' and the last with 'no' count as participants, and are then asked to give the following data on energy consumption: heating system, annual oil, gas or power demand of the heating system, specific consumption of the main car, annual kilometres travelled and age of the participants.

2.1.3.5 Questionnaire

In the third step, the questionnaire is prepared and sent to the participants. The first part of the questionnaire covers general questions asked all the participants the same way: i.e. on socio-economic issues, car information, house details and inquiries about position on environmental friendliness. The second part consists of nine different Stated-Preference scenarios, personalized so that the energy consumption level corresponds to the information given on the phone. The questionnaires are sent within one week of the call. An instruction letter, a reply-paid envelope and

CHF 20 (motivation incentive) are sent together with the questionnaire. Participants under the age of 50 are given a CHF 40 incentive to increase response rate among younger people. A pre-test we made showed that the sample lacked younger participants (compared to the population statistics from the Swiss Federal Statistics Office) (Swiss Federal Statistical Office (BFS), 2010). Please note that the monetary incentive was not mentioned in either the announcement letter or in the recruitment call.

2.1.3.6 Priority Evaluator

The next step in the process uses the Priority Evaluator experiment as an Internet application. At the end of the questionnaire, it is mentioned that the last part of the study is on the Internet, and that the participants will be sent a letter with the Internet-address. After the questionnaire is returned, it is analysed, and the Internet tool for the Priority Evaluator is prepared. Participants who did not fill in the SP completely, or always chose the same answer (non-traders), as well as participants who specified that they do not have an Internet access, are excluded from this part of the study. For every participant, an account is created with a separate password. Because the Priority Evaluator design depends on information given in the questionnaire, the account is personalized within three workdays after questionnaire arrival. A detailed description of the design is given in the Survey Design chapter. When the account is set up, we send a letter with the Internet-address and password to participants, asking them to fill in the last part of the survey. The reason not to use email for the second contact is because we expect a higher response rate to the more formal contact and because it would be an additional expenditure to collect and store email addresses. If participants did not fill in the Priority Evaluator within three to four weeks, we sent a reminder letter to increase the response rate.

2.1.3.7 Comments on the Protocol

The reason for the pre-recruitment by phone, apart from increasing an efficient use of the monetary incentive, is our need for information on energy consumption in advance to personalize the SP section. Personalization is important because the participants differ enormously in terms of their house size, energy demand and kilometres travelled. Normal annual demand for heating oil is between 1.000 litres and 4.000 litres, while the range of kilometres travelled per year goes from 7.000 (for a typical pensioner) up to 60.000 (car also used for home and private business). Non-individualized, a-priori fixed scenarios would have been very unrealistic for most of the participants.

We used traditional mail for the questionnaire in addition to the Internet tool because a questionnaire using paper and pen is more formal, commands more respect and should elicit a better response rate. We also try to avoid adding to the increasing amount of 'spam' an email account receives. We also assumed that home-owners are often between 50 and 80 years old and therefore less used to electronic communication than younger people.

Participants reported needing between 60 and 90 minutes to complete the paper and pen questionnaire. We have no feedback on how long people needed for the PE section. We assume that participants need between 10 and 30 minutes for the PE, depending on the complexity of the household (e.g. number of cars, etc.)

2.1.4 Survey Design

2.1.4.1 Stated Preference

The survey attempts to determine whether energy used for cars has a different perceived value than energy used for housing. The key is allowing participants to select among investments with different cost-benefit ratios under different labels. The costs of investments are lump sums, the benefits the expected annual savings. Therefore, the cost-benefit ratio corresponds to an expected payback time without interest for the investment. For this purpose the participants are confronted with their energy expenses and are asked which alternative they would choose to reduce costs. Every participant is given nine scenarios with variable energy prices, each with 5 alternative (described below). An example of the SP experiment is shown in figure 2.1. Table 2.1 lists the variables used for personalizing the experiments. We obtained the values of these variables at the recruiting phone calls, except for the CO_2 output which is calculated from fuel consumption.

All variables used in the SP Design including the levels are presented in table 7.37. Energy expenses presented are based on two variables: price of heating fuel and price of gasoline. Heating fuel is either: oil [liters], gas [kWh], or power [kWh]. Gasoline price is composed of heating fuel price plus a variable tax, to ensure that gasoline is always more expensive than heating fuel, preventing scenarios with unrealistic relative values. Nevertheless, perfect correlation between these two fuels can be avoided. Each scenario is based on a different composition of energy prices giving heating and variable mobility costs, which include expenses for gasoline, tire, service, reparations, exhaust control and depreciation, but exclude

Table 2.1: Input data from the participants

Variable	Name	Unit
D_{Oil}	Oil consumption	liter / year
D_{Gas}	Natural gas consumption for heating	kWh / year
D_{El}	Eletricity consumption for heating	kWh / year
con	Car efficiency (consumption)	liter / 100 kilometer
vmt	vehicle miles travelled	kilometer / year
CO2	CO_2 output	t CO_2 / year

Table 2.2: Variables of the stated preference scenarios

Variable	Name	Levels	Unit
P_{Oil}	Oil price	1 / 2.5 / 4	CHF / liter
P_{Gas}	Gas price	0.08 / 0.2 / 0.32	CHF / kWh
P_{El}	Electricity price	0.08 / 0.2 / 0.32	CHF / kWh
T_G	Gasoline tax	0.5 / 1 / 1.5	CHF / liter
C_{Heat}	Heating costs	$\sum D_i \cdot P_i$	CHF / year
C_{Car}	Variable mobility costs	$(P_{Oil} + T_G \cdot \text{con} \cdot \text{vmt}) + 2.500$	CHF / year
I_{House}	Investment house	40 / 60 / 80	10^3 CHF
I_{HP}	Investment heat pump	20 / 40 / 60	10^3 CHF
I_{Car}	Investment car	5 / 10 / 15	10^3 CHF
vmt_{CS}	mileage of Car Sharing’	$[0.2 / 0.3 / 0.4] \cdot \text{vmt}$	km / year
S_{Insu}	Financial savings for ’Insulation’	$[0.7 / 0.5 / 0.3] \cdot C_{Heat}$	CHF / year
S_{HP}	Financial savings for ’Heat Pump’	$[0.7 / 0.5 / 0.3] \cdot C_{Heat}$	CHF / year
S_{NC}	Financial savings for ’New Car’	$[0.6 / 0.4 / 0.2] \cdot C_{Car}$	CHF / year
S_{CS}	Financial savings for ’Car Sharing’	$[0.9 / 0.7 / 0.5] \cdot C_{Car}$	CHF / year
$CO2_i$	Reduction in CO_2-output	$S_i / C_i \cdot CO2$	t CO_2 / year

fixed costs. To reduce either heating costs or variable mobility costs, participants are presented with 4 alternatives.

The choice set alternatives follow:

1. Insulation: Insulate the house.
2. Heat pump: Install a heat pump.
3. New Car: Buy a more efficient car to replace the current one.

Figure 2.1: Stated preference scenarios

Scenario 1

Measure	No Change	Insulation of House	Installing a Heat Pump	Buy new, more efficient car	Sell Car PT & Car Sharing
Investment Costs CHF	0	20'000	30'000	10'000	Gains from Selling Car
	Gasoline Price: CHF 5.5 / Liter => Variable Mobility Costs [1]: CHF 6'800 / Year				
Savings in Mobility Costs CHF/Jahr	0	0	0	4'100	4'800
Kilometers driven km / Year	12'000	12'000	12'000	12'000	4'800
	Heating Oil Price: CHF 400 / 100 Liter: => Heating Costs: CHF 8'800 / Year				
Savings in Heating Costs CHF/Year	0	4'400	4'400	0	0
CO_2 Savings tons CO_2/Year	0	2.9	2.9	1.1	1.3
Your Choice→	☐	☐	☐	☐	☐

[1] Variable Mobility Costs = depreciation, fuel, tires, service, emission control, reparations

4. Car Sharing: Sell the car and use public transportation and car sharing instead.

The fifth alternative is a decision not to improve energy efficiency. Two of the four measures concern energy consumption of the house, the other two private transport.

Insulation This alternative would mean a minor or major house refurbishment, depending on investment costs suggested. In the SP, it is not specified what degree of renovation is meant. But annual savings due to the reduced energy consumption of the house are indicated. The savings for the car are zero and annual kilometres driven remain unchanged.

Heat Pump This alternative would mean replacing the current heating system with a heat pump. Investment sums are smaller than for the insulation, but annual savings are in the same range. Savings in mobility costs are zero and annual kilometres driven remain unchanged.

More Eefficient Car This alternative would entail replacing the current car with a new, more efficient model. No technology is specified (e.g. hybrid, electric, small conventional). Investment is smaller than for the house improvements and savings in variable mobility costs depend on annual kilometres driven. Savings in heating costs are zero and the annual kilometres driven remain unchanged.

Car Sharing and Public Transport This alternative involves selling the car and reducing annual kilometres driven. Public transport would be the primary means of mobility and the remaining annual kilometres of private transport would be travelled via car sharing. Savings in variable mobility costs are larger than in the alternative 'more efficient car'. No investment is needed for this alternative, but the respondent would receive the money from the sale of the car.

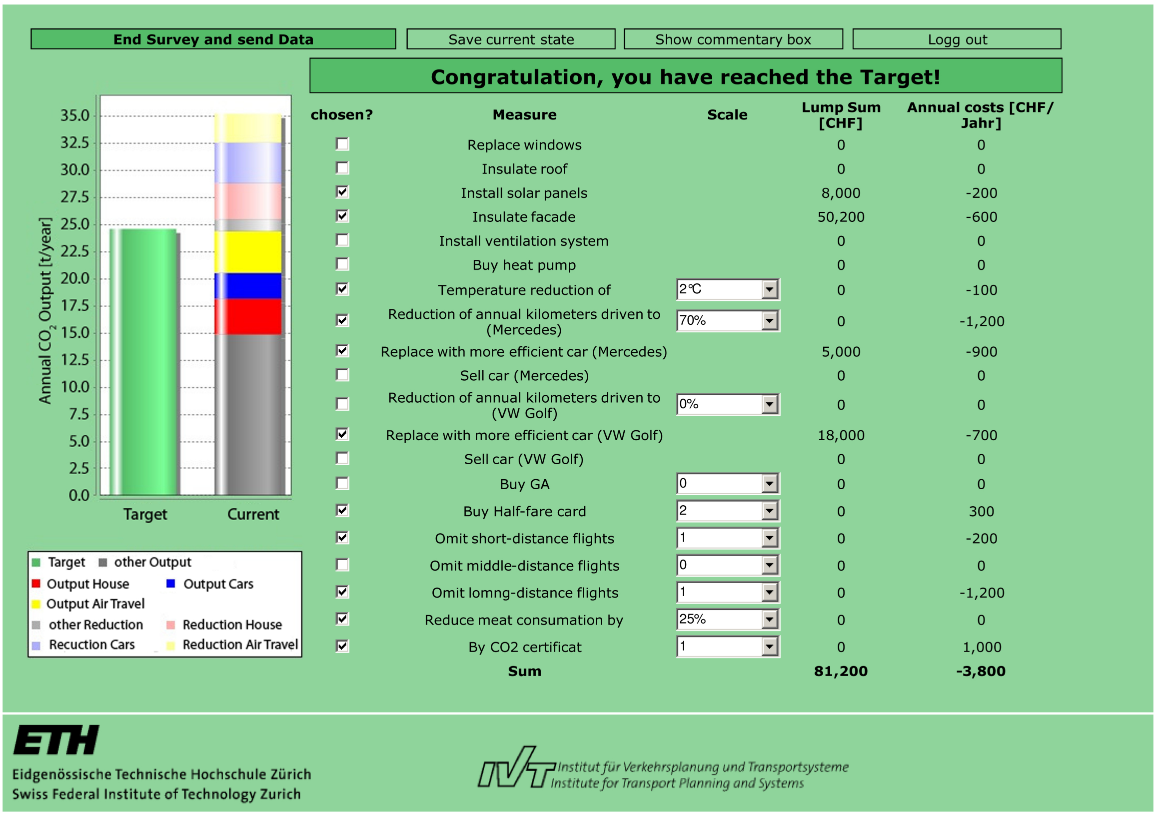
2.1.4.2 Priority Evaluator

In contrast to the Stated Preference part of the survey, where respondents are given the option of making no investment, the Priority Evaluator section forces them to reduce their energy consumption; but they have a wider and more differentiated list of options to choose from. The level of energy consumption in the Priority Evaluator is presented as CO_2 output on a household basis. We are aware of the fact that CO_2 output and energy consumption are not exactly the same, particularly in Switzerland, where electricity is almost CO_2 free (Gantner et al., 2001). CO_2 output was chosen because we assumed that it is better known and easier for respondents to understand than the rather abstract figure of overall energy consumption. We also assumed that a tax or a restriction on CO_2 output is more likely to happen than a restriction on overall energy use and is, therefore easier to imagine. However, for the purpose of the survey, CO_2-free electricity production was ignored and the CO_2 output was computed with the simple assumption: 1 litre of oil is equivalent to 10 kWh of gas or 10 kWh of electricity, which is then equivalent to 2.65 kg of CO_2. In the current situation, any substantial increase in power supply in Switzerland (due to heat pumps) probably would not be CO_2 free any more.

On the left side, two bars indicate the CO_2 output. The right bar shows the current CO_2 output of the household divided in four sectors:

1. Grey energy (grey) is the energy embedded in consumer goods and other indirectly influenced sectors. This is assumed to be the average Swiss CO_2 output of 4.5 tons of CO_2 / year per person.

Figure 2.2: Priority Evaluator tool



2. Heating energy (red) corresponds to energy used for heating.
3. Private Transport (blue) is energy for cars and motorbikes dependent on specific consumption and the annual kilometers driven, for all vehicles in the household.
4. Air trips (yellow) are a rough estimate of air travel CO_2 output.

In the first part of the survey, respondents declare how many trips they made over the last 3 years. The trips are divided into short (<1000 km), middle (<5000 km) and long (>5000 km) distances, which are assumed to be equivalent to 0.5, 1 and 2 t CO_2 / a, respectively. The left bar indicates the reduction target consisting of the non-changeable (grey) and 50 percent of the changeable CO_2 output.

On the right side, options for reductions are listed with a column for investment (lump) sum and related savings (or costs). This list contains only options reasonable for the respondent. For example, if one respondent states in the questionnaire that he already replaced his windows after 1995, this option will not be available because it is assumed to be unrealistic.

Table 2.3: Variables of the Priority Evaluator

Option	CO_2 reduction	Price (lump sum)	Annual costs[3]
		[CHF 10^3]	[CHF / year]
Refurbishment of roof	21%[1]	15 / t CO_2	-300 / t CO_2
Refurbishment of facades	30%[1]	25 / t CO_2	-300 / t CO_2
Replacement of windows	15%[1]	12 / t CO_2	-300 / t CO_2
Install solar panels	12%[1]	10 / t CO_2	-300 / t CO_2
Install ventilation system	12%[1]	20 / t CO_2	-300 / t CO_2
Heat pump	66%[2]	19.5 + 5.5 / t CO_2	-300 / t CO_2
Temperature reduction	5% per degree[2]		-300 / t CO_2
Reduction of vmt	10% steps of reduction		analgue to reduction
Buy more efficient car (motorbike)	(con - 5) · vmt / 100 · 2.65	30 - value	(con - 5) · vmt / 100 · 1.55
Sell current car (motorbike)		- value	-2.650 - 0.134 · value
Buy season ticket			3.100
Buy half-fare card			150
Reduction of meat consumption	max 0.5 ton / person		
Buy CO_2 certificate	1 ton		1.000 - 1900 per ton CO_2

[1] : % of CO_2 output of housing
[2] : % of CO_2 output remaining after refurbishments chosen
[3] : negative costs = savings

Table 2.3 gives the list the variables of the option and how CO_2 output reduction and financial consequences are calculated in the PE.

If a respondent has more than one car, options are given for every car separately. Choosing the option 'Sell car' does not reduce CO_2 output because it is assumed that annual kilometres driven are driven by car sharing. It is not possible to choose the options 'Sell car' and 'Buy more efficient car' simultaneously. By offering options for public transport season cards, the respondents can arrange their mobility style in a very detailed way. The CO_2 output of consuming meat is assumed to be 0.5 t/a per person and can be reduced in steps of 25 percent. To reduce CO_2 output of air travel, respondents can cancel flights each year, depending on

Table 2.4: Response behaviour pre-test

		of sample	**of valid addr.**	**of particip.**
	[abs]	[%]	[%]	[%]
Sample size	451	100.0		
Invalid addresses	227	50.3		
- Not reached	139			
- Person deceased	8			
- Wrong addresses	10			
- No car ownership	20			
- No house ownership	15			
- Already a heat pump	35			
Valid addresses	224	49.7	100.0	
Participation denied	124	27.5	55.4	
- To old (according to respondent)	21			
- Other reasons	103			
Participation agreed	100	**22.2**	**44.6**	**100.0**
Valid responses	78	**17.3**	**34.8**	**78.0**
Incomplete responses	11	2.4	4.9	11.0
Returned responses	89	**19.7**	**39.7**	**89.0**
No return	11	2.4	4.9	11.0
PE-Letter sent	73	16.2	32.6	73.0
PE participated	50	**11.1**	**22.3**	**50.0**

what data they submitted in the questionnaire. If the respondents did not indicate any air travel, these options will not be available in the experiment. The last option is buying CO_2 certificates. The (annual) prices for the certificates do not represent current market conditions, but are chosen to be comparable to other prices to avoid easy choices. The price increases exponentially to ascertain a wider range of possible 'willingness to pay' figures from the respondents.

2.1.5 Field Work

Before the main study started, two pre-tests, with 50 participants each, were conducted to test response behaviour, as well as difficulty and design of the Stated Response experiments and the Priority Evaluator. In table 2.4, the response behaviour in the pre-tests is shown.

The main study started in April, 2010 and finished in December 2011. The response behaviour in the main study is shown in 2.5.

Sample size includes all addresses (obtained from a local address dealer) that were called at least once. Valid addresses can be defined as

Table 2.5: Response behaviour main study

		of sample	**of valid addr.**	**of particip.**
	[abs]	[%]	[%]	[%]
Sample size	1768	100.0		
Invalid addresses	680	38.5		
- Not reached	*320*			
- Person deceased	*34*			
- Wrong addresses	*53*			
- No car ownership	*45*			
- No house ownership	*75*			
- Already a heat pump	*139*			
Valid addresses	1088	61.5	100.0	
Participation denied	597	33.8	54.9	
- To old (according to respondent)	*91*			
- Other reasons	*506*			
Participation agreed	**491**	**27.8**	**45.1**	**100.0**
Valid responses	**333**	**18.8**	**30.6**	**67.8**
Incomplete responses	69	3.9	6.3	14.1
Returned responses	**402**	**22.7**	**36.9**	**81.9**
No return	89	5.0	8.2	18.1
PE-Letter sent	331	18.7	30.4	67.4
PE participated	**261**	**14.8**	**24.0**	**53.2**

those people who could be reached with the given phone number and had all the attributes required for the study, including not having a heat pump. Of these potential candidates, almost half agreed to participate in the study, and 37% returned a questionnaire. Of people who received the questionnaire, an impressive 82% returned it, and still 68% were valid responses, meaning they completed the fairly difficult SP section.

One interesting factor from field work: people over 70 often wrote in the commentary field at the end of the questionnaire that they are ". . . too old to make major changes to the house". Most comments indicated that SP scenarios were difficult to understand, and that the questionnaire took too long to fill in correctly, indicating that the study is clearly on the upper end in terms of complexity. However, there were also several comments saying that other options like electric cars, or better windows, were missing.

In the two pre-tests preceding the main study, two versions of the SP were tested. In the first pre-test, the version described in section Survey Design and finally used in the main study was tested. In the second pre-test, a version with three alternatives (plus the Null alternative) was tested. The alternatives of this version are:

1. Renovation on the house.
2. Change in private transport.
3. Combination of alternatives 1 and 2.

The forth alternative was not to invest in energy efficiency.

The alternative 'Refurbishment' is either insulation or heat pump. The alternative 'private transport' is either: buy a more efficient car, or sell the car and switch to public transport. The combination is an alternative that implies savings through energy efficiency in housing as well as private transport. Values of the variable in the combination alternative are independent of the values of the other two alternatives.

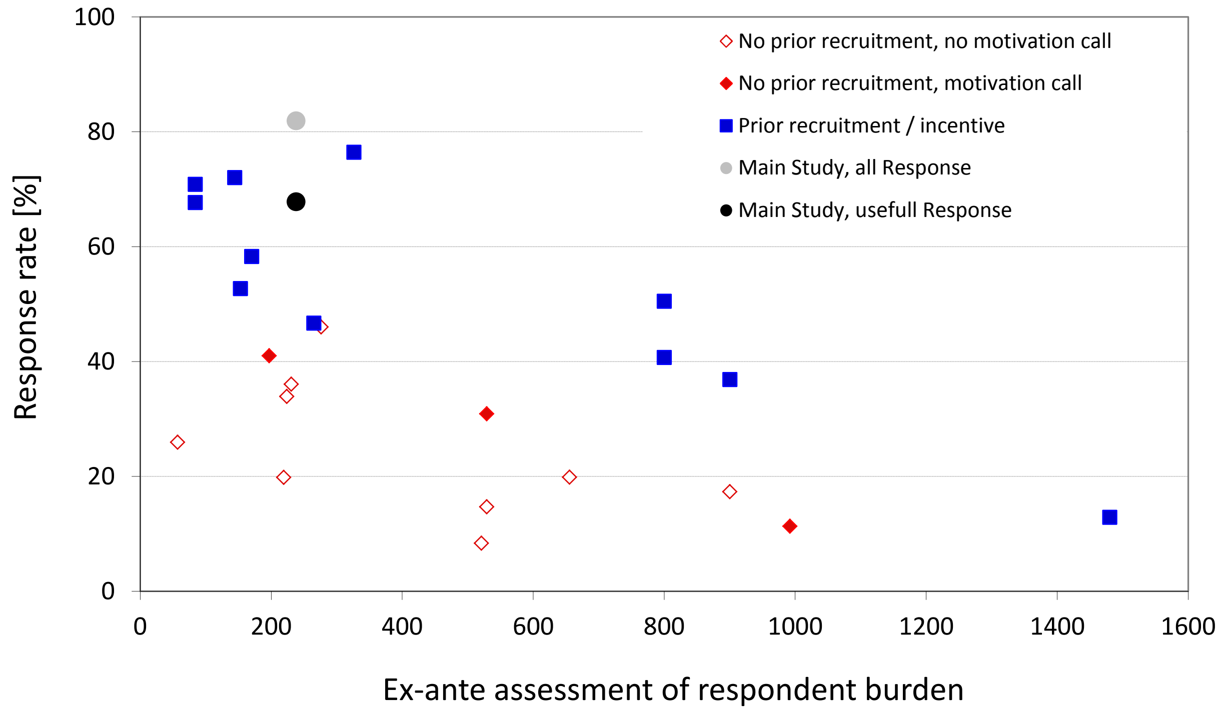
This version was tested because of several comments in the first pretest, demanding to be able to save energy in both sectors when high energy prices are given. However, a simple multinomial model of the data of the second pre-test gave less precise results than the first pretest with 4 alternatives. In addition, the version including a combination of alternatives does not force the participants to trade off between housing and transportation as strongly as the first version and thus is less able to provide the information needed.

The second pretest has shown that the alternative 'no investment' was chosen twice as much in this version (with 3 alternatives) and a simple multinomial model gave less precise results than the first pretest with 4 alternatives. In addition, the version including a combination of alternatives does not force the participants to trade off between housing and transportation as strongly as the first version and thus is less able to provide the information needed.

The response rate of the survey is comparable to other surveys, using an ex-ante assessment of the response burden. In Axhausen and Weis (2010) various surveys were collected and compared by response rate. To compare different studies, every question of a survey is assessed with a number, depending on its difficulty. Adding up these numbers gives a value that is a proxy for the response burden. In figure 2.3, the correlation between the response burden and the response rate is shown.

Assessing the SP experiments is difficult. In this case, the burden of one SP experiment is judged to be 12 times that of a closed 'yes or no' question. Given that the respondent needs to evaluate 5 variables in 4 alternatives in each experiment, we consider this a lower boundary. Compared to the other surveys in figure 2.3, the response rate of over 80% is clearly above average, however the response rate of useful and complete

Figure 2.3: Response rate of ex-ante assessed surveys



Source: Axhausen and Weis (2010)

answers fits in well. One explanation is that many home-owners are very interested in energy efficiency - and other topics related to their homes - because it is likely to be their largest asset. Conducting the recruitment by phone, many participants told us that they would be very interested and would like to participate, although they did not fit in the profile.

The fact that only home-owners can participate to the survey meant that, respondents are not representative of the general population. 81% of household heads (person who filled in the questionnaire) and 51% of all people reported in the questionnaire are male. In the "Mikrozensus Verkehr" (Swiss Federal Statistical Office (BFS), 2006), only 48% of the population is male. Higher-income classes are also over represented; in our survey we have 26% of all households in the lowest (< CHF 8.000/month), 51% in the middle (CHF 8.000/month - CHF 12.000/mmont) and 23% in the highest income class compared to 73.1%, 19.0% and 7.9%, respectively, in the "Mikrozensus". Presumably, home-owners generally have a higher income level than people living in rented housing. As far as the age distribution, we have too many respondents over 65 (33% compared to 26%) and too few respondents below 45 (20% compared to 26.1%).

Table 2.6: Description of the sample of the SP respondents

Variable	**All household members**	**Heads of households**
	[%]	[%]
Adults	80.1	100.0
Males	51.3	81.4
Age groups		
Younger than 26	29.6	0.0
26 to 45	16.8	18.6
46 to 65	33.1	48.9
Older than 65	20.5	32.5
Highest level of education		
Up to apprenticeship	56.6	40.3
Matura (first 2 years of college)	6.6	4.7
Bachelor’s degree or equivalent	24.3	41.7
Master’s degree	8.9	12.8
Driver’s license ownership	71.7	98.3
Commute by car	25.6	39.2
Mean distance to workplace	8.8 km	10.3 km
Car availability		
Never/seldom/often	37.0	15.7
Always	63.0	84.3

2.1.6 Descriptive Statistics

This section gives a short overview of the data used for modelling. Table 2.6 gives a summary of the participating persons and households. "Head of household" refers to the person who filled out the questionnaire, and it is assumed that this person usually dealt with issues concerning the residence or fleet and was therefore defined as the owner of the house for this survey. The numbers are not directly comparable with statistical data because the survey includes only home-owners and their families.

For example, more than 80% of the heads of household were male, while the gender distribution among all persons living in the households was equal. Also, driver’s license ownership was overrepresented because only households with cars were recruited. However, a comparison with data from the Swiss Federal Statistical Office (2010) clearly indicates that the age group of persons older than 65 is overrepresented in this survey, while home-owners younger than 45 are under-represented. Unlike many other surveys on transport issues, we did not have overly many persons with higher education, but rather the opposite. Though it is very common in Switzerland for people to have no education beyond an apprenticeship, that share is too high, probably because of the great share of older participants.

Especially in the countryside, many home-owners are farmers or small business people without further education.

Table 2.7 shows information on the participants‘ houses and cars. The average mileage per car was 11,635 km (for home-owners in the Canton Zurich), which is lower than 12,580 km, the national average given in Microzensus, the national travel diary survey (Swiss Federal Statistical Office (BFS), 2006). More than half of all of the cars were less than 6 years old and were bought new. Of the houses, 58.1% were heated with oil while 23.6% were heated with gas, which concurs with the percentages given by the Statistical Office of the Canton Zurich (2011b) for apartments and single-family houses, listed as 58.4% and 22.9% respectively. Most of the participants considered their insulation to be good or very good. We could not collect data on the actual condition of the insulation because that would have entailed a major assessment by professionals. The age of the houses differed somewhat from the percentages in the data collected by the Statistical Office of the Canton Zurich (2011a). In our survey there were fewer houses built after 1990: 18.82% compared to 24.7%. The greatest difference was for houses built between 1971 and 1980: 18.3% compared to 13.9%.

Information about the financial situation of the participants is given in table 2.8. For comparison, we have the income data for non-tenants for the whole of Switzerland and for the Zurich Metropolitan Area for the year 2008, which is the closest year available. The table shows two main things: First, the participating households were relatively affluent, with almost half of the households earning more than CHF 10.000/month (gross income). Second, a large share of the participants had enough liquid assets to potentially finance a major renovation of the house, since 55% of the households had assets over CHF 70.000. Consequently, for most participants the investment costs given in the SP experiments were imaginable and within reach. Compared to the official statistics from (Swiss Federal Statistical Office (BFS), 2008), the home owner survey in this study had a similar income distribution like Switzerland, although the only were from the canton of Zurich. The survey however under represents the lowest income households. The income distribution of the Zurich metropolitan area shows more higher income households than the survey.

The mean household income for Switzerland (Zurich) in 2008 was CHF 8.399 (9.220). Compared to the general population of Switzerland, the surveyed population has a slight income bias, the population of the Zurich metropolitan area however is matched relatively well.

Table 2.7: Descriptive statistics of the houses and cars owned by the respondents

Variable	**Houses**	**Variable**	**Cars**
	[%]		**[%]**
Year of construction		*Year of manufacture*	
before 1946	28.9	before 1990	1.2
1946 to 1970	19.1	1990 to 2000	18.6
1971 to 1980	18.3	2001 to 2004	22.5
1981 to 1990	14.9	2005 to2007	27.1
1991 to 2000	12.9	2008 to 2010	30.5
2001 to 2010	5.9		
Type of residence		*Type*	
Detached	48.2	Used car	48.7
Semidetached	24.6	New car	51.3
Row	19.1		
Attached	8.1		
Insulation of the roof		*Engine fuel*	
Good, very good	64.5	Gasoline	81.1
Medium, poor	35.5	Diesel	17.7
Insulation of the facade		Hybrid	0.9
Good, very good	63.5	Other	4.3
Medium, poor	36.5		
Equipment		*Engine size*	
Solar panels	6.3	< 1,400 cm^3	16.7
Ventilation system	2.3	1,401 to 1,900 cm^3	32.5
Warm water generation		1,901 to 2,400 cm^3	28.6
With heating	56.2	2,401 to 2,900 cm^3	9
Boiler	38.9	>2,900 cm^3	12.1
Other	2.8		
Solar	2.0	*Usage*	**[km/y]**
Heating system		VMT	11’635
Oil furnace	58.1		
Natural gas furnace	23.6		
Electricity	7.9		
Wood stove	7.9		
District heating	2.3		

2.2 Household Car-Fleet Choice Data Set

In this section, data and corresponding survey for the household fleet choice model of chapter 5 are introduced and briefly described.

Table 2.8: Income and assets distribution (home owners)

Variable	Households of survey	Switzerland 08	ZH 08
	[%]	[%]	[%]
Income [CHF / month]			
1,000 - 4,900	5.1	14.9	9.9
5,000 - 9,900	48.7	44.5	37.2
10,000 -15,900	34.0	30.2	34.5
> 16,000	12.2	10.4	18.4
Mean income [CHF / month]	9.788	9.908	11.663
Assets [CHF]			
< 30,000	16.5		
30,000 - 69,900	28.2		
70,000 - 149,900	19.7		
> 150,000	35.6		
Mean assets [CHF]	91.280		
No mortgage	15.7		
Mortgage less than insurance value	72.1		

2.2.1 Survey

The data set described here was collected within a project funded by the Swiss Federal Office of Energy and the Federal Office for the Environment on long term fuel price elasticity and the effects on mobility tool ownership and residential location choice (Erath and Axhausen, 2010). In the survey, 409 households were questioned about their long term reactions to rising fuel costs. The survey was divided in a part on socio-economic and mobility tool related questions and a three stage stated response survey. In the first part, the respondents are presented six scenarios of fuel prices ranging from CHF 1.5/l to CHF 5.5/l for gasoline. The survey was conducted in face-to-face interviews, in which the interviewer was equipped with a computer-software that simultaneously calculated the personalized mobility costs (fixed cost separate from variable cost) based on personal information collected previously. The respondents could choose their car fleet and annual mileage for every chosen car at a high level of detail including car type, engine size, drive-train, and if they would buy a new or a used car, while being supported by the real time calculations of the computer. Public transport season tickets, a common alternative, was always available as a choice. Figure 2.4 shows a screen shot of the survey.

Figure 2.4: Screen shot of interactive computer software used in the survey

They could also choose and/or change the mileage travelled by public transport. In the second stage of the respondents were confronted with six different residential locations as well as varying fuel prices and were again asked to choose the preferred mobility tool (and mileage) for each situation. For the third stage of stated preference experiment another six choice situations were created. The choice sets in this consisted of two alternatives, one from both previous stages each. The data used in this chapter comes from the first stage only.

2.2.2 Descriptive Statistics

The representativeness of the data in term of mobility tools, car ownership and socio-economic variables is summarized in table 2.9. The column MZ describes the targeted share according to the Swiss national transport survey (Swiss Federal Statistical Office (BFS), 2006), the column sample the actual share in the survey. In our data, male participants are slightly over-represented, as well as the age group of 36-50 years old. We have also a significantly higher share of single person household and persons without a public transport season ticket. In terms existing fleet composition, the

Table 2.9: Sample characteristics

Variable	**MZ**	**Sample**	**Variable**	**MZ**	**Sample**
	[%]	[%]		[%]	[%]
Sex					
Male	48.3	55.0	*Car availability*		
Female	51.7	45.0	always	83.5	84.0
Age in years			occasional	16.5	12.8
18 - 35	27.2	25.0	*Transit season ticket*		
36 - 50	32.0	38.0	none	63.2	73.8
51 - 65	24.5	25.5	Half-fare	29.9	16.1
> 65	16.4	11.5	GA	6.9	4.1
Highest ed.			*Cars in household*		
Compulsory education	18.4	20.6	1	62.4	
Professional school	55.6	57.6	2	32.0	
Tertiary ed.	26.0	21.8	> 2	6.6	
Household inc. [CHF/month]			*Car type*		
< 2,000	1.8	2.4	Sports car	2.6	8.1
2,000 - 4,000	14.6	12.5	Luxury / SUV	6.3	6.3
4,000 - 6,000	28.6	25.7	Upper middle class	8.9	7.9
6,000 - 8,000	23.6	17.6	Middle class	22.3	17.9
8,000 - 10,000	14.3	15.4	Minivan/van	14.1	13.3
10,000 - 12,000	7.8	10.3	Compact	23.1	20.3
12,000	9.3	9.0	Subcompact	19.0	18.1
n.a.	-	6.8	Micro	3.7	8.1
Persons per household					
1	20.5	34.5			
2	38.9	39.1			
3	14.7	11.0			
4	18.0	12.0			
> 4	7.9	3.4			

most frequent car types, such as upper middle class, middle class, minivan and compact, are under-represented while the more special ones like sports car and micro are over-represented. The income distribution is matched reasonably well, although there are more high income households than expected.

2.3 Household Income and Expenditure Data Set

2.3.1 Introduction

The third data set used in this thesis is a data set from the Swiss Household Income and Expenditure Survey (Swiss Federal Statistical Office (BFS), 2008). The Swiss Federal Statistical Office (BFS) conducts an annual survey of between 3.000 and 3.700 households per year in a statistically representative sample of the whole of Switzerland to collect detailed data about the income and the spending habits of households. The data set used here covers all years between 2001 and 2008 with a total number of 27'200 households. Every household had to report on socio-economic information, household composition, housing characteristics etc. and fill in a detailed income and expenditure diary for all household members. The time span for the diary is always one calendar month, making it impossible to track or analyse the course of income and spending of a particular household over a longer time period.

2.3.2 Categorization of Income and Expenditure

Every entry of an amount of income or expenditure in the survey diary is categorized. The categorization changed only little between 2001 and 2008, making it easy to find a useful categorization for the whole timespan. However, integrating older surveys would have been much more difficult due to the substantially different data format, categorization and variables. The categories are divided in five hierarchies, from a very general level (first hierarchy) to a extremely detailed level (fifth hierarchy). Table 2.10 shows the categorization of for income and spending used in the survey by the Swiss Federal Statistical Office. The same categorization is also used for the calculation of Consumer Price Indices.

One can see that the level of detail in the fifth hierarchy goes beyond what can be considered useful in the context of this thesis, especially for the categories "Food and Non-alcoholic Beverages", "Housing and Energy" and "Entertainment, Leisure and Culture". The total of 29 subcategories for "Communication" (4) and "Transportation" (25) however offer additional information that can be incorporated in the analysis to intensify the focus on transportation expenditures. The categorization of Transportation and Communication for the hierarchy levels three and five are shown in table 2.11.

Table 2.10: Categories of hierarchy level 1 and 2

Category		Number of subcategories		
	Hierarchy level			
1	**2**	**3**	**4**	**5**
Income from work	Income from employed work	2	2	10
	Income from selfemployed work	2	2	5
Income from	Income from renting	1	2	5
Renting/wealth	Income from wealth	1	1	3
Transfer income	Social benefits	3	4	16
	Other transfer income	2	2	23
Consumer	Food and non-alcoholic beverages	2	11	120
spending	Alcoholic beverages and tabaco	2	4	9
	Clothing and shoes	2	10	45
	Housing and energy	5	15	62
	Furniture, accomodation and housekeeping	5	9	34
	Health	2	2	9
	Transportation	2	12	25
	Communication	2	2	4
	Entertainment, leisure and culture	5	20	55
	Education fees	1	4	6
	Hotels and restaurants	2	4	13
	Other goods and services	3	5	12
Transfer	Insurance	4	8	18
spending	Charity, contributions and transfer spending	1	3	15
	Fees and taxes	1	3	10

2.3.3 Descriptive Statistics

2.3.3.1 General Overview

The samples for the Income and Expenditure Surveys are representative for the Swiss population (Swiss Federal Statistical Office (BFS), 2008). In our analysis we focused on the most generic socio-economic variables like household composition, income and residential location. Table 2.12 gives an overview over the socio-economic and spatial distribution of the households. Couples and families are the most common household type with each around a third of all households. Single household make up nearly a fourth. In terms of residential location we can see that more than half of all households live either in a city or a regional centre or in its suburban surroundings. Unfortunately, the geographical resolution shown in table 2.12 is the highest possible one. Although addresses,

Table 2.11: Categories of hierarchy level 3 and 5 for communication and transportation

Category	
Level 3	**Level 5**
Mail	Postage
Electronic communication	Purchasing of telephone fax devices
	Telecomunication
	Internet
Private transport	New cars
	Used cars
	Motorbikes
	Scooters
	Bicycles
	Spare parts for vehicles
	Accessories for vehicles
	Petrol fuel
	Diesel fuel
	Motoroil
	Reparations on vehicles
	Rent for garages
	Other parking expenditures
	Leasing
	Other private services
Public transport	Rail tickets
	Interregional season tickets
	Bus tickets and taxis
	City season tickes
	Airtravel
	Travel by boat
	Other public services

municipalities and cantons of the respondents were collected, we could not obtain this information due to data protection laws. The smallest entity of a geographical variable must contain at least 600 households for every year to ensure total anonymity for all the participants.

Figure 2.5 shows how many households were surveyed every month. The number oscillates around 250 households, with no month having a very high or very low number of survey households, providing some stability for time series analysis.

2.3.3.2 Income Composition and Distribution

To provide an insight about the income patterns of Swiss households, figure 2.6 shows the income distribution. Figure 2.7 gives an overview about the

Table 2.12: Socio-economic figures (all households 2001 to 2008)

Variable	**Sample**	**Variable**	**Sample**
	[%]		[%]
Metropolitan area of residence		*Household Type*	
Lake Geneva area	15.6	Single	26.4
Espace Mittelland	22.8	Single parent	4.4
North-west Switzerland	13.3	Couple	32.4
Zurich region	17.4	Familiy with 1 child	11.1
East Switzerland	12.9	Familiy with 2 childr.	16.3
Central Switzerland	9.1	Familiy with 3+ childr.	6.7
Ticino region	8.8	Other households	2.7
Type of municipality of residence		*Persons per household*	
Regional centre	27.5	1	26.4
Suburban and high Income	34.1	2	36.0
Periurban	12.1	3	13.5
Industrial and touristic	12.8	4	17.0
Rural commuting	6.5	> 4	7.1
Rural agrarian	7.0		

Figure 2.5: Number of surveyed households for every month

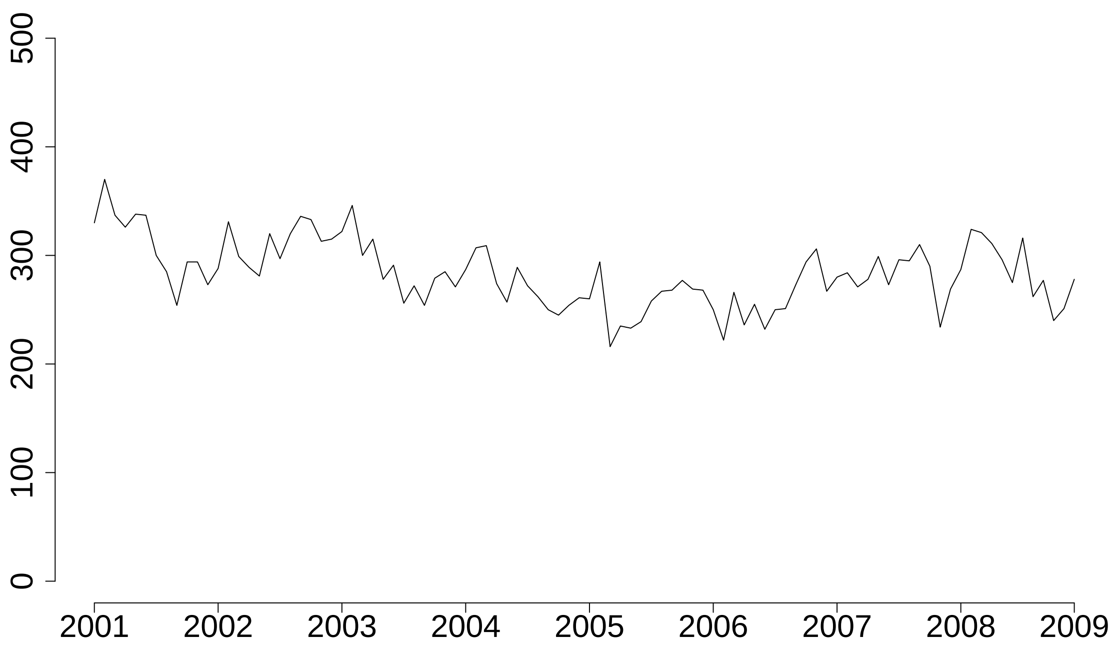


Figure 2.6: Income distribution

income sources for every income class. Social benefits and state pensions are the main source for lower income classes. Especially the second lowest income class is mainly dependent on state pensions. Employed labour constitutes the biggest share for all higher classes. Self-employed labour is about 5% to 10% for all classes, with the biggest share for the highest income class.

Figure 2.8 shows the mean absolute income for different household types. Single households, pensioners and single parents have a lower mean income than the other types. Pensioners live mainly from pensions, while families and single parent household live mainly from employed labour. Alimony and social benefits are higher for single parent households than for any other household type, but only add up to an average of slightly less than CHF 2.000/month. The household type with the highest income are families with three or more children. That may sound surprising, but a closer look reveals that the main difference is between households with 2 income earners (couples or families) and with one income earner (single or single parent). Within these two households groups, the (very small) difference of average income comes from social benefits in the form of child allowances and alimony in the case of single parents.

Figure 2.7: Income composition by income class

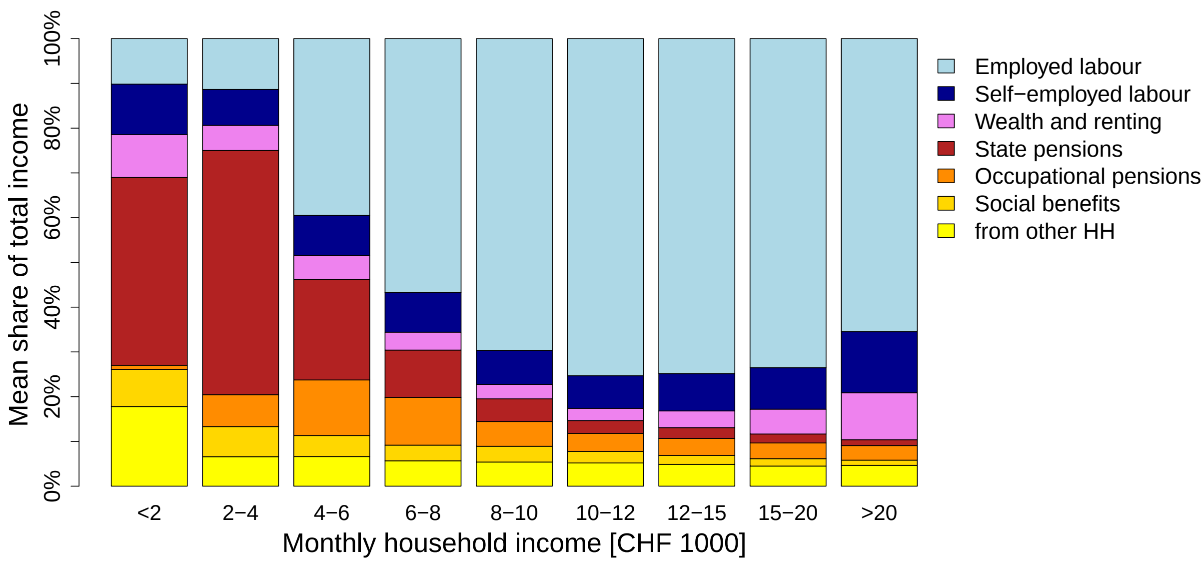
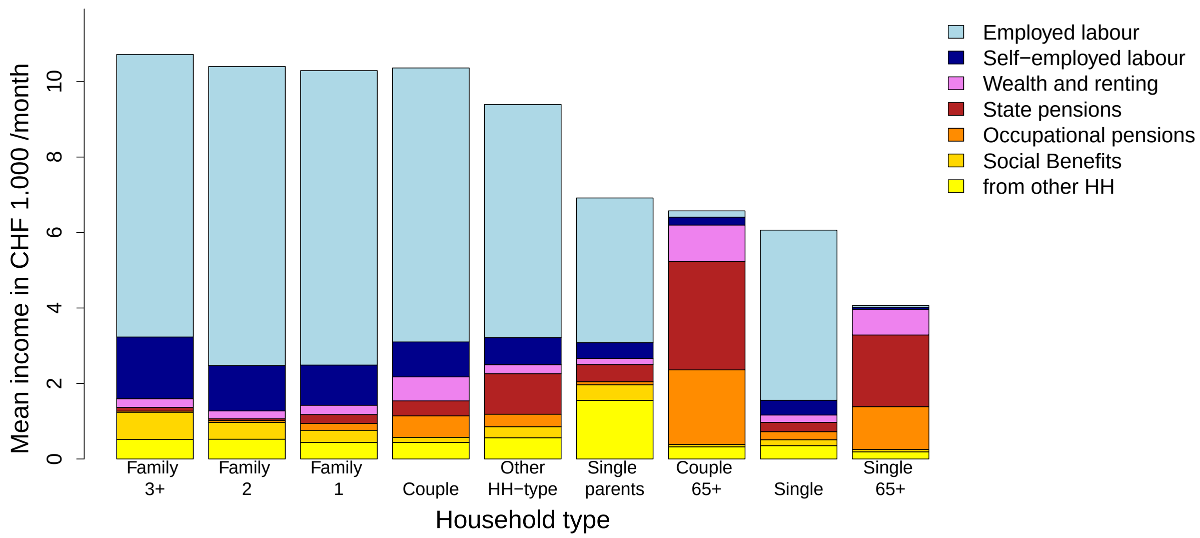


Figure 2.8: Income composition by household type



2.3.3.3 Household Expenditures Distribution

Share and composition of transfer spending are shown in Figure 2.9. Both the progressive nature of the Swiss tax system, the increasing share of income and payroll taxes for higher income classes, as well as the regressive nature of the healthcare system with higher shares for lower income households can be observed. The effect of progressive taxation was still substantially greater than the effect of healthcare spending for the observed years 2001 to 2008. The yearly increasing insurance premiums and slightly decreasing taxes since 2008 and in the near future would likely to have narrowed this gap. It can be seen that even for households in the highest income class the share of consumer spending of total gross income is higher than 50%.

Composition of consumer spending is shown in figure 2.10. The lower four parts of the stacked bar with colours from light-yellow to orange stand for what we assume to be "semi-fixed costs". While households are normally not forced by law to carry these expenses, they are fixed in the sense that they are required in order to maintain a decent or appropriate standard of living. That includes fixed costs (additional educational costs and healthcare spending not covered by insurance such as dental care for example), transportation because of it being absolutely necessary in order to work or engage in social contacts, housing appropriate to the social class, household composition and requirement of living standard, food and communication. While communication in the form of smart-phones for example could be viewed by many not as a necessary communication tool and rather as deliberate entertainment, it is nowadays very difficult to find and get a job without internet access and/or a mobile phone number. Also recent applications for virtual social networks, such as Facebook or Whatsup, become more and more important for the organisation of real life social networks, especially for younger persons, who, without these tools, are in danger to be excluded from a significant part of social life.

Expenditure for Consumer Goods such as Clothing, Entertainment (including television devices or computers) and Alcohol, Tobacco and Eating out are considered as deliberate spending and more subjected to ad-hoc decision making than the above described semi-fixed categories. While the share of total consumer spending is greater for richer households as seen in figure 2.9, the opposite is true for the deliberate spending categories which have a higher share of total spending for richer households, resulting in an even bigger absolute amount.

Figure 2.11 shows amount and composition of consumer spending by household types. Families with more children have higher expenditures, especially for housing, food and consumer goods. Interestingly, average expenditures for transportation or communication aren't higher for families than for couples without children. In total, the higher number of people in the household reflects the higher earning potential, higher income and higher expenditure, with little qualitative differences. The most striking qualitative difference is the much higher share for savings for households

Figure 2.9: Share and composition of transfer spending per income class

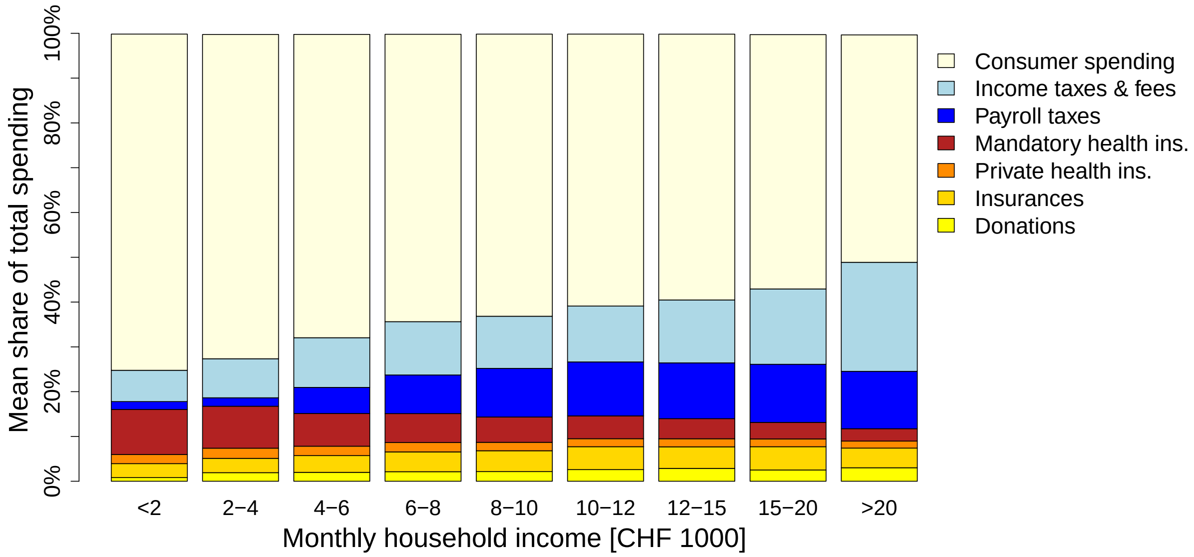


Figure 2.10: Composition of consumer spending per income class

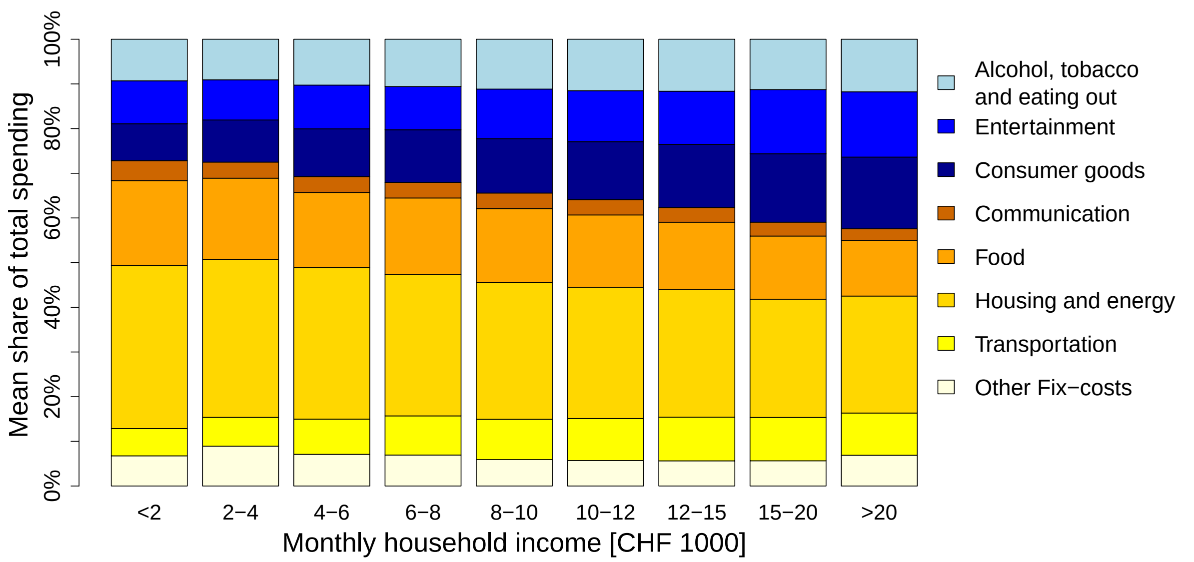
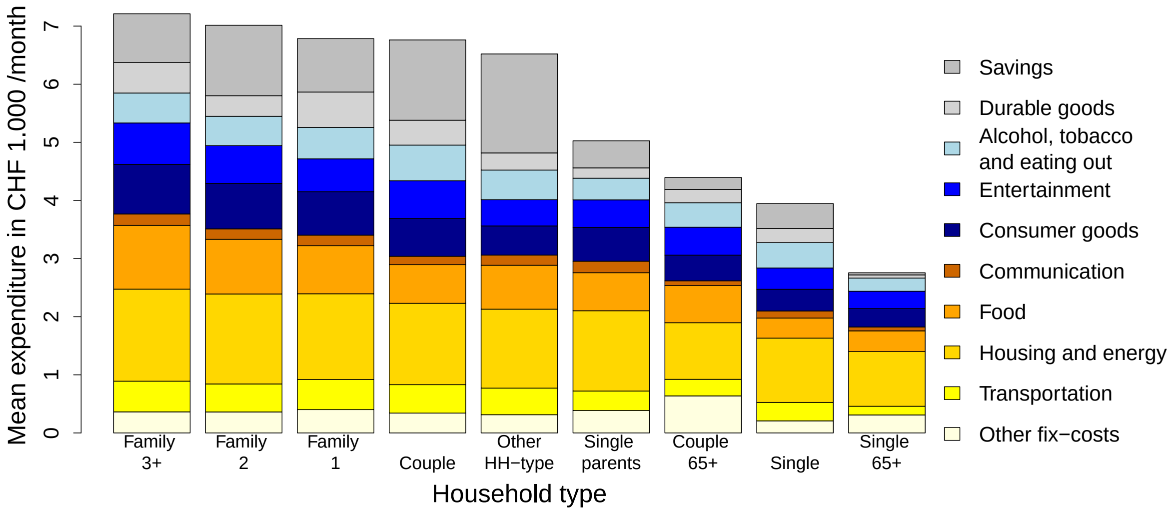


Figure 2.11: Amount and composition of consumer spending per household type



with two or more income earners. Singles, single parents and retired couples have substantially lower savings.

Figure 2.12 shows amount and composition of consumer spending by type of residential municipality. Households living in suburban, peri-urban or high income municipalities have higher incomes on average, and accordingly higher expenses for all categories, but with no notable qualitative differences. Peri-urban is used in this context for towns and villages that typically lie beyond the suburban agglomerations but have more urban characteristics than isolated villages in the countryside. They are not fully oriented towards the city like suburban areas and have a substantial part of distinct rural land use.

2.3.3.4 Transportation Expenditures

Figure 2.13 shows the share of the different subcategories of transportation expenses by income classes. Lower income households clearly spend much more for public than for private transportation. But also for the two lowest income classes, almost half of average transportation expenses are for private motorized transportation. Interestingly, the middle income households spend the highest share of its transportation budget for private transportation. This is related to the fact fuel costs are dominant for private transport expenses but are only linear scalable through a more frequent use of the transport mode in question. For the purchase of cars or air

Figure 2.12: Amount and composition of consumer spending per municipality type

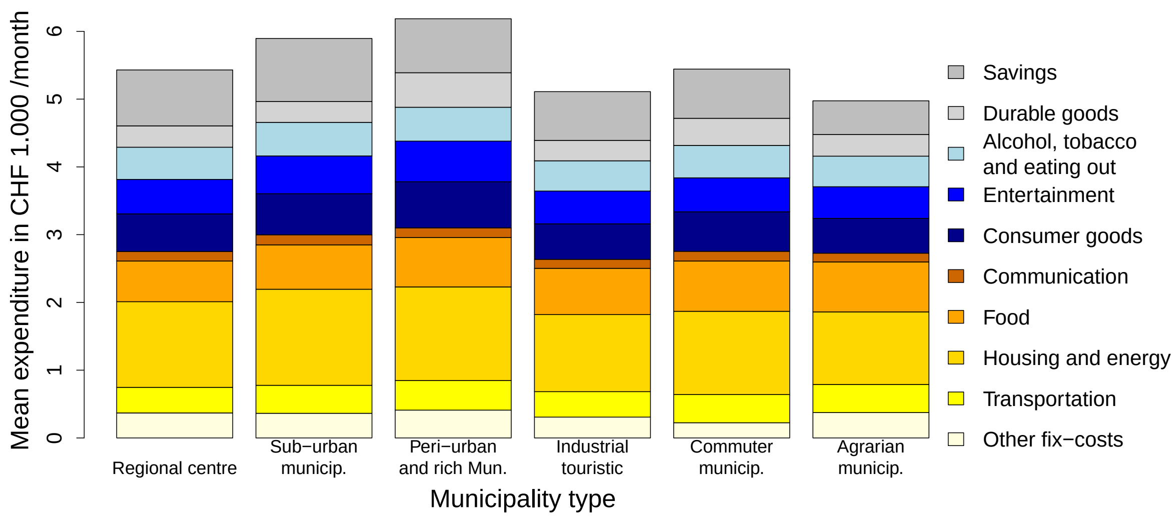
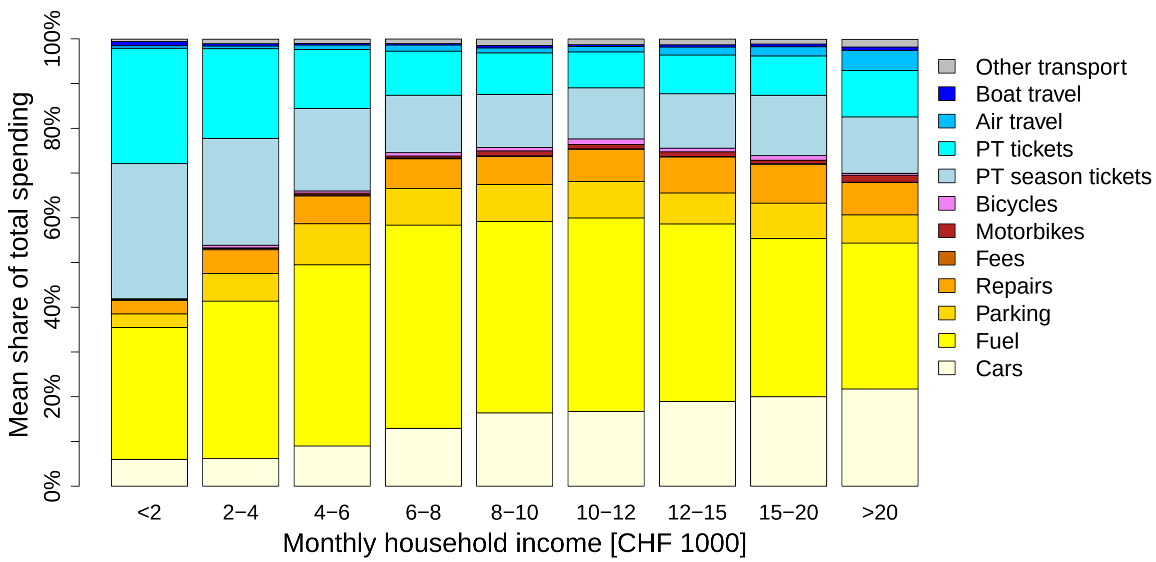


Figure 2.13: Expenditure for transportation by income class



travel or public transport, expenditures can be scaled also by buying higher comfort or quality (luxurious cars, 1. class tickets or taxis). In the case of public transport, the budget is divided in half single tickets and half season tickets for all income classes almost identically.

Figure 2.14 gives car ownership by income classes. Higher income is correlated strongly with a higher average number of cars per household.

The transition from zero cars (no car ownership) to one or more cars (car ownership) takes place in the four lower income classes. For the same classes we can also see the increase in the share of expenditure for private transportation in figure 2.13. That supports the finding that car ownership plays a vital role in determining the composition of transportation expenditures. This can also be seen in figure 2.15.

The effect of income and car ownership on distribution of expenditure on private or public transportation shows some interesting points worth further discussion. Higher income generally means a bigger share for the opposite mode (public transport for car owners and private transport for households without cars). This could be because it is more economical to stick with the fix-costs associated with the primary mode, which is especially relevant for lower income families. While the mean share of public transport expenditure goes up to 25% for high income households with cars, the share of private transportation is almost 40% for high income households without a car. From a practical point of view this is counter-intuitive, because it is easier for a rich household to use public transport than to organize a car if none is available in the household. One explanation could be that private transport gives the possibility to reach less accessible places more easily and faster. Richer household that could afford a car make the choice of having no car under the condition of occasionally renting car for the mentioned situations. For lower income households with cars the share of public transport spending is around 15% and thus higher than the share of private transport in the case of lower income households wit no car ownership, which is 10%. Spending on private transportation for households with no car ownership consists of spending on motorcycles, car sharing, renting cars and buying fuel when driving another household's vehicle.

Figure 2.16 shows expenditures for Transportation for different household types. Main driver of total transportation expenses seems to be the number of working income earners rather then the total amount of persons in the household. Counting a retired, and thus non-working, income earner as half as transportation intensive as a working income earner, the patterns is quite consistent. A retired couple spends about the same amount for transport as a single or single parent family, a couple or family twice and a single retired person about half as much. The age effect comes partially from the substantially lower income of older people, as seen in figure 2.8, and partially from lower mobility and travel demand of older people.

Families with less children spend more on cars and on transportation generally. We can also see that for families or couples the expenditure

Figure 2.14: Car ownership by income class

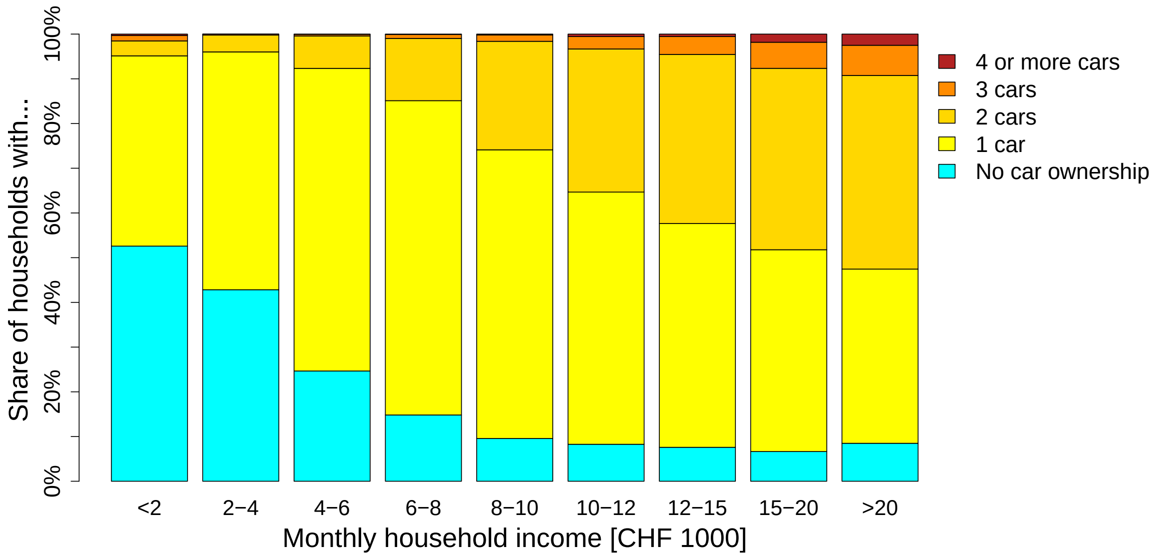


Figure 2.15: Transportation expenditure by car ownership and income class

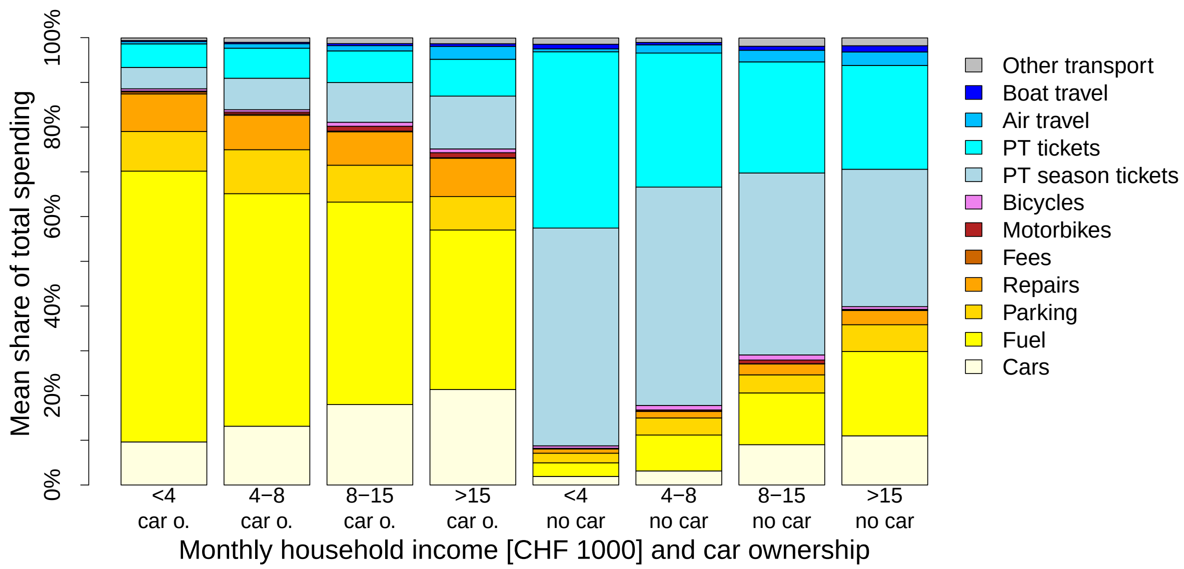
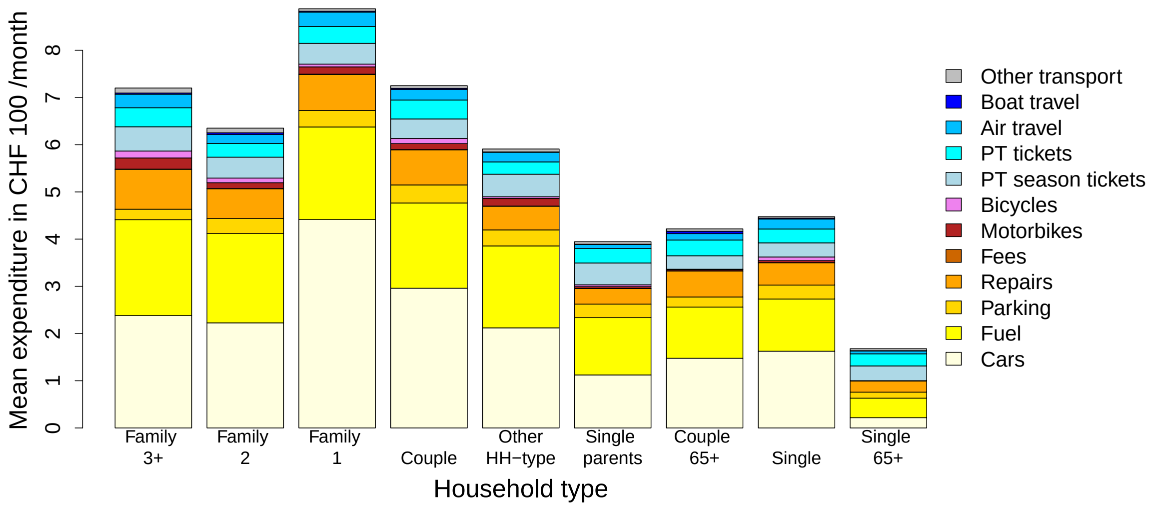


Figure 2.16: Amount and composition of transportation expenditures by households type



for the purchase or leasing of a car is more substantial than fuel costs. Families and couples tend to have more than one car, making capital cost relatively bigger, as a second (or third) car usually does not double (or triple) annual mileage. Other than that, no qualitative differences between the modes or categories can be observed. A family with one child spends an average of CHF 700/month or CHF 8.400/year for private transport.

Figure 2.17 shows expenditures for transportation for different types of residential municipality. Total transport expenditure has the same pattern as total consumer spending as seen in 2.12, but with a bigger difference between urban and peri-urban or rich municipalities. Households living in urban areas spend the least on transportation on average, but with the highest share for public transport. Although the differences in how much is spent for which mode are noticeable, they are not as considerable as one may assume given the vast gap in public transport accessibility between urban and rural areas. One should be aware of however, that the geographical resolution of the used types is not high enough to clearly separate high density inner-cities from low-density neighbourhoods in mid-sized towns, which both, among others, are categorized as regional centre. This is confirmed by figure 2.18 which shows car ownership for different municipality types. While the share of no car households is more than twice as high in regional centres than in all other municipality types, it is still only about 30%. That means that also the most urbanized

Figure 2.17: Amount and composition of transportation expenditures by municipality type

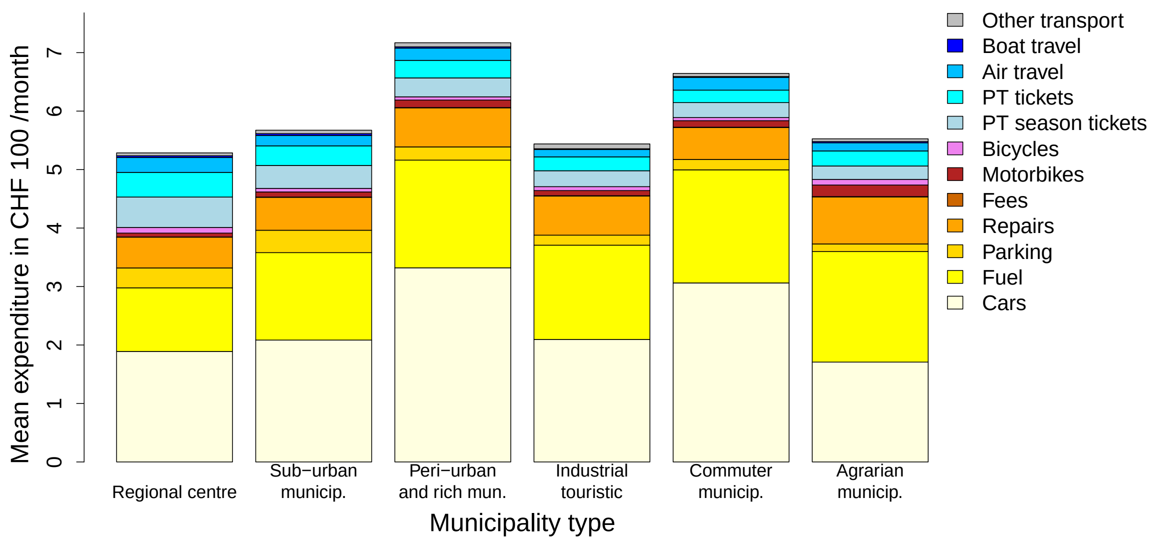
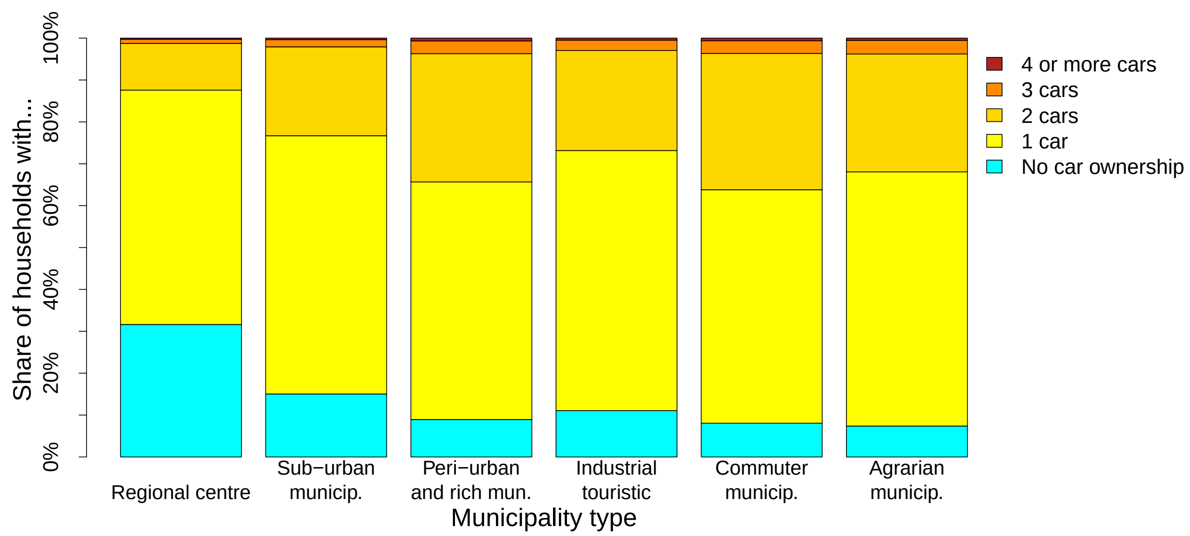


Figure 2.18: Car ownership by municipality Type

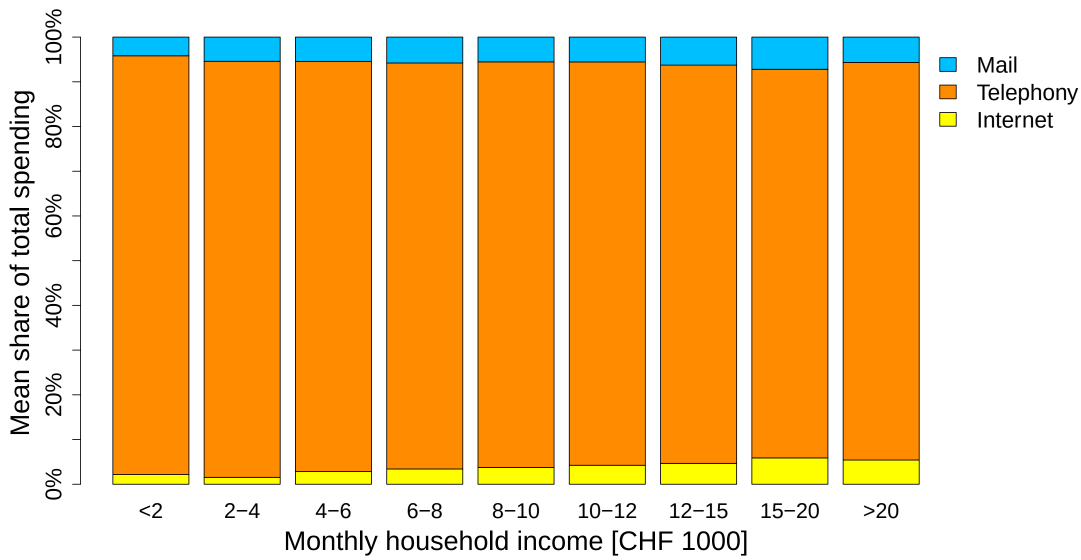


municipality type in our analysis is dominated by households with car ownership.

2.3.3.5 Communication Expenditures

Figure 2.19 shows expenditure for communication by income class. Telephony includes standard wired telephones as well as mobile phones,

Figure 2.19: Expenditure for communication by income classes



because the survey only started to differentiate between the two in 2004. Since then, the shares are roughly 50-50. Telephony is by far the biggest part of communication expenses, independent of income. Internet takes a higher share for higher income households. This could come from the fact that richer households are more likely to have internet access and that they are willing to pay for faster connections, showing the Internet's relative importance. In total however, households spend on average about 9 times as much on telephones than on internet access.

Figure 2.20 shows communication spending for different household types. The number of children in the households has a substantial impact, with families and single parents spending more on telephony than couples or singles. Older people spend much less on communication, with a lower share of internet spending, which could reflect a) an lack of adaptation of new technologies (internet) and b) the shrinking of social networks (telephony).

Figure 2.21 shows communication spending for different municipality types. Spending reflects overall budget, with no qualitative differences between municipality types.

Figure 2.22 shows the absolute amount of transportation and communication expenditure in time. In the 10 years between 1998 and 2008, expenditures for these categories increased by almost 40 %, with most of the increase happening in the three years between 2004 and 2007, with

Figure 2.20: Amount and composition of communication expenditures by households type

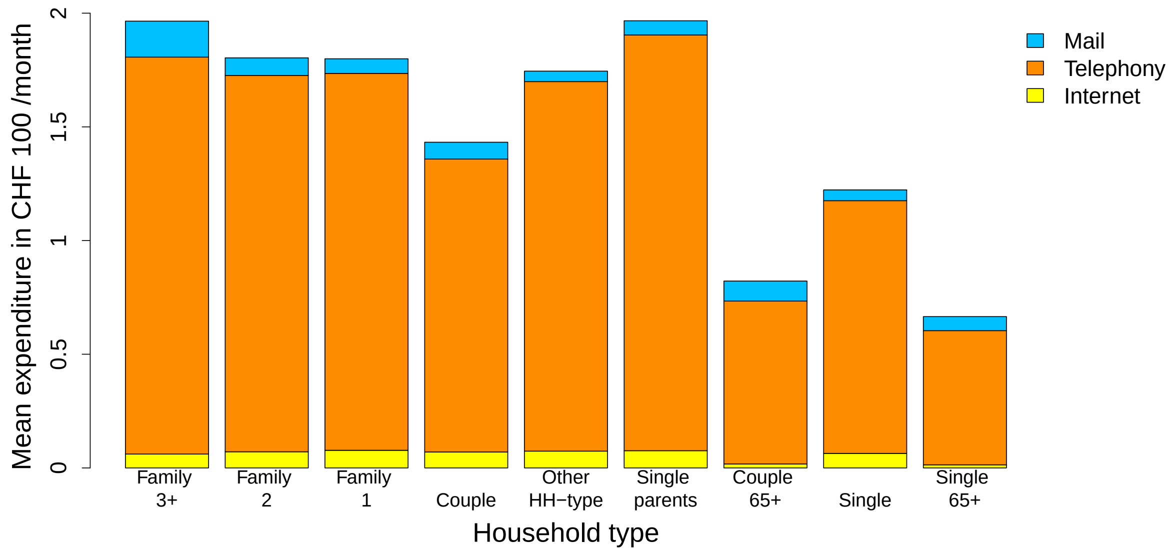


Figure 2.21: Amount and composition of communication expenditures by municipality type

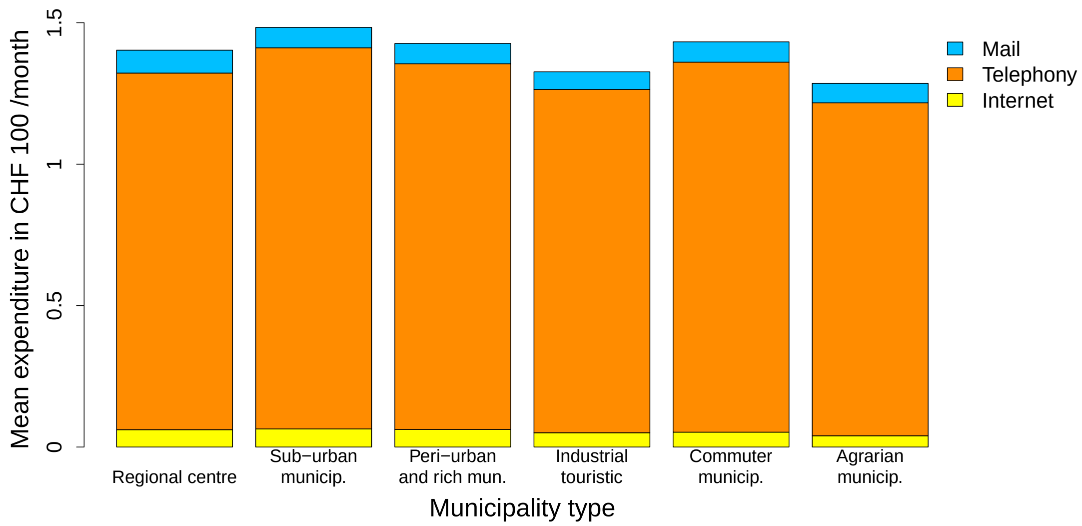
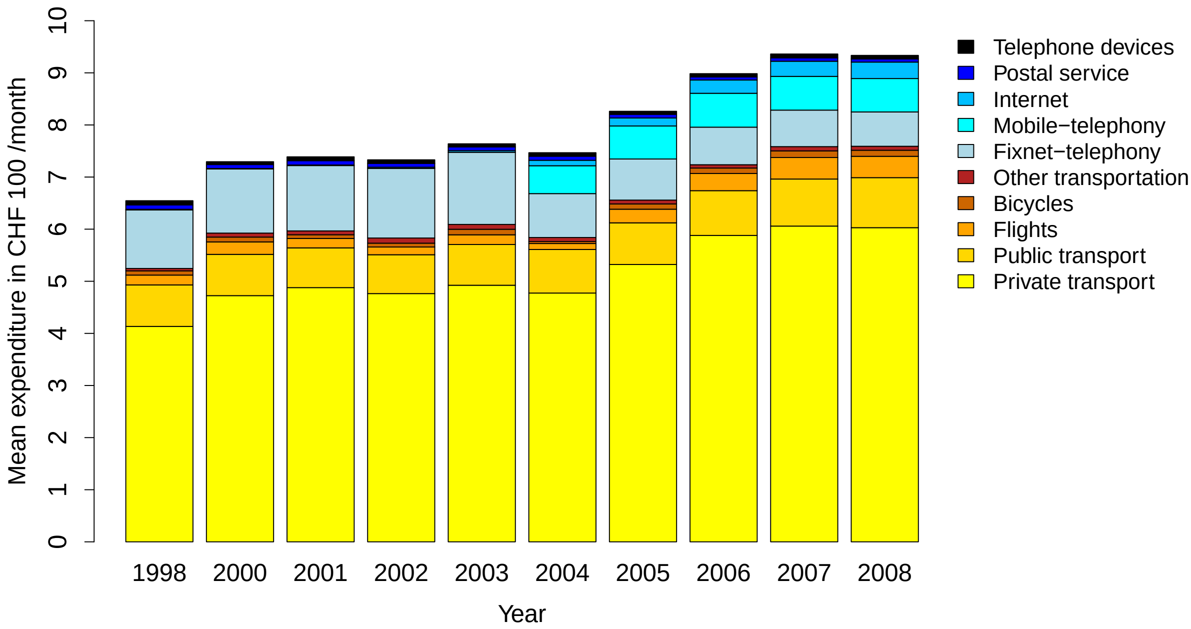


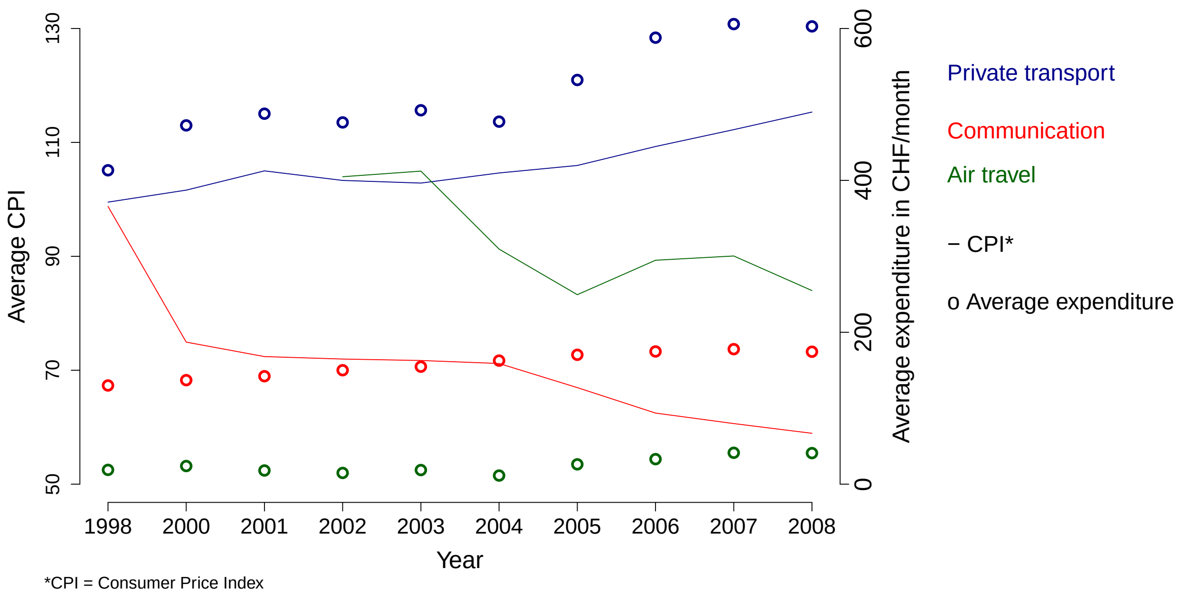
Figure 2.22: Amount and composition of transportation and communication expenditures by year



the most notable increases in private transportation, air travel and internet access.

The increase in spending for the above mentioned categories cannot be explained by an equal increase in prices, as easily demonstrable with figure 2.23. The straight lines depict the average consumer price index (CPI) fo each year (left axis), while the circles stand for the average expenditures (right axis). The prices for communication have fallen 40% in this ten years but people spend more on communication. The same can be observed for air travel. In the case of private transport however, prices have risen steadily from 2003 to 2008 and expenses increase sharply between 2004 and 2007. We cannot identify a clear pattern of elasticities.

Figure 2.23: Price trend and expenses for communication, private transport and air travel



Chapter 3

A Multinomial Logit Model for Total Household Energy Consumption

The content of this chapter was published in Jäggi and Axhausen (2011)

3.1 Introduction

3.1.1 Research Topic

According to the Intergovernmental Panel on Climate Change, global warming caused by increasing emissions of carbon dioxide and other greenhouse gases (GHG) is one of the major problems facing the world (Pachauri and Reisinger, 2007). Carbon dioxide is generated by burning fossil fuels such as coal, oil or natural gas to supply energy. In Switzerland, oil accounts for approximately 60% of all energy consumption (Swiss Federal Office of Energy (SFOE), 2009). Switzerland is fully dependent on oil-exporting countries and the highly volatile global market for crude oil with its recurring price spikes, like one that happened in the summer of 2008 (Smith, 2009). While the Swiss public transport system is mainly electrified and electricity generation in Switzerland is either nuclear or hydro-power, fossil fuel consumption is concentrated in heating or industrial process heat (50.7%), airborne transportation (9.6%) or private transportation (39.7%) (Federal Office for the Environment (FOEN), 2010).

To reduce GHG emissions in the mentioned sectors, the government has to rely on cooperation by households, because a majority of private fossil fuel consumption in households is associated to larger, capital intensive infrastructure such as heating systems, insulation or cars. To be able to reduce emissions without making large sacrifices in quality of live, the mentioned infrastructure has to be replaced or refurbished. A decision to change one's car or refurbish one's house involves not only substantial financing but also a thorough consideration of long term outcomes. For which combination of energy prices, investment costs and environmental as well as financial benefits are households willing to invest in reducing GHG emissions?

One of the primary research questions asks how people would reduce their energy consumption under specific given economic and legal circumstances and parameters. When forced to reduce their energy consumption (through financial pressure), would people, think of their overall consumption as one budget or would they divide it up into budget silos by sector? Would they make trade-offs between sectors (e.g. completely refurbish the house, but maintain the inefficient luxurious car) or reduce energy consumption equally in each sector?

The model presented in this chapter explores quantitatively how households, when faced with very high energy prices for both heating their house as well as for fuel for their car, would make these long term investment decisions, using Multinomial Logit models based on Stated Preference data.

Descriptions of the data set and the corresponding survey are given in, section 2.1.

3.1.2 Literature

No literature specifically comparing the two energy sectors in question - in terms of consumer behaviour - was found. The survey presented in this chapter addresses this issue for the first time, offering a direct choice between these major energy sectors. Although no comparative study about consumer behaviour with regard to different energy sectors was found, literature on energy consumption in different sectors does exist.

3.1.2.1 Residential Sector

Residential energy consumption varies greatly between regions and countries: On the one hand, energy demand for heating and cooling depends on climatic conditions; on the other hand, different fuels are common in different countries. Insulation standards also vary substantially across regions. Pérez-Lombard et al. (2008) presented a review of international energy consumption in buildings and the relevance of heating and cooling systems. For Switzerland, the above-mentioned "Gesamtenergiestatistik" (Swiss Federal Office of Energy (SFOE), 2009) provides comprehensive, detailed information on energy consumption in Switzerland, differentiating between sectors and energy sources.

Other studies in Switzerland focus on the possibilities and costs of reducing energy consumption in the residential sector. In his dissertation Jakob (2007) derived the marginal costs of different measures for improving energy efficiency. He found that in the long run, the marginal costs of improving efficiency would be lower than the fuel costs in most cases. In Banfi et al. (2008), the authors used specific choice experiments to analyse consumers' willingness to pay (WTP) for energy-saving measures. They found a substantial WTP for both environmental and comfort benefits.

3.1.2.2 Transportation Sector

Studies on energy consumption in transportation generally do not assess the overall energy consumption, but focus instead on determining the effects of specific aspects of transportation. An important study on the effect of fuel prices on energy consumption (Goodwin et al., 2004), for example, determined fuel price elasticities for the UK and the USA, and a similar study with a wider range of prices was conducted by Erath and Axhausen (2010) for Switzerland. Other topics of research are route choice, as in Ahn and Rakha (2008), and freight transport as in Léonardi and Baumgartner (2004). Another interesting study (Poudenx, 2008), analysed the effects of different policies in different cities on energy consumption. His findings suggest that policies should aim at raising the competitiveness of low-energy-intensive modes such as cycling or public transport rather than at reducing private vehicle usage.

3.1.2.3 Comparative Studies

Comparative studies of energy consumption have mainly focused on urban planning and the effects of the structure of urban development on energy consumption. More densely populated urban areas require different transportation patterns and also feature different kinds of dwellings than sparsely populated ones. A study in Australia by Perkins et al. (2009) showed that persons living in inner-city apartments had a higher carbon-intensity level per capita than (outer-city) suburban residents, despite having a lower energy consumption rate for transportation. The reason was that city apartments had higher operational and embodied-energy consumption rates. A similar study for Oslo by Holden and Norland (2005) produced similar findings. Due to the high demand for heating energy because of the cold climate, multifamily housing in the compact city was still more energy efficient than decentralized housing. However, inner-city households proved to have a higher energy demand due to leisure travel; energy-intensive means, especially flying, diminished efficiency gains.

3.2 Methodology

The econometric models used in this chapter were standard and nested Multinomial Logit models (MNL). MNL models are discrete choice models that predict the choice of one alternative from among a limited number of available alternatives. The models were based on the utility theory of standard microeconomic theory. It was assumed that the alternative with the greatest utility would be preferred. The utility of an alternative was defined as:

$$U(A) = V(A) + \epsilon \tag{3.1}$$

where V(A) is the systematic utility described by the model and ϵ is the random utility that cannot be observed by the modeller. When calculating the probability that an agent will choose an alternative using a Gumbel distribution for ϵ and assuming that the alternative with the higher utility U(A) will be chosen, one obtains the probability function (for alternative i) in the following form:

$$P_i = \frac{e^{V_i}}{\sum_{i=1}^{K} e^{V_i}} \tag{3.2}$$

A detailed deduction and explanations of the probability function are given by Louviere et al. (2000); Train (2003).

3.2.1 Basic Model

The utility function for alternative i in the basic model presented in 2.1.4.1 is as follows:

$$V_i = \mathrm{ASC}_i + \beta_{Inv_i} \cdot \mathrm{Inv}_i + \beta_{Sav_i} \cdot \mathrm{Sav}_i + \beta_{CO2_i} \cdot \mathrm{CO2}_i + \beta_{Fuelprice_i} \cdot \mathrm{Fuelprice} \tag{3.3}$$

This model only included variables given in the SP scenarios and was meant to be a basic model to be further developed using socio-economic data as well as variables specific to the respondents' house, household and car. The ASC (Alternative Specific Constant) and the β parameter were estimated for each alternative and each variable. The variables in the basic model were the investment sum, the projected savings and the stated CO_2 reduction.

3.2.2 Advanced Model

The advanced model consisted of a modified basic model with additional linear socio-economic terms. Instead of estimating the parameters for investment and savings separately, the expected payback period (PBP) was incorporated into the model and estimated explicitly. The payback period is the ratio between the parameters for savings and investment β_{Sav}/β_{Inv}. This ratio tells how much more one CHF is valued when it represents annual income in contrast to one-off savings. The monthly household income (Inc) was built into the model with a non-linear parameter λ that captured the influence of income on the respondents' willingness to invest and acceptance of high fuel prices. This formulation is from Mackie et al. (2003) and has been used successfully in recent models (Hess et al., 2008; Axhausen et al., 2008; Weis et al., 2010a)) to capture the unobserved heterogeneity of a sample. The PBP was estimated for different asset groups separately in the case of the insulation alternative, using a dummy variable that was 1 if the observation was in the given range of the J asset groups. Other non-linear effects were not found to be significant.

$$
\begin{aligned}
V_i \; = \; \mathrm{ASC}_i \; + \; \beta_{Inv_i} \cdot \left(\frac{Inc}{\overline{Inc}}\right)^{\lambda_{inv_i}} \cdot \mathrm{Inv}_i \\
l \qquad + \beta_{Inv_i} \cdot \sum_{j=1}^{J} \left(PBP_{ij} \cdot Dummy_j\right) \cdot \mathrm{Sav}_i \qquad (3.4) \\
+ \beta_{Fuelprice_i} \cdot \left(\frac{Inc}{\overline{Inc}}\right)^{\lambda_{fp_i}} \cdot \mathrm{Fuelprice} \; + \; \beta_{Ass_i} \cdot Assets_i \; + \ldots
\end{aligned}
$$

Table 3.1: Parameters of the basic model

Parameter	Value	Robust std. err.	Robust t-test	p - value
ASC				
Insulation	**-1.87**	**0.33**	**-5.69**	**0.00**
Heat pump	**-1.21**	**0.31**	**-3.86**	**0.00**
New car	**-1.59**	**0.24**	**-6.74**	**0.00**
Car sharing	**-4.56**	**0.32**	**-14.18**	**0.00**
β - Investment [in CHF 10^3]				
Insulation	**-0.03**	**0.00**	**-7.30**	**0.00**
Heat pump	**-0.05**	**0.01**	**-6.80**	**0.00**
New car	0.00	0.01	0.10	0.92
β - Savings [in CHF 10^3 / y]				
Insulation	**0.25**	**0.08**	**2.99**	**0.00**
Heat pump	**0.25**	**0.09**	**2.88**	**0.00**
New car	**0.22**	**0.10**	**2.30**	**0.02**
Car sharing	0.09	0.11	0.86	0.39
β - CO_2 reduction				
Insulation	0.28	0.21	-0.63	0.53
Heat pump	**0.33**	**0.09**	**5.81**	**0.00**
New car	**0.04**	**0.09**	**3.80**	**0.00**
Car sharing	**-0.13**	**0.11**	**10.34**	**0.00**
β - Energy price [in CHF/kWh]				
Insulation	**0.08**	**0.01**	**7.18**	**0.00**
Heat pump	**0.08**	**0.01**	**6.84**	**0.00**
β - Gasoline price [in CHF/l]				
New car	**0.51**	**0.11**	**10.34**	**0.00**
Car sharing	**1.15**	**0.09**	**5.81**	**0.00**
Adjusted ρ^2	0.18			
Number of observations	2’319			

3.3 Results

3.3.1 Basic Model

The basic model was an MNL model. The utility functions are given by equation (3.3) in section 3.2. . The utility functions included only variables from the SP design without socio-economic variables. The estimated parameters of this model are shown in table 3.1. **Bold** parameters are significant at the 95% level and *italic* parameters are significant at the 90% level.

We observed that almost all of the variables presented in the SP were significant. We could also see that the parameters for the expected financial savings were significant for all alternatives involving investment.

The parameters for the investment costs were highly significant for the housing alternatives, but not for the "new car" alternative. The signs of the parameters, negative for investments and positive for savings, were as expected. The required lump sum and the expected savings clearly played a major role in decisions regarding investment in the energy efficiency of the house, especially as compared with investing in a more efficient car. Calculating the ratio between the parameters for savings [1/ (CHF/year)] and for investment [1/CHF] gives the average expected payback period [y] of an investment for the sample. For insulating the house, it was 0.25/0.03 = 8 years, and for a heat pump it was 0.25/0.05 = 5 years. The average payback period for energy efficiency given from an explicit question elsewhere in the questionnaire was 10 years. This means that the respondents did not answer the SP consistent with that time frame, and when faced with a concrete sum of money (as in the SP), they tended to request a higher interest rate than if they thought about energy efficiency in general (as in the explicit question). Assuming that a homeo-wner did not take the increase in the value of the house as a result of an investment into consideration, the investment would double the amount of money within twice the PBP. Similarly, the explicitly stated 10 PBP would be equivalent to an interest rate of 3.5%, which would also double the money within 20 years. This seems to be a reasonable interest rate compared to ten-year government bonds (as a lower threshold) which ranged between 1.5% and 2.0% during the period of the survey and between 1.5% and 4.0% over the decade from 2000 to 2010. The respective interest rates for the estimation results were 7.5% for a heat pump and 4.5% for insulating the house.

Another finding was that more people were willing to invest in heat pumps than in insulation. However, looking at all significant constants, it is obvious that no investment or change in habits was preferred above all other alternatives, but the heat pump was the least rejected of the investments. The most rejected alternative (by a factor of 3 compared to the other alternatives) was car sharing, which implied a behavioural change.

One can calculate the equivalent in annual savings through the contribution to the utility for the ASC with ASC_{CHF} = ASC / β_{SAV}. These monetary values should only be viewed as relative to each other and not as absolute values, because the zero alternative cannot be monetized. If the smallest constant (heat pump) is CHF 0/year, the resulting values are as shown in table 5. That would mean, for example, that the insulation alternative would have to save CHF 2.700 more per year to reach the same utility as the heat pump alternative. The car sharing alternative would even have to save CHF 44.500/year. The average Swiss household income

Table 3.2: Alternative Specific Constants (ASC) in CHF/year

	Basic model				Advanced model			
Alternative	**ASC**	**β-SAV**	**ASC_{CHF}**	**ASC^{rel}_{CHF}**	**ASC**	**β-SAV**	**ASC_{CHF}**	**ASC^{rel}_{CHF}**
Insulation	-1.87	0.25	-7,571	-2,731	-4.86	0.22	-22,324	-11,561
Heat pump	-1.21	0.25	-4,840	0	-3.28	0.30	-10,764	0
New car	-1.59	0.22	-7,260	-2,420	-4.39	0.23	-19,087	-8,323
Car sharing	-4.56	0.09	-49,351	-44,511	-7.32	0.10	-71,765	-61,001

was CHF 108.000/year in 2008 (Swiss Federal Statistical Office (BFS), 2008). For the two house alternatives, the investment equivalent can also be calculated as ASC_{CHF} = ASC / β_{INV} which gives the values CHF 61.700 for insulation and 26.400 for the heat pump. Therefore, in this model the insulation alternative is seen less favourable than the heat pump alternative, because it would cost CHF 35.300 more.

Comparing the "car" alternatives with the "house" alternatives confirms an expected difference between the two domains: While the dominant "house" variables were the investment sum and the savings, for the "car" alternatives the investment sum had no influence and the expected savings only mattered for the option of buying a new car. However, the price of gasoline had a much greater influence than the expected financial savings. The 95% quantile of savings is CHF $5.7 \cdot 10^3$, which gives a utility of 1.25. The utility from the highest value for the price of gasoline is $5.5 \cdot 0.51 = 2.8$. That means that the respondents oriented their decision for a more efficient car more on the gasoline price visible at the gas station than on the overall financial consequences. This is a very interesting finding that should be considered in policy making, because it suggests that changes in car fleets may be achieved (and estimated) more easily than expected (see also section 3.3.3). The decision to sell the car, reduce one's annual mileage and switch to car sharing was even more determined by the price of gasoline than by the overall financial consequences.

The price of heating fuel also had a significant impact on decisions to renovate as compared to the expected savings and the investment sum. This finding implies that in the case of investments in the house involving large sums of money, people are influenced equally by the communicated prices and the real financial consequences. However, this result must be interpreted with caution. The effect could also have come from the high complexity of the task in the SP experiments, which may have made people more likely to consider only one figure (the price of fuel) rather than two or more (the investment sum and the expected savings), although the rough consistency in the payback period does not suggest this interpretation.

Another interesting finding was the influence of CO_2 output reduction, which is indicative of the respondents' general attitude of consideration for the environment. It shows that for all alternatives besides insulation, the reduction of CO_2 had the most significant and greatest impact on decisions. This suggests that current communication and marketing strategies to promote energy efficiency which point out benefits for the environment (e.g., CO_2 reduction) are justified by having the desired effect. It is important to note that the goodness of fit (adjusted $\rho^2 = 0.18$) is low. Given the complexity of the task and the fact that a trade-off between the two sectors, as required in the SP, is something new for most people who have no experience in this kind of decision-making, we consider it to be acceptable.

3.3.2 Advanced Model

The estimation results of the advanced model, consisting of a modified basic model plus various other socioeconomic and house or car specific variables, are shown in 3.3 and 3.4.

The parameters adopted from the basic model did not change substantially and were also equally significant. The ASC became more negative as a result of the additive utility from the socio-economic variables. The relative pattern remained the same, however, as shown in table 3.2. The main socio-economic variables, income and assets, were implemented differently in this model. While income had a fair influence on the respondents' perception of the investment sum and the fuel price, assets had a linear effect on all alternatives involving investment. Higher asset levels led to a greater likelihood to invest, as expected. The home-owner's age was not included in the model because it was not found to be significant, even when different age groups were used.

The directly estimated payback period included income effects by the λ parameter on investment. While the payback period for a heat pump was independent of assets, a significant pay back period for the insulation alternative was only estimated for people with assets exceeding CHF 150.000 (AG3). Asset Group (AG) 1 included assets up to CHF 70.000, and AG2 included those between CHF 70.000 and CHF 150.000. The decision to retrofit the house depended on whether home-owners could afford to finance it by themselves. People were more likely to take out a loan or increase their mortgage for a heat pump than for retrofitting.

Table 3.3: Parameters of the advanced model, part 1

	MNL		**Mixed Logit**	
Parameter	**Estimate**	**T-value**	**Estimate**	**T-value**
ASC				
Insulation	**-4.86**	**-7.90**	**-6.99**	**-4.87**
σ -Insulation			**1.72**	**6.68**
Heat pump	**-3.28**	**-6.16**	**-3.65**	**-2.55**
σ -Heat pump			**1.89**	**-6.5**
New car	**-4.39**	**-10.08**	**-5.91**	**-4.59**
σ -New car			**1.66**	**6.44**
Car sharing	**-7.32**	**-11.33**	**-11.20**	**-4.69**
σ -Car sharing			**3.44**	**7.18**
β - Investment [in CHF 10^3]				
Insulation	**-0.03**	**-7.18**	**-0.05**	**-7.18**
Heat pump	**-0.04**	**-6.29**	**-0.07**	**-5.66**
λ - Income on investment				
Insulation	*0.44*	*1.84*	*0.33*	*1.36*
Heat pump	**0.34**	**2.09**	**0.33**	**1.49**
PBP - payback periode [years]				
Insulation AG 1	*-5.38*	*-1.62*		
Insulation AG 2	-3.19	-1.07		
Insulation AG 3	**-6.51**	**-2.43**		
Insulation			-2.81	-0.51
σ -Insulation			*8.89*	*1.63*
Heat pump	**-6.91**	**-2.58**	**-9.67**	**-2.33**
σ -Heat pump			**5.54**	**2.52**
β - Savings [in CHF 10^3 / y]				
New car	**0.23**	**2.36**	**0.40**	**2.38**
σ -New car			**0.30**	**2.71**
Car sharing	0.10	0.95	-0.12	-0.50
σ -Car sharing			**0.36**	**4.60**
β - Asset [in 10^4]				
Insulation	**0.04**	**2.04**	0.04	1.20
Heat pump	**0.03**	**2.48**	0.01	0.16
New car	**0.03**	**2.69**	0.00	0.10
β - CO_2 reduction				
Insulation	**0.37**	**5.10**	**0.46**	**3.24**
Heat pump	**0.30**	**2.99**	**0.36**	**1.91**
New car	-0.01	-0.04	0.07	0.24
Car sharing	-0.11	-0.55	0.15	0.37
β - Wood heating				
Insulation	**1.13**	**3.97**	**1.39**	**2.01**
Heat pump	**-0.89**	**-2.07**	-0.77	-0.75

Table 3.4: Parameters of the advanced model, part 2

	MNL		Mixed Logit	
Parameter	**Estimate**	**T-Value**	**Estimate**	**T-Value**
β - Energy Price [in CHF/100 kWh]				
Insulation	**0.10**	**7.77**	**0.13**	**5.85**
Heat pump	**0.08**	**6.60**	**0.09**	**3.37**
β - Gasoline price [in CHF/l]				
New car	**0.59**	**6.38**	**0.73**	**4.85**
Car sharing	**1.16**	**9.88**	**1.90**	**7.52**
λ - Income on fuel price				
Insulation	**0.48**	**3.82**	**0.45**	**2.36**
Heat pump	**0.71**	**3.91**	**0.85**	**2.13**
New car	**0.32**	**2.77**	0.31	1.39
Car sharing	0.00	-0.10	0.05	0.48
β - Higher education				
Insulation	-0.30	*-1.65*	-0.59	-0.93
Heat pump	**-0.44**	**-2.69**	**-0.91**	**-1.96**
New car	**-0.66**	**-4.41**	**-0.78**	**-1.88**
Car sharing	**-0.54**	**-2.73**	**-1.08**	**-1.33**
β - University degree				
Insulation	**-0.81**	**-2.83**	-0.91	-1.11
Heat pump	**-1.35**	**-5.49**	**-1.97**	**-2.18**
New car	**-0.90**	**-4.13**	**-1.11**	**-1.86**
Car sharing	**-0.76**	**-2.65**	-2.33	-0.97
β - Age car				
New car	0.02	**2.43**	0.02	1.13
Car sharing	0.02	**2.19**	0.00	-0.04
β - Big engine car				
New car	0.22	**1.81**	*0.77*	*1.80*
Car sharing	-0.03	**-0.18**	-0.31	-0.19
β - Good facade ins.				
Insulation	**-0.62**	**-3.82**	**-0.76**	**-1.88**
Heat pump	-0.04	-0.33	-0.12	-0.24
β - Good roof ins.				
Insulation	-0.25	-1.55	-0.41	-0.94
Heat pump	-0.03	-0.20	0.43	0.79
β -Environmentally friendly				
Insulation	**0.24**	**6.61**	**0.40**	**4.12**
Heat pump	**0.18**	**5.86**	*0.20*	*1.87*
New car	**0.22**	**7.70**	**0.28**	**2.83**
Car sharing	**0.24**	**5.67**	**0.24**	**1.45**
Adjusted ρ^2	**0.31**			
Number of observations	**2’278**			

The λ-parameters show that the effects of investment and fuel price were indeed dependent on income level. All λ-parameters were positive and fluctuated between 0 and 1 (with a decreasing marginal utility of income). Positive effects on the necessary investment indicate that more affluent households were more price sensitive in that the required investment sum decreased in utility more for them than it did for less affluent ones. This finding is contrary to what was expected. In the case of fuel price, the positive λ parameter indicates that people with a higher income were even more determined to invest when fuel prices were high. In other words, they based their decision to invest more on the fuel price (instead of on savings) than did people with a lower income. Thus, people with a higher income were less price sensitive, which contradicts the above statement. How these two effects worked together is shown in section 3.3.3.

The parameters for the dummy variables for higher education (tertiary education, non-university) or a university degree (= Master's) offer interesting insights. A high level of education had a significantly negative influence on decisions pertaining to all energy efficiency measures. This is somewhat surprising and contradicts the common assumption that more educated persons tend to be more environmentally friendly. One explanation could be that people with higher education are more sensitive to financial investments and hesitate to invest in energy efficiency measures that have low monetary benefits. Well-educated people perceive a renovation or a heat pump more as an investment than as the purchase of a consumer good. Hence, the more a measure is an investment, the more likely it will be subjected to economic scrutiny about how well it will pay off. Better educated people also tend to have greater access to information about other investment opportunities with potentially better returns. They might therefore study the SP experiments and choose their investments more carefully. In short, higher educated persons do more math, as one would expect.

All other given variables had relatively little influence in the model, including the age of the car. Even if a car was 20 years old, the alternative of saving energy by purchasing a new, more efficient car contributed only 0.4 points to utility. The condition of a house's facade and roof (as given by the respondents) had a negative impact on the probability of insulating the house, as shown by the two dummy variables for a good condition. This is not only logical and understandable, but also quite useful for the overall energy model, despite the fact that it did not include the real existing condition but rather an assessment by the owner. Also useful and not surprising is that the presence of wood heating had a strong negative influence on the heat pump alternative, since wood heating is already CO_2 neutral and fossil-fuel independent (though not energy efficient). However, the positive influence on the willingness to insulate is surprising.

In the model we also included an index for environmental friendliness derived from attitudinal questions. In their answers the participants could valuate how much they agreed with certain statements on a scale of 1 ("do not agree at all") to 5 ("totally agree"). The questions for the index were: "Energy consumption in Switzerland is too high", "Climate change is a major problem for humanity" and "Although Switzerland is a small country, it can contribute to global environmental protection". People who agreed with those statements were more likely to choose any of the alternatives. Participants who strongly agreed with all three statements had an index of 15 and a contribution to utility (compared to a person who strongly disagreed) of between 2.2 and 2.9, which is in the same order of magnitude as the price of fuel or the investment sum.

Nested MNL models were tested, but no significant nests were found. We tried the nests "house" and "car" as well as the nests "investment" and "behavioral change".

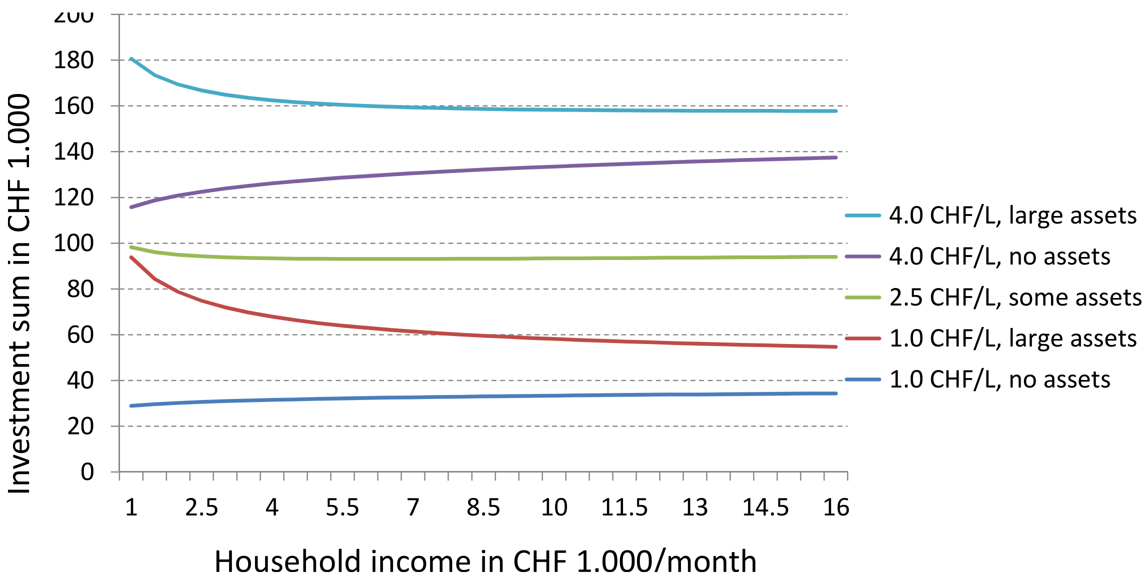
3.3.3 Utility Trade-Offs

In this section utility trade-offs are analysed to provide a deeper insight into how the parameters interacted with each other and to make the interpretation more understandable. For this purpose iso-curves were plotted for the first three alternatives, as shown in figures 3.1, 3.2 and 3.3. The iso-curves define all points with the same utility, assuming that all other variables are equal. The formula for the two house alternatives is therefore:

$$0 = \beta_{Inv_i} \cdot \left(\frac{Inc}{\overline{Inc}}\right)^{\lambda_{inv_i}} \cdot Inv_i + \beta_{Fuelprice_i} \cdot \left(\frac{Inc}{\overline{Inc}}\right)^{\lambda_{fp_i}} \cdot Fuelprice + \beta_{Ass_i} \cdot Assets_i \tag{3.5}$$

which essentially shows the trade-off between the price of fuel and the investment sum as a function of household income and available assets. The curves on the figures are labeled with equivalent oil prices, but are true for all fuels. To illustrate, if in figure 3.2 a household had an income of CHF 3.500/month, a fuel price equivalent of CHF 4.0/l of heating oil compensated an investment sum of about CHF 70.000. For households with a very high income (CHF 16.000+ /month), the same fuel

Figure 3.1: Utility trade-off for the "Insulation" alternative: isocurve as a function of oil price, income, assets and investment

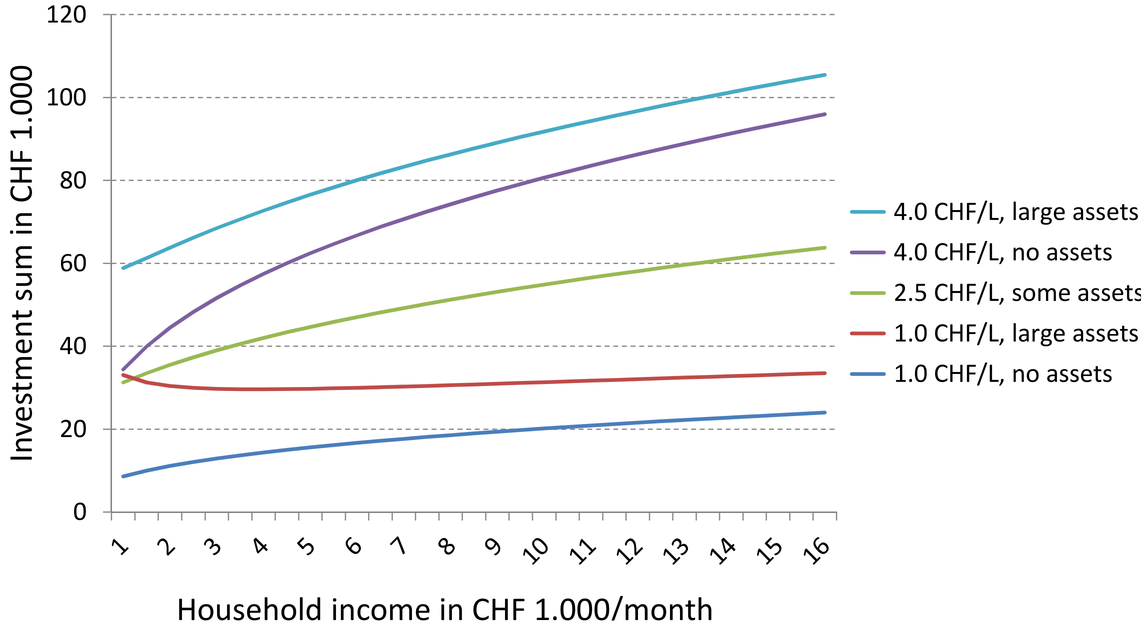


price equaled over CHF 100.000. As expected, higher fuel prices could compensate utility losses for higher investment sums: The higher the fuel price, the higher the investments the participants were willing to make (note that the influence of the financial savings is already captured in the model). In the case of the "insulation" alternative (figure 3.1), the income effects on the fuel price and the investment sum almost neutralized each other for all households except those with a very low income level. When iso-curves with the same fuel prices are compared, it becomes evident that people with greater assets were willing to invest significantly higher sums.

However, the decision to invest in a heat pump was much more dependent on the income level, as seen in figure 3.2. The non-price-sensitivity effect that income had on fuel prices overruled the price sensitivity of the investment sum in virtually all cases. Especially in the case of high fuel prices, more affluent households were much more willing to invest than we had expected. This indicates that households with a higher income based their decisions more on the fuel price, whereas poorer families calculated more carefully and gave more consideration to the actual savings.

In the case of the "new car" alternative, not the necessary investment

Figure 3.2: Utility trade-off for the "Heat pump" alternative: isocurve as a function of oil price, income, assets and investment

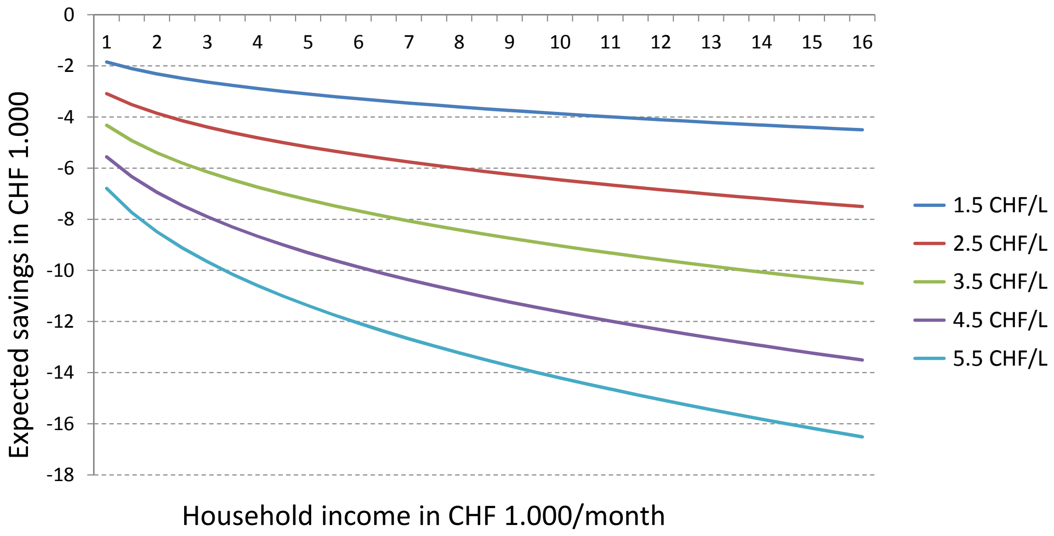


was relevant, but rather the expected savings, as given in the trade-off formula:

$$0 = \beta_{Sav_i} \cdot Sav_i + \beta_{Fuelprice_i} \cdot \left(\frac{Inc}{\overline{Inc}}\right)^{\lambda_{fp_i}} \cdot Fuelprice \tag{3.6}$$

Both the expected savings and the fuel price had a positive effect on utility, which is why the expected savings were negative in figure 3.3. This shows how little savings could be compensated by high fuel prices with regard to utility. A perfectly rational *homo oeconomicus* would only consider the expected savings and would not be psychologically influenced by the fuel price level. However, the model clearly shows that fuel prices had a strong impact which was substantially greater for higher income households. In the case of really high gasoline prices (CHF 5.5 per liter equals USD 27 per gallon as of July 2011), rich households (CHF 16.000/month) would need almost CHF 7.000 less in savings than poor households (CHF 3.0000/month). In simpler terms: Rich people would buy new, more efficient cars during times of high fuel prices anyway, without looking at the actual figures.

Figure 3.3: Utility trade-off for the "More efficient car" alternative: isocurve as a function of gasoline price, income and savings



3.4 Discussion

3.4.1 Conclusion

Establishing a decision model for investments in energy efficiency in the case of unprecedented fuel prices and for two such different energy sectors was difficult, given that revealed preference data about the subject is non-existent. The stated preference data collected in the survey can compensate for this lack, but the problem of making rather complex and unfamiliar decisions between two different energy sectors remains. The aim of the estimated model was to predict in which financial conditions home-owners were willing to invest in energy efficiency and to account for trade-offs between housing and transportation. It could quantify the expected payback period for energy investments as well as for general preferences between different measures. A very interesting finding is the role of the income level as well as the available assets of the households. That the mortgage level had no significant impact is another interesting finding, suggesting that financing energy efficiency is a secondary problem. This does not mean that all households have enough available liquid assets, but that a great majority of households are not limited by the size of their mortgage and would therefore be able to finance such investments with a mortgage increase.

The issue of whether people look at energy consumption as one budget or divide it into separate budgets for different sectors could not be conclusively answered with this model. However, the fact that decisions were mainly influenced by the fuel price and the expected savings points in the direction of separate budgets. Heads of household try to optimize the costs of both sectors and choose the alternatives with the best returns on investment. But an opposite argument can be made: The fact that the alternative "sell car" was very unpopular, rarely chosen and not dependent on the expected savings indicates that people do make trade-offs as long as they can still keep their car. But as the "new car" alternative was always available and a trade-off within the sector was possible, this question cannot be answered by the presented model.

Although the initial intention was to gain more insight about the question of separate or joined energy budget, one important thing we learned is, that it is very difficult to ask (also implicitly) people a question, when the underlying conceptual framework of that said question is not understood by the people questioned. The concept of energy as being a budget that needs to be optimized may very well be concept that is very convenient for economists or sociologists, but has no representation in the decision process of normal people. In that case, finding behavioural patterns of people is impossible if that behaviour does not exist.

The results of the methodology applied is not able to answer the question of one single or two separate budgets, as it also fails to rigorously proof the existence of energy budgets in household's decision processes in general.

3.4.2 Outlook

To gain more information on the question of trade-offs between energy sectors, a next SP experiment would need to focus more specifically on the trade-off situation between the alternatives of giving up the car or saving energy through investments in the home. It would be very interesting to pinpoint the threshold at which households start to give up a lifestyle choice such as car ownership and to find out what they are willing to trade it for.

Chapter 4

A Multiple Discrete-Continuous Extreme Value Model (MDCEV) for Total Household Energy Consumption

The content of this chapter was originally published in Jäggi et al. (2012a).

4.1 Introduction

4.1.1 Context

Household decisions to reduce energy consumption in the long term by investing in housing infrastructure or more efficient cars are modelled in chapter 3, using the data from the Stated Preference experiments. The model in this chapter uses data from the same survey, but from the Priority Evaluator part. It is about households hypothetical decisions how to reduce overall GHG emissions (or energy consumption) across all sectors when forced to do so. To understand whether and how energy consumption and GHG emissions of different sectors are perceived and weighted against each other, the hypothetical situation of a severe, forced reduction in emissions was assumed. Although such a coercion is unrealistic for Switzerland at the moment, future economic and political development or a dramatic reduction in energy supply could make measures of the sort necessary. In any case, the assumed setting gives the possibility to gain insight in the decision making process of energy savings and may contribute to smarter policy design based on voluntary measures and incentives. That would be assuming a home-owner is aware of the negative effects of disproportionate energy consumption and wants to contribute his share in a optimal way across all sectors, or he/she receives information, encouragement and incentives from local authorities for the reduction of overall energy consumption instead of specific subsidies.

The data used for this model is described in chapter 2, more specifically in sections 2.1.2.2, 2.1.3.6 and 2.1.4.2.

4.1.2 Literature

Banfi et al. (2008) estimated the willingness to pay for different refurbishment measures using stated choice experiments for home owners as well as apartment tenants. The study showed a significant willingness to pay (WTP). In a similar survey by Achtnicht (2010) home owners were asked to choose between insulation or a modern heating system in a series of stated choice experiments. Younger respondents showed higher preferences towards alternative heating systems instead of insulation. A similar preference of heating system replacement over insulation (façade and roof) in Germany was found by Grösche and Vance (2009). A survey among 509 Korean households conducted by Kwak et al. (2009) showed significant WTP for energy efficiency measures in the case of a purchase of a new house. An early study about acceptance of alternative-fuel vehicles was done by (Ewing and Sarigöllü, 2000) and found that younger and high income participants are the most concerned about energy efficiency and in the case of equal performance alternative-fuel vehicles are generally preferred over gasoline cars. Similar results come from Germany where Achtnicht (2009) found that emissions have a negative influence on car choice in general and particularly for younger and female individuals. Müller and de Haan (2009) established a sophisticated consumer choice model to asses how incentives on more efficient cars affect car purchase. With this model, de Haan et al. (2009) state abatement costs through incentives to be between 6 and 13 EUR per ton CO_2.

These previous studies neglected a trade off or a relationship between energy consumption of both sectors, housing and private transport. Our study does not aim at estimating WTP for different energy efficiency measures, but to find out how an overall energy consumption approach in behavioural modelling could look like. The goal was to survey and model the behaviour that includes all possible alternatives of reducing energy consumption a household has, including all sectors. Such a model can give information about if and how households view their energy consumption: as one combined budget for energy or separate independent budget for each sector. If a combined budget is the reality, more flexible and specific policy measures can be thought of for different regions, purposes or economies. Such an overall approach that explicitly focuses on trade-offs between sectors has not been reported in the literature so far.

4.2 Methodology

4.2.1 Behavioural Framework

To understand the choices and preferences regarding CO_2 reduction within a restricted budget, the household is the basic decision-making unit where these decisions can be explicitly observed. The choice made by each household consists of a discrete and a continuous component. The discrete component relates to the alternatives selected to reduce either heating costs or variable mobility costs, whereas the continuous component relates to the amount of CO_2 the households choose to reduce. Further, given the nature of the survey, households can choose one or more alternatives. The MDCEV relies on satiation as a force to explain multiple-discreteness, where satiation refers to diminishing marginal utility as the level of consumption of any particular alternative increases. In our application, satiation plays a strong role on the choice process, because households face increasing marginal costs and marginal utility losses when reducing CO_2 output. The first 1.000 km a household chooses not to drive are much easier to endure, compared to having reduced vehicle miles travelled (VMT) already by 50% and still considering a reduction.

The model structure used in the research effort is based on the MDCEV approach (Bhat, 2008), derived from the traditional random utility maximizing theory of consumer behaviour. The MDCEV, being a discrete-continuous model, enables the seamless integration of the discrete and continuous components, besides capturing multiple discreteness. Additionally, this model provides an elegant closed form probability and a clear interpretation of the estimated parameters. This approach is superior to multinomial models as it enables exploiting quantity information for inference (the continuous component), and facilitates policy analysis by being based on a utility function. The model is also superior to approaches that treat each alternative-quantity combination as a choice alternative, as it does not introduce new random utility errors terms into consumer preferences for each potential combination.

4.2.2 Model Specification

The MDCEV model (Bhat, 2008) is based on utility maximization theory, assuming that each household tries to maximize their utility, which is a measure of satisfaction, by selecting various quantities of CO_2 reduction among the available alternatives. The utility function U for each household is:

$$U(x) = \sum_{k=1}^{K} \frac{\gamma_k}{\alpha_k} \psi_k \left(\left(\frac{x_k}{\gamma_k} + 1 \right)^{\alpha_k} - 1 \right) \tag{4.1}$$

where x ≥ 0 is the amount of CO_2 reduced associated with alternative k (vector of dimension $(Kx1)$), measured in tons per year, α_k and γ_k are parameters and ψ_k is the baseline utility associated with alternative k. The utility function belongs to the family of translated utility functions. α_k is the satiation parameter, reducing the marginal utility with increasing CO_2 reduction of alternative k. The utility function in equation (1) is valid for $\alpha \leq 1$: the limit case when $\alpha = 1$ for all alternatives represents absence of satiation effects, and when α moves downward from the value of 1, the satiation effect for alternative k increases ($\alpha \to -\infty$ represents the case of immediate full-satiation). The primary role of the γ_k, called location parameter, is to allow for corner solutions (i.e., zero CO_2 reduction for some alternatives) and it is also related with satiation effects. The location parameter is defined $\gamma_k \geq 0$, such that when its value increases, there is a stronger preference (or lower satiation) for alternative k. Finally, ψ_k is named baseline utility function, and it represents the marginal utility of one ton of CO_2 reduction of alternative k at the point of zero consumption for the alternative. To guarantee the positivity of the baseline utility, we parametrize $\psi(z_k, \epsilon_k) = \exp(\beta' z_k + \epsilon_k)$, where z_k is a set of attributes that characterize alternative k and the households (including a constant), β is a vector of parameters influencing baseline utility, and ϵ_k captures the idiosyncratic (unobserved) characteristics that impact the baseline utility of good k.

The utility function is maximized by each household, subject to the reduction target imposed by the survey design, $\sum_{k=1}^{K} x_k = CO_2^{target}$. To find the optimal CO_2 reduction allocation x_k^*, we construct the Lagrangian assuming that alternative 1 is always chosen, and derive the Khun-Tucker (KT) conditions presented in equation (2) (see Bhat (2008)).

$$\begin{aligned} V_k + \epsilon_k &= V_1 + \epsilon_1, if x_k^* > 0, k = 2, 3, ..., K \\ V_k + \epsilon_k &< V_1 + \epsilon_1, if x_k^* = 0, k = 2, 3, ..., K \end{aligned} \tag{4.2}$$

where $V_k = \beta' z - k + (\alpha - 1) \ln \left(\frac{x_k^*}{\gamma}_k + 1 \right)$. These stochastic KT conditions can be used to write the joint probability expression of consumption patterns if the density function of the stochastic terms is known. Following Bhat (2008), we assume that the error terms are assumed to follow an independent and identically distributed (iid) and standard Gumbel distribution. The probability that the household choose M of the K alternatives is given by an elegant and compact closed form structure:

$$P(x_2^*, x_3^*, ..., x_M^*, 0, 0, ..., 0) = \left[\prod_{i=1}^{M} c_i \right] \left[\prod_{i=1}^{M} \frac{1}{c_j} \right] \left[\frac{\prod_{i=1}^{M} e^{V_i}}{(\sum_{j=1}^{K} e^{V_i})^M} \right] (M-1)! \tag{4.3}$$

where $c_i = \frac{1-\alpha_i}{x_i^* + \gamma_i}$. In the case when $M = 1$ for a particular household, the model in equation (3) collapses to the standard multinomial logit structure. The model can be estimated using standard maximum likelihood procedures.

4.3 Results

This section presents detailed description of the model estimation results. A variety of explanatory variables were considered in the model specification including head of the household and household socio-demographics, house characteristics, accessibility of the house and alternatives costs. The final specification was based on a systematic process of removing statistically insignificant variables and combining levels when their effects were not significantly different. A number of alternative model forms were explored and it was found that the data fit was superior for the gamma profile (Bhat, 2008), a specification in which the values of α_k are set to zero for all alternatives. The final specification obtained after this procedure is presented in table 4.1 (Refurbishment Alternatives) and table 4.2 (Lifestyle Changes); in general, the model is found to offer plausible behavioural interpretations across a wide range of explanatory variables. In the next section, the estimation results are discussed in detail, and in the then following section, the model performance is analysed. Most parameters are dummy variables, unless its mentioned explicitly as linear or the unit is specified. ASC means alternative specific constant.

In the context of head of the household characteristics, it is found that households with older individuals are less inclined install solar panels, automated ventilation and heat pumps. In particular, individuals aged over 75 years are less likely to reduce their CO_2 emissions via house refurbishment. This result is consistent with comments made during the interviews, who stated they were "too old to make major changes to the house" (Jäggi and Axhausen, 2010); in fact, Poortinga et al. (2003) also concluded that younger participants find home alternatives more acceptable than older participants. Also, households with older individuals are likely to buy CO_2 certificates and more likely to reduce their meat consumption. Households where the head is a female, compared to men, are inclined to reach the CO_2 target by installing automated ventilation systems. The highest education level of the head of the household impacts the household choices. Households where the head has a Master degree are less likely to replace windows, but more likely to buy a certificate (because CO_2 certificates are an "abstract" option, people with higher levels of education may be more inclined to choose that alternative), and when the head of the household has a Bachelor degree, households are more likely to replace windows; this result is consistent with the finding of Achtnicht (2009), who concluded that individuals, that are better educated are more likely to choose insulation alternatives than heating technologies (in our case, heat pumps). When the head of the household is an employed worker, they have a smaller probability to install a heat pump, but are more likely to reduce their air trips. This last finding is consistent with the notion that workers have less available time than non-workers, because they are constrained by their work schedule, and therefore prefer to keep their current number of flights per year in order to save time. As expected, people who declared to have the household car always available, are less likely to reduce their mileage compared to people whose cars are not always accessible. Finally, workers whose workplace is located far from home (more than 35 km away) tend to choose more often the reduction of travelled distance. A plausible explanation of these results is that individuals who have to travel every day long distances to work spend a considerable amount of time travelling; thus, they are willing to travel less. Among household characteristics, income has important consequences for the choice and amount of CO_2 reductions undertaken by the households. If the income is larger than CHF 16.000 /month, households are more likely to install automated ventilation

Table 4.1: Estimation results, house refurbishment alternatives

Variable	Repl. windows		Refurb. roof		Inst. solar panels		Refurb. fac.		Aut. ventilation		Heat pump	
	β-par	**t-stat.**	**β-par**	**t-stat.**	**β-par**	**t-stat.**	**β-par**	**t-stat.**	**β-par**	**t-stat.**	**β-par**	**t-stat.**
ASC			-2.26	-3.07	0.16	0.21	-1.78	-2.14	-0.62	-0.49	-0.09	-0.08
Satiation γ	0.09	4.75	0.13	4.67	0.08	5.80	0.30	3.62	0.12	2.92	0.34	5.05
Household (head)												
Age [years]					-0.02	-2.22			-0.03	-1.38	-0.03	-2.31
Aged > 75 y	-0.46	-1.48	-0.46	-1.48	-0.46	-1.48	-0.46	-1.48	-0.46	-1.48	-0.46	-1.48
Female									-1.09	-1.41		
Masters degree	0.57	1.51										
Bachelor	-0.81	-2.10										
Worker											-0.88	-2.82
Inc. > 16k CHF									0.75	1.54	0.81	2.16
Inc. 10k-16k CHF											0.65	2.23
Number of adults			0.30	1.81			0.52	2.75				
Number of children											-0.40	-2.51
1 Person HH					-1.97	-1.91						
House												
Age house [years]			0.01	2.98					-0.02	-1.98		
House > 200 years			-4.61	-2.61							-1.22	-1.93
Size [m^2]							-0.01	-2.27				
House > 250 m^2									1.21	1.72		
Row house							-0.56	-1.21				
Heating fuel												
Oil	-0.89	-1.73			0.39	1.62					1.06	3.82
Nat. gas	-1.42	-2.51										
Electric	-1.13	-1.69									1.26	3.13
Ins. value > 90k CHF					-0.64	-1.69	0.74	1.62				
Reason for renovation												
Only energy savings									-2.05	-1.96	0.57	2.23
Current condition												
Good roof			-0.69	-2.21								
Good facade							-0.81	-2.22				
Costs												
Rel. ren. costs > 0.8	-0.21	-1.33	-0.21	-1.33	-0.21	-1.33	-0.21	-1.33	-0.21	-1.33		
ASC			-2.26	-3.07	0.16	0.21	-1.78	-2.14	-0.62	-0.49	-0.09	-0.08
Sat. par. γ	0.09	4.75	0.13	4.67	0.08	5.80	0.30	3.62	0.12	2.92	0.34	5.05

Table 4.2: Estimation results, lifestyle changes, transportation & non transportation

Variable	**More efficient car**		**Reduce VMT**		**Reduce air trips**		**Reduce temp.**		**Buy certificate**		**Reduce meat cons.**	
	β-par	**t-stat.**	**β-par**	**t-stat.**	**β-par**	**t-stat.**	**β-par**	**t-stat.**	**β-par**	**t-stat.**	**β-par**	**t-stat.**
ASC	-1.65	-3.25	-1.39	-2.29	-2.15	-2.95	-1.77	-3.20	0.41	0.43	-5.82	-3.65
Satiation γ	0.18	5.27	0.12	5.81	0.17	5.04	0.02	6.28	0.30	3.46	0.06	4.28
Household (Head)												
Age [years]									-0.06	-3.62	0.05	2.23
Masters degree									0.91	2.27		
Inc. > 16k CHF	0.52	1.94			0.71	2.38					0.80	2.22
Number of adults					0.36	2.22					0.32	1.76
Number of children											0.39	1.70
Head is female + child	1.27	3.39					1.25	3.51				
1 Person HH			0.80	1.79								
2 Persons HH			0.57	2.48							-1.42	-2.89
Heating duel												
Oil							0.62	1.84				
Nat. gas							0.76	2.12				
Public transp. acc.												
linear			-0.75	-1.65	-0.98	-1.90						
Private transp acc.												
linear			2.48	2.15	3.38	2.48						
Acc. > 0.8			-1.27	-1.49	-2.33	-2.11						
Costs												
Carbon costs new car	-0.06	-1.52										

systems and heat pumps (which, among house refurbishment alternatives, are two of the most expensive ones), to buy new/more efficient car (which also is an expensive alternative), to reduce air trips and meat consumption.

Poortinga et al. (2003) concluded too that, when asked about energy-saving scenarios, participants with a higher average income find alternatives more acceptable than participants with low incomes. When the household earns between CHF 10.000 and 16.000/month its more likely to reduce their CO_2 output by installing a heat pump, although the effect is smaller than for households whose income is larger than CHF 16.000 /month. Regarding household composition, when the number of adults increases, the household is more likely to refurbish roof and facades, reduce the number of air trips and the meat consumption. The number of children in the house (defined as people aged less than 19 years old) decreases the chances to install a heat pump, but increases the probability of reducing meat consumption. This last result was unexpected, as we anticipated that households would not limit the amount of meat given to the children based on nutritional concerns. More research on the relationship between meat consumption and households-with-children based preferences might shed more light on this issue. It was also found that when the head of the household is a female and there are children in the house, the preferences change: these households are inclined to buy new/more efficient cars (similarly, Achtnicht (2009) confirmed that women assess the emission variable more negatively than men do) and to reduce the house temperature. Regarding the number of persons in the household (without distinguish between adults and children), it was found that when the household consists of less than three persons, it is more likely to travel less. Kenny and Gray (2009), surveying households emissions, found that single and two person households travel the most; therefore, we can think that these households perform more non-mandatory trips, allowing them to easily reduce their traveled distance). Also, single-individual's households are less likely to install solar panels.

Poortinga et al. (2003), had a similar conclusion, as single participants found home alternatives less acceptable than couples and families), while households with two persons are less inclined to reduce their meat consumption. Several preference differences were found regarding the house characteristics. Among the characteristics that have a significant effect on the households CO_2 reductions are age and size of the house, type of the house (row house compared to detached, double and end-of-the-row houses), heating fuel, large insurance value (more than CHF 90.000) and mortgage, reason for renovation (seven ordinal levels, from only comfort to only energy savings) and condition of the roof and facades (good or bad, according to the respondent's perception). The accessibility of the municipality the house is located in has the expected effects on the transportation-related alternatives. Accessibility measures, defined in section 5.3.1, were standardized between 0 and 1 to reduce its variance. As result, the estimates show that people living in houses with good public transportation are less likely to reduce their travelled distance or flight trips. We believe that this effect is produced by the perception of high mobility, which discourages individuals to reduce the CO_2 emission via travelling less. On the other hand, people living in houses with good private transportation are more likely to reduce their travelled distance or flight trips, an effect that is reversed when the accessibility is very high (more than 0.8, which correspond to the houses with accessibility equal or larger than 80% of the highest accessibility in the sample).

Finally, it was found that the relative costs of house renovation (excluding the alternative install a heat pump) and the potential carbon cost of new/more efficient vehicles affects the probability of choosing the corresponding alternatives. In particular, when the potential carbon cost increases in one unit, households are less likely to buy new/more efficient vehicles. When the relative costs of house renovation are greater than 0.8 (that is, the cost of the renovation is very close to the household assets), households are less inclined to make any type of house refurbishment.

4.4 Discussion

The presented model studied household preferences for different energy saving alternatives, based on priority evaluator data. Alternatives included house refurbishment options and life-style changes. Specific information regarding socio-economic characteristics of the household, house characteristics and accessibility measures were part of the survey. Because households were asked to reach a energy reduction target, measured in CO_2 emissions per year, and they could chose several alternatives simultaneously, the multiple-discrete continuous extreme value model MDCEV (Bhat, 2008) was selected to model the household preferences.

The model presented is based on a unique data set. The tasks of the survey were not only fairly complex, but contained unusual questions. In the survey respondents had to treat all different kinds of CO_2 output together as one budget silo and make trade-offs between very different sectors. People or households have in most (if not all) cases have no experience of such choices. This partly explains the relatively poor model fit. People are very used to be forced to distribute a fixed budget of for example time (24h) into predefined activities. CO_2 output reduction however most households do not regard as something they make decisions about and is therefore an externality. And the concept of a fixed budget of CO_2 is even less common. A second problem for the model arises from the PE survey design, which was optimized to reproduce reality through extended personalization: in reality a household cannot choose the amount of CO_2 emissions it wants to reduce with each measure, because that is determined by technology.

However, one must keep in mind, that the survey as described in section 2.1 was not designed to get an optimal model fit or to estimate a precise willingness-to-pay for investments in energy efficiency, but to test whether households consider their energy consumption as one budget silo or distinct between separate silos. The more general question was if and how this can be tested and what a good approach would look like.

The conclusions from this work are that it is very hard to get information about the decision process in a situation as it is presented in the chapter. The choices we tried to model have proven to be very emotional and personal. As costs did not change in the experiments and comfort levels are given by reality, the real underlying relevant attributes could hardly be observed as they are personal and individually different. The emotional costs and implications of a major refurbishment can differ a lot and be dependent on inheritance, location, family issues, other renovation plans, individual conditions, etc. Not to forget that the house itself has an emotional value for many home owners. The same is true for a reduction of miles travelled (air and road) which has specific ramifications for specific situations. Just the replacement of the car with a more efficient one can be viewed as emotionally neutral. But today a more efficient car still implicates a loss of status or comfort in many cases. The combination of emotional different sectors gives even more unobservable preferences in this case. The conclusion is that a household's choice, on which lifestyle aspect is to change to save energy, is largely independent from socio-economic and other observable variables. Also, a quantification of trade-off behaviour could not be achieved. A design that focuses more on the influence of specific attributes would probably give more significant parameters and a better model fit, but would have to rely on more hypothetical questions and we would not know how important these parameters are compared to unobservable attributes.

The difficulty to establish a model with highly significant parameters and a good simulation performance from the data set shows us that the hypothesis of one overall energy budget can be rejected. Despite sophisticated modelling efforts consistent trade-off behaviour could not be found whenh using the available explanatory variables. If trade-offs exist in this field they are either determined by attributes we were not able to quantify or they are negligible compared to other influences regarding house refurbishment and lifestyle changes.

Further research includes the use of more sophisticated multiple-discrete continuous models, such as the mixed-MDCEV and the nested MDCEV or a survey methodology that would focus more on the emotional aspects of lifestyle, car ownership and housing.

Chapter 5

A Multiple Discrete-Continuous Extreme Value Model (MDCEV) of Household Fleet Choice

The content of this chapter was published originally in (Jäggi et al., 2012b).

5.1 Introduction

5.1.1 Context

In Switzerland, 34% of energy consumption is in the transportation sector (Swiss Federal Office of Energy (SFOE), 2009), making it the single biggest sector for greenhouse gas (GHG) emissions. Therefore various policies and taxes are discussed to reduce carbon emission in the private transport sector, which could cause a significant rise in fuel prices. Regulatory agencies therefore are interested how an increase in fuel prices changes the fleet composition, vehicle miles travelled (VMT) and the resulting energy and CO_2 savings.

But also other factors can influence fuel prices, mainly the world oil-market. The increase in demand of the developing countries as well as stagnation and shortages on the supply side (crude oil as well as refineries) influence the oil price. The Reference scenario of the oil price projections of Energy Information Administration (EIA) (2011) is substantially higher than the price spike in 2008.

This chapter presents a model estimating the effects of very high fuel prices on how households make decision what car to buy, whether to change an existing car and how many miles they travel with each of the cars they own, given a certain level of fuel price.

5.1.2 Research Question

The main research question now is how these unprecedented changes in fuel costs affect fleet choice and usage, how this can be modelled and how the resulting models can be implemented in existing transportation models.

In sophisticated transport models like the SACSIM model of the Sacramento Area, California (Bradley et al., 2010), the ILUTE model in Toronto (Salvini and Miller, 2005) or the Albatross model from the Netherlands (Beckx et al., 2009), choice modelling is used to capture a wide range of behaviours, such as mode choice, fleet choice or route choice. Discrete choice models in their standard formulations cannot integrate multivariate choices and associated continuous attributes of these choices. Still, there is a number of questions where this capability would allow the modeller to improve the realism of the description. One prime example is the composition of the fleet of mobility tools (Simma et al., 2002; Simma and Axhausen, 2003, 2001) and their associated mileage. The recent development of the MCDEV framework by Bhat (2005) offers a new approach to address this gap.

The overall transport model currently developed at IVT in collaboration with TU-Berlin is MATSim (Balmer, 2007; Meister et al., 2009; Balmer et al., 2008), an agent based micro-simulation tool for travel demand and traffic flow modelling. The present paper is part of the ongoing work to implement multiple discrete-continuous extreme value (MDCEV) models into the model frameworks of different fields.

In MATSim travel demand is activity based and generated using activity chains from the Swiss national travel diary survey, the Mikrozensus (Swiss Federal Statistical Office (BFS), 2006).The Mikrozensus is conducted every five years. In the current version of MATSim, the agents can conduct activities (e.g. home, shopping, work, leisure, etc.) inside facilities (buildings). In the iterative solution process the agents optimize their given activity chain. The agents are not part of a household and they have no specific car type allocated to them yet. They only have an attribute that describes their car availability for the mode choice processes.

The aim of this work is part of the future improvement of MATSim, so that the agents shall be members of households and specific car fleets will be allocated to the households. This will not only enable analysis of energy consumption on a microscopic level, but also allow the implementation of a behavioural model to forecast the development of the car fleet based on scenarios of different fuel prices and, as a result, of the energy consumption.

Because the model presented in this chapter deals with the ownership of cars, is part of the family of household decision models dealing with the more general, long term behaviour of households in transportation. Other models that deal with the general, long term behaviour are time use models, like those developed by (Jara-Diaz and Guevara, 2003) and (Jara-Diaz et al., 2008) on the basis of (DeSerpa, 1971) and (Becker, 1965), or applied in Pinjari and Bhat (2010b). These time use models explain how pleasant (e.g. leisure) and unpleasant (e.g. work, transport) activities are valued and therefore how much time is allocated for each of them, depending on socio-economic characteristics. In contrast, the model presented here only looks at a specific part of behaviour (the choice of the car type) of a specific group (car owners) in a specific situation (very high fuel prices). Other aspects, such as location choice, work or leisure time, car ownership, etc. are assumed to be fixed and regarded as explanatory variables.

5.1.3 Literature

The model presented in this chapter is estimated using the MDCEV approach by Bhat (2005) on Stated Adaptation data collected in the survey described in section 2.2, conducted by Erath and Axhausen (2010). Since 2004, when the MDCEV model was originally developed to analyse time use (Bhat, 2005), various researchers have used it to estimate preferences: Sen (2006) presented a MDCEV Model in the context of examining vehicle type, model and usage decisions of households in his dissertation and in Bhat and Sen (2006). The impact of demographics, built environment attributes, vehicle characteristics and gasoline prices on the same issue are analysed in (Bhat et al., 2009). Pinjari et al. (2009) analysed residential self-selection effects in time-use models and Spissu et al. (2009) presented an analysis of weekly out-of-home activity participation. Copperman and Bhat (2007) analysed the determinants of children week end activity participation. In Pinjari and Bhat (2010b), the authors introduce the nested version of the MDCEV, the multiple discrete-continuous nested extreme value (MDCNEV) model and present an application on non-worker time-use behaviour. A detailed description of the MDCEV and the role of its parameters can be found in (Bhat, 2008).

Early studies of household fleet composition models were undertaken by Lave and Train (1979) and Hensher and Le Plastrier (1985). de Jong (1990) found a negative relationship between fixed and variable car costs on ownership and use respectively. A good overview over all different types of car ownership and use models is given in de Jong et al. (2004). All these models focus on the influence of income and costs generally. The work presented focuses only on the part of costs due to fuel. An increase in this area does not necessarily only mean a decrease in use, but could also lead to a change of car type (to a type with lower fuel consumption) or to a switch of drive-train technology. The spectrum of fuel price for revealed preference data is small compared to what is expected to become reality within the next decades. Stated Preference experiments with a fuel price variation in the expected range of up to +400% were not found in the literature, except for the study whose data is used in this paper (Erath and Axhausen, 2010).

Other studies focus explicitly on the purchase of low consumption cars. A study about acceptance of alternative-fuel vehicles by Ewing and Sarigöllü (2000) found that given equal performance, alternative fuel vehicles are preferred over conventional, particularly for younger and high income participants. Achtnicht (2009) found in his model that emissions have a negative influence on car choice in general and particularly for younger and female individuals. Using a sophisticated consumer choice model for car purchase, de Haan et al. (2009) showed how incentives for environmentally friendlier cars could decrease CO_2 emissions of new cars.

5.2 Methodology

5.2.1 Review of Methodology

The methodology used in this fleet choice model is the multiple discrete-continuous extreme value (MDCEV) approach developed by Bhat (2005). In his paper he gives a detailed description and derivation of the model. The following section is a short summary of the third section of the paper. The MDCEV was originally developed to estimate the influence of attributes on the decisions of allocating time (continuous) to activities (discrete) within a 24-hour budget. Because the various activities are equivalent and simultaneously chosen for each day the model considers multiple chosen alternatives. In the presented model, the discrete choices are car types, the continuous amount is annual mileage (VMT) and it is a multiple discrete model because households can own and use more than one car simultaneously.

Kim et al. (2002) defines the utility an individual obtains for his decisions as a sum over all j alternatives (in our case: car types):

$$U = \sum_{j=1}^{K} \psi(x_j, \varepsilon_j)(t_j + \gamma_j)^{\alpha_j} \tag{5.1}$$

In this utility structure, t_j is the continuous amount of annual mileage driven with car type j (j = 1,2,. . . ,K), γ_j and α_j are satiation parameter to be estimated within the model. These satiation parameters are two different ways to account for the decreasing marginal utility of the continuous amount (VMT). The function $\psi(x_j,\varepsilon_j)$ gives the baseline utility function for the mileage driven with car type j. In section 3.1 of his paper, Bhat (2005) presents a random utility function for the baseline utility:

$$\psi(x_j, \varepsilon_j) = \exp(\beta' x_j + \varepsilon_j) \tag{5.2}$$

In which β' is a vector of parameters that define the influence of the observed characteristics of the alternative x_j. ε_j captures the unobserved random utility. By combining the formulas (1) and (2) the overall random utility function for the MDCEV model can be defined as:

$$\bar{U} = \sum_{j=1}^{K} \exp(\beta' x_j + \varepsilon_j) \cdot (t_j + \gamma_j)^{\alpha_j} \tag{5.3}$$

The probability function can be derived by forming the Lagrangian and applying the Kuhn-Tucker conditions and assuming that the optimal allocation of annual mileage satisfies the budget constraint:

$$\sum_{j=1}^{K} t_j^* = T \tag{5.4}$$

Bhat specifies a standard extreme value distribution for ε_j and assumes that it is independent from x_j as well as independently distributed across alternatives. The final result for the probability function is

$$P(t_2, t_3, ...; t_M, 0, 0, ..., 0) = \left[\prod_{i=1}^{M} c_i\right] \left[\prod_{i=1}^{M} \frac{1}{c_j}\right] \left[\frac{\prod_{i=1}^{M} e^{V_i}}{(\sum_{j=1}^{K} e^{V_i})^M}\right] (M-1)! \tag{5.5}$$

whereas:

$$c_i = \left(\frac{1-\alpha_i}{t_i + \gamma_i}\right) \tag{5.6}$$

M is the number of alternatives chosen by the individual. If only one alternative is chosen, the model collapses to the form of a standard Multinomial Logit model. Therefore this model is an extension of the standard MNL model, allowing multiple choices of continuous amounts. The parameters of the model are estimated using the Log-Likelihood method that maximizes the sum of the log of P over all observations.

5.2.2 Model Specification

The model used in this research has no outside good, meaning that there was no alternative that was chosen in every observation. It is obvious that there is no car type which has to be chosen by all households, as for example 'in home time' in time use models.

For the estimation process, the Gauss code provided at Bhat's Webpage (Bhat, 2011) is used. The program 'No Outside Good' is used and two configurations were tested. In the first the estimated satiation parameters of the model are α parameters and the γ values are constraint to be equal to one for all goods. In this case, the specific utility function is:

$$U(t) = \sum_{j=1}^{K} \frac{1}{\alpha_j} \exp(\beta' x_j + \varepsilon_j) \cdot \{(t_j + 1)^{\alpha_j} - 1\} \tag{5.7}$$

In the other configuration tested γ parameters are estimated while α values are fixed to be equal 0. In that case, the specific utility function is:

$$U(t) = \sum_{j=1}^{K} \gamma_j \cdot \exp(\beta' x_j + \varepsilon_j) \cdot \ln\left(\frac{x_j}{\gamma_j} + 1\right) \tag{5.8}$$

The models estimated assumed satiation parameters that differ across individuals. The γ parameters are estimated as a function of household income, fuel price and a constant. We did not reach convergence for models using α parameters differing across individuals. Because of this, and because of the slightly better model fit, only results using γ satiation parameters are presented.

With the software application used in the interviews, the respondents could determine the type of every car choosing among nine different car types, five classes of engine size, five drive-trains(gasoline, diesel, natural gas, hybrid, electric) vehicle) and whether it would be a newly bought car or a used car (used means either to keep the currently owned car or to buy a second hand car). The options give 9·5·5·2 = 450 alternatives, which requires a classification. The choices were classified in 17 alternatives distinguishing between gasoline, diesel and alternative drive-trains (ATD) and between the separate car types. 17 was an upper bound for alternatives due to computational reasons. The list of alternatives is shown in table 5.1. Observations is how often this alternative was chosen as first car to give a sense of the distribution of the classification and explain why certain car types are put together.

5.3 Results

The estimation results are shown in table 5.2 and 5.3. Please note that estimates are written **boldly** and the t-statistics are below written in *italic* and indicate the significance level. The Alternatives are labelled according to table 5.1. For an easier and quicker reading of the table, an indication is given in the column "Alternative", where the car type is indicated. Alternatives D0 to D6 are diesel cars, B0 to B7 are gasoline cars and other means all car types with alternative drive-trains.

In the next three sections, first the β parameters for the discrete choice are discussed with the exception of fuel price, then fuel price is looked at separately and in the third section θ parameters that determine satiation of the allocated VMT are analysed. To model γ parameters that differ across

Table 5.1: Alternatives for fleet choice model B

Alternative	Drive-train	Car Types	Observations
D0	Diesel	Micro	58
D1	Diesel	Subcompact	123
D2	Diesel	Compact	134
D3	Diesel	Mini MPV	103
D4	Diesel	Mid-Sized	127
D5	Diesel	MiniVan, Full-Sized	100
D6	Diesel	Luxurious, Sportscar	56
B0	Gasoline	Micro	135
B1	Gasoline	Subcompact	366
B2	Gasoline	Compact	289
B3	Gasoline	Mini MVP	149
B4	Gasoline	Mid-Sized	222
B5	Gasoline	MiniVan, Full-Sized	77
B6	Gasoline	Luxurious	69
B7	Gasoline	Sportscar	136
Other	Gas, Hybrid, Electric	All Types	268
OEV		Public Transport	

individuals, they were parametrized in the following equation, depending on household monthly income and the given fuel price:

$$\gamma_j = \exp(\theta_C + \theta_I \cdot Income + \theta_F \cdot Fuelprice) \tag{5.9}$$

5.3.1 Choice Model Parameters

To evaluate the model in terms of model fit, the mean log likelihood values are compared with mean log likelihood value when all parameters are set zero which is -6.1. That gives a pseudo ρ^2 of 0.55, which seems to be very high. However, this value should not be compared with pseudo ρ^2 of Multinomial Logit Models, but only with values of the same MDCEV modelling framework.

The variable Const is the alternative specific constant compared to the Diesel-Micro choice. In general (few exceptions) bigger cars have lower constants than smaller cars. The strongest negative constants have the two luxurious car types. But the constants are most likely also driven by the availability and market penetration of the car types in question. People are less used to and aware of diesel cars which reflects the lower constant. For Mid-Sized (="normal") cars this difference is particularly evident (diesel:

Table 5.2: Estimated β and θ parameters of fleet choice model, mean log likelihood: -2.70

Alternative	Const	Income	Fuel	Fuel2	DistW	Male	Age	Urban	Inertia/Taste	Ac.1	Ac.2	GA	HT	θ_C	θ_I	θ_F
D0 (Micro)														4.30	-0.39	0.39
T-Stat.														*2.74*	*-3.08*	*1.16*
D1 (Subcompact)	**0.95**	**-0.07**	**0.30**	**-0.05**	**6.71**	**0.12**	**-0.07**	**-0.54**	**1.73**					**5.55**	**-0.30**	**-0.34**
T-Stat.	*0.98*	*-1.74*	*0.63*	*-0.68*	*2.90*	*0.38*	*-0.65*	*-1.62*	*3.67*					*4.35*	*-4.03*	*-1.51*
D2 (Compact)	**-0.96**	**0.00**	**0.24**	**-0.05**	**7.14**	**0.31**	**0.13**	**0.16**	**2.73**					**3.38**	**-0.22**	**0.53**
T-Stat.	*-0.93*	*0.07*	*0.50*	*-0.69*	*3.09*	*0.91*	*1.10*	*0.49*	*10.78*					*2.30*	*-1.79*	*0.94*
D3 (MiniMVP)	**-1.70**	**-0.10**	**0.69**	**-0.13**	**7.12**	**0.41**	**0.20**	**0.01**	**2.69**					**0.89**	**2.69**	**1.95**
T-Stat.	*-1.36*	*-2.04*	*1.11*	*-1.44*	*3.09*	*1.08*	*1.46*	*0.03*	*10.59*					*0.00*	*0.00*	*0.00*
D4 (MidSized)	**-4.38**	**0.14**	**1.34**	**-0.23**	**7.01**	**0.18**	**0.27**	**-0.32**	**2.37**					**3.56**	**-0.09**	**-0.29**
T-Stat.	*-3.75*	*3.41*	*2.43*	*-2.85*	*3.02*	*0.51*	*2.07*	*-0.91*	*9.98*					*2.48*	*-1.14*	*-1.05*
D5 (FullSized)	**-2.00**	**0.12**	**-0.06**	**-0.02**	**7.30**	**0.15**	**0.11**	**-0.19**	**3.84**					**4.24**	**-0.26**	**0.02**
T-Stat.	*-1.49*	*2.50*	*-0.09*	*-0.25*	*3.15*	*0.38*	*0.73*	*-0.47*	*12.65*					*2.86*	*-2.83*	*0.08*
D6 (Luxus)	**-5.13**	**0.00**	**0.98**	**-0.15**	**6.62**	**1.45**	**0.40**	**0.39**	**3.59**					**0.50**	**0.08**	**0.09**
T-Stat.	*-3.53*	*-0.08*	*1.37*	*-1.44*	*2.81*	*3.21*	*2.70*	*1.02*	*10.61*					*0.31*	*0.51*	*0.32*
B0 (Micro)	**-1.12**	**0.00**	**-0.01**		**7.68**	**-1.40**	**0.25**	**0.19**	**3.00**					**1.00**	**-0.13**	**0.06**
T-Stat.	*-1.42*	*0.00*	*-0.08*		*3.33*	*-3.96*	*2.12*	*0.55*	*13.56*					*1.61*	*-3.17*	*0.40*
B1 (Subcompact)	**0.89**	**-0.11**	**-0.19**		**6.71**	**0.08**	**0.22**	**-0.13**	**2.33**					**1.93**	**-0.10**	**-0.12**
T-Stat.	*1.28*	*-2.86*	*-1.83*		*2.90*	*0.27*	*2.11*	*-0.44*	*17.00*					*2.92*	*-2.33*	*-0.83*
B2 (Compact)	**0.14**	**-0.06**	**-0.32**		**7.38**	**-0.15**	**0.12**	**0.30**	**3.20**					**2.20**	**-0.13**	**-0.01**
T-Stat.	*0.21*	*-1.47*	*-2.93*		*3.20*	*-0.51*	*1.17*	*0.99*	*17.06*					*3.11*	*-3.07*	*-0.06*
B3 (MiniMVP)	**-2.00**	**0.08**	**-0.73**		**6.90**	**-0.60**	**0.21**	**0.36**	**5.65**					**1.37**	**-0.17**	**0.15**
T-Stat.	*-2.11*	*1.49*	*-5.21*		*3.00*	*-1.58*	*1.56*	*0.98*	*12.51*					*1.74*	*-2.73*	*0.73*
B4 (MidSized)	**0.68**	**0.00**	**-0.40**		**7.38**	**-0.02**	**-0.12**	**0.70**	**3.38**					**1.77**	**-0.16**	**0.31**
T-Stat.	*0.92*	*-0.06*	*-3.50*		*3.19*	*-0.08*	*-1.07*	*2.28*	*16.82*					*2.17*	*-3.20*	*1.49*
B5 (FullSized)	**-0.37**	**0.01**	**-0.53**		**7.06**	**0.57**	**-0.08**	**-0.59**	**4.31**					**3.17**	**-0.22**	**-0.02**
T-Stat.	*-0.38*	*0.31*	*-3.74*		*3.03*	*1.12*	*-0.48*	*-1.55*	*12.12*					*2.47*	*-2.77*	*-0.11*
B6 (Luxus)	**-7.14**	**-0.09**	**-0.59**		**6.48**	**-0.56**	**-0.23**	**0.29**	**14.57**					**0.00**	**-0.05**	**0.34**
T-Stat.	*-0.31*	*-1.70*	*-3.58*		*2.72*	*-1.19*	*-1.19*	*0.59*	*0.64*					*0.00*	*-0.66*	*1.25*
B7 (Sport)	**-1.43**	**0.12**	**-0.81**		**7.75**	**-0.38**	**-0.03**	**-0.01**	**6.85**					**-2.23**	**-0.04**	**0.45**
T-Stat.	*-1.38*	*2.21*	*-5.29*		*3.35*	*-0.97*	*-0.19*	*-0.03*	*13.48*					*-3.12*	*-0.75*	*2.76*
Other	**-0.51**	**-0.08**	**0.17**		**6.95**	**-0.91**	**0.33**	**0.22**	**3.24**	**0.08**	**0.16**			**0.39**	**2.32**	**1.37**
T-Stat.	*-0.70*	*-2.13*	*1.55*		*3.01*	*-2.96*	*3.10*	*0.72*	*6.67*	*2.32*	*4.36*			*0.00*	*0.02*	*0.02*
Publ. Transp.	**4.12**	**-0.12**	**-0.24**		**7.11**	**-0.28**	**0.22**	**0.22**		**0.00**	**-0.02**	**2.39**	**1.04**	**-4.25**	**0.11**	**0.08**
T-Stat.	*6.33*	*-3.24*	*-2.38*		*3.09*	*-1.02*	*2.29*	*2.29*		*0.08*	*-1.15*	*13.03*	*16.68*	*-23.02*	*7.15*	*1.74*

Table 5.3: Estimated β and θ parameters of fleet choice model (no inertia), mean log likelihood: -3.70

Alternative	Const	Income	Fuel	Fuel2	DistW	Male	Age	Urban	Inertia/Taste	Ac.1	Ac.2	GA	HT	θ_C	θ_I	θ_F
D0 (Micro)														4.24	-0.39	0.37
T-Stat.														*2.76*	*-3.18*	*1.21*
D1 (Subcompact)	**0.93**	**-0.07**	**0.28**	**-0.04**	**6.91**	**0.09**	**-0.06**	**-0.50**						**5.36**	**-0.31**	**-0.29**
T-Stat.	*0.94*	*-1.73*	*0.60*	*-0.64*	*3.00*	*0.29*	*-0.53*	*-1.50*						*4.48*	*-4.37*	*-1.37*
D2 (Compact)	**-0.88**	**0.00**	**0.17**	**-0.04**	**7.45**	**0.51**	**0.16**	**0.01**						**3.20**	**-0.22**	**0.52**
T-Stat.	*-0.87*	*0.05*	*0.36*	*-0.57*	*3.26*	*1.51*	*1.39*	*0.03*						*2.59*	*-2.08*	*1.09*
D3 (MiniMVP)	**-0.98**	**-0.10**	**0.68**	**-0.13**	**7.88**	**0.72**	**0.09**	**0.06**						**0.82**	**2.47**	**1.81**
T-Stat.	*-0.84*	*-2.14*	*1.19*	*-1.57*	*3.45*	*1.92*	*0.67*	*0.16*						*0.00*	*0.00*	*0.00*
D4 (MidSized)	**-3.45**	**0.15**	**1.23**	**-0.22**	**6.97**	**0.48**	**0.13**	**-0.21**						**3.33**	**-0.03**	**-0.30**
T-Stat.	*-3.07*	*3.77*	*2.27*	*-2.73*	*3.03*	*1.37*	*1.04*	*-0.62*						*2.08*	*-0.34*	*-0.96*
D5 (FullSized)	**-2.48**	**0.18**	**-0.34**	**0.01**	**7.33**	**0.07**	**0.35**	**-0.47**						**4.45**	**-0.20**	**0.03**
T-Stat.	*-2.05*	*4.29*	*-0.57*	*0.12*	*3.19*	*0.18*	*2.59*	*-1.28*						*2.37*	*-1.72*	*0.12*
D6 (Luxus)	**-5.21**	**0.03**	**0.94**	**-0.14**	**6.66**	**1.09**	**0.50**	**0.32**						**-1.38**	**0.42**	**0.05**
T-Stat.	*-3.73*	*0.76*	*1.42*	*-1.51*	*2.83*	*2.56*	*3.52*	*0.87*						*-0.64*	*1.54*	*0.16*
B0 (Micro)	**1.18**	**0.02**	**-0.05**		**7.52**	**-1.67**	**-0.01**	**-0.28**						**1.20**	**-0.13**	**0.07**
T-Stat.	*1.59*	*0.39*	*-0.47*		*3.29*	*-4.91*	*-0.07*	*-0.86*						*1.96*	*-3.10*	*0.47*
B1 (Subcompact)	**2.38**	**-0.17**	**-0.19**		**6.92**	**-0.65**	**0.26**	**-0.10**						**2.99**	**-0.14**	**-0.21**
T-Stat.	*3.54*	*-4.44*	*-1.84*		*3.03*	*-2.23*	*2.53*	*-0.34*						*4.54*	*-3.21*	*-1.38*
B2 (Compact)	**1.51**	**-0.04**	**-0.30**		**7.44**	**-0.22**	**0.20**	**0.04**						**3.64**	**-0.17**	**-0.14**
T-Stat.	*2.20*	*-1.03*	*-2.79*		*3.26*	*-0.73*	*1.94*	*0.14*						*4.69*	*-3.86*	*-0.87*
B3 (MiniMVP)	**1.17**	**0.02**	**-0.46**		**7.92**	**0.14**	**-0.01**	**0.28**						**2.63**	**-0.10**	**-0.20**
T-Stat.	*1.52*	*0.39*	*-3.71*		*3.48*	*0.40*	*-0.06*	*0.85*						*3.39*	*-1.75*	*-1.03*
B4 (MidSized)	**1.69**	**-0.01**	**-0.32**		**6.81**	**0.55**	**-0.03**	**0.44**						**3.22**	**-0.20**	**0.15**
T-Stat.	*2.44*	*-0.36*	*-2.96*		*2.97*	*1.78*	*-0.26*	*1.47*						*3.68*	*-3.63*	*0.68*
B5 (FullSized)	**-0.38**	**0.07**	**-0.51**		**7.35**	**1.82**	**-0.08**	**0.39**						**3.98**	**-0.21**	**-0.13**
T-Stat.	*-0.43*	*1.62*	*-3.85*		*3.21*	*3.94*	*-0.63*	*1.12*						*3.26*	*-2.91*	*-0.56*
B6 (Luxus)	**-0.39**	**0.12**	**-0.34**		**6.81**	**-0.24**	**0.10**	**-0.83**						**2.94**	**-0.16**	**0.07**
T-Stat.	*-0.45*	*2.69*	*-2.52*		*2.89*	*-0.65*	*0.76*	*-2.02*						*2.27*	*-2.03*	*0.25*
B7 (Sport)	**1.77**	**0.10**	**-0.39**		**7.87**	**-0.17**	**-0.24**	**-0.18**						**0.39**	**0.01**	**-0.07**
T-Stat.	*2.43*	*2.68*	*-3.31*		*3.45*	*-0.51*	*-2.00*	*-0.55*						*0.67*	*0.23*	*-0.49*
Other	**-0.63**	**-0.05**	**0.15**		**7.19**	**-0.85**	**0.34**	**0.25**		**0.05**	**0.16**			**0.54**	**2.39**	**1.68**
T-Stat.	*-0.86*	*-1.31*	*1.40*		*3.14*	*-2.79*	*3.15*	*0.82*		*1.43*	*4.60*			*0.00*	*0.01*	*0.01*
Publ. Transp.	**4.02**	**-0.12**	**-0.24**		**7.35**	**-0.28**	**0.23**	**0.23**		**0.01**	**-0.02**	**2.23**	**1.00**	**-4.21**	**0.11**	**0.08**
T-Stat.	*6.20*	*-3.27*	*-2.35*		*3.23*	*-1.03*	*2.39*	*2.39*		*0.42*	*-1.29*	*12.86*	*16.28*	*-23.24*	*7.10*	*1.83*

-4.38, gasoline: 0.7). Alternative drive-trains (ADT) are favoured over most conventional car types.

Income is defined in the model as gross household income in CHF 1.000/month. The significant effect indicates, that high income households are less likely to use small and family cars and are also less likely to use public transport. Interestingly, cars with ADT are negatively influenced by income, although they are more expensive. This indicates that early adopters are not necessarily high income people. In general the effect of income is not as strong as expected. However, it has a stronger influence on the satiation parameters as discussed below.

Dist. is the respondent's distance between home and workplace in 100 km. The longer this distance, the more mileage the respondents have to allocate to commuting. All alternatives have a high parameter for commuting distance. That means that people with longer distance to the workplace tend to own more cars, because the utility of making the discrete choice for every car type increases. The difference between the car types is very small. We can see no effect, that people with longer commuting distances, and therefore higher consumption, would favour more efficient cars.

Male is a dummy for the gender of the respondent. ADT, public transport and gasoline are preferred by women, while diesel is preferred by men. This is a quite interesting finding, because it rejects the general assumption, that men are more interested in, and therefore more open to new technologies. The most visible effect is between diesel SUVs which are preferred by men and gasoline Micro cars preferred by women.

The influence of age of the respondent is modelled linearly, because neither a quadratic function nor a division in age groups showed better results. But it is still hard to make clear statements about the influence for the linear formulation.

Urban is a dummy which is equal one for people living in inner city or urban areas and zero for people in suburbs and rural areas. Resident location has not a big influence on fleet choice, except that public transport and ADT are preferred in urban areas, which is plausible. SUV, which are cars designed and advertised for the use in rural, mountainous regions have a positive sign for urban environment. This indicates that the possibility of driving off road is more appealing to people that need it less.

Acc.1 and Acc.2 are two variables for accessibility, coming from a factor analysis of private transport accessibility and public transport accessibility, based on a national aggregate transport model (Fröhlich et al., 2006). Ac.1 stands for general accessibility of the respondent's home municipality (or quarter in the case of a city) and Acc.2 for any differences in public transport accessibility. The parameter is only estimated for alternative fuel alternatives and public transport, because differences between conventional alternatives regarding accessibility impacts are neither expected nor found. ADT are more often chosen in areas with higher accessibility in comparison to gasoline and diesel cars, and the effect is even greater for the public transport accessibility. ADT cars have not yet the same capability level as gasoline or diesel cars. This can be less space (Toyota Prius), small network of fuel stations (natural gas cars) or less range (electric cars). Thus it cannot necessarily be used for every occasion and the more suitable the public transport option is, the less important is the described lack in its capability.

The parameters for GA, HT and SC describe the influence of existing mobility tools for the public transport use in the model which includes public transport. GA (Generalabonnement) is a dummy for a season ticket for the whole of Switzerland, HT (Halbtax) one for a half-fare ticket for the whole of Switzerland and SC for a regional season ticket. The presence of such a mobility tool has the expected strong positive effect on the choice to use public transportation.

5.3.2 Role of Inertia/Taste Variable

Inertia/Taste is a dummy to capture inertia effects. It is one if the chosen car type is one of the actual cars types the household already owns. This has the expected significant and substantial influence, because it can be considered as capturing a substantial part of unobserved influence that led to the decision for the specific car type. The higher this parameter, the more likely the car type is chosen because it is already known. To lower this parameter, the more this alternative is considered to be a car type to change to. The parameter is smaller for all diesel alternatives, indicating that households switch from gasoline to diesel. The smaller the car type, the more likely it is to be switched to. Inertia effects are especially high for three different car types: Luxurious, sports and family gasoline cars. Luxurious and sports cars in many cases fulfil the purpose of a status symbol and thus bring an increased utility from unobserved emotional attributes. Because they have an already high fuel consumption in general, these car types are chosen in the case of rising fuel prices predominantly because they are already owned. In the case of MiniMVP it is rather its function than status that limits the choice to household that already have one.

In econometric terms that means, that there might be a correlation between the error terms and the inertia/taste variable (because of the taste part) that would violate the assumption of independent error terms and bias the estimates. A comparison between the the two models, with and without the inertia/taste variable shows that many estimates have only minor changes. Parameters affected by the inertia/taste variable are insignificant parameters, mostly age and gender. These are apparently the parameters with which taste was (insufficiently) covered in the model without the inertia/taste variable. Given the t-statistics and the differences in Log-Likelihood, it is clear that the inertia/taste variable is very effective and should be kept in the model. Key variables like fuel price and fuel price square are not affected at all which means that the main point of the model is still unbiased.

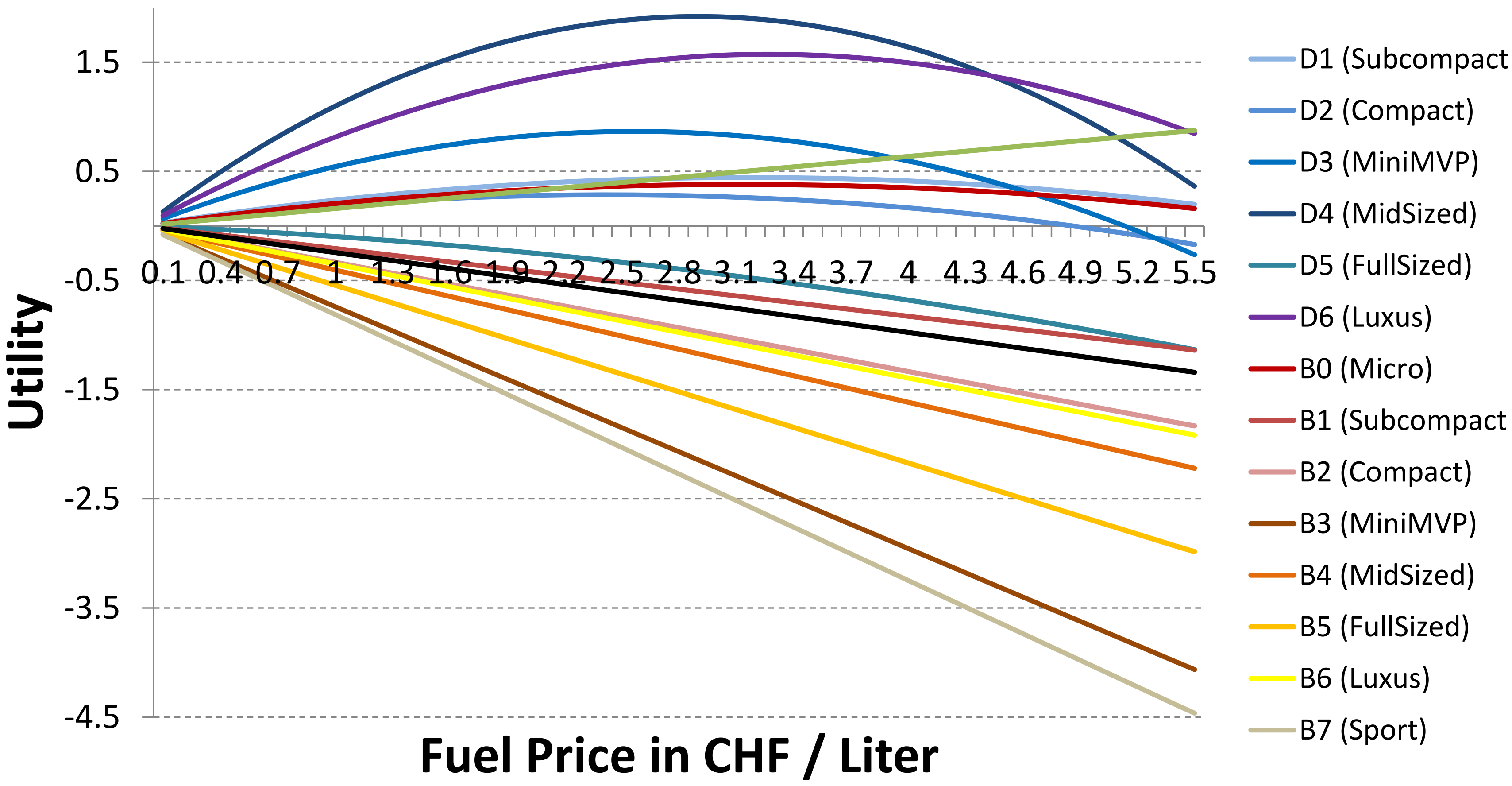
5.3.3 Influence of Fuel Price on Fleet Choice

Fuel is the fuel price, varying in the experiment from CHF 1.5/l to CHF 5.5 /l, Fuel^2 is the square of the fuel price. The impact of these parameters is summarized in figure 5.1 which shows the influence of fuel price on the utility and thus on the decision of the household for every alternative. Higher utility means that the alternative is more likely to be chosen. The graph assumes all other parameters equal to make the different curves of the alternatives comparable.

The x-axis indicates the fuel price from 0 to the maximum of CHF 5.5 per litre (USD 27 per gallon as of July 2011); the value range in the survey. Three different shapes can be distinguished: linearly negative for gasoline cars and Full-sized diesel cars, parabolic for other diesel cars and Micro gasoline cars linearly positive for ADT. The best visible parabolic curves are for these three diesel cars: MiniMVP, Mid-sized and Luxus. Households do not want do down-grade initially when fuel gets expensive but rather switch to diesel cars that have a lower consumption. Switching increases up to a price level of about CHF 3.0 per litre (USD 15 per gallon), after that level utility declines also for diesel cars. Car types with higher consumption tend to be more negatively influenced by fuel prices as expected.

Utility of ADT increases with fuel prices, although only weakly. The maximum differences between the maximum and minimum is only about a fifth of the differences for gasoline sports cars. But still the results indicate that households begin to switch also to ADT cars, but only when fuel prices get very high, or in other words: Fuel needs to be extremely expensive to overcome the lack of comfort and capability of ADT cars

Figure 5.1: Influence of fuel price on utility in model B



that still exists. We can assume that results would look different in ten years if the comfort gap were shrunk by then.

5.3.4 Individual Satiation of VMT

Above we stated that the influence of income on choice is smaller than in the allocation of VMT. This makes sense considering the following: Households with higher income may also have more cars than ones with lower income and the second or third car is often a smaller than the first. That means that car types are more equally distributed over income levels than VMT allocated to them. The satiation parameter determines how much VMT is allocated to a car type once it is chosen. Satiation for Sport-cars and Luxus-cars is low, that means that if a household owns such a car, it is likely to be used often. This is also true for Public Transport and to MiniMVP-cars, which are often used by families. Small diesel cars are used less frequently when chosen than their gasoline counterparts, indicating that they usually function as secondary car.

As mentioned, the effect of Income on the satiation for allocating VMT is interesting. In general the effect is negative, meaning that higher income means more VMT which this particular car type. However, for MiniMVP (family-car) and ADT higher income means less use of this type. While lower income people depend more on these car types, richer household can afford own such a car for status reasons or because they are interested in the technology while relying on other (conventional) car types for travelling. A direct policy advise that would follow from this is if ADT are to be promoted for environmental reasons, it would be important to focus on lower income families because here usage is much higher.

The influence of fuel price on satiation is much weaker, but is strongest also for family-cars and ADT-cars. This is interesting insofar that high fuel prices gives additional satiation mainly to cars that have already a high efficiency. When households decide to switch to more efficient cars due to high fuel prices, they also reduce the allocated VMT, which is surprising in first view. The interpretation resulting is that the VMT of an existing (or well known) fleet is very inelastic to fuel prices and more determined by commuting distance and lifestyle choices. The first reaction would be to change the car to a more efficient diesel or smaller gasoline car that fits the accustomed lifestyle best. When fuel prices are so high that a more severe change is necessary, a switch to ADT is needed that comes with a change of lifestyle and results in adjusted VMT. The associated lifestyle change may come from the fact that the offer of ADT cars is much smaller than for conventional cars and they still differ in convenience and range.

If ADT-technology manages to adapt further to the comfort and lifestyle level of conventional cars in the future, this behaviour may be different, and the usage of ADT begins at lower fuel prices and for broader layers.

The satiation parameters γ = f(Income, fuel price) describe the decreasing marginal utility with an increasing amount of travelled kilometre. The θ constant is highly significant. The more luxurious the car type, the lower that constant. That means that people are are more likely to allocate their annual mileage in the more luxurious of two or more cars. For example: the main car, with a higher mileage, is the bigger, more comfortable car and the second car is for the case the first is not available. Cars with alternative fuel are not likely to be affected by reduction, meaning that if one has for example a hybrid car, the person is not likely to have a second car with which it drives even more. Income has the expected influence on the satiation such that higher income gives less satiation throughout all car types except alternative fuels. Fuel price has almost no significant impact on satiation which is surprising.

5.4 Discussion

The model presented is not the first one using a multiple discrete-continuous framework to model car choice and use simultaneously. But it is the first that includes a wide range fuel prices as an explanatory variable. The model gives insight in how car choice and car use is influenced by fuel price. The low effect of fuel price on satiation and strong impact on car type choice indicates that car use is inelastic regarding fuel price compared to car type selection. Household are willing to change the car type, especially switch to diesel cars with less consumption but they will not reduce their VMT substantially. This indicates for further policy consideration that, given a choice set with sufficient low consumption alternatives, a rise in fuel price would lower the overall consumption and the environmental burden, but not diminish the mobility of the population. But it also shows that for this purpose very high fuel prices are necessary.

A study of Ewing and Sarigöllü (2000) using discrete choice experiments showed a preference for cleaner vehicle in the case of equal comfort and capability. The gap between the current level of fuel prices and the level where households switch to ADT can be seen as a willingness to pay for the comfort differences between gasoline/diesel and ADT vehicles. A optimal policy approach would consider a mixture of closing that gap by both increase fuel prices and decrease the differences in comfort. Further research in this area would be to repeat a similar survey not only in other regions than Switzerland, but also after a few years when the choice set of car types with ADT has increased and the comfort gap has decreased. Further research should also include electric vehicles more explicitly than in this work. When the survey was conducted only few electric vehicles were available in the market and they were not broadly known. Given the technological development in the field the situation might be very different within the next five years.

The other conclusion drawn from this work is that the multiple discrete-continuous framework used can be appropriate and useful. Performance tests of disaggregate simulation of the model are presented in chapter 6. The classification is reasonable although limited to 17 alternatives. Future work includes further exploration of the existing data set with a greater (or different) choice set classification and a nested structure to capture similarities between drive-train technologies or other attributes.

Chapter 6

An Analysis of Residuals in Multiple Discrete-Continuous Extreme Value Models (MDCEV)

The content of this chapter was published originally in (Jäggi et al., 2013).

6.1 Introduction

The Households fleet choice model enables researchers working with disaggregate agent based transport simulations to include the specification of car types with different attributes to the household that is not only based on socio-economic and geographical characteristics but also on the level of fuel prices. The model as presented in chapter 5 is based on the MDCEV Methodology that not only models the discrete choice of multiple possible car types but also the annual mileage associated with each type.

In a future development of MATSim, the agents will be pooled into households and specific car types will be allocated to the households. This will not only enable energy consumption to be analysed on a microscopic level, but will also allow the implementation of a behavioural model to forecast the development of car usage and, as a result, energy consumption. A first application of the model was used by Saner et al. (2013).

When applying the fleet choice model to a transportation model and simulating actual traffic scenarios, the issue of accuracy of the models gains importance. How well does the model reproduce car type distribution and annual mileage allocation? How big is the error we make when incorporating car fleet choice? The present chapter analyses the goodness of fit and accuracy of multiple discrete-continuous extreme value model applications and providing insight of the performance and the specific nature of such models.

To test the performance of the model for an application like MATSim or other agent based transport simulation, we repeatedly applied a forecast of the MDCEV approach and analysed the residuals by comparing the results to the actual choices made in the survey. Residuals are the arithmetic difference between the forecast and the original data used for the forecast, just like in a simple regression where residuals are defined as the arithmetic difference on the y-axis between the regression line and the data points used for the regression.

Pinjari and Bhat (2010a) have presented an efficient forecasting procedure for such models. We tested the performance of MDCEV forecasting results using models for household fleet choice, household total energy consumption and induced demand. Unfortunately no useful literature on the disaggregate validation of (multiple) discrete-continuous models was found. In most MNL models, validation occurs at an aggregate level when actual and predicted market shares are compared, as researchers have done since MNL models were first introduced; see for example Train (1978).

In the case of multiple discrete-continuous models, however, a disaggregate validation would be more valuable because it would give more insight into their characteristics.

The analysis presented in this chapters focuses on the Fleet-Choice Model of chapter 5 but includes also the model for total household energy consumption of chapter 4 and an model for the prediction of induced demand based on stated preference data (Weis and Axhausen, 2012).

6.2 The Forecasting Procedure

Both the forecasting procedure as well and the Gauss code used for this research were developed and introduced by Pinjari and Bhat (2010a). In chapter four of their paper, two algorithms are presented, one for estimations with γ_j as satiation parameters and a fixed α, and one for estimations with α_j as satiation parameters. The algorithms are both intended for models with an outside good. The Gauss code of the forecasting procedure can also be downloaded from Bhat's web-page (Bhat, 2011).

In the first step of the algorithm, the baseline utilities $\exp(\beta' x_j + \varepsilon_j)$ of all alternatives are calculated from the model parameters β, the input data and the Gumbel distributed unobserved utility ε. In the code developed by Pinjari and Bhat (2010a), the random numbers used are from a Halton sequence, after Halton (1960). In this chapter, random numbers were drawn on the fly using the random function of the Gauss program.

The 17 alternatives are then sorted according to their decreasing baseline utility, and it is assumed that the first alternative was chosen. In the case of an outside good, the first alternative in the list would be the outside good. Since there is no outside good in the case of fleet choice, the first alternative is the one with the highest baseline utility. To check if a second alternative (with the second-highest baseline-utility) was chosen, an estimate of the overall budget is calculated. If the estimated budget is smaller than the actual budget, the next alternative in line is considered until the budget is exhausted. If the estimated budget is higher than the actual one, an iterative procedure described in detail by Pinjari and Bhat (2010a) is used to find an adjusted baseline utility for the last alternative to meet the actual budget within a tolerance band.

After the exact number of chosen alternatives is determined, the mileage allocated to each of the alternatives chosen is calculated using the adjusted baseline utility of the previous steps and the satiation parameters γ.

The algorithm described above calculates the consumption data (mileage) for one observation. It can be repeated multiple times to achieve more robust results. In our current work, simulations with 10 repetitions and 50 repetitions were calculated. These will now be presented and compared.

6.3 Using Stated Adaption MDCEV Models for Comparison

In this section, two further models that also used stated adaption data sets for MDCEV modelling are briefly introduced. The models differed in terms of their context, survey methodology, sample size and, most importantly, number of available alternatives. These differences allowed us to produce and assess a broader range of different possible forecasting outcomes by MDCEV models. It is important to note that the following assessments solely pertain to specific models, including some MDCEV models, based on stated response data; they are not intended as assessments of MDCEV methodology per se.

The first model used for comparison was the Multiple Discrete-Continuous Extreme Value Model (MDCEV) for total Household Energy Consumption as described in chapter 4. The data set was collected using a Priority Evaluator in a survey of home-owners regarding energy efficiency investments in the home and in mobility, as described in chapter 2.1.6 and by Jäggi and Axhausen (2010); Jäggi et al. (2011). Here, the participants of the survey were asked to reduce their household's energy consumption by selecting from different measures such as insulating the facade of their home, replacing the windows, installing a heat pump, buying a more efficient car or flying less. Although the potential energy savings of each measure were pre-specified for each participant, it was assumed that the participants could easily determine their pattern of energy reduction, thanks to the interactive nature of the internet tool. The continuous amount refers fo the energy saved, and the 'budget' signifies the total reduction. In this special form of an MDCEV model, participants did not maximize utility by buying goods, but instead minimized damage by allocating bads. The number of alternatives in the model was 12, and there were 197 observations in total.

The second model used for comparison was the induced demand (ID) model. The data set was collected in a survey about travellers' reactions to changing travel times. The survey was described by Weis et al. (2010b). The participants in this survey were confronted with significant changes in travel time (between -30 and + 90minutes) to a typical, previously reported, schedule. The survey was conducted via face-to-face interviews supported by computer software, so the participants could adjust their activity schedules interactively. The adjustments were categorized according to three alternatives: changes to departure times, changes to activity times and changes in travel time. Time was the continuous amount and the budget was the total compensation of travel time stated by the respondents. The number of alternatives in the model was 3, and there were 612 observations in total.

6.4 Estimation Results of Alternative Fleet Choice Model

In addition to the model discussed in section 5.3 with the choice set as given in table 5.1, a similar model derived form the same data set and with the same methodology but with a different choice set, meaning a different categorisation of car types, was estimated, to evaluate the different forecasting outcomes for the different models. The model with the choice set categorization given in table 5.1 is named Model B. Car types classes are more detailed in Model B, but there is no distinction between newly bought cars and second hand cars. The comparison Model, named Model A, groups similar car types together but makes the distinction between new and second hand cars. The choice set for Model A is given in 6.2.

The estimation process was done the same way as in Model B. Table 6.1 shows the estimated parameters. Note that numbers in **bold** are significant at a 95% level, and numbers in *italics* are significant at a 90% level. For an easier and quicker reading, the car type is indicated by general category (in parentheses) in the 'Alternative' column. A1 to A8 signify new cars, while A9 to A17 are used cars.

The satiation parameters presented are θ parameters. To model γ parameters that differ across individuals, they were parametrized in the following equation, depending on household monthly income and the given fuel price:

$$\gamma_j = \exp(\theta_C + \theta_I \cdot Income + \theta_F \cdot Fuelprice) \tag{6.1}$$

The results of th estimation correspond qualitatively to the interpretation given section 5.3.

6.5 Results

6.5.1 Disaggregate Simulation Results

This section presents, compares and analyses the results of the forecasting procedure for the above-mentioned models. The simulation results of the household fleet choice model will eventually be used to allocate car types to households and agents in the MATSim environment, and are thus part of a wider transport modelling framework. For that reason, it is important to know the accuracy of the predictions and to have indicators for evaluating and comparing the models. The instruments used for this research were hit ratio and the absolute and relative residuals, calculated as the differences between the forecast and the data used for the estimation. The predictions were also tested for their stability by comparing the results of forecasts with 10 or 50 repetitions.

The hit ratio gives the percentage of chosen alternatives in observed data that were matched in the forecast (discrete choice only). The hit ratio was calculated for each repetition separately, and then the mean was

Table 6.1: Estimated β parameters of household fleet choice model A; Mean log likelihood: -3.41

Alternative	Const	Income	Fuel	Fuel2	DistW	Male	Urban	Inertia	Ac.1	Ac.2	GA	HT	SC	θ_C	θ_I	θ_F
A1 (small)														**2.60**	**-0.14**	0.18
A2 (middle)	-7.81	0.02	1.03	**-0.18**	0.52	-0.25	-0.07	1.15						*18.19*	-0.08	*-3.29*
A3 (lux)	-7.43	0.02	*0.75*	**-0.14**	0.24	**0.52**	0.34	2.76						1.02	0.09	-0.11
A4 (hybrid)	-1.02	-0.03	*0.13*		0.42	**-1.41**	0.23	-6.06	0.01	-0.01				0.64	2.61	1.69
A5 (small)	*0.93*	**-0.06**	**-0.17**		0.44	**-0.40**	0.04	**1.43**						**1.42**	**-0.13**	0.04
A6 (small)	0.31	0.02	**-0.40**		0.57	0.04	0.18	**1.57**						**1.44**	**-0.08**	-0.02
A7 (middle)	0.34	0.01	**-0.38**		0.29	-0.15	*0.29*	**2.20**						**2.74**	**-0.15**	-0.08
A8 (lux)	-0.34	0.00	**-0.53**		*0.63*	**-0.43**	*-0.31*	**5.20**						**1.46**	-0.04	**-0.24**
A10 (small)	-0.33	*-0.05*	**-0.23**		*0.67*	**0.49**	-0.22	**2.10**						**5.28**	**-0.35**	0.04
A11 (middle)	-7.32	**0.14**	0.18	*-0.08*	**1.28**	0.10	*0.31*	**2.58**						**2.00**	*-0.08*	-0.01
A12 (lux)	**-2.67**	**0.17**	**-0.29**		**1.58**	**1.17**	**0.70**	**3.30**						1.07	-0.01	0.16
A13 (hybrid)	0.62	-0.03	0.10		**1.01**	**-0.77**	0.28	**3.51**	0.01	-0.01				0.38	1.95	1.43
A14 (small)	0.00	-0.02	**-0.34**		**1.31**	**-0.48**	0.24	**3.13**						**1.69**	**-0.11**	-0.05
A15 (small)	-0.56	0.02	**-0.32**		**1.57**	0.30	0.10	**2.30**						**5.06**	**-0.28**	-0.19
A16 (middle)	0.55	**0.07**	**-0.57**		**1.23**	-0.13	**0.72**	**3.27**						0.89	2.42	1.76
A17 (lux)	*-1.96*	**0.09**	**-0.63**		**1.04**	**0.65**	**-0.65**	**6.78**						**2.19**	**-0.19**	*0.19*
A99 (PT)	**4.40**	**-0.06**	**-0.29**		**1.02**	**-0.33**	**0.36**		0.01	-0.01	**2.24**	**1.06**	**1.42**	**-4.14**	**0.09**	**0.06**

Table 6.2: Alternatives for fleet choice model A

Alternative	New/used	Drive-train	Car types	Engine size	Observations
A1	New	Diesel	Micro, subcompact, compact		160
A2	New	Diesel	Mini MPV, minivan mid-sized		89
A3	New	Diesel	Luxurious, sports-car full-sized		76
A4	New	Gas, hybrid, electric			119
A5	New	Gasoline	Micro, subcompact, compact	<1500 cm^3	279
A6	New	Gasoline	Micro, subcompact, compact	>1500 cm^3	110
A7	New	Gasoline	Mini MPV, minivan mid-sized		155
A8	New	Gasoline	Luxurious, sports-car full-sized		123
Not included					94
A10	Used	Diesel	Micro, subcompact, compact		170
A11	Used	Diesel	Mini MPV, minivan mid-sized		141
A12	Used	Diesel	Luxurious, sports-car full-sized		49
A13	Used	Gas, hybrid, electric			136
A14	Used	Gasoline	Micro, subcompact, compact	<1500 cm^3	272
A15	Used	Gasoline	Micro, subcompact, compact	>1500 cm^3	135
A16	Used	Gasoline	Mini MPV, minivan mid-sized		198
A17	Used	Gasoline	Luxurious, sports-car full-sized		130
A99			Public transport		

taken. For example, if mileage was allocated to alternatives A3 and A4 in the forecast but to alternatives A1, A2 and A3 in the observed data, then the hit ratio would be 33.33% because one third of the observed choices matched.

$$HR = \frac{N_{match}}{N_{data}} \tag{6.2}$$

To calculate the residuals, the mean of the predicted mileage for every alternative was taken over all repetitions. The residuals were calculated with the formula

$$R_{abs} = \sum_{j=1}^{K} \frac{|t_j - \hat{t_j}|}{2} \tag{6.3}$$

whereby $\hat{t_j}$ was the predicted amount of mileage and t_j was the observed value. The differences were divided by 2, because otherwise the mileage would have shown up twice in the residual: once in the alternative to which it was falsely allocated, and once in the alternative it should have been allocated to, but was not.

Because the mileage budget differed among observations (in contrast to time-use models, for instance), only residuals relative to the total amount of annual mileage of the observation could be used for comparison, as shown in equation (6.4).

$$R_{rel} = \frac{R_{abs}}{\sum_{j=1}^{K} t_j} \tag{6.4}$$

This also allows a standardized comparison between different models with different budgets, as we will discuss in the next section. Table 6.3 shows the hit ratio and the residuals for the forecasts of the two household fleet choice models with different repetitions per observation as well as different satiation parameters. The reference model of the last row of table 6.3 was derived from a forecast with all parameters set to 0. The same values were also calculated for the two comparison models (PE and ID). It is important to note that note those values, but only the improvement between the reference models and the actual model should be compared across models.

Table 6.3 allows to analyse the influence of several factors on simulation

Table 6.3: Model simulation overview

				Hit Ratio [%]			R_{rel} [%]		
Model	Alt.	Sat.	Rep	**Mean**	< 5%	> 50%	1. Quartile	**Mean**	3. Quart
Ref. Model			50	**8.7**	14.3	0.0	85.4	**88.9**	92.9
Model A, no PT	16	α	10	**39.6**	40.0	35.8	45.1	**70.7**	100.0
Model A, no PT	16	α	50	**39.6**	39.0	37.8	43.4	**70.5**	100.0
Model A	17	α	10	**25.3**	11.1	1.2	57.6	**71.9**	90.0
Model A	17	α	50	**25.3**	8.3	1.4	57.6	**71.3**	87.6
Model A, no PT	16	γ	50	**36.8**	41.1	34.2	43.1	**69.3**	100.0
Model A	17	γ	50	**55.3**	12.9	47.3	42.6	**65.4**	90.9
Model B	17	γ	50	**66.5**	12.3	56.6	10.7	**48.7**	90.0
MNL Model	17	-	-	**25.4**	51.6	5.6	16.7	**76.2**	95.5
PE Ref. Model			50	**51.7**	0.0	69.0	59.2	**67.1**	75.4
PE Model	12	γ	50	**78.7**	5.1	93.3	40.0	**52.8**	66.8
ID Ref. Model			50	**58.7**	10.5	54.7	31.9	**65.9**	100.0
ID Model	3	γ	50	**59.5**	4.2	68.0	0.0	**56.7**	100.0

performance by comparing the different specifications. Firstly, the number of simulation draws had only a small influence on the quality of the results, since the same residuals were achieved with 10 draws per observation as with 50.

Secondly, the models with specifications showed substantial improvements in performance in comparison to the random model. However, models with satiation parameter α performed worse than those with satiation parameter γ. Excluding the public transport alternative led to higher hit ratios and lower residuals (better performance) in models with satiation parameter α, and had the reverse effect with models with satiation parameter γ. The best specification of the Model A choice set was achieved using satiation parameter γ and including the public transport alternative, as shown in table 6.1. This specification allocated 6.5% more of the overall budget correctly than the worst specification of the Model A choice set. Nevertheless, with even the best specifications allocated only about 35% of the overall budget correctly.

Thirdly, the more detailed distinctions between car types led to better performance in Model B. This model specification, shown in table 5.2 was able to allocate more than half of the overall budget correctly (R_{Rel} = 48.7%) and managed to reproduce almost two-third of the observed choices (HR = 66.5%). Thus we can identify this model specification as the best one for this data set so far. For the purpose of comparison a simple MNL model was estimated and simulated using the same choice set and variable specifications as in Model B. To estimate the MNL model, only one alternative was chosen: the one with the highest VMT. For the enumeration, the overall budget was entirely allocated to this single alternative, so the simulation results are perfectly comparable. We are aware that this MNL framework is very simple and more sophisticated discrete continuous frameworks exist. However, such a model applied to the presented data set would be a chapter on its own and would go beyond the scope of this work. In any case, a simple MNL model provides a lower boundary of performance for a given data set. The performance was substantially worse in every regard, confirming the assumption that more sophisticated modelling frameworks such as MDCEV ones lead to substantially better models.

The hit ratios of the two comparison models were significantly higher because fewer alternatives were involved. In the ID model with only three alternatives, even the reference model has a high hit ratio. This was also true for the PE model, in which usually about 3 to 7 out of 12 alternatives were generally chosen. An overview of all the models showing the number of alternatives chosen and the percentage of corner solutions is given in table 6.4. It is evident that for some of the household fleet choice model specifications, about 40% of all cases had a hit ratio of <5% and may be considered total failures.

On the other hand, the relative residual was not determined by the number of alternatives and is thus a better measure for comparison. The best household fleet choice model achieved a reduction of 40.2% of the mean relative residual compared to the reference model. The PE model and the ID model achieved reductions of 14.3% and 9.2%, respectively. Whether these figures may be considered as especially low or acceptable can not yet be determined. However, they will provide a first set for assessing further models.

The distribution of residuals supports the findings of the hit ratio. Figure 6.1 shows distributions for the reference model and for Model A, both excluding and including the public transport (PT) alternative. All of the distributions were calculated with 50 repetitions.

The shapes of the distributions differed among the three models. The bars in the figure show how many predictions were made within a 2% range. For example, the R_{rel} value in the reference model, was between 0.9 and 0.92 in about 13% of the cases. In this totally random model, all of the forecasts were between 65% and 100% wrong, giving the expected shape of a Gumbel distribution. The estimated models had totally different

Figure 6.1: Distribution of residuals: household fleet choice model A

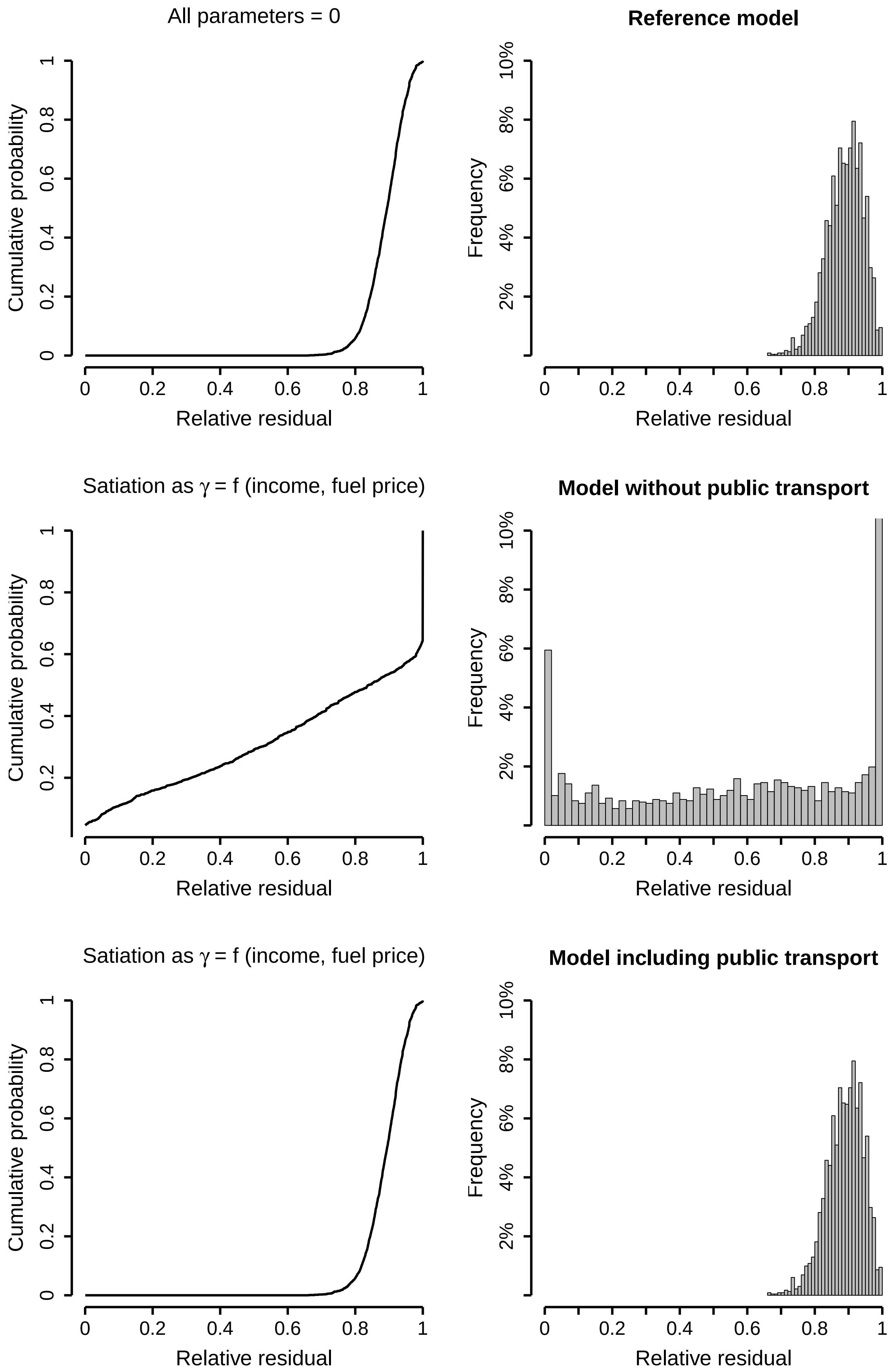
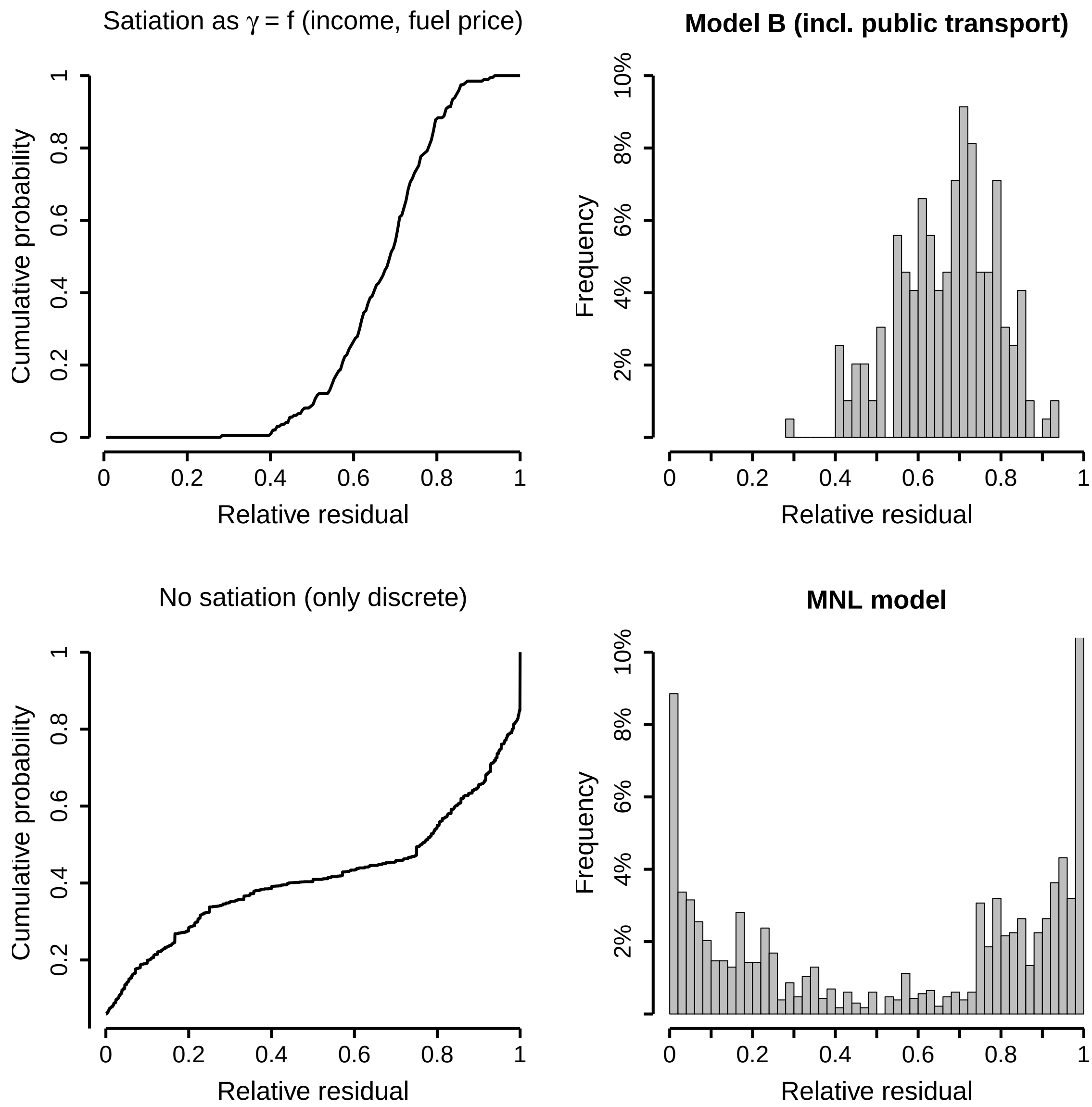


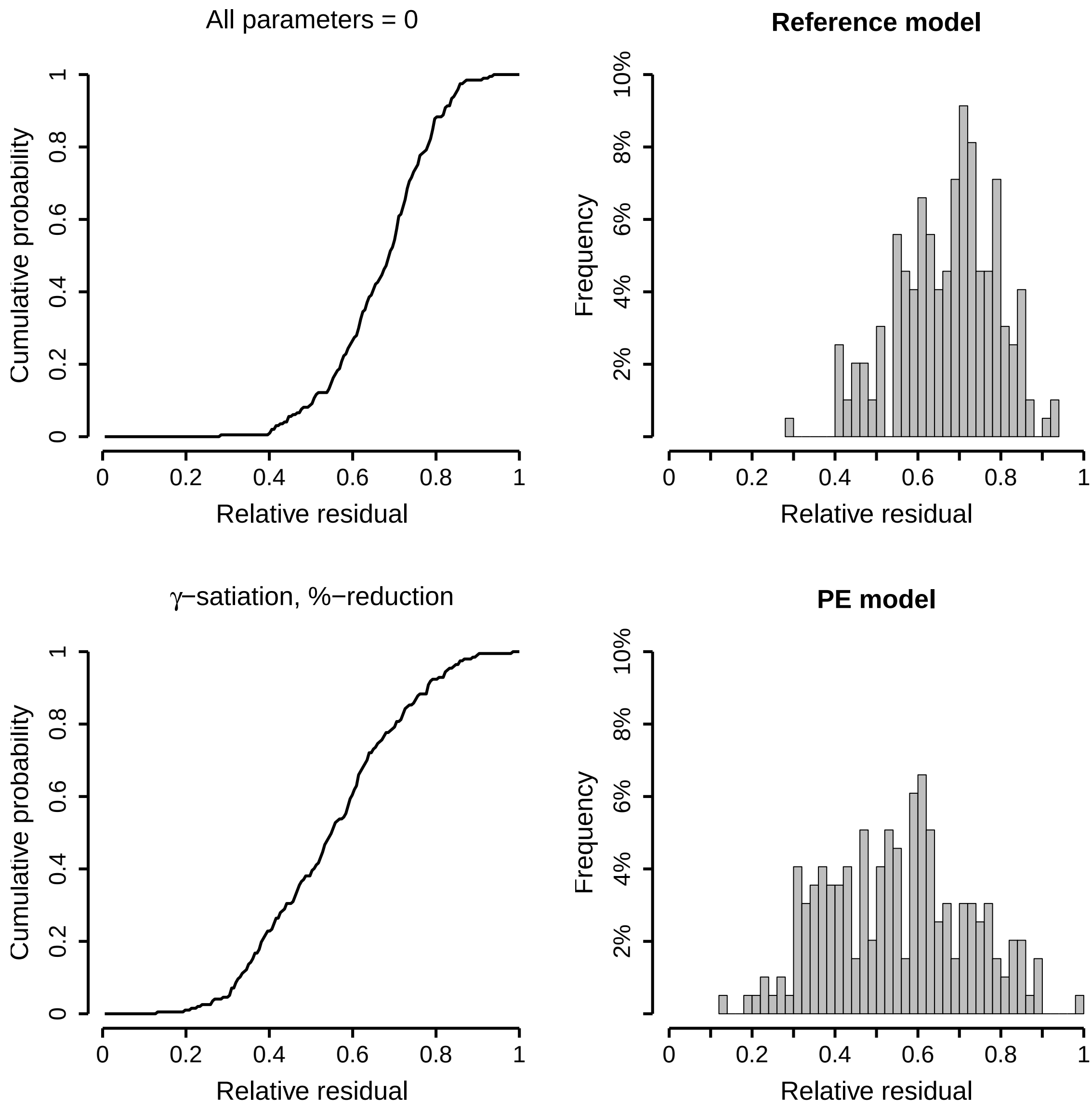
Figure 6.2: Distribution of residuals: household fleet choice model B and MNL model



shapes: Except for the almost 40% completely wrong cases excluding PT (see hit ratio numbers) and the 16% wrong cases in the model including PT, the relative residuals were fairly equally distributed. The great advantage of the PT model is the much smaller portion of completely false predictions. Nevertheless, 16% share of wrongly predicted observations is still high.

Figure 6.2 shows the residual distribution of Model B and the MNL model. The residuals again had a different shape, with a substantial number of both correct and incorrect allocations. The MNL model had a high share of completely false allocations due to the characteristic of

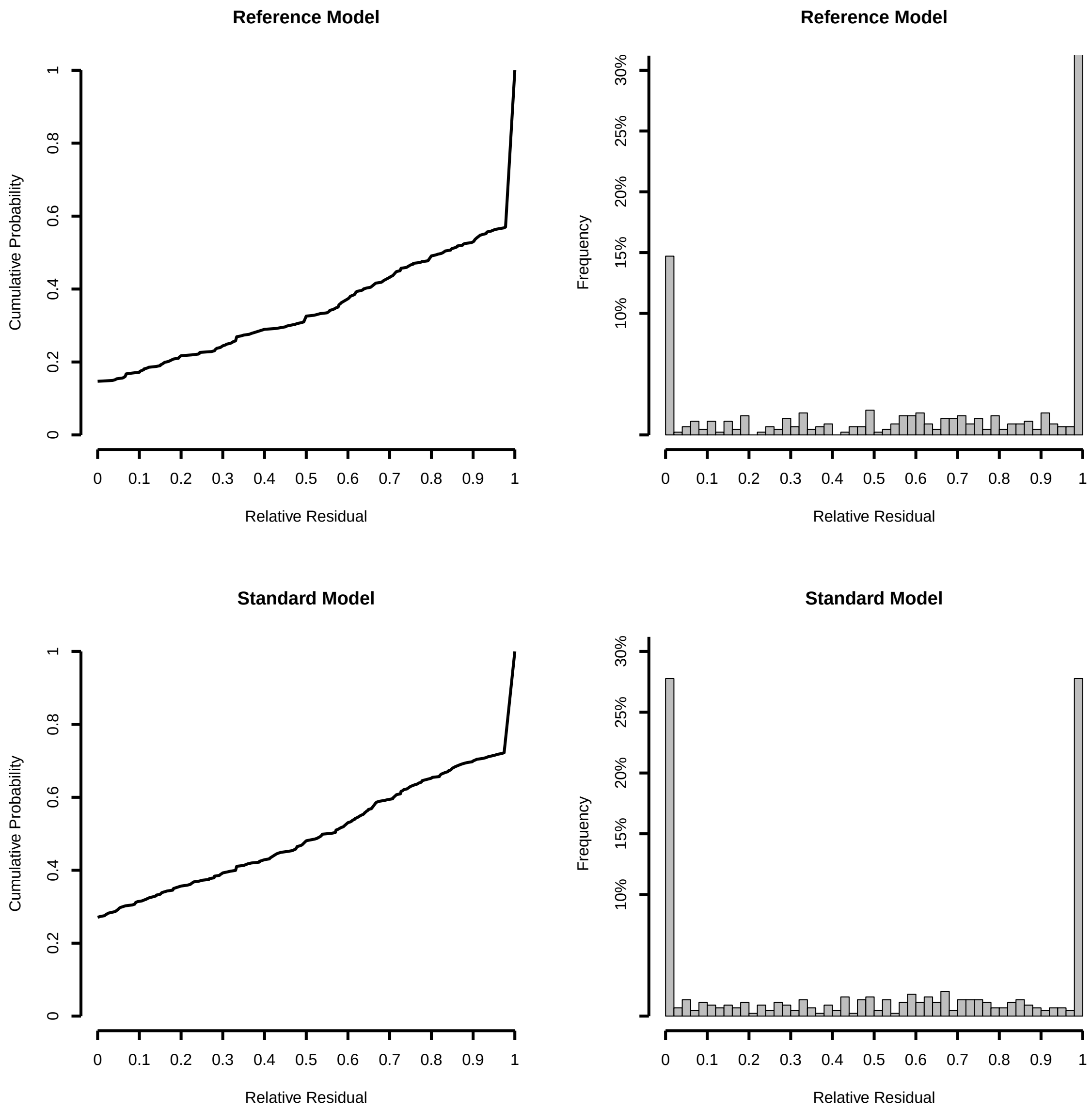
Figure 6.3: Distribution of residuals: priority evaluator model



having only one chosen alternative: If the wrong alternative was chosen, then R_{rel} was 1. Model B showed a significant share of relatively good predictions, however.

The shapes of the residual distributions of the two comparison models, the PE and ID models, differed significantly from those of the household fleet choice models, as shown in figures 6.3 and 6.4. While the PE residuals were relatively normally distributed in both random and specified cases, the ID residuals had a step-like shape, with a large part of completely false forecasts (30%), a large portion of completely correct forecasts (30%) and an equal distribution in between. It is difficult to determine what caused

Figure 6.4: Distribution of residuals: induced demand model



these different characteristics. Our results strongly indicate that it had less to do with the specification than with the data set.

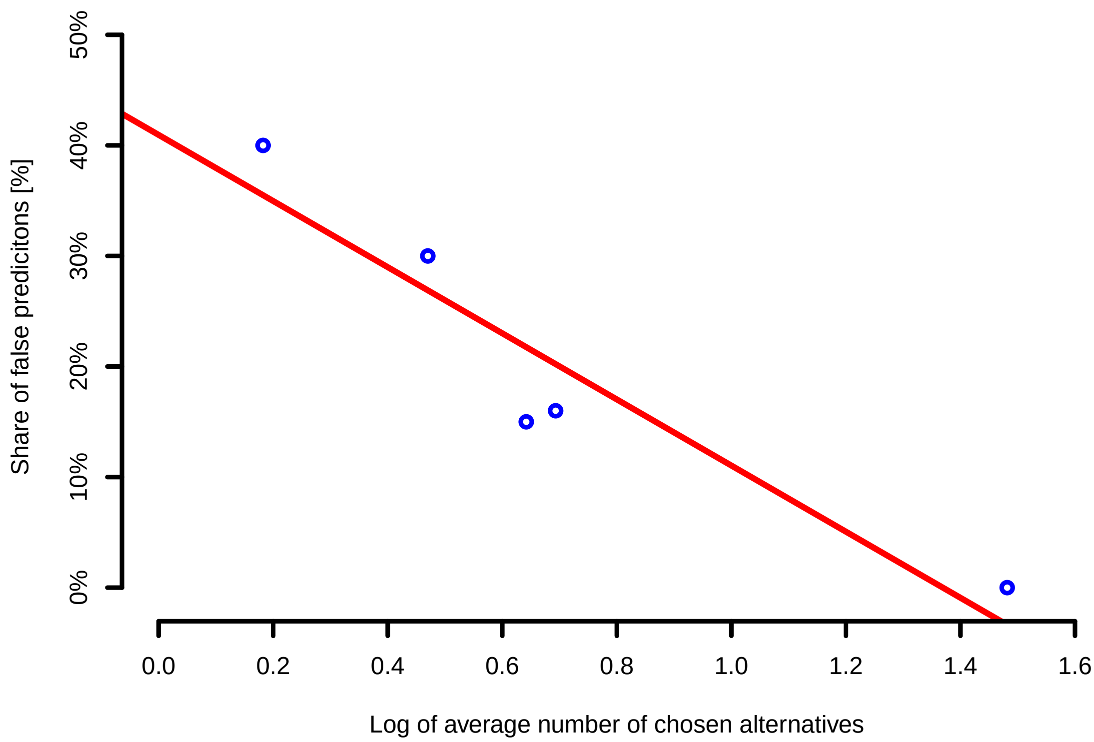
One hypothesis is that the share of wrong forecasts depended on the percentage of non-chosen alternatives or corner solutions. Table 6.4 gives an overview of this relationship for the models presented:

More corner solutions correlated to a higher share of completely false predictions, both for the household fleet choice model and for the PE model. This indicates that there was some kind of relationship. However,

Table 6.4: Relationship corner solutions - forecast accuracy

	Alt.	Alt. chosen		Corner solutions [%]		Completely false [%]
Model		**Mean**	**Range**	**Data**	**Simulation**	**Simulation**
FC model A, no PT	16	1.2	1 to 4	92.3	90.8	40.0
FC model A	17	2.0	1 to 5	88.5	86.6	16.0
FC model B	17	1.9	1 to 5	88.8	87.8	15.0
FC MNL	17	1.0	1	88.8	94.1	20.9
Induced demand	3	1.6	1 to 3	48.4	56.0	30.0
Priority Evaluator	12	4.4	1 to 10	63.0	38.0	0.0

Figure 6.5: Influence of data characteristics on residuals



the ID model also had a high share of wrong predictions despite a modest number of corner solutions. The hypothesis must therefore be rejected.

Another hypothesis is that the presence of a strong alternative that was predominantly the only one chosen was responsible for a high share of false predictions,since in the ID model over 67% of the observations, the same (single) alternative (changing the departure time) was chosen. But this does not explain the high share of false predictions in the household fleet choice model without public transport, when the strongest alternative, PT, was left out and all other alternative were relatively equal.

The strongest correlation with to the share of false predictions was found to be the absolute number of chosen alternatives in a model. Figure 6.5 depicts the plot including the linear regression. The relationship is clear, though very few data sets were compared. Although the log-linear relationship might look different if more models were considered, it nonetheless shows the existence of a relationship. Since the share of predictions cannot be negative, the line may also be steeper, as we do not know where the threshold of zero false prediction lies. We only know the upper boundary of 4.4 chosen alternatives on average.

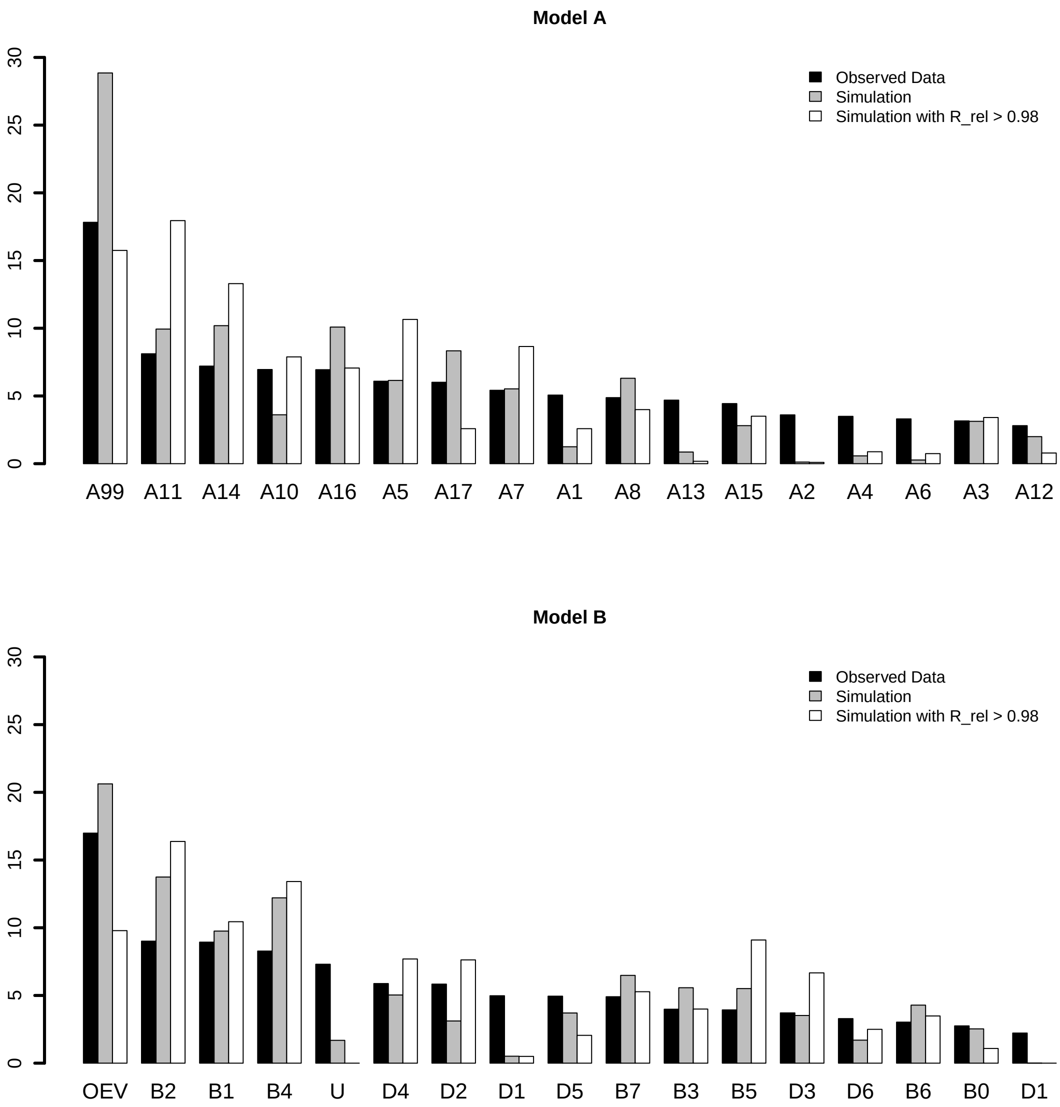
6.5.2 Aggregate Simulation Results

In this section we will briefly consider the aggregate 'market shares' of the car types from the household fleet choice model. Figure 6.6 shows the market shares for the observed data, both for the simulation and also for the completely wrong predictions alone. Clearly, alternatives with a medium-sized market share were are fairly well predicted while alternatives with a high market share were over-predicted and alternatives with a low market share were under-predicted. The high number of completely false predictions is mainly attributable to greatly over-predicted alternatives. The MNL model that had only one chosen alternative and 20.9% false predictions does not fit well into this model, but it does not fully contradict it either. It has been left out of the consideration because the methodological framework was different.

6.6 Discussion

The results shown in this chapter are intriguing yet fairly difficult to interpret because of the lack of comparable work in the literature. This is the first time that discrete continuous models of sophisticated stated adaption data have been assessed and compared in a disaggregate way. We have demonstrated how models that were established to predict changes in behaviour in the case of high fuel prices, drastic energy laws or dramatic travel time changes will perform when implemented. We have furthermore shown how different model specifications and models from different data sets perform and have discussed how they differ. The models and forecasting procedure used for this chapter are relatively new. We consider this to be a useful choice modelling approach because the methodology is simple to understand and is well documented and the necessary software is freely available. However, the results of such model estimations are not particularly easy to interpret, and neither an evaluation of the model fit nor its suitability for implementation is obvious. We therefore suggest using an indicator set to analyse the residuals and compare different models. As this chapter shows, the outcome of a forecast is never trivial or useless. The extreme differences in the distribution of the residuals and the (often unsatisfactory) overall accuracy show that analysis is needed not only to assess specific models but also to improve them in an iterative process. Analysing residuals gives insight into the usefulness of a model beyond providing model fit parameters from the estimation. Simulation assessments pertain mainly to the models and not so much to the methodology per se.

Figure 6.6: Aggregate shares of the household fleet choice models



The analysis presented in this chapter may be considered as a first step towards a concise assessment of the forecasting quality of stated preference models or even of MDCEV methodology: four models from three data sets were analysed and compared. The differences between the distributions of the residuals were of particular interest. We assume that the shapes were strongly linked to the share of false predictions ($R_{Rel} \geq 0.98$). The correlation we discovered between the number of chosen alternatives and the distribution of the residuals indicates that the MDCEV framework in combination with the applied simulation algorithm performs better when more multiple choices are observed. The evidence is still scant, but it will hopefully increase when the process of analysis presented here is applied to the additional models and data sets.

It would also be helpful to have models based on revealed preference data to assess in the same, disaggregate way in order to gain more experience in judging the quality of predictions. From an absolute viewpoint, the specified models presented in this chapter are significantly better than mere random ones, but not as accurate as one might expect looking only at the estimation parameters and their significance. The models were all based on very complex, difficult and relatively new survey methods that required the participants to imagine very unfamiliar choice situations, thus exhibiting a much lower consistency than revealed preference data. Nevertheless, with an accurate assessment, the estimated models can provide useful insights.

Chapter 7

Interdependencies and Modelling of Household Expenditure Categories

In this chapter, the Swiss national income and expenditure statistics (Swiss Federal Statistical Office (BFS), 2008) described in chapter 2.3 is analysed. It tests the hypothesis of interdependencies between the different expenditure categories and estimated linear regression models for all expenditure categories.

7.1 Introduction

7.1.1 Context

Why using expenditure data for transportation demand modelling? To answer this question I would like to go deeper on the subject of the nature of variables in transportation models.

Microscopic agent based modelling, as used in models like the SACSIM model of the Sacramento Area, California (Bradley et al., 2010), the ILUTE model in Toronto (Salvini and Miller, 2005), the Albatross model from the Netherlands (Beckx et al., 2009) or MATSim, an overall transport model currently developed at IVT in collaboration with TU-Berlin (Balmer, 2007; Meister et al., 2009; Balmer et al., 2008), requires detailed microscopic information to model agents. Models with very detailed agents have many advantages, first and foremost the possibility to observe and track single agents in various, reproducible situations and interactions. A major disadvantages however is the need for detailed, disaggregate information. Agents' disaggregate characteristics that drive the behaviour and transport related decisions are to a major part non-observable personal preferences, that are modelled as random error terms. Other characteristics can be considered a specific combinations resulting from the individual, close environment of a person such as family, household, specific residential location, job, social network, car ownership and so on. Irregular working hours, the need to support a family member, diet requirements of a household member, the nature of neighbourhood or street one lives in or status requirements of a job are all examples of perfectly observable but incredibly detailed variables that are difficult to collect, handle, quantify or implement into a model. Yet they are responsible for a substantial part of transport related decisions. While we can model car ownership, we cannot model car ownership of a young, low income couple living in an urban area close to the public transport system because their hobby requires them to travel to mountains on weekends with a lot of equipment, other than with randomness. These kinds of decisions are still out of reach in both surveying as well as modelling. Making assumption over these variables for a longer time period is near to impossible.

Individual social state of a person, typically the socio part of socio-economic variables, influences transportation indirectly through influencing the before mentioned environmental and personal characteristics. These are variables like age, gender, education, household composition and profession. They are relatively easy to collect and quantify and understand in surveys and data sets and are usually part of the backbone of transport models. Examples are: Family size increases car ownership, younger people or women use more public transport, higher education increases likelihood for air travel etc. While making assumptions for the long term for some of these variables can be rather difficult, others like gender or age can more easily be assumed or derived from demographical models.

Individual (or household level) economic information consist of income and expenditures, with income as the strongest and important one. Household or personal income is most widely used as an explanatory variable as it is relatively easy to collect in surveys and can also be assumed with a satisfying accuracy through models of regional economic growth and changes in distribution.

Table 7.1 gives an overview of the general categorization described above.

When activity chains and transport demand are to be forecast over a longer time period, a model is needed that generates the future person's household with it's characteristics. If the present population is simply

Table 7.1: Variable categories for transportation demand models

	Impact	Observable	Collectable	Applicable	Assumable (long term)
Personal preferences	High	No	No	No	No
Environment	High	Yes	No	No	No
Social state	Low	Yes	Yes	Partially	Partially
Economic state	Low	Yes	Yes	Yes	Yes
Geographic inform.	Low	Yes	Partially	Partially	Yes

scaled up assuming only population growth and known activity chains, then our model can tell us nothing about the dynamics in future of transportation other than an increase in population results in equally more traffic. Müller and Axhausen (2012) provide a state of the art model for the generation of artificial households in Switzerland. These artificial population generators have to make assumptions over the general state of economy and demography in a given year in the future, and based on that generate synthetic households on the basis of current survey and census data. Applying standard models for the simulation or estimation of travel demand or car ownership of these synthetic future households would require information on activity patterns.

A model that is based on household expenditures and derives travel demand from transportation expenditure makes it possible to incorporate scenarios of economic and political development through changes in expenditure categories. A steep increase in energy prices could be modelled through energy related expenditures, political development regarding farm subsidies and tariffs through food expenditures and developments in the finance sector through housing expenditures. Such a model could also be implemented in synthetic population generation for example in the case of modelling car ownership.

In this chapter the hypothesis is tested that cross effects between expenditure categories exist and expenditure categories influence each other. To test the hypothesis I apply different modelling methodologies. The data used for the analysis is described and explored at length in chapter 2. In section 7.1.2 a short overview of the existing literature of household expenditure models is given. In section 7.2 the expenditure categories are defined and described. In sections 7.4 and 7.5 the correlation matrices of absolute expenditure and shares are analysed for various subgroups to confirm the hypothesis of interdependencies among expenditure categories. In section 7.6 the formation of pseudo panels for time series analysis is introduced. Section 7.7 contains the linear regression models for all expenditure categories. The model focuses on generic variables which could be used for long term forecast, mainly income, household composition, age and residential location by municipality type, as well as information on car ownership and the presence of durable goods.

7.1.2 Literature

The first comprehensive study on household expenditure patterns was conducted by Houthakker (1957) who compared expenditure elasticities for various international household expenditure surveys.

In (Castro, 2012), household expenditure is categorized in vehicle purchase, gasoline, vehicle insurance, vehicle maintenance, air travel, public transportation and non-transportation related goods, which as they are chosen by all households, are treated as outside goods in the model. She found that the number of workers in a household increases vehicle related expenses, that middle and higher income household spend a lower proportion on transportation and that race and household location has a significant impact on public transport related expenses.

Several authors studied transportation expenditure alone or in relation to other expenditure categories. Thakuriah and Liao (2006) for example found a positive relationship between income and transportation expenditure.

Gicheva et al. (2007) show a substitution effect between expenditure for gasoline and for food. Choo et al. (2007b) and Choo et al. (2007a) found a complementary relationship between communication and transportation expenditures using a almost ideal demand system. Other studies working with the almost ideal demand system developed by Deaton and Muellbauer (1980) found a complementary relationship between communication and transportation expenditures. Other studies, focused more on household budget allocation dependent on income sources of multiple worker households are the following:

Lundberg et al. (1997) who rejected the hypothesis of income pooling among spouses by saying that a higher income share from the wife resulted in higher expenditures for wife and children. Browning and Chiappori (1998) present a model framework to determine how a spouses income share influences expenditures of different categories. Browning et al. (1994) showed that the decision process within a household is different according to the household composition.

Blundell et al. (1993) estimated parameters for a demand system with seven categories: food, alcohol, fuel, clothing, transport, services, and other. The authors found that an aggregated model performs with similar accuracy than a model based on micro data. Deaton et al. (1989) tested the existence of adult goods to determine the influence of demography on expenditure patterns using Spanish household expenditure data. In Mokhtarian et al. (2011) the authors looked at trends within the household expenditure categories of communication and transportation between 1984 and 2002. Fan and Zuiker (1998) used annual household expenditure data from the United States for the period from 1980 to 1992 to compare the spending patterns between Hispanic Americans and Non-Hispanic White Americans.

7.2 Expenditure Categories

In the official survey and the month long diary of the federal bureau of statistics, all expenditures were categorized according to categories defined by the federal bureau of statistics. These are:

1. Food and non-alcoholic Beverages
2. Alcohol and Tobacco
3. Restaurants and Accommodation
4. Clothing and Shoes
5. Housing and Energy
6. Furniture and Housekeeping
7. Healthcare
8. Transportation
9. Communication
10. Entertainment and Culture
11. Education
12. Other Goods and Services
13. Insurance (social and private)
14. Taxes and Fees
15. Donations

This categorization was made from a rather technical point of view. In order to understand and model the behaviour of households, this division has some minor weaknesses. In some categories, it does not differentiate enough between a need-based aspect of the good or service and a choice-based aspect. In the category "Restaurants and Accommodation" for example, expenditure for lunch at a canteen was lumped together with drinking wine at a dinner and visiting a hotel for the weekend. To model behaviour, a more clear distinction between mandatory, need-based and choice-based spending is needed. For further analysis and for the

Table 7.2: Categorization of consumer expenditure

Abb.	Category	Includes
F	Food	Food, lunch and non-alcoholic beverages in cantines
EAT	Eating out, alc. and t.	Alcohol, tobacco and restaurants
HR	Housing: rent	Rent, interest and down-payment, maintainance
HE	Housing: energy	Energy, heating, water and waste disposal
CG	Consumer goods	Clothing, shoes, housekeeping, kitchen appliances, dinnerware, textiles, etc.
Ent	Entertainment	Entertainment, culture, out-of-home accomodation
Com.	Communication	Communication
Pr. T	Private transportation	Fuel, reparations, fees, parking
Pu. T	Public transportation	Tickets and season tickets
Fix	Fix costs	Education and additional healthcare
SaDG	Savings and durable goods	Savings, cars, motorbikes, tV, refrigerator, freezer, sport equipment, other durable goods

modelling part, a slightly different and more adjusted classification was used, as given in table 7.2. Table 7.2 only shows categories for consumer spending. Donations, taxes, fees, insurances and other transfer spending are taken out of further analysis as they are fixed, often required by law and are not a function of a households decision.

The "Food" category refers to all food and beverages households need to buy in order not to stay hungry. The "Eating out" category refers to all activities and goods seen as luxury food including going out for dinner and drinking alcohol. The third category is the finance aspect of housing cost, normally related to location and relative value of the dwelling a household lives in. The next category, "Energy" is more related to the insulation capacity of the building and of individual behaviour of the household. "Consumer goods" is a category that sums up goods that are not especially necessary to survive, but a typical nice-to-have for maintaining a certain standard and style of live. "Entertainment" means all expenditure for things and activities that bring fun and entertainment to their leisure time. That could be a ticket for a sport-event, a day going skiing in the mountains, a board game, a concert or opera ticket or accommodation in a hotel. The "Communictaion" category contains expenditure for telephoning, internet and mail services. The transportation category is divided in two, to be able to separately analyse private transportation and public transportation. The category "Fix Costs" is a category of minor importance. It covers additional health care spending and private schooling. In Switzerland, primary and secondary schools are public and free of costs for everybody.

Attendants of tertiary or higher education are covered a small fee. Private institutes for specialized further education and advanced training however can be costly. But overall, only a small percentage of households pay for educational purposes. As for healthcare, the great majority of necessary treatments are covered by the mandatory health insurance, for which the premiums are counted under transfer payments. This category is labelled "Fix Costs" as I assume thire costs to be necessary and not traded-off against other goods. When matriculated at a university or when having a health issue the associated cost are viewed as fixed and not the result of a deliberate spending decision, or in the case of donations don't buy any goods or services nor fulfil any purpose other than altruism.

The last category described in table 7.2 is "Savings and Durable Goods". The reason to lump together these seemingly unrelated classes comes from the nature of the survey method it self. The survey only covered one month per household. When the household was surveyed in exactly that month in which it may have bought a durable consumer good, i.e. a TV, which in many cases exceeded the normal spending for that category, the household has probably not bought a TV in the previous month, nor would he buy a TV in the next month. If the household borrowed the money for the TV it would be partially paying for the TV in the next months. If the household had the money in cash, it would to have saved for it during the previous months (either explicitly or implicitly). Either way, from a generalized point of view, the household financed the purchase of the durable good (TV) over a time period of multiple months. Attributing this financing solely on the random month during which the TV was actually purchased, overstates the expenditure of this household, and understates the expenditure of a household that was saving for a TV to buy it in a month that was not surveyed. The categories "Housing: Energy" and "Fixed Cost" are not modelled in this chapter.

To counter that problem I discounted all expenditures for durable goods in the respective categories and added them to the "Savings and Durable Goods" category.

7.3 Inflation

All expenditures used for the analysis in this chapter are adjusted for inflation using the official Swiss consumer Price Index (Swiss Federal Statistical Office (BFS), 2014). Base year is 1998.

Table 7.3: Correlation matrix (all households)

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.19	0.14	0.21	0.34	0.22	0.23	0.2	0.12	0.11	0.04
EAT	0.19	1	0.16	0.09	0.3	0.32	0.23	0.23	0.2	0.06	0
HR	0.14	0.16	1	0.03	0.21	0.16	0.16	0.13	0.1	0.05	-0.11
HE	0.21	0.09	0.03	1	0.13	0.12	0.09	0.09	0.02	0.05	-0.02
CG	0.34	0.3	0.21	0.13	1	0.31	0.22	0.22	0.17	0.12	-0.05
Ent	0.22	0.32	0.16	0.12	0.31	1	0.17	0.17	0.2	0.11	-0.1
Com	0.23	0.23	0.16	0.09	0.22	0.17	1	0.25	0.12	0.05	0.02
PrT	0.2	0.23	0.13	0.09	0.22	0.17	0.25	1	-0.02	0.06	-0.03
PuT	0.12	0.2	0.1	0.02	0.17	0.2	0.12	-0.02	1	0.08	0.02
Fix	0.11	0.06	0.05	0.05	0.12	0.11	0.05	0.06	0.08	1	-0.22
SaDG	0.04	0	-0.11	-0.02	-0.05	-0.1	0.02	-0.03	0.02	-0.22	1

7.4 Correlation of Absolute Expenditure

7.4.1 Methodology

To calculate correlation among expenditure categories, the Pearson Correlation Coefficient (PCC) was used. The coefficient is calculated as:

$$PCC = \frac{\sum_{i=1}^{n}\left(E_{i1}-\bar{E}_1\right)\left(E_{i2}-\bar{E}_2\right)}{\sqrt{\sum_{i=1}^{n}\left(E_{i1}-\bar{E}_1\right)^2}\sqrt{\sum_{i=1}^{n}\left(E_{i2}-\bar{E}_2\right)^2}} \tag{7.1}$$

with for n as the number of observations and E_1 and E_2 the two expenditure categories compared. The PCC ranges from -1 (perfect negative correlation) to +1 (perfect positive correlation). 0 means no correlation at all between the two categories. The matrices shown in this section as well as in section 7.5 all contain the above shown PCC correlation measure.

7.4.2 All Households

A first analysis is to test the hypothesis that expenditure categories are interdependent, that expenditure of one category influences spending of another category, is looking at the correlation matrix of the expenditure categories. Table 7.3 shows the correlation matrix for the above defined categories including all households of the whole time period from 2001 to 2008.

Table 7.4: Correlation matrix, retired singles

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.04	0.09	0.06	0.28	0.09	0.16	0.09	-0.01	0.07	-0.14
EAT	0.04	1	0.13	0.06	0.19	0.21	0.24	0.24	0.12	0.02	-0.06
HR	0.09	0.13	1	-0.01	0.12	0.13	0.14	0.07	0.09	0.13	-0.28
HE	0.06	0.06	-0.01	1	0.1	0.06	0.1	0.09	-0.03	-0.02	-0.05
CG	0.28	0.19	0.12	0.1	1	0.27	0.33	0.13	0.16	0.12	-0.21
Ent	0.09	0.21	0.13	0.06	0.27	1	0.27	0.16	0.22	0.09	-0.24
Com	0.16	0.24	0.14	0.1	0.33	0.27	1	0.24	0.14	0.1	-0.19
PrT	0.09	0.24	0.07	0.09	0.13	0.16	0.24	1	-0.09	0.01	-0.07
PuT	-0.01	0.12	0.09	-0.03	0.16	0.22	0.14	-0.09	1	0.07	-0.03
Fix	0.07	0.02	0.13	-0.02	0.12	0.09	0.1	0.01	0.07	1	-0.3
SaDG	-0.14	-0.06	-0.28	-0.05	-0.21	-0.24	-0.19	-0.07	-0.03	-0.3	1

The correlations between the expenditure categories are fairly low. The highest value is 0.34 for the correlation between expenditure on Food and on Consumer Goods. A causal interpretation for these category is very difficult to make as there is no obvious idea why these two categories should be correlated other than through income. But the correlation is still quite week.

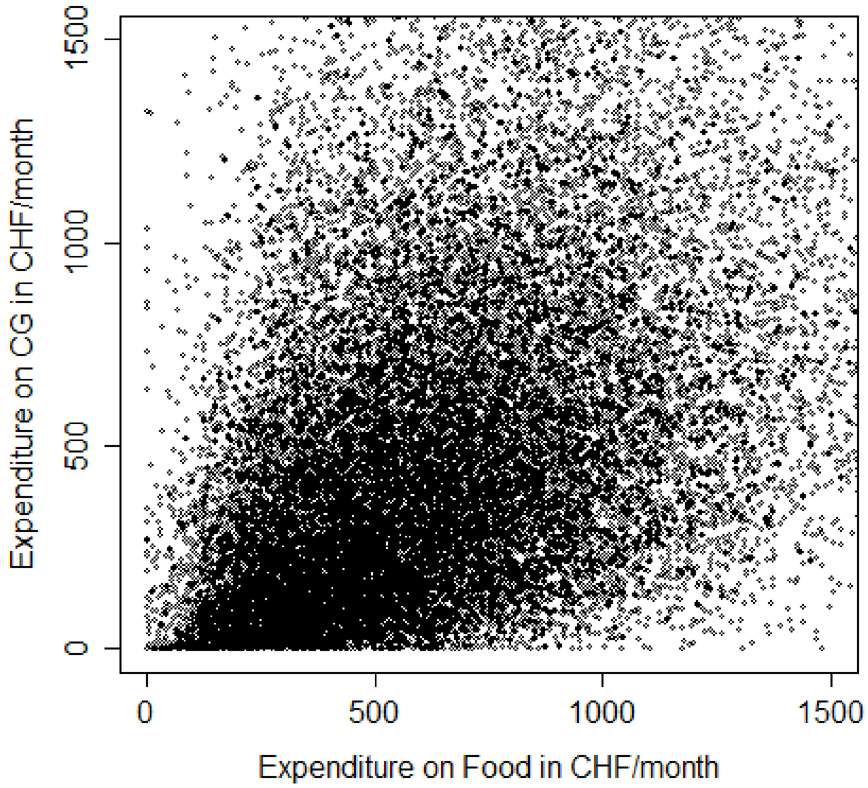
Figure 7.1 shows the scatter and the box plot for the correlation between "Food" and "Consumer Goods". In the upper graph, each data point representing a single household, showing how scattered the data points are. The high variance of the data and the underling correlation is better visible in the lower graph, depicting box plots.

7.4.3 By Household Type

If looking at all Households at the same time it is hard to see any correlation at all. To detect correlations and patterns within subgroups we can look at the correlation matrix for different household types.

Tables 7.4 to 7.11 show the correlation matrices for all household types.

Figure 7.1: Correlation between food and consumer goods



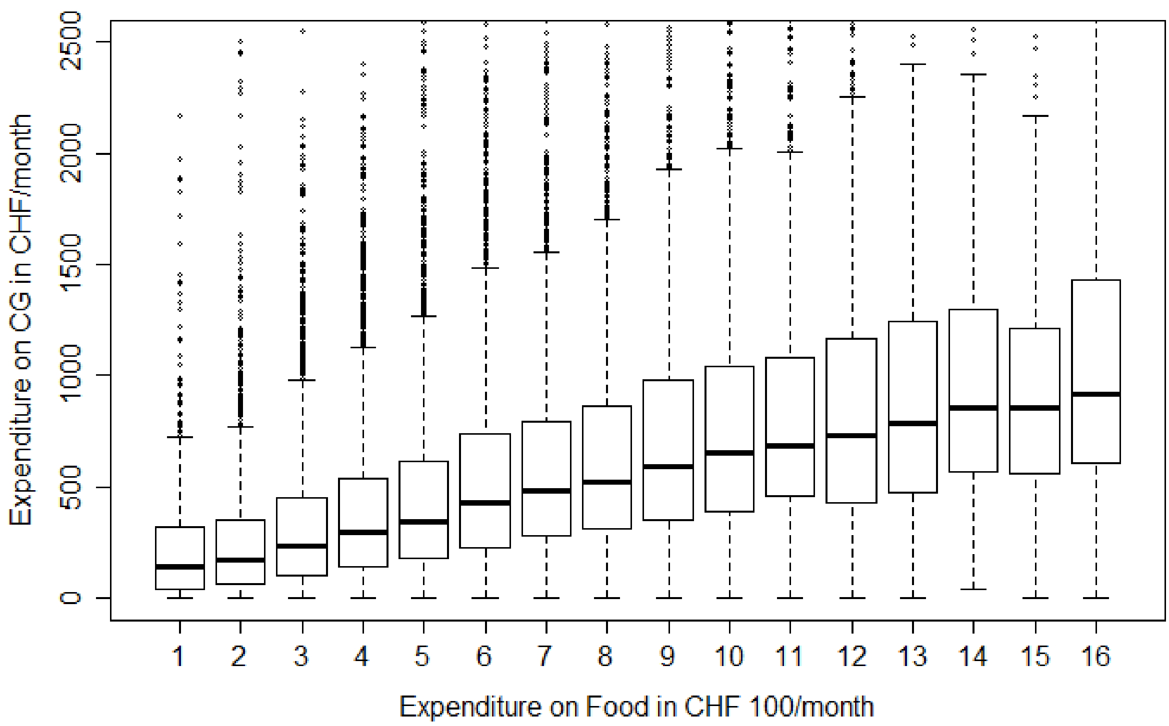


Table 7.5: Correlation matrix, working age singles

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.02	0.08	0.13	0.2	0.08	0.01	0.02	0.02	0.08	-0.09
EAT	-0.02	1	0.17	0.02	0.12	0.17	0.17	0.18	0.08	0.02	-0.01
HR	0.08	0.17	1	0.04	0.18	0.12	0.1	0.1	0.06	0.02	0.03
HE	0.13	0.02	0.04	1	0.07	0.07	0.06	0.07	-0.07	0.02	-0.04
CG	0.2	0.12	0.18	0.07	1	0.24	0.09	0.06	0.11	0.08	-0.17
Ent	0.08	0.17	0.12	0.07	0.24	1	0.12	0.1	0.18	0.08	-0.13
Com	0.01	0.17	0.1	0.06	0.09	0.12	1	0.19	0.04	0.04	-0.06
PrT	0.02	0.18	0.1	0.07	0.06	0.1	0.19	1	-0.15	0.02	-0.09
PuT	0.02	0.08	0.06	-0.07	0.11	0.18	0.04	-0.15	1	0.06	-0.01
Fix	0.08	0.02	0.02	0.02	0.08	0.08	0.04	0.02	0.06	1	-0.27
SaDG	-0.09	-0.01	0.03	-0.04	-0.17	-0.13	-0.06	-0.09	-0.01	-0.27	1

Table 7.6: Correlation matrix, retired couple

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.12	0.08	0.1	0.28	0.11	0.22	0.12	0.05	0.06	-0.13
EAT	0.12	1	0.18	0.07	0.29	0.4	0.26	0.22	0.25	0.06	-0.15
HR	0.08	0.18	1	0.03	0.17	0.15	0.18	0.11	0.15	0.03	-0.22
HE	0.1	0.07	0.03	1	0.08	0.05	0.07	0.02	0.01	0.06	-0.08
CG	0.28	0.29	0.17	0.08	1	0.31	0.29	0.22	0.12	0.14	-0.19
Ent	0.11	0.4	0.15	0.05	0.31	1	0.29	0.21	0.18	0.11	-0.21
Com	0.22	0.26	0.18	0.07	0.29	0.29	1	0.28	0.11	0.05	-0.09
PrT	0.12	0.22	0.11	0.02	0.22	0.21	0.28	1	-0.03	0.07	-0.13
PuT	0.05	0.25	0.15	0.01	0.12	0.18	0.11	-0.03	1	0.05	-0.03
Fix	0.06	0.06	0.03	0.06	0.14	0.11	0.05	0.07	0.05	1	-0.34
SaDG	-0.13	-0.15	-0.22	-0.08	-0.19	-0.21	-0.09	-0.13	-0.03	-0.34	1

Table 7.7: Correlation matrix, working age couples

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.07	0.04	0.13	0.23	0.08	0.02	0.08	0.03	0.09	-0.1
EAT	0.07	1	0.18	0.03	0.28	0.26	0.17	0.17	0.2	0.05	-0.05
HR	0.04	0.18	1	0	0.22	0.12	0.15	0.12	0.11	0.03	-0.03
HE	0.13	0.03	0	1	0.09	0.05	0.03	0.05	-0.05	0.02	-0.1
CG	0.23	0.28	0.22	0.09	1	0.22	0.15	0.2	0.15	0.1	-0.06
Ent	0.08	0.26	0.12	0.05	0.22	1	0.1	0.1	0.17	0.07	-0.16
Com	0.02	0.17	0.15	0.03	0.15	0.1	1	0.2	0.1	0.02	0
PrT	0.08	0.17	0.12	0.05	0.2	0.1	0.2	1	-0.06	0.08	-0.05
PuT	0.03	0.2	0.11	-0.05	0.15	0.17	0.1	-0.06	1	0.04	0.03
Fix	0.09	0.05	0.03	0.02	0.1	0.07	0.02	0.08	0.04	1	-0.21
SaDG	-0.1	-0.05	-0.03	-0.1	-0.06	-0.16	0	-0.05	0.03	-0.21	1

Table 7.8: Correlation matrix, single parents

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.24	0.2	0.16	0.29	0.3	0.18	0.17	0.22	0.12	-0.05
EAT	0.24	1	0.13	0.11	0.23	0.33	0.23	0.27	0.15	0.15	-0.13
HR	0.2	0.13	1	-0.01	0.27	0.24	0.17	0.17	0.11	0.09	-0.02
HE	0.16	0.11	-0.01	1	0.05	0.15	0.05	0.03	0.09	0.01	0.06
CG	0.29	0.23	0.27	0.05	1	0.41	0.15	0.19	0.11	0.13	-0.02
Ent	0.3	0.33	0.24	0.15	0.41	1	0.12	0.26	0.19	0.07	-0.07
Com	0.18	0.23	0.17	0.05	0.15	0.12	1	0.2	0.1	0.1	-0.02
PrT	0.17	0.27	0.17	0.03	0.19	0.26	0.2	1	-0.05	0.04	-0.12
PuT	0.22	0.15	0.11	0.09	0.11	0.19	0.1	-0.05	1	0.11	-0.04
Fix	0.12	0.15	0.09	0.01	0.13	0.07	0.1	0.04	0.11	1	-0.25
SaDG	-0.05	-0.13	-0.02	0.06	-0.02	-0.07	-0.02	-0.12	-0.04	-0.25	1

Table 7.9: Correlation matrix, family with one child

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.23	0.07	0.12	0.22	0.18	0.09	0.09	0.12	0.11	-0.04
EAT	0.23	1	0.15	0.08	0.29	0.28	0.2	0.22	0.18	0.08	-0.07
HR	0.07	0.15	1	-0.03	0.22	0.17	0.12	0.1	0.11	0.13	-0.13
HE	0.12	0.08	-0.03	1	0.07	0.12	0.04	0.06	0.04	0.07	-0.02
CG	0.22	0.29	0.22	0.07	1	0.29	0.13	0.18	0.16	0.09	-0.08
Ent	0.18	0.28	0.17	0.12	0.29	1	0.15	0.15	0.17	0.14	-0.11
Com	0.09	0.2	0.12	0.04	0.13	0.15	1	0.21	0.07	0.05	-0.08
PrT	0.09	0.22	0.1	0.06	0.18	0.15	0.21	1	-0.05	0.04	-0.06
PuT	0.12	0.18	0.11	0.04	0.16	0.17	0.07	-0.05	1	0.11	0
Fix	0.11	0.08	0.13	0.07	0.09	0.14	0.05	0.04	0.11	1	-0.25
SaDG	-0.04	-0.07	-0.13	-0.02	-0.08	-0.11	-0.08	-0.06	0	-0.25	1

Table 7.10: Correlation matrix, family with two children

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.22	0.05	0.12	0.3	0.21	0.13	0.11	0.19	0.15	-0.03
EAT	0.22	1	0.05	0.12	0.32	0.37	0.22	0.22	0.24	0.11	-0.04
HR	0.05	0.05	1	0.01	0.12	0.1	0.02	0.05	0.04	0.04	-0.31
HE	0.12	0.12	0.01	1	0.13	0.16	0.09	0.1	0.06	0.05	0.01
CG	0.3	0.32	0.12	0.13	1	0.36	0.19	0.17	0.21	0.19	-0.06
Ent	0.21	0.37	0.1	0.16	0.36	1	0.17	0.15	0.25	0.15	-0.12
Com	0.13	0.22	0.02	0.09	0.19	0.17	1	0.23	0.14	0.1	-0.02
PrT	0.11	0.22	0.05	0.1	0.17	0.15	0.23	1	0.01	0.12	-0.09
PuT	0.19	0.24	0.04	0.06	0.21	0.25	0.14	0.01	1	0.13	0.02
Fix	0.15	0.11	0.04	0.05	0.19	0.15	0.1	0.12	0.13	1	-0.16
SaDG	-0.03	-0.04	-0.31	0.01	-0.06	-0.12	-0.02	-0.09	0.02	-0.16	1

Table 7.11: Correlation matrix, family with three or more children

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.21	0.02	0.1	0.22	0.23	0.11	0.14	0.22	0.19	-0.07
EAT	0.21	1	0.13	0.15	0.3	0.35	0.21	0.24	0.21	0.15	0
HR	0.02	0.13	1	0.05	0.17	0.19	0.09	0.14	0.08	0.14	-0.11
HE	0.1	0.15	0.05	1	0.11	0.2	0.1	0.1	0.11	0.05	-0.04
CG	0.22	0.3	0.17	0.11	1	0.27	0.13	0.16	0.17	0.17	-0.14
Ent	0.23	0.35	0.19	0.2	0.27	1	0.11	0.17	0.26	0.19	-0.06
Com	0.11	0.21	0.09	0.1	0.13	0.11	1	0.21	0.14	0.1	-0.03
PrT	0.14	0.24	0.14	0.1	0.16	0.17	0.21	1	0.04	0.14	-0.15
PuT	0.22	0.21	0.08	0.11	0.17	0.26	0.14	0.04	1	0.18	0.05
Fix	0.19	0.15	0.14	0.05	0.17	0.19	0.1	0.14	0.18	1	-0.16
SaDG	-0.07	0	-0.11	-0.04	-0.14	-0.06	-0.03	-0.15	0.05	-0.16	1

Table 7.12: Correlation matrix, regional centre

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.18	0.23	0.28	0.37	0.19	0.24	0.2	0.12	0.12	0.05
EAT	0.18	1	0.26	0.08	0.31	0.28	0.22	0.2	0.22	0.06	-0.02
HR	0.23	0.26	1	0.05	0.3	0.2	0.22	0.16	0.17	0.06	0
HE	0.28	0.08	0.05	1	0.15	0.11	0.13	0.12	0.02	0.04	0.03
CG	0.37	0.31	0.3	0.15	1	0.28	0.23	0.17	0.18	0.11	-0.02
Ent	0.19	0.28	0.2	0.11	0.28	1	0.15	0.11	0.22	0.09	-0.16
Com	0.24	0.22	0.22	0.13	0.23	0.15	1	0.23	0.12	0.03	0.02
PrT	0.2	0.2	0.16	0.12	0.17	0.11	0.23	1	-0.07	0.06	0.01
PuT	0.12	0.22	0.17	0.02	0.18	0.22	0.12	-0.07	1	0.07	0.02
Fix	0.12	0.06	0.06	0.04	0.11	0.09	0.03	0.06	0.07	1	-0.23
SaDG	0.05	-0.02	0	0.03	-0.02	-0.16	0.02	0.01	0.02	-0.23	1

Table 7.13: Correlation matrix, suburban area

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.19	0.17	0.2	0.34	0.25	0.24	0.18	0.14	0.12	0.05
EAT	0.19	1	0.17	0.1	0.3	0.32	0.22	0.23	0.19	0.06	0.02
HR	0.17	0.17	1	0.02	0.24	0.17	0.18	0.14	0.1	0.09	-0.03
HE	0.2	0.1	0.02	1	0.15	0.14	0.09	0.05	0.05	0.04	0
CG	0.34	0.3	0.24	0.15	1	0.35	0.21	0.22	0.17	0.13	-0.07
Ent	0.25	0.32	0.17	0.14	0.35	1	0.19	0.18	0.2	0.13	-0.07
Com	0.24	0.22	0.18	0.09	0.21	0.19	1	0.24	0.12	0.06	0.02
PrT	0.18	0.23	0.14	0.05	0.22	0.18	0.24	1	0.01	0.06	-0.06
PuT	0.14	0.19	0.1	0.05	0.17	0.2	0.12	0.01	1	0.09	0.02
Fix	0.12	0.06	0.09	0.04	0.13	0.13	0.06	0.06	0.09	1	-0.23
SaDG	0.05	0.02	-0.03	0	-0.07	-0.07	0.02	-0.06	0.02	-0.23	1

7.4.4 By Residential Municipality Type

Tables 7.12 to 7.17 show the correlation matrices for every residential location municipality type.

Table 7.14: Correlation matrix, suburban area

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.22	0.09	0.17	0.3	0.26	0.24	0.18	0.15	0.08	0.04
EAT	0.22	1	0.08	0.1	0.27	0.35	0.27	0.26	0.2	0.09	0.01
HR	0.09	0.08	1	0.06	0.13	0.12	0.08	0.08	0.04	0.01	-0.34
HE	0.17	0.1	0.06	1	0.09	0.14	0.09	0.05	0.02	0.11	-0.09
CG	0.3	0.27	0.13	0.09	1	0.31	0.23	0.25	0.13	0.13	-0.02
Ent	0.26	0.35	0.12	0.14	0.31	1	0.2	0.22	0.2	0.12	-0.04
Com	0.24	0.27	0.08	0.09	0.23	0.2	1	0.28	0.12	0.02	0.04
PrT	0.18	0.26	0.08	0.05	0.25	0.22	0.28	1	-0.01	0.06	-0.02
PuT	0.15	0.2	0.04	0.02	0.13	0.2	0.12	-0.01	1	0.08	0.03
Fix	0.08	0.09	0.01	0.11	0.13	0.12	0.02	0.06	0.08	1	-0.18
SaDG	0.04	0.01	-0.34	-0.09	-0.02	-0.04	0.04	-0.02	0.03	-0.18	1

Table 7.15: Correlation matrix, industrial or tourism municipality

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.2	0.14	0.18	0.39	0.26	0.22	0.2	0.16	0.15	0
EAT	0.2	1	0.16	0.09	0.34	0.38	0.25	0.28	0.22	0.06	-0.04
HR	0.14	0.16	1	0.01	0.2	0.15	0.17	0.17	0.09	0	0.02
HE	0.18	0.09	0.01	1	0.16	0.14	0.08	0.09	0.05	0.08	-0.03
CG	0.39	0.34	0.2	0.16	1	0.34	0.21	0.24	0.2	0.15	-0.06
Ent	0.26	0.38	0.15	0.14	0.34	1	0.2	0.22	0.24	0.12	-0.09
Com	0.22	0.25	0.17	0.08	0.21	0.2	1	0.29	0.13	0.06	0
PrT	0.2	0.28	0.17	0.09	0.24	0.22	0.29	1	0.02	0.06	-0.08
PuT	0.16	0.22	0.09	0.05	0.2	0.24	0.13	0.02	1	0.09	0.03
Fix	0.15	0.06	0	0.08	0.15	0.12	0.06	0.06	0.09	1	-0.27
SaDG	0	-0.04	0.02	-0.03	-0.06	-0.09	0	-0.08	0.03	-0.27	1

Table 7.16: Correlation matrix, commuter municipality

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.2	0.2	0.15	0.36	0.21	0.23	0.22	0.2	0.13	0.03
EAT	0.2	1	0.17	0.11	0.33	0.3	0.22	0.3	0.2	0.03	-0.04
HR	0.2	0.17	1	0.04	0.24	0.19	0.17	0.23	0.1	0.04	-0.06
HE	0.15	0.11	0.04	1	0.15	0.12	0.06	0.1	0.06	0.06	-0.05
CG	0.36	0.33	0.24	0.15	1	0.31	0.24	0.28	0.2	0.14	-0.08
Ent	0.21	0.3	0.19	0.12	0.31	1	0.12	0.23	0.18	0.08	-0.1
Com	0.23	0.22	0.17	0.06	0.24	0.12	1	0.34	0.14	0.09	0.04
PrT	0.22	0.3	0.23	0.1	0.28	0.23	0.34	1	0.07	0.06	-0.02
PuT	0.2	0.2	0.1	0.06	0.2	0.18	0.14	0.07	1	0.09	0.04
Fix	0.13	0.03	0.04	0.06	0.14	0.08	0.09	0.06	0.09	1	-0.14
SaDG	0.03	-0.04	-0.06	-0.05	-0.08	-0.1	0.04	-0.02	0.04	-0.14	1

Table 7.17: Correlation matrix, rural municipality

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.18	0.11	0.21	0.27	0.13	0.18	0.19	0.14	0.08	-0.02
EAT	0.18	1	0.14	0.11	0.2	0.25	0.27	0.23	0.11	0.05	-0.03
HR	0.11	0.14	1	0.04	0.17	0.16	0.13	0.14	0.04	-0.01	-0.21
HE	0.21	0.11	0.04	1	0.08	0.08	0.11	0.13	0.04	0.03	-0.07
CG	0.27	0.2	0.17	0.08	1	0.18	0.15	0.18	0.13	0.05	-0.12
Ent	0.13	0.25	0.16	0.08	0.18	1	0.13	0.13	0.12	0.05	-0.17
Com	0.18	0.27	0.13	0.11	0.15	0.13	1	0.26	0.12	0.08	-0.04
PrT	0.19	0.23	0.14	0.13	0.18	0.13	0.26	1	0.02	0.12	-0.1
PuT	0.14	0.11	0.04	0.04	0.13	0.12	0.12	0.02	1	0.07	0.02
Fix	0.08	0.05	-0.01	0.03	0.05	0.05	0.08	0.12	0.07	1	-0.23
SaDG	-0.02	-0.03	-0.21	-0.07	-0.12	-0.17	-0.04	-0.1	0.02	-0.23	1

Table 7.18: Correlation matrix, household income smaller than CHF 2'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.21	0.21	0.24	0.34	0.21	0.2	0.35	-0.01	0.11	-0.53
EAT	0.21	1	0.39	0.1	0.4	0.37	0.26	0.44	0.28	0.09	-0.61
HR	0.21	0.39	1	0.1	0.35	0.19	0.25	0.27	0.14	0.07	-0.66
HE	0.24	0.1	0.1	1	0.22	0.07	0.34	0.18	-0.06	0.02	-0.27
CG	0.34	0.4	0.35	0.22	1	0.44	0.22	0.34	0.2	0.19	-0.66
Ent	0.21	0.37	0.19	0.07	0.44	1	0.19	0.23	0.18	0.19	-0.54
Com	0.2	0.26	0.25	0.34	0.22	0.19	1	0.34	0.12	0.03	-0.37
PrT	0.35	0.44	0.27	0.18	0.34	0.23	0.34	1	-0.05	-0.03	-0.51
PuT	-0.01	0.28	0.14	-0.06	0.2	0.18	0.12	-0.05	1	0.11	-0.19
Fix	0.11	0.09	0.07	0.02	0.19	0.19	0.03	-0.03	0.11	1	-0.34
SaDG	-0.53	-0.61	-0.66	-0.27	-0.66	-0.54	-0.37	-0.51	-0.19	-0.34	1

Table 7.19: Correlation matrix, household income between CHF 2'000 and 4'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.08	0	0.19	0.27	0.09	0.12	0.17	-0.05	0.11	-0.36
EAT	0.08	1	0.06	0.02	0.25	0.29	0.27	0.28	0.1	0.02	-0.44
HR	0	0.06	1	-0.12	0.1	0.03	0.17	0.06	0.11	0.03	-0.31
HE	0.19	0.02	-0.12	1	0.11	0.1	0.02	0.09	-0.05	0.11	-0.21
CG	0.27	0.25	0.1	0.11	1	0.27	0.17	0.16	0.13	0.1	-0.49
Ent	0.09	0.29	0.03	0.1	0.27	1	0.16	0.18	0.14	0.07	-0.49
Com	0.12	0.27	0.17	0.02	0.17	0.16	1	0.23	0.13	0.01	-0.31
PrT	0.17	0.28	0.06	0.09	0.16	0.18	0.23	1	-0.13	0.03	-0.37
PuT	-0.05	0.1	0.11	-0.05	0.13	0.14	0.13	-0.13	1	0.02	-0.12
Fix	0.11	0.02	0.03	0.11	0.1	0.07	0.01	0.03	0.02	1	-0.42
SaDG	-0.36	-0.44	-0.31	-0.21	-0.49	-0.49	-0.31	-0.37	-0.12	-0.42	1

7.4.5 By Income Class

When looking at the correlation matrices of different income classes, we can observe that correlations are very weak even within groups of homogeneous incomes. The only notable correlations are negative correlations between the "Savings and Durable Goods" category and "Consumer Goods" and "Entertainment. That means that savings work as a substitution for these categories. The correlation is especially high for the lowest income class, which is mostly composed by households that have irregular income patterns and in the observed month an income

Table 7.20: Correlation matrix, household income between CHF 4'000 and 6'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.02	-0.02	0.18	0.2	0.08	0.05	0.06	-0.01	0.09	-0.3
EAT	0.02	1	0	0.03	0.09	0.16	0.11	0.18	0.06	0.01	-0.28
HR	-0.02	0	1	-0.11	0.06	0.01	0.12	0.04	0.05	0.01	-0.34
HE	0.18	0.03	-0.11	1	0.04	0.03	-0.01	0.02	-0.05	0	-0.13
CG	0.2	0.09	0.06	0.04	1	0.19	0.1	0.06	0.06	0.07	-0.42
Ent	0.08	0.16	0.01	0.03	0.19	1	0.04	0.08	0.09	0.07	-0.38
Com	0.05	0.11	0.12	-0.01	0.1	0.04	1	0.2	0.02	-0.01	-0.19
PrT	0.06	0.18	0.04	0.02	0.06	0.08	0.2	1	-0.13	0.03	-0.29
PuT	-0.01	0.06	0.05	-0.05	0.06	0.09	0.02	-0.13	1	0.06	-0.11
Fix	0.09	0.01	0.01	0	0.07	0.07	-0.01	0.03	0.06	1	-0.4
SaDG	-0.3	-0.28	-0.34	-0.13	-0.42	-0.38	-0.19	-0.29	-0.11	-0.4	1

Table 7.21: Correlation matrix, household income between CHF 6'000 and 8'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.03	-0.01	0.17	0.21	0.07	0.08	0.06	-0.03	0.06	-0.3
EAT	0.03	1	0.03	0.03	0.1	0.15	0.11	0.11	0.11	0.03	-0.34
HR	-0.01	0.03	1	0.01	0.03	0.04	0.12	0.04	0.03	-0.02	-0.28
HE	0.17	0.03	0.01	1	0.06	0.04	0.06	0.03	-0.05	0.09	-0.22
CG	0.21	0.1	0.03	0.06	1	0.19	0.09	0.05	0.07	0.08	-0.43
Ent	0.07	0.15	0.04	0.04	0.19	1	0.07	0.06	0.15	0.05	-0.42
Com	0.08	0.11	0.12	0.06	0.09	0.07	1	0.18	0.03	-0.02	-0.21
PrT	0.06	0.11	0.04	0.03	0.05	0.06	0.18	1	-0.13	0	-0.3
PuT	-0.03	0.11	0.03	-0.05	0.07	0.15	0.03	-0.13	1	0.04	-0.11
Fix	0.06	0.03	-0.02	0.09	0.08	0.05	-0.02	0	0.04	1	-0.43
SaDG	-0.3	-0.34	-0.28	-0.22	-0.43	-0.42	-0.21	-0.3	-0.11	-0.43	1

that was considerably lower than in the average month and thus lower than the normal level of expenditures. These households have also the highest level of negative savings. Figure 7.2 shows the scatter plots for the relationship between Savings and Consumer Goods, for the households of three different income classes. The green point represent households from the lowest income class, with a noticeable correlation of -0.66, highest correlation found in all matrices shown (see table 7.18, fifth row, last column). The blue points represent medium income households with a less obvious correlation of -0.45 and the orange points represent the

Table 7.22: Correlation matrix, household income between CHF 8'000 and 10'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.01	0.03	0.15	0.17	0.03	0.06	0.05	-0.02	0.08	-0.25
EAT	-0.01	1	0.04	0.01	0.11	0.14	0.09	0.11	0.12	0.04	-0.35
HR	0.03	0.04	1	-0.11	0.06	0.03	0.09	0.01	0.03	-0.01	-0.24
HE	0.15	0.01	-0.11	1	0.05	0.04	0.01	0.04	-0.02	0.01	-0.12
CG	0.17	0.11	0.06	0.05	1	0.11	0.08	0.08	0.07	0.07	-0.45
Ent	0.03	0.14	0.03	0.04	0.11	1	0.03	0.04	0.11	0.07	-0.54
Com	0.06	0.09	0.09	0.01	0.08	0.03	1	0.17	0.03	0.03	-0.18
PrT	0.05	0.11	0.01	0.04	0.08	0.04	0.17	1	-0.13	0.01	-0.3
PuT	-0.02	0.12	0.03	-0.02	0.07	0.11	0.03	-0.13	1	0.08	-0.14
Fix	0.08	0.04	-0.01	0.01	0.07	0.07	0.03	0.01	0.08	1	-0.39
SaDG	-0.25	-0.35	-0.24	-0.12	-0.45	-0.54	-0.18	-0.3	-0.14	-0.39	1

Table 7.23: Correlation matrix, household income between CHF 10'000 and 12'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.03	0	0.14	0.2	0.1	0.11	0.07	0.05	0.08	-0.24
EAT	-0.03	1	-0.01	0	0.1	0.15	0.1	0.12	0.11	0	-0.25
HR	0	-0.01	1	-0.03	0.03	0.03	0	0.02	0.01	-0.01	-0.54
HE	0.14	0	-0.03	1	0.06	0.08	0.06	0.06	-0.02	0.03	-0.12
CG	0.2	0.1	0.03	0.06	1	0.15	0.08	0.06	0.05	0.1	-0.4
Ent	0.1	0.15	0.03	0.08	0.15	1	0.02	0.04	0.11	0.09	-0.4
Com	0.11	0.1	0	0.06	0.08	0.02	1	0.2	0.07	0.01	-0.13
PrT	0.07	0.12	0.02	0.06	0.06	0.04	0.2	1	-0.09	0.01	-0.26
PuT	0.05	0.11	0.01	-0.02	0.05	0.11	0.07	-0.09	1	0.06	-0.12
Fix	0.08	0	-0.01	0.03	0.1	0.09	0.01	0.01	0.06	1	-0.35
SaDG	-0.24	-0.25	-0.54	-0.12	-0.4	-0.4	-0.13	-0.26	-0.12	-0.35	1

richest households were savings aren't correlated to any of the expenditure categories.

Figure 7.3 gives a overview over the correlations of all expenditure categories with the category "Savings and Durable Goods", for all Income classes from income class 1 (< CHF 2.000/month) to income class 9 (> CHF 20.000/month). Negative correlation for savings can be interpreted as substitute for the observed expenditure category. Low negative correlation for private transportation for example means that households do not make a decision between using their money for private transportation and saving

Table 7.24: Correlation matrix, household income between CHF 12'000 and 15'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.02	-0.01	0.13	0.18	0.09	0.11	0.04	0.07	0.09	-0.27
EAT	-0.02	1	0.05	-0.01	0.13	0.19	0.09	0.1	0.1	0.02	-0.33
HR	-0.01	0.05	1	0	0.08	0.03	0.07	0.06	0.01	0	-0.38
HE	0.13	-0.01	0	1	0.08	0.08	0.03	-0.01	0.01	0.02	-0.16
CG	0.18	0.13	0.08	0.08	1	0.15	0.06	0.06	0.09	0.07	-0.43
Ent	0.09	0.19	0.03	0.08	0.15	1	0.03	0.03	0.14	0.1	-0.46
Com	0.11	0.09	0.07	0.03	0.06	0.03	1	0.13	0.01	0.01	-0.16
PrT	0.04	0.1	0.06	-0.01	0.06	0.03	0.13	1	-0.07	0.01	-0.29
PuT	0.07	0.1	0.01	0.01	0.09	0.14	0.01	-0.07	1	0.03	-0.14
Fix	0.09	0.02	0	0.02	0.07	0.1	0.01	0.01	0.03	1	-0.38
SaDG	-0.27	-0.33	-0.38	-0.16	-0.43	-0.46	-0.16	-0.29	-0.14	-0.38	1

Table 7.25: Correlation matrix, household income between CHF 15'000 and 20'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.02	-0.01	0.15	0.18	0.07	0.16	0.12	0.07	0.09	-0.24
EAT	-0.02	1	-0.01	0.06	0.14	0.19	0.17	0.13	0.08	-0.01	-0.29
HR	-0.01	-0.01	1	0	0.14	0.04	0.02	0.03	0	0	-0.4
HE	0.15	0.06	0	1	0.04	0.05	0.06	0.06	-0.03	0.02	-0.13
CG	0.18	0.14	0.14	0.04	1	0.1	0.08	0.15	0.04	0.03	-0.45
Ent	0.07	0.19	0.04	0.05	0.1	1	0.09	0.04	0.11	0.05	-0.45
Com	0.16	0.17	0.02	0.06	0.08	0.09	1	0.16	0.05	0.02	-0.16
PrT	0.12	0.13	0.03	0.06	0.15	0.04	0.16	1	-0.11	0	-0.25
PuT	0.07	0.08	0	-0.03	0.04	0.11	0.05	-0.11	1	0.09	-0.13
Fix	0.09	-0.01	0	0.02	0.03	0.05	0.02	0	0.09	1	-0.32
SaDG	-0.24	-0.29	-0.4	-0.13	-0.45	-0.45	-0.16	-0.25	-0.13	-0.32	1

it. They spend it anyway. The high negative correlation for Entertainment for example means that households either use a given amount of money for Entertainment, or if they do not need it for entertainment, they save it.

The shown correlation with savings should not be viewed as a proxy for necessity (low correlation for high necessity), because the category "Fix costs" has a relatively high negative correlation with savings. Households who spend money on additional healthcare or additional education do save less money as a consequence. So it should be viewed more as a proxy for regularity. The categories with the lowest correlation are

Table 7.26: Correlation matrix, household income higher than CHF 20'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	0.05	0.02	0.15	0.23	0.07	0.22	0.03	0.11	0.01	-0.07
EAT	0.05	1	0.09	0	0.21	0.28	0.12	0.11	0.22	0.03	-0.16
HR	0.02	0.09	1	0	0.18	0.12	0.07	0.05	0.05	0.09	-0.17
HE	0.15	0	0	1	0.1	0.13	0.06	0.03	0	0.01	-0.04
CG	0.23	0.21	0.18	0.1	1	0.3	0.22	0.19	0.08	0.11	-0.16
Ent	0.07	0.28	0.12	0.13	0.3	1	0.21	0.14	0.17	0.06	-0.2
Com	0.22	0.12	0.07	0.06	0.22	0.21	1	0.22	0.17	0.07	-0.12
PrT	0.03	0.11	0.05	0.03	0.19	0.14	0.22	1	-0.07	0.12	-0.07
PuT	0.11	0.22	0.05	0	0.08	0.17	0.17	-0.07	1	0.05	-0.11
Fix	0.01	0.03	0.09	0.01	0.11	0.06	0.07	0.12	0.05	1	-0.21
SaDG	-0.07	-0.16	-0.17	-0.04	-0.16	-0.2	-0.12	-0.07	-0.11	-0.21	1

Figure 7.2: Correlation between savings and durable goods and consumer goods

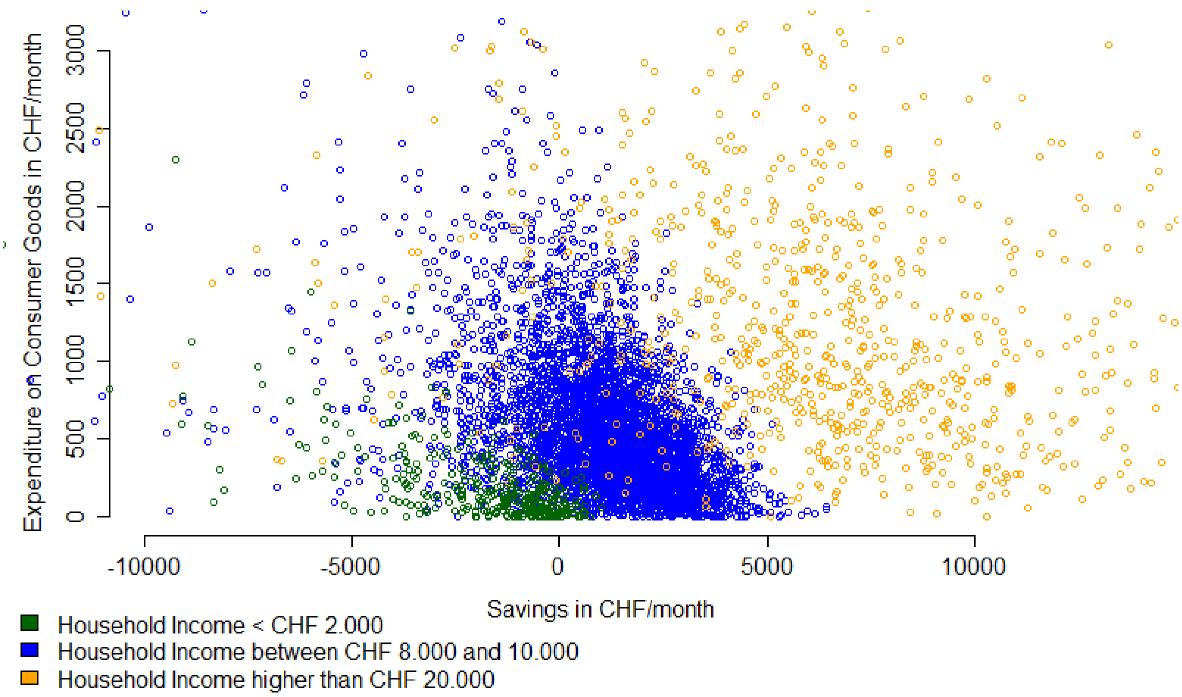
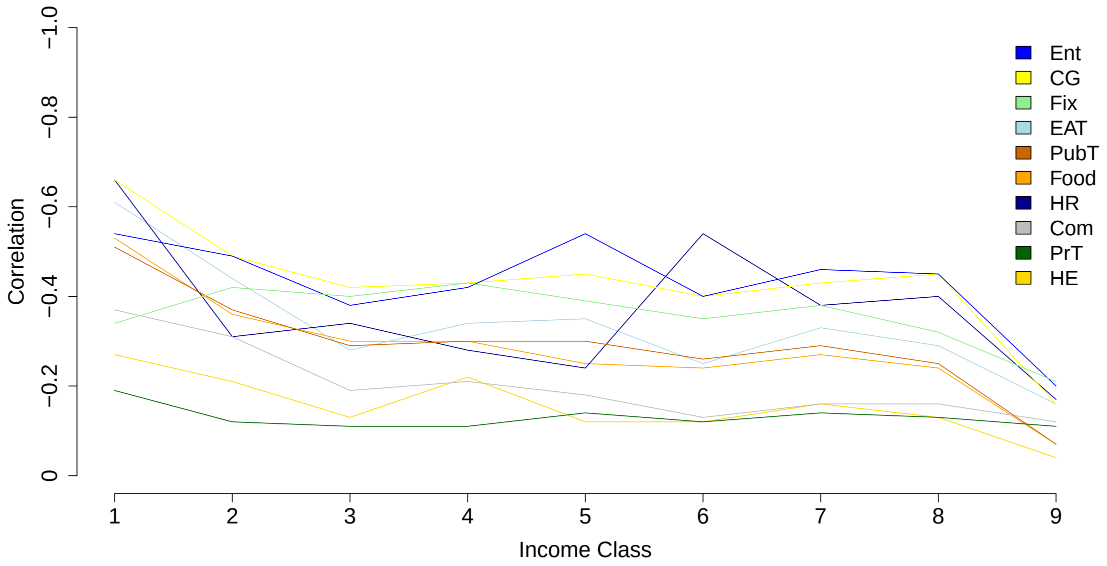


Figure 7.3: Negative correlation with savings and durable goods for all income classes and expenditure categories



Energy, Private Transportation and Communication, which seem to remain rather unaffected by the current financial situation. Healthcare, education or entertainment however are expenditures that a household views as temporarily limited and thus is traded off with savings. An example would be if a household spends a lot for vacations (=Entertainment), it knows that it does not save much money during that month, but next month when the vacations are over, the household will be back at saving. For the longer term the example would be a household financing an additional education in a private school, knowing that it would be impossible to save money during the 2 years of school, but also knowing that the education eventually will be over and the household would be able to save again.

The correlations however all remain relatively low indicating a generally high standard of living for most households. There is no difference in the need to trade off savings with consumer goods or food or transportation between households with an income of CHF 4.000 - 6.000 /month (income class 3) and an income of CHF 15.000 - 20.000 /month (income class 8). Only the poorest (richest) households have higher (lower) correlation.

Table 7.27: Correlation matrix of shares (all households)

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.17	-0.12	0.22	-0.04	-0.14	0.06	-0.1	-0.06	-0.11	0.18
EAT	-0.17	1	-0.16	-0.07	-0.1	-0.02	0	0.01	0.03	-0.17	0.02
HR	-0.12	-0.16	1	-0.13	-0.28	-0.31	0.08	-0.15	-0.02	-0.25	0.05
HE	0.22	-0.07	-0.13	1	-0.05	-0.03	0.06	-0.03	-0.04	-0.05	0.11
CG	-0.04	-0.1	-0.28	-0.05	1	-0.02	-0.11	-0.1	-0.01	-0.09	-0.05
Ent	-0.14	-0.02	-0.31	-0.03	-0.02	1	-0.13	-0.09	0.05	-0.1	-0.05
Com	0.06	0	0.08	0.06	-0.11	-0.13	1	0.08	0	-0.15	0.1
PrT	-0.1	0.01	-0.15	-0.03	-0.1	-0.09	0.08	1	-0.22	-0.13	-0.02
PuT	-0.06	0.03	-0.02	-0.04	-0.01	0.05	0	-0.22	1	-0.01	0.03
Fix	-0.11	-0.17	-0.25	-0.05	-0.09	-0.1	-0.15	-0.13	-0.01	1	-0.14
SaDG	0.18	0.02	0.05	0.11	-0.05	-0.05	0.1	-0.02	0.03	-0.14	1

7.5 Correlation of Expenditure Shares

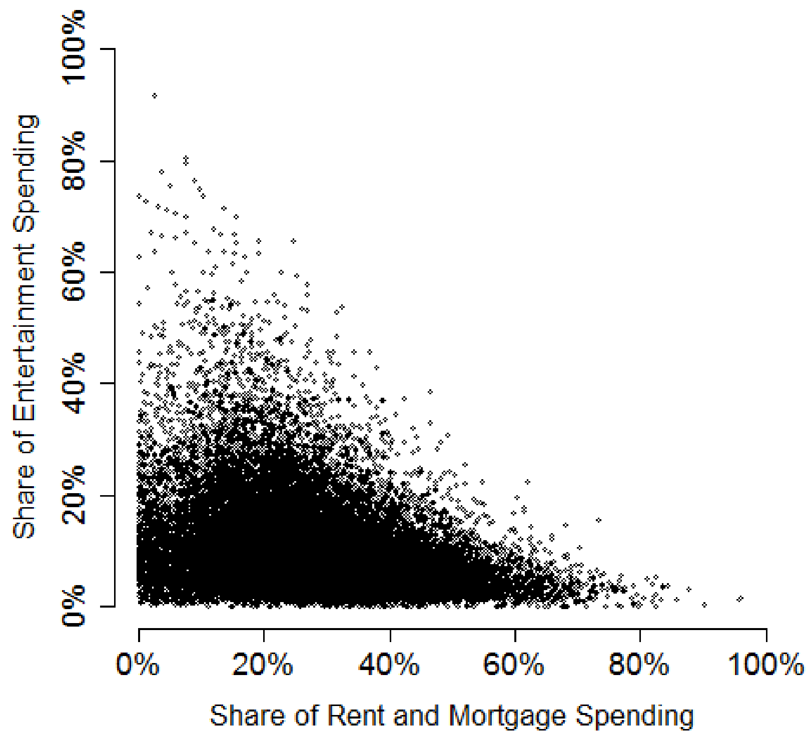
7.5.1 All Households

The previous section analysed the correlation of the absolute values of the amount of expenditure for every category. This section analyses the correlation between the shares of the expenditure categories. Table 7.27 shows the correlation matrix for the above defined categories including all households of the whole time period from 2001 to 2008.

The correlations between the shares of expenditure categories are again very low. The highest value is -0.31 for the correlation between expenditure on rent and on entertainment. A causal interpretation for these category is again very difficult to make as there is no obvious idea why these two categories should be correlated, and the correlation is still quite week. Most of the correlations are negative correlations which is to be expected since by definition the shares add up to one for every household. An increase in one share means a decrease in the share of most of the other categories.

Figure 7.4 shows the scatter and the box plot for the correlation between "Eating out, Alcohol and Tobacco" and Energy, each data point representing one single household in upper graph. The lower graph shows the same data in a box blot, making median and standard deviation for different brackets more visible.

Figure 7.4: Correlation between share of housing and share of entertainment



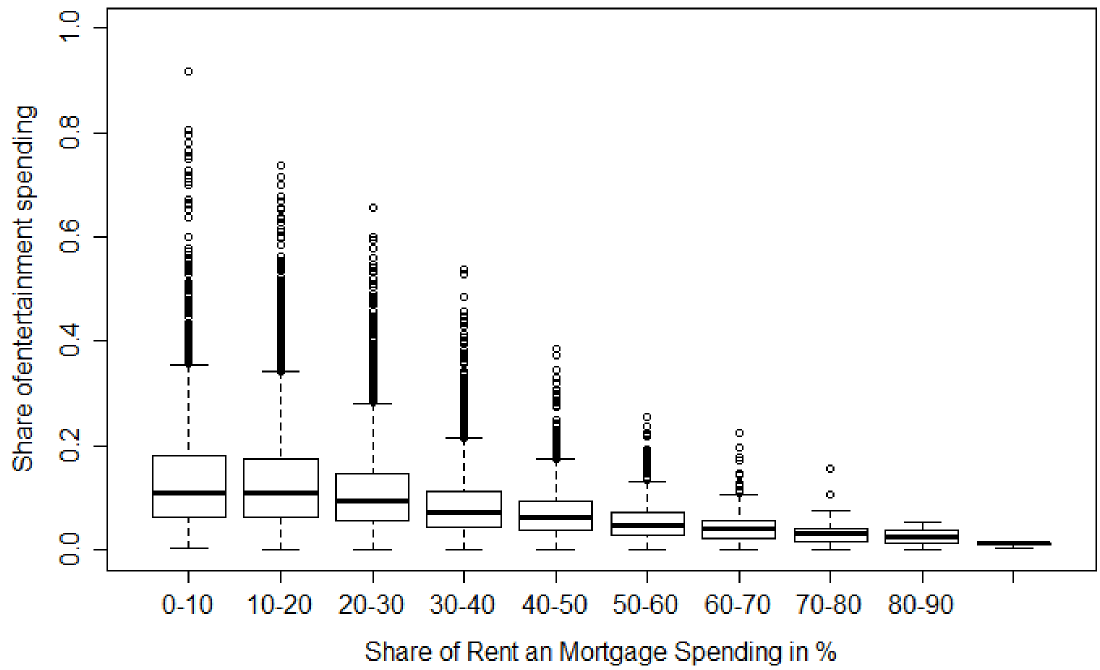


Table 7.28: Expenditure share correlation matrix, household income smaller than CHF 2'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.25	-0.33	0.24	0.03	-0.01	0.08	0.02	-0.19	-0.13	0.33
EAT	-0.25	1	-0.2	-0.07	-0.08	-0.02	-0.06	0.16	0.12	-0.17	-0.12
HR	-0.33	-0.2	1	-0.28	-0.32	-0.4	-0.07	-0.21	-0.08	-0.27	-0.06
HE	0.24	-0.07	-0.28	1	0.02	0.02	0.13	0.01	-0.14	-0.08	0.3
CG	0.03	-0.08	-0.32	0.02	1	0.09	-0.06	-0.05	0.03	-0.04	-0.12
Ent	-0.01	-0.02	-0.4	0.02	0.09	1	0.07	-0.04	0.09	-0.07	-0.02
Com	0.08	-0.06	-0.07	0.13	-0.06	0.07	1	0.04	0	-0.18	0.14
PrT	0.02	0.16	-0.21	0.01	-0.05	-0.04	0.04	1	-0.22	-0.19	-0.2
PuT	-0.19	0.12	-0.08	-0.14	0.03	0.09	0	-0.22	1	0.02	0.01
Fix	-0.13	-0.17	-0.27	-0.08	-0.04	-0.07	-0.18	-0.19	0.02	1	-0.05
SaDG	0.33	-0.12	-0.06	0.3	-0.12	-0.02	0.14	-0.2	0.01	-0.05	1

Table 7.29: Expenditure share correlation matrix, household income between CHF 2'000 and 4'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.19	-0.3	0.25	0.03	-0.06	0.02	-0.05	-0.13	-0.17	0.27
EAT	-0.19	1	-0.23	-0.08	-0.11	-0.01	0.07	0.1	0	-0.17	-0.05
HR	-0.3	-0.23	1	-0.27	-0.33	-0.32	-0.05	-0.23	0.02	-0.3	0.09
HE	0.25	-0.08	-0.27	1	0	0.04	0.06	0	-0.06	-0.06	0.15
CG	0.03	-0.11	-0.33	0	1	0.02	-0.08	-0.08	0.01	-0.08	-0.12
Ent	-0.06	-0.01	-0.32	0.04	0.02	1	-0.03	-0.01	0.04	-0.13	-0.06
Com	0.02	0.07	-0.05	0.06	-0.08	-0.03	1	0.07	0.05	-0.19	0.15
PrT	-0.05	0.1	-0.23	0	-0.08	-0.01	0.07	1	-0.26	-0.11	-0.13
PuT	-0.13	0	0.02	-0.06	0.01	0.04	0.05	-0.26	1	-0.05	0.03
Fix	-0.17	-0.17	-0.3	-0.06	-0.08	-0.13	-0.19	-0.11	-0.05	1	-0.18
SaDG	0.27	-0.05	0.09	0.15	-0.12	-0.06	0.15	-0.13	0.03	-0.18	1

7.5.2 By Income Class

When looking at the correlation matrices of different income classes, we can observe that also regarding shares of expenditure categories, correlations are very weak even within groups of homogeneous incomes. Also the correlations between the "Savings and Durable Goods" category with other categories are very small, much smaller than for the correlations between the actual amounts of money. For the lower income classes, that comes partially from the fact that a share of a households budget cannot be negative in contrast to comparing the effective amounts. Especially

Table 7.30: Expenditure share correlation matrix, household income between CHF 4'000 and 6'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.17	-0.23	0.24	-0.03	-0.09	-0.01	-0.11	-0.07	-0.11	0.24
EAT	-0.17	1	-0.17	-0.05	-0.14	-0.04	-0.01	0.03	0.02	-0.17	-0.01
HR	-0.23	-0.17	1	-0.21	-0.27	-0.3	0.07	-0.15	-0.03	-0.29	0.15
HE	0.24	-0.05	-0.21	1	-0.02	-0.02	0.02	-0.02	-0.05	-0.07	0.12
CG	-0.03	-0.14	-0.27	-0.02	1	0.01	-0.08	-0.12	0.01	-0.08	-0.14
Ent	-0.09	-0.04	-0.3	-0.02	0.01	1	-0.12	-0.08	0.05	-0.09	-0.1
Com	-0.01	-0.01	0.07	0.02	-0.08	-0.12	1	0.09	-0.02	-0.19	0.16
PrT	-0.11	0.03	-0.15	-0.02	-0.12	-0.08	0.09	1	-0.25	-0.13	-0.11
PuT	-0.07	0.02	-0.03	-0.05	0.01	0.05	-0.02	-0.25	1	-0.01	0.04
Fix	-0.11	-0.17	-0.29	-0.07	-0.08	-0.09	-0.19	-0.13	-0.01	1	-0.19
SaDG	0.24	-0.01	0.15	0.12	-0.14	-0.1	0.16	-0.11	0.04	-0.19	1

Table 7.31: Expenditure share correlation matrix, household income between CHF 6'000 and 8'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.17	-0.14	0.21	-0.02	-0.13	0.02	-0.09	-0.06	-0.13	0.28
EAT	-0.17	1	-0.11	-0.08	-0.12	-0.03	-0.02	-0.03	0.05	-0.17	-0.03
HR	-0.14	-0.11	1	-0.14	-0.28	-0.28	0.1	-0.09	-0.01	-0.3	0.21
HE	0.21	-0.08	-0.14	1	-0.05	-0.03	0.05	-0.01	-0.07	-0.04	0.18
CG	-0.02	-0.12	-0.28	-0.05	1	-0.01	-0.11	-0.14	-0.01	-0.06	-0.17
Ent	-0.13	-0.03	-0.28	-0.03	-0.01	1	-0.11	-0.1	0.08	-0.09	-0.12
Com	0.02	-0.02	0.1	0.05	-0.11	-0.11	1	0.11	-0.01	-0.18	0.17
PrT	-0.09	-0.03	-0.09	-0.01	-0.14	-0.1	0.11	1	-0.23	-0.15	-0.09
PuT	-0.06	0.05	-0.01	-0.07	-0.01	0.08	-0.01	-0.23	1	-0.02	0.05
Fix	-0.13	-0.17	-0.3	-0.04	-0.06	-0.09	-0.18	-0.15	-0.02	1	-0.2
SaDG	0.28	-0.03	0.21	0.18	-0.17	-0.12	0.17	-0.09	0.05	-0.2	1

for households with low incomes where spending often is financed by previously saved money, the correlation between negative saving and other expenditure categories can be significant. This cannot be observed by only looking at the shares.

The most significant and substantial correlation between shares is between the "Housing: Rent and Interest" category and the categories "Entertainment", "Consumer Goods", "Fix Costs", and "Savings and Durable Goods". Throughout all income classes, the correlations between the above mentioned relations are almost always between -0.21 and -0.40,

Table 7.32: Expenditure share correlation matrix, household income between CHF 8'000 and 10'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.18	-0.08	0.2	0	-0.16	0.04	-0.1	-0.08	-0.12	0.29
EAT	-0.18	1	-0.13	-0.03	-0.13	-0.01	-0.01	-0.02	0.06	-0.15	-0.03
HR	-0.08	-0.13	1	-0.14	-0.23	-0.28	0.08	-0.13	-0.03	-0.27	0.22
HE	0.2	-0.03	-0.14	1	-0.04	-0.03	0.05	0	-0.03	-0.05	0.21
CG	0	-0.13	-0.23	-0.04	1	-0.07	-0.09	-0.13	-0.02	-0.09	-0.17
Ent	-0.16	-0.01	-0.28	-0.03	-0.07	1	-0.14	-0.13	0.07	-0.07	-0.16
Com	0.04	-0.01	0.08	0.05	-0.09	-0.14	1	0.07	-0.01	-0.13	0.19
PrT	-0.1	-0.02	-0.13	0	-0.13	-0.13	0.07	1	-0.2	-0.13	-0.06
PuT	-0.08	0.06	-0.03	-0.03	-0.02	0.07	-0.01	-0.2	1	0.02	0.03
Fix	-0.12	-0.15	-0.27	-0.05	-0.09	-0.07	-0.13	-0.13	0.02	1	-0.19
SaDG	0.29	-0.03	0.22	0.21	-0.17	-0.16	0.19	-0.06	0.03	-0.19	1

Table 7.33: Expenditure share correlation matrix, household income between CHF 10'000 and 12'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.15	-0.06	0.17	0	-0.14	0.08	-0.09	0	-0.11	0.28
EAT	-0.15	1	-0.1	-0.04	-0.14	-0.06	0.03	-0.02	0.03	-0.17	0.03
HR	-0.06	-0.1	1	-0.11	-0.21	-0.3	0.08	-0.1	-0.04	-0.25	0.22
HE	0.17	-0.04	-0.11	1	-0.05	-0.02	0.08	0.01	-0.03	-0.07	0.17
CG	0	-0.14	-0.21	-0.05	1	-0.09	-0.09	-0.15	-0.04	-0.09	-0.16
Ent	-0.14	-0.06	-0.3	-0.02	-0.09	1	-0.16	-0.14	0.04	-0.06	-0.2
Com	0.08	0.03	0.08	0.08	-0.09	-0.16	1	0.11	0.03	-0.15	0.23
PrT	-0.09	-0.02	-0.1	0.01	-0.15	-0.14	0.11	1	-0.18	-0.12	-0.02
PuT	0	0.03	-0.04	-0.03	-0.04	0.04	0.03	-0.18	1	0	0.09
Fix	-0.11	-0.17	-0.25	-0.07	-0.09	-0.06	-0.15	-0.12	0	1	-0.22
SaDG	0.28	0.03	0.22	0.17	-0.16	-0.2	0.23	-0.02	0.09	-0.22	1

very often around 0.27. While this is still a weak correlation, it is the most visible pattern with the strongest correlation found.

Figure 7.5 shows the scatter plots for the relationship between Housing Rent and Interest and Entertainment. The interpretation of this kind of correlation would be that a high rent or a high mortgage payment would negatively affect spending on consumer goods, entertainment, education and healthcare and savings. That means that these categories are the weakest ones, where spending is cut first before addressing the other categories. For this interpretation we assume, that a households decision

Table 7.34: Expenditure share correlation matrix, household income between CHF 12'000 and 15'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.14	-0.08	0.15	-0.01	-0.13	0.11	-0.1	0.04	-0.07	0.3
EAT	-0.14	1	-0.12	-0.08	-0.09	-0.03	-0.01	-0.01	0.03	-0.15	0.02
HR	-0.08	-0.12	1	-0.07	-0.21	-0.27	0.08	-0.08	-0.05	-0.27	0.22
HE	0.15	-0.08	-0.07	1	-0.01	-0.03	0.06	-0.04	0	-0.06	0.16
CG	-0.01	-0.09	-0.21	-0.01	1	-0.08	-0.09	-0.12	0	-0.1	-0.11
Ent	-0.13	-0.03	-0.27	-0.03	-0.08	1	-0.14	-0.15	0.06	-0.07	-0.19
Com	0.11	-0.01	0.08	0.06	-0.09	-0.14	1	0.11	-0.02	-0.12	0.2
PrT	-0.1	-0.01	-0.08	-0.04	-0.12	-0.15	0.11	1	-0.2	-0.13	-0.03
PuT	0.04	0.03	-0.05	0	0	0.06	-0.02	-0.2	1	-0.04	0.04
Fix	-0.07	-0.15	-0.27	-0.06	-0.1	-0.07	-0.12	-0.13	-0.04	1	-0.2
SaDG	0.3	0.02	0.22	0.16	-0.11	-0.19	0.2	-0.03	0.04	-0.2	1

Table 7.35: Expenditure share correlation matrix, household income between CHF 15'000 and 20'000 per month

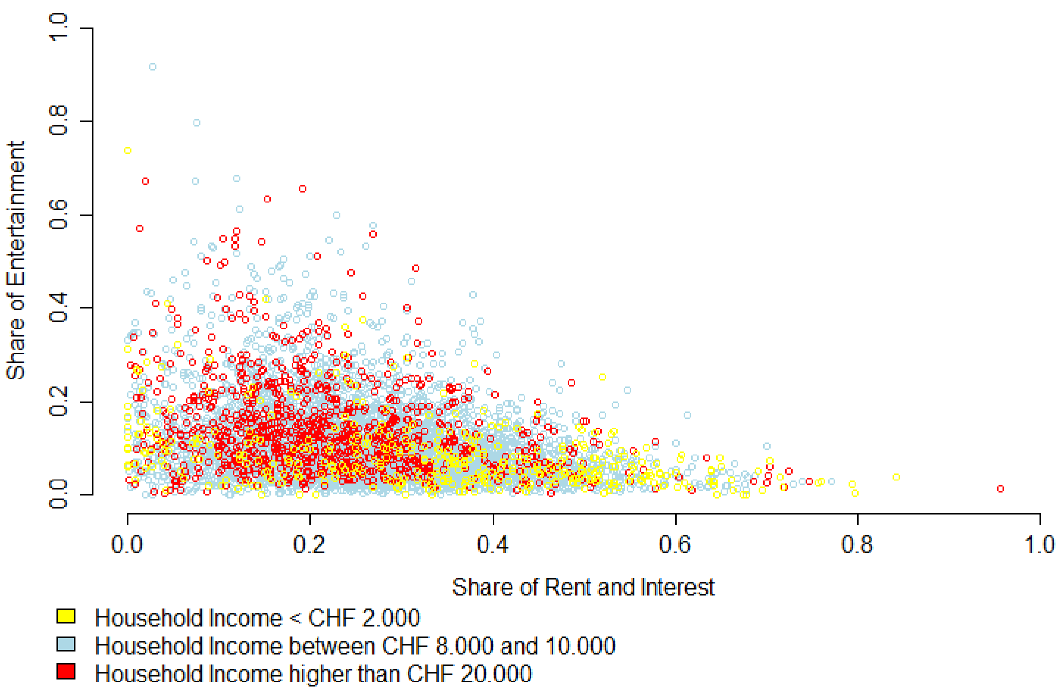
	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.12	-0.07	0.16	-0.03	-0.13	0.21	-0.01	0.05	-0.08	0.39
EAT	-0.12	1	-0.12	-0.02	-0.1	-0.04	0.09	-0.01	0.02	-0.17	0.06
HR	-0.07	-0.12	1	-0.06	-0.15	-0.25	0.01	-0.1	-0.03	-0.2	0.17
HE	0.16	-0.02	-0.06	1	-0.07	-0.05	0.08	0.03	-0.05	-0.02	0.17
CG	-0.03	-0.1	-0.15	-0.07	1	-0.15	-0.1	-0.14	-0.03	-0.12	-0.11
Ent	-0.13	-0.04	-0.25	-0.05	-0.15	1	-0.09	-0.14	0.03	-0.09	-0.19
Com	0.21	0.09	0.01	0.08	-0.1	-0.09	1	0.1	0.03	-0.11	0.23
PrT	-0.01	-0.01	-0.1	0.03	-0.14	-0.14	0.1	1	-0.2	-0.13	0
PuT	0.05	0.02	-0.03	-0.05	-0.03	0.03	0.03	-0.2	1	0.02	0.04
Fix	-0.08	-0.17	-0.2	-0.02	-0.12	-0.09	-0.11	-0.13	0.02	1	-0.15
SaDG	0.39	0.06	0.17	0.17	-0.11	-0.19	0.23	0	0.04	-0.15	1

where to live and how much to spend on housing is done prior to the decisions to entertain themselves or buy consumer goods and is of a much higher priority. It is very unlikely and not really feasible to cut down on the rent, if one spends a lot for consumer goods for example.

Table 7.36: Expenditure share correlation matrix, household income higher than CHF 20'000 per month

	F	EAT	HR	HE	CG	Ent	Com	PrT	PuT	Fix	SaDG
F	1	-0.06	0.01	0.21	0.01	-0.19	0.22	-0.07	0.08	-0.15	0.31
EAT	-0.06	1	-0.12	-0.07	-0.05	-0.07	0.04	-0.03	0.08	-0.19	0.08
HR	0.01	-0.12	1	-0.06	-0.26	-0.29	0.01	-0.12	-0.05	-0.21	0.14
HE	0.21	-0.07	-0.06	1	-0.04	-0.01	0.1	-0.03	-0.02	-0.06	0.1
CG	0.01	-0.05	-0.26	-0.04	1	-0.13	-0.04	-0.07	-0.03	-0.14	-0.08
Ent	-0.19	-0.07	-0.29	-0.01	-0.13	1	-0.12	-0.11	0	-0.13	-0.13
Com	0.22	0.04	0.01	0.1	-0.04	-0.12	1	0.09	0.06	-0.09	0.05
PrT	-0.07	-0.03	-0.12	-0.03	-0.07	-0.11	0.09	1	-0.18	-0.1	-0.01
PuT	0.08	0.08	-0.05	-0.02	-0.03	0	0.06	-0.18	1	-0.01	0
Fix	-0.15	-0.19	-0.21	-0.06	-0.14	-0.13	-0.09	-0.1	-0.01	1	-0.1
SaDG	0.31	0.08	0.14	0.1	-0.08	-0.13	0.05	-0.01	0	-0.1	1

Figure 7.5: Correlation between rent and interest for housing and entertainment



7.6 Pseudo Panels

As it can be clearly seen from the correlation matrices in sections 7.4 and 7.5, it is hard to see patterns and clear relationships between the expenditure categories. The scatter plots are very disperse only allowing for models with a high variance and low R^2 values. One reason for this is the fact that every observation is one households expenditure for only one month. Every year and every month of the observed period, the observations are from a different household. This makes it very hard to make time series analysis as the differences between the households are far greater than the possible effects from time or other factors.

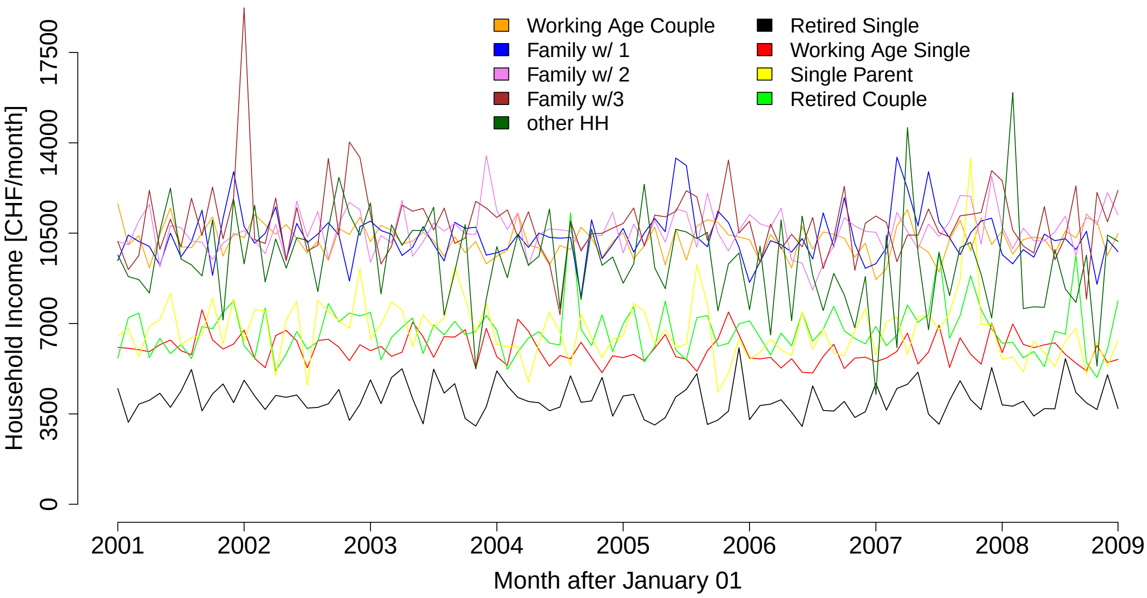
To account for this fact and to have less variance and more stable results, the households were aggregated into so called Pseudo Panels. A Panel is a set of data points were the same unit of observation (household) is observed over multiple points in time, allowing to analyse effects in time and other situational variables that may have changed in time. A pseudo panel is a set of data points that is created artificially to be able to analyse similar effects. The pseudo panel is created in this case by aggregating all households of a given household type of every month together to obtain one data point. In this case we have 96 months (all month between January 2001 and December 2008) resulting in 96 pseudo observations for every household type.

As not in every month the number of households from a given type was the same, the pseudo observations are based on a variable number of real households. For every of the following 9 household types, a pseudo panel with 96 data points each was created:

1. Retired Single Households (65 years or older)
2. Working Age Single Households (younger than 65)
3. Single Parent with 1 or more children
4. Retired Couples (65 years or older)
5. Working Age Couples (younger than 65)
6. Family with two Adults and 1 Child
7. Family with two Adults and 2 Children
8. Family with two Adults and 3 or more Children
9. Other Household Types

As every pseudo observation was obtained by aggregating a number of households, the variation is smaller than the variation among the original real data points, also because the strong outliers were averaged out by the aggregation. However, the variation is still large and it is still very hard to identify effects in time. In figure 7.6 household income for all pseudo

Figure 7.6: Time series: household income



panels is shown. As in the descriptive statistics on the aggregate level in section 2.3.3.2, we can identify 3 different levels of household income: The lowest level is the level of households with one retired adult, bringing in about half of the income as households of the second level, with one working income earner or two retired persons. The third level with the highest incomes are households with two income earners.

The variation of the pseudo observation is still quite significant and in any case much greater than any observable influence or changes in time. The same is true for other expenditure categories. Figures 7.7 to 7.15 show the time series of the pseudo panels for all expenditure categories. Some categories like "Food" and "Private Transport" show notable differences among household types, while others like "Entertainment" and "Public Transport" have very messy patterns and household types are not separable. The difference between public and private transport is striking as they show very different time series pattern. In none of the figures we can identify significant trends over the whole period.

Figure 7.7: Time series: savings and durable goods

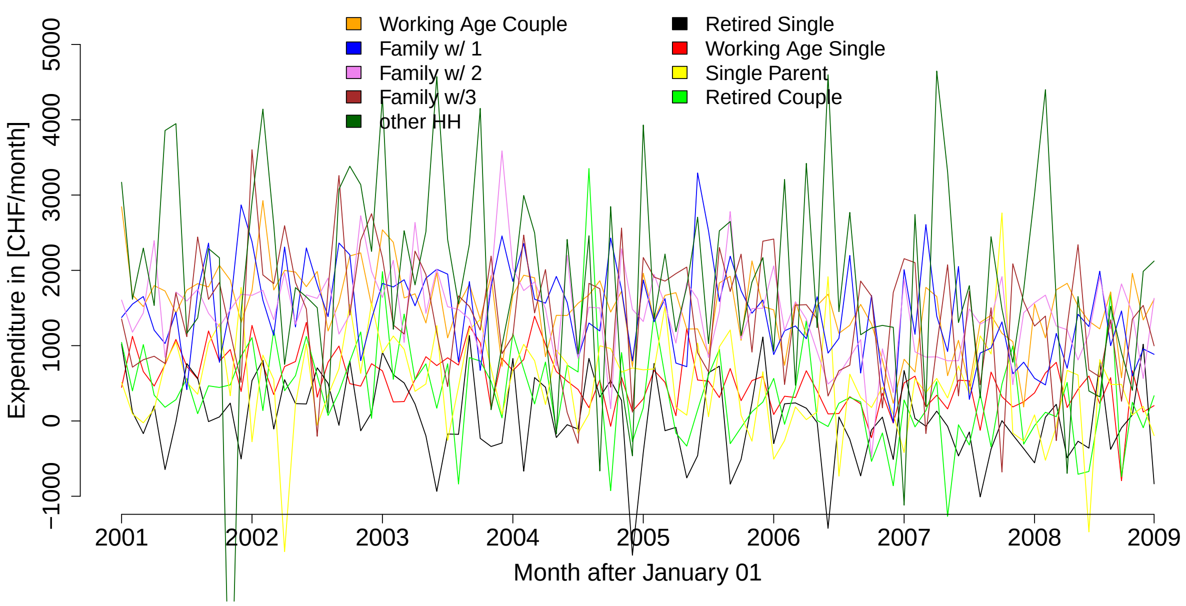


Figure 7.8: Time series: food

Figure 7.9: Time series: housing, rent and interest

Figure 7.10: Time series: consumer goods

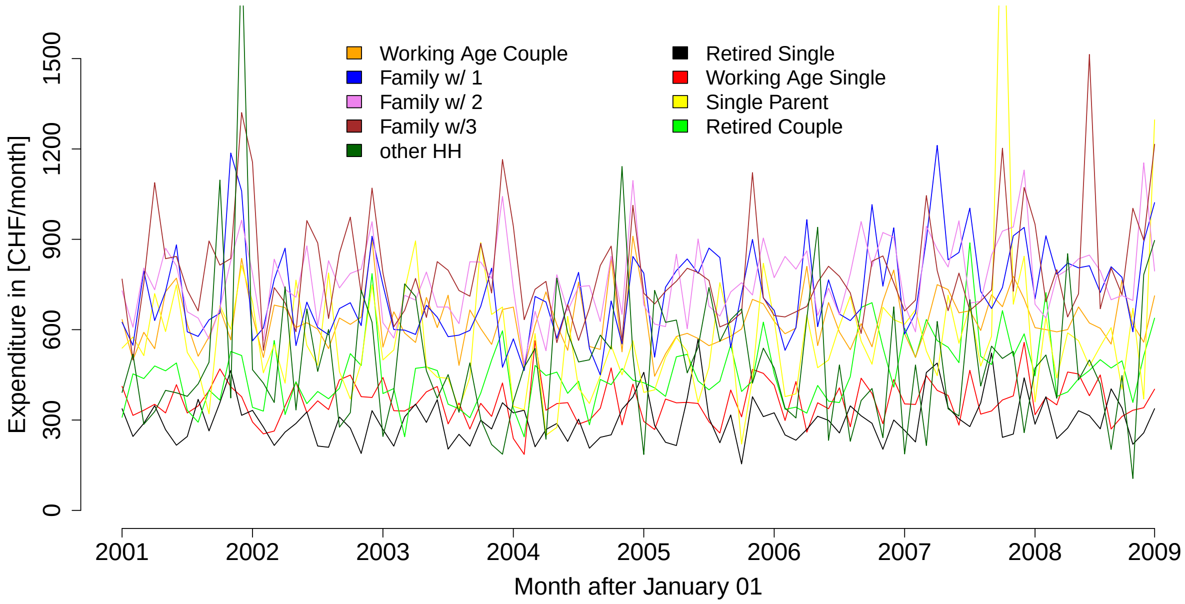


Figure 7.11: Time series: entertainment

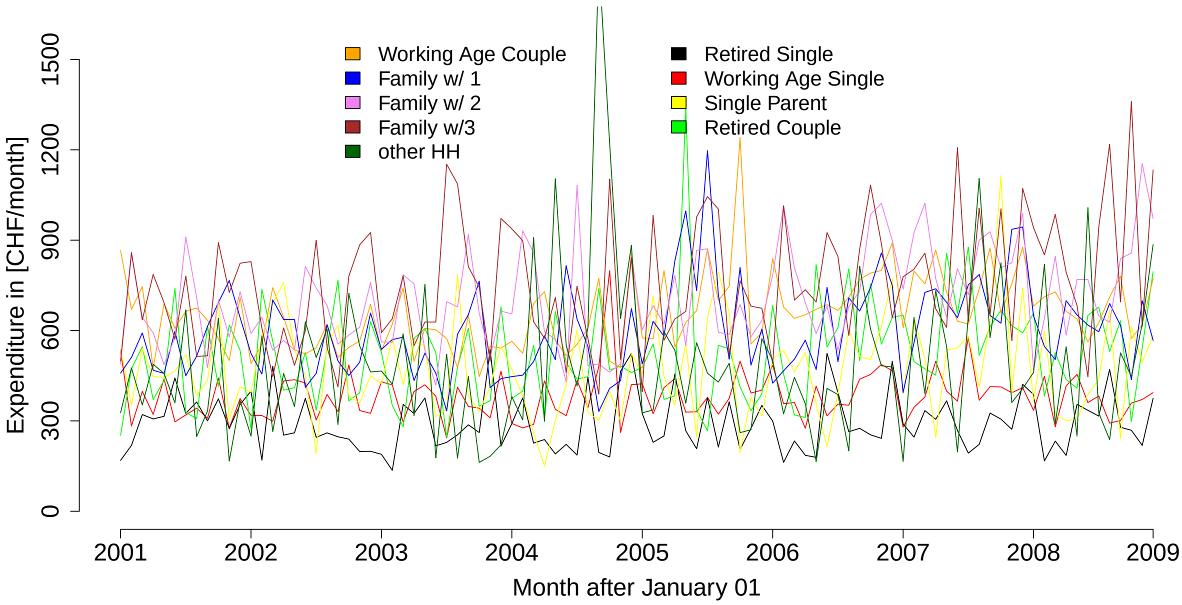


Figure 7.12: Time series: eating out, alcohol and tobacco

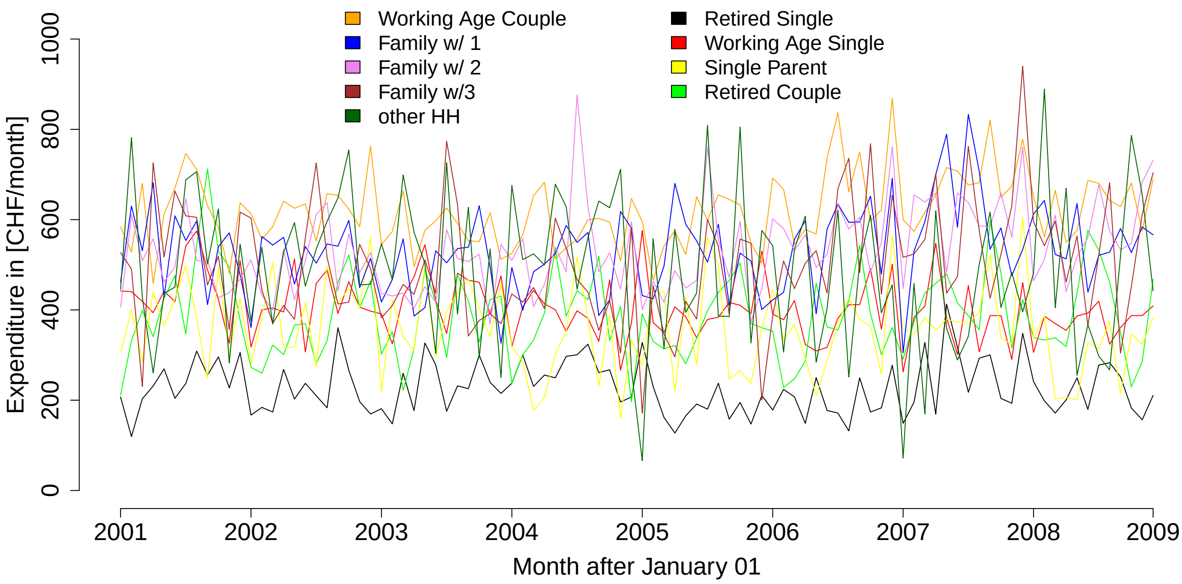


Figure 7.13: Time series: communication

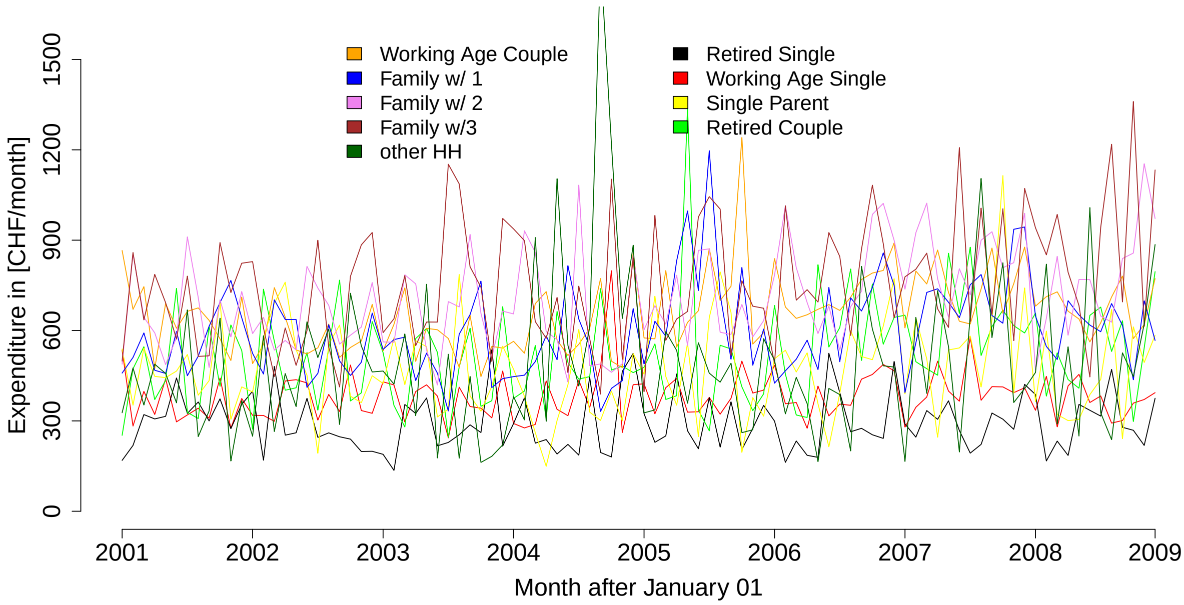
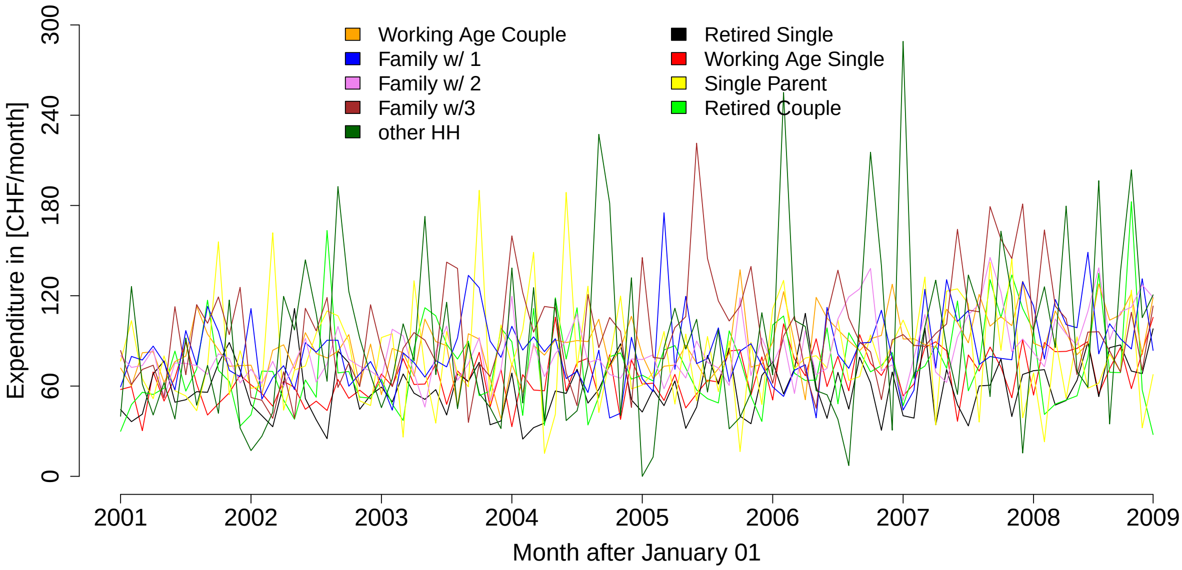


Figure 7.14: Time series: private transportation

Figure 7.15: Time series: public transportation



7.7 Linear Regressions

In this section, the linear regression models for all of the expenditure categories shown in table 7.2 are presented. The methodology used was standard linear least square regression. As shown in section 7.4 and 7.4, the correlation between the different (dependent) expenditure categories are weak. What is shown here, is how independent explanatory variables like socio economic and geographical variables, information about durable consumer goods and information about the time of observation influence expenditure for a given category. These models allow us to understand which of the observable characteristics have an influence on the amount of expenditure and also what the differences or similarities between expenditure categories are.

All of the following sections from 7.7.2 (Expenditures on Food) to 7.7.8 (Public Transportation) contain a) a linear multivariate regression model for all originally observed real households (with a total of 27182 observed households from 2001 to 2008), b) nine linear multivariate regression models for every household type pseudo panel (each with 96 pseudo observations for every month between 2001 and 2008) and c) a plot of the pseudo panels visualizing the relationship between the expenditure category and household income.

Table 7.37 gives an overview over the most important explanatory variables used in models.

Table 7.37: Explanatory variables

Abb.	Type	Variable	Explanation
Inc.	c	Income	Gross household pre tax Income
Age	c	Mean Age	Mean age of all household members
Pers	c	Number of Persons	Number of persons living in HH
NewC	c	New Cars	Number of new cars in HH
UsedC	c	Used Cars	Number of used cars in HH
HHGood	c	HH Goods	Number of durable goods for housekeeping
FuGood	c	Fun Goods	Number of durable goods for enterteainment
Cgood	c	Com. Goods	Number of durable goods for communication
RS	d	Retired Single	HH with 1 person age >= 65.
WAS	d	Working Age Single	HH with 1 person age < 65
SP	d	Single Person	HH with 1 Parent and min. 1 Child
RC	d	Retired Couple	HH with 2 persons, mean age >= 65
WAC	d	Working Age Couple	HH with 2 persons, mean age < 65
Fam1	d	Familiy with 1	HH with 2 parents and 1 child
Fam2	d	Familiy with 2	HH with 2 parents and 2 children
Fam3	d	Familiy with 3+	HH with 2 parents and 3 or more children
oth	d	other HH	other HH
Cent	d	Centre	HH located in regional centre
Cent_L	d	Centre Low	HH located in regional centre, income < 6.000
Cent_M	d	Centre Midium	HH located in regional centre, 6.000 < income < 15.000
Cent_H	d	Centre High	HH located in regional centre, income > 15.000
Subu	d	Suburbia	HH located in suburban area
Subu_L	d	Suburbia Low	HH located in suburban area, income < 6.000
Subu_M	d	Suburbia Middle	HH located in suburban area, 6.000 < income < 15.000
Subu_H	d	Suburbia High	HH located in suburban area, income > 15.000
Peri	d	Peri-urban	HH located in peri-urban area
Peri_L	d	Peri-urban Low	HH located in peri-urban area, income < 6.000
Peri_M	d	Peri-urbanMiddle	HH located in peri-urban area, 6.000 < income < 15.000
Peri_H	d	Peri-urban High	HH located in peri-urban area, income > 15.000
Comu	d	Commuter	HH located in commuter municipality
Comu_L	d	Commuter Low	HH located in comm. m., income < 6.000
Comu_M	d	Commuter Middle	HH located in comm. m., 6.000 < income < 15.000
Comu_H	d	Commuter High	HH located in comm. m., income > 15.000
IndT	d	Industrial	HH located in industrial/turistic municipality
IndT_L	d	Industrial Low	HH located in ind./tur. m., income < 6.000
IndT_M	d	Industrial Middle	HH located in ind./tur. m., 6.000 < income < 15.000
IndT_H	d	Industrial High	HH located in ind./tur. m., income > 15.000
Jan	d	January	Month of observation was January
Feb	d	February	Month of observation was February
Mar	d	March	Month of observation was March
Apr	d	April	Month of observation was April
May	d	May	Month of observation was May
Jun	d	June	Month of observation was June
Jul	d	July	Month of observation was Junly
Aug	d	August	Month of observation was August
Sep	d	September	Month of observation was September
Oct	d	October	Month of observation was October
Nov	d	November	Month of observation was November
Dec	d	December	Month of observation was December

c = continuos, d = dummy

7.7.1 Savings and Durable Goods

7.7.1.1 Observed Households

Table 7.38 shows the multivariate linear regression model for the "Savings and Durable Goods" expenditure category. As it is to be assumed, savings and expenditure for durable goods depend heavily on household income. The influence of income is much greater than in other categories. For every CHF 1.000/month of more income, about 400 go to savings and durable goods when controlled for household type and other variables. The second highest value for influence of income is 8 times lower, CHF 54 for every CHF 1.000/month more income, in the case of rent or mortgage payment for housing. This means that large savings is still almost exclusively possible for richer households.

Household Type is also a major influencing factor. Families with children can save much less than other households. The income controlled difference between a family with 3 children and a working aged couple is about CHF 1.000/month. The presence of cars and durable goods have also a quite significant impact on savings. A newly bought car decreases savings by about CHF 300 per month, which can be seen as a good proxy for the cost of car in Switzerland. Much harder to interpret is the fact that the other durable goods, like household appliances or cameras or computers, have a negative impact on savings and expenditure of these durable goods. The interpretation here is that households with more of these appliances spend less on buying these goods (because they already have them) and also save less. Instead, they spend the money for other things. This findings support the assumption made in section 7.2, that savings and durable goods must be lumped together. Savings are generally higher then expenditure for durable goods, and yet the effect that, the more durable goods a household owns, the less it saves, holds and indicates a certain satiation for savings caused by the possession of such goods.

The residential location type has also a significant influence. People living in cities and suburbs save less money than people living in peri-urban or rural areas. This could come from the much higher accessibility in urban areas, where households have more options to spend the money rather then buying durable goods or saving, and from potentially higher housing costs that. Also seasonal effects can be observed: The Christmas effect, that people save much less in December than in January or February, is quite impressive. The difference between December and January is over CHF 530 in average.

Table 7.38: Coefficients of the linear model for savings and durable goods (observed households)

Variable	**Type**	**Estimate**	**Std. Error**	**T - Value**
Intercept		673.06	160.05	4.21
Income [/ 10^3 CHF]	c	398.52	6.52	61.08
Income^2 [/ 10^6 CHF]	c	0.47	0.08	5.6
Age	c	-49.47	6.35	-7.79
Age^2	c	0.32	0.07	4.48
MotorB	c	157.86	27.12	5.82
New Cars	c	-309.16	23.89	-12.94
Used Cars	c	-40.53	11.66	-3.47
Freezer	c	83.22	31.01	2.68
Dryer	c	-301.23	34.18	-8.81
Dishw	c	-341.53	34.43	-9.92
TV	c	55.91	25.02	2.23
Camera	c	-134.39	34.45	-3.9
VideoG	c	71.19	31.68	2.25
Comp	c	-198.6	23.26	-8.54
CellPh	c	-122.79	18.51	-6.63
Printer	c	-92.72	33.74	-2.75
Retired Single	d	191.81	123.81	1.55
Working Age Single	d	-237.75	96.42	-2.47
Single Parent	d	-741.88	113.75	-6.52
Working Age Couple	d	-220.55	115.9	-1.9
Retired Couple	d	-451.32	92.45	-4.88
Familiy w/1	d	-798.32	97.9	-8.15
Familiy w/2	d	-956.58	98.82	-9.68
Familiy w/3+	d	-1199.3	112.57	-10.65
Centre Low	d	-244.18	60.9	-4.01
Centre Mid	d	-290.51	47.32	-6.14
Centre High	d	-551.84	104.21	-5.3
Subu Low	d	-284.85	61.08	-4.66
Subu Mid	d	-173.92	42.86	-4.06
Subu High	d	-629.08	91.46	-6.88
Peri Low	d	-86.46	94.43	-0.92
Peri Mid	d	-123.03	59.61	-2.06
Peri High	d	-387.24	124.31	-3.12
Dec	d	-306.53	54.10	-5.67
Jan	d	230.17	53.02	4.34
Feb	d	180.52	51.37	3.51
Jul	d	-144.52	53.61	-2.7
Oct	d	-159.22	53.53	-2.97
Adjusted R^2	0.398			

c = continuous, d = dummy

7.7.1.2 Pseudo Panel

Tables 7.39 and 7.40 show the multivariate linear regression models for all nine pseudo panels for the "Savings and Durable Goods" expenditure category. Presented are nine models for nine household types, each with 96 data points representing the average household of the given type for a given month. Through the process of aggregation, random variance is reduced, household types are taken out of the model and because of that, the influence of other variables can be seen more clearly. The influence of income in ranges from CHF 209 for a Family with 3 children to CHF 535 for retired singles. Other significant influences are the number of durable household goods and durable goods for entertainment and communication, for retired singles, families and other households. Most coefficients however are not significant at the 95% interval level and most of the relatively high explaining power of between 40% and 50% seems to come from income.

Figure 7.16 gives us a much clearer insight on the influence of income on savings. The scatter plots of the nine household types are grouped in three ranges of income: retired singles with one pensioners income, retired couples, working singles and single parents with about one working persons income and working couples and families with the income of two working age adults. Savings and durable goods on the y-axis show the positive correlation between income and savings within all household types. Families have a very similar relationship, regardless of the number of children. And retired single households (together with single parents and retired couples) are most in danger of having negative income and living of savings.

Table 7.39: Coefficients of the linear model for savings and durable goods (pseudo panel)

Variable	**RS**		**WAS**		**SP**		**WAC**		**RC**	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	-892	*-1.3*	-723	*-0.95*	-2052	*-2.77*	554	*0.53*	-1600	*-1.25*
Inc.	535	*7.23*	324	*5.55*	415	*7.65*	412	*6.28*	317	*4.74*
NewC	-912	*-1.37*	-537	*-0.89*	526	*0.97*	-1629	*-1.6*	168	*0.18*
UsedC	-1533	*-2.46*	-158	*-0.28*	259	*0.48*	-1125	*-1.46*	-1043	*-1.04*
FuGood	-2360	*-2.68*	390	*0.48*	-48	*-0.07*	-1584	*-1.57*	192	*0.17*
HHGood	-1330	*-1.26*	1547	*1.45*	1334	*1.61*	-1034	*-0.73*	-1213	*-0.83*
CGood	-352	*-2.09*	-211	*-2.07*	-293	*-1.6*	-323	*-1.51*	-635	*-4.58*
Centre	48	*0.31*	-9	*-0.09*	-5	*-0.03*	482	*2.34*	235	*1.65*
Subu	203	*0.39*	720	*1.42*	-97	*-0.22*	-826	*-1.36*	515	*0.85*
Peri	331	*0.68*	744	*1.6*	719	*1.93*	-117	*-0.19*	296	*0.58*
Comu	134	*0.55*	-157	*-0.87*	-90	*-0.74*	-361	*-1.25*	-179	*-0.71*
Dec	-50	*-0.25*	-53	*-0.28*	-188	*-1.06*	-108	*-0.35*	283	*1.1*
Jan	-507	*-2.51*	-281	*-1.65*	-28	*-0.24*	-225	*-1.12*	-100	*-0.51*
Year 02	239	*1.38*	3	*0.02*	-301	*-1.48*	237	*1.06*	98	*0.64*
Year 03	62	*0.34*	-90	*-0.84*	-107	*-0.51*	161	*0.68*	-58	*-0.37*
Year 04	-73	*-0.41*	-72	*-0.63*	178	*0.85*	188	*0.75*	-108	*-0.66*
Year 05	165	*0.88*	-128	*-1.1*	-4	*-0.02*	105	*0.36*	-190	*-1.07*
Year 06	251	*1.1*	-129	*-0.66*	-123	*-0.44*	-63	*-0.19*	-540	*-1.98*
Year 07	-55	*-0.27*	-127	*-0.72*	-292	*-1.05*	-344	*-0.98*	-655	*-2.11*
Year 08	266	*1.13*	-156	*-0.85*	-127	*-0.43*	-1	*0*	-263	*-0.78*
Adj. R^2	0.47		0.49		0.47		0.37		0.5	

Figure 7.16: Influence of income on savings and durable goods

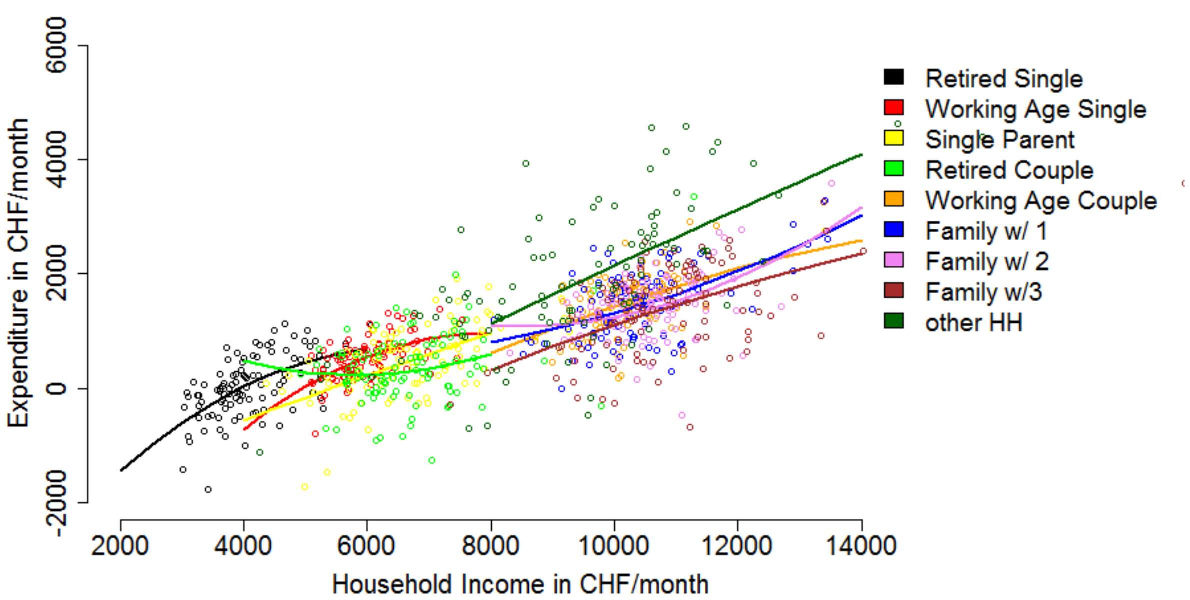


Table 7.40: Coefficients of the linear model for savings and durable Goods (pseudo panel)

Variable	**Fam1**		**Fam2**		**Fam3**		**oth**	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	-812	*-0.73*	-1938	*-1.65*	-1248	*-1.04*	-2857	*-2.76*
Inc.	435	*7.73*	362	*4.45*	209	*2.89*	525	*7.93*
NewC	-729	*-0.79*	-184	*-0.17*	391	*0.38*	491	*0.56*
UsedC	-791	*-0.96*	79	*0.08*	691	*0.87*	-257	*-0.34*
FuGood	-2473	*-2.2*	-140	*-0.11*	441	*0.42*	1860	*1.84*
HHGood	-2761	*-2.35*	-1707	*-1.3*	-1142	*-0.97*	-2134	*-1.42*
CGood	-38	*-0.22*	30	*0.15*	-204	*-0.69*	-462	*-1.14*
Centre	361	*2.06*	320	*1.71*	268	*0.91*	762	*1.89*
Subu	-150	*-0.31*	784	*1.11*	618	*1.05*	327	*0.65*
Peri	185	*0.36*	583	*1.02*	771	*1.44*	190	*0.39*
Comu	184	*0.94*	-211	*-0.98*	1	*0.01*	-35	*-0.18*
Dec	-471	*-1.9*	102	*0.28*	-229	*-0.7*	-192	*-0.7*
Jan	-163	*-0.88*	-165	*-0.92*	-50	*-0.35*	-148	*-1.04*
Year 02	223	*1.18*	51	*0.24*	453	*1.46*	351	*0.8*
Year 03	243	*1.23*	163	*0.71*	245	*0.81*	944	*2.03*
Year 04	295	*1.44*	-64	*-0.27*	51	*0.16*	-138	*-0.31*
Year 05	8	*0.03*	11	*0.04*	406	*1.25*	322	*0.7*
Year 06	57	*0.18*	-404	*-1.1*	158	*0.42*	1060	*2.1*
Year 07	-203	*-0.6*	-440	*-1.14*	-130	*-0.27*	452	*0.92*
Year 08	60	*0.16*	-186	*-0.47*	-105	*-0.23*	166	*0.33*
Adj. R^2	0.50		0.33		0.25		0.48	

7.7.2 Expenditures for Food

7.7.2.1 Observed Households

Table 7.41 shows the multivariate linear regression model for the "Food" expenditure category. Expenditure on food is determined largely through the number of persons and family type. Families with more children and a higher average age spend more on food than single or couple households. Household income has a significant positive effect, but that effect is very small compared to household composition. The difference between a working age single and a family with two children is 148 -(-71) + 3 x 144 = CHF 651, which is equal to a difference in income of 651/16 = CHF 40.000/month. Residential location type has also a significant influence, but it is considerably smaller. The presence of a freezer as a marginal effect of CHF 17/month, which is also negligible. Seasonal effects can be observed which could be interpreted as the Christmas effect: In December, expenditure on food are significantly higher than for other month, while they are significantly lower in January and February. The total difference between December and January are 83 -(-61) = CHF 144 which is about the same effect as one person more living in the household. The R^2 value, representing which part of the variance of the dependent variable can be explained by the explanatory variables, is 0.48. In the context of this research and in comparison to other expenditure categories, this is a relatively high value. As a short summary we can say that expenditure for food are mainly determined by the household composition and relatively independent of income.

7.7.2.2 Pseudo Panel

Tables 7.42 and 7.43 show the multivariate linear regression models for all nine pseudo panels for the "Food" expenditure category. Presented are nine models for nine household types, each with 96 data points representing the average household of the given type for a given month. Through the process of aggregation random variance is reduced, household types are taken out of the model and because of that the influence of other variables can be seen more clearly. Working age couples, retired couples and families with one child can be explained the best. The most significant influence across all household types is a higher spending for December and a lower one for January analogous to the above mentioned Christmas effect. The residential municipality has almost no significant influence. The coefficients for income are not significant, except for single parents, families with 2 children and other households.

Table 7.41: Coefficients of the linear model for expenditure on food (observed households)

Variable	Type	Estimate	Std. Error	T - Value
Intercept		-385.49	25.02	-15.41
Income [/ 10^3 CHF]	c	15.56	0.78	20.03
Income^2 [/ 10^6 CHF]	c	-0.11	0.01	-11.13
No. Pers.	c	143.94	5.61	25.65
Age	c	21.47	0.69	30.97
Age^2	c	-0.19	0.01	-23.81
Freezer	c	16.78	3.36	4.99
Retired Single	d	-45.19	17.44	-2.59
Working Age Single	d	-71.18	15.03	-4.74
Single Parent	d	101.39	12.89	7.86
Retired Couple	d	36.06	13.95	2.59
Working Age Couple	d	25.29	11.54	2.19
Familiy w/1	d	111.48	10.96	10.17
Familiy w/2	d	148.19	12.21	12.13
Familiy w/3+	d	154.40	17.34	8.90
Centre Mid	d	14.98	5.66	2.64
Centre High	d	24.50	12.94	1.89
Subu Mid	d	9.48	5.34	1.77
Subu High	d	17.91	11.75	1.52
Peri Mid	d	17.69	7.15	2.48
Peri High	d	15.26	15.05	1.01
Comu Mid	d	31.52	8.82	3.57
Comu High	d	52.65	21.95	2.40
Indu Mid	d	17.26	6.97	2.48
Indu High	d	35.63	18.18	1.96
Dec	d	83.23	5.98	13.91
Jan	d	-61.46	5.86	-10.49
Feb	d	-42.29	5.67	-7.45
c = continuous, d = dummy				
Adjusted R^2	0.4778			

Figure 7.17 gives us a much clearer insight on the influence of income on expenditure for food. The scatter plots of the nine household types are grouped in three ranges of income: retired singles with one pensioners income, retired couples, working singles and single parents with about one working persons income and working couples and families with the income of two working age adults. Expenditure for food on the y-axis shows a clear separation among the number of persons living in the household. The more persons live in a household, the higher expenditures for food. The curves going through the scatter plots represent the a regression model

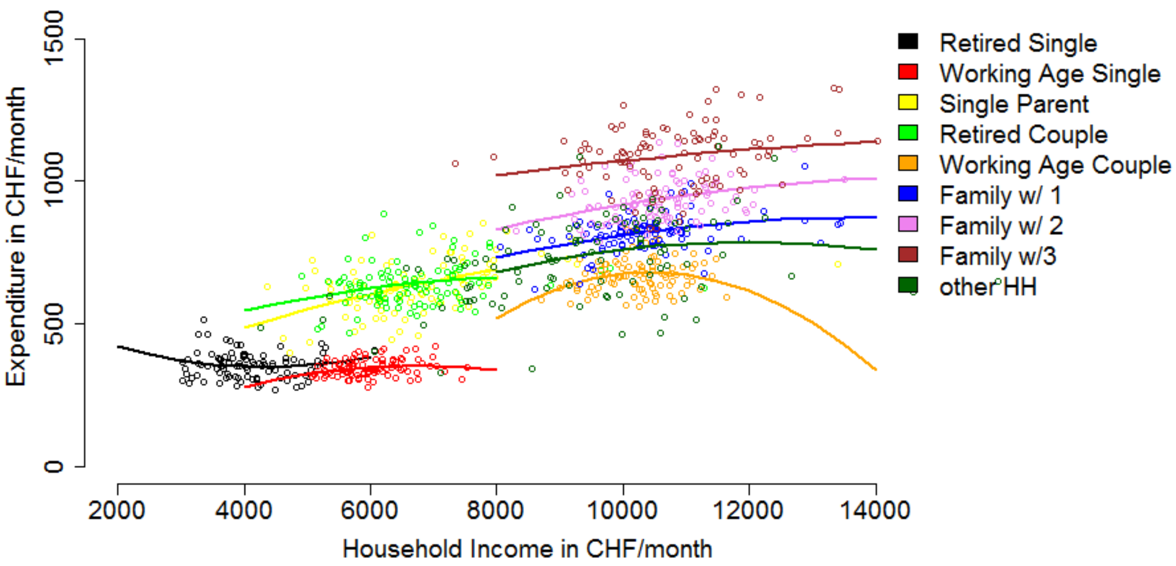
Table 7.42: Coefficients of the linear model for food (pseudo panel)

Variable	RS		WAS		SP		WAC		RC	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	878.98	*2.81*	38.47	*0.13*	284.28	*1.47*	830.17	*2.11*	-903.17	*-0.79*
Inc.	-63.98	*-0.85*	84.16	*0.9*	71.73	*1.85*	31.57	*0.7*	230.01	*1.04*
$Inc.^2$	7.2	*0.82*	-6.22	*-0.82*	-2.62	*-1.11*	-1.61	*-0.55*	-10.59	*-0.98*
Age	-6.18	*-1.93*	1.24	*0.62*	1.81	*0.54*	-5.84	*-1.18*	4.78	*1.79*
Centre	120.13	*1.87*	-12.7	*-0.22*	-106.23	*-1.17*	79.66	*0.82*	-42.58	*-0.39*
Subu	64.88	*1.05*	-50.5	*-0.94*	11.73	*0.13*	58.72	*0.77*	230.05	*2.02*
Peri	81.19	*0.94*	-22.16	*-0.27*	-25.94	*-0.22*	130.9	*1.34*	195.74	*1.47*
Comu	61.6	*0.59*	-44.66	*-0.42*	-260.83	*-1.89*	325.67	*2.51*	-40.01	*-0.23*
Dec	72.63	*4.59*	40.69	*4.07*	62.53	*2.04*	182.49	*9.37*	112.2	*6.72*
Jan	-28.05	*-1.84*	-16.41	*-1.65*	-37.72	*-1.21*	-60.35	*-3.13*	-58.53	*-3.59*
Year 02	-25.51	*-1.57*	-3.55	*-0.33*	0.89	*0.03*	-3.18	*-0.15*	-10.88	*-0.61*
Year 03	-24.72	*-1.48*	-0.33	*-0.03*	-16.26	*-0.48*	-11.88	*-0.55*	-2.31	*-0.12*
Year 04	-2.07	*-0.12*	-0.71	*-0.07*	-37.92	*-1.11*	-12.77	*-0.59*	7.4	*0.41*
Year 05	-0.52	*-0.03*	-17.77	*-1.61*	-23.22	*-0.68*	-7.72	*-0.36*	-14.71	*-0.83*
Year 06	-15.59	*-0.91*	-16.08	*-1.4*	14.16	*0.41*	9.17	*0.42*	16.9	*0.93*
Year 07	8.13	*0.49*	6.36	*0.58*	-34.3	*-1*	28.24	*1.25*	12.83	*0.7*
Year 08	-8.5	*-0.52*	14.25	*1.32*	-22.66	*-0.59*	29.28	*1.32*	32.93	*1.83*
Adj. R^2	0.25		0.25		0.24		0.54		0.48	

Table 7.43: Coefficients of the linear model for food (pseudo panel)

Variable	Fam1		Fam2		Fam3		oth	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	-74.84	*-0.2*	-973.68	*-1.38*	545.45	*1.74*	136.6	*0.61*
Inc.	88.62	*1.25*	310.76	*2.3*	-6.22	*-0.13*	133.04	*3.02*
$Inc.^2$	-3.27	*-1*	-13.3	*-2.14*	0.65	*0.36*	-5.62	*-2.53*
Age	9.12	*3.05*	10.33	*1.31*	24.49	*2.69*	-3.23	*-1.51*
Centre	41.59	*0.5*	-96.26	*-0.73*	148.82	*1.14*	-26.38	*-0.29*
Subu	77.51	*1.04*	-175.63	*-1.35*	-23.88	*-0.23*	-0.6	*-0.01*
Peri	83.42	*0.75*	-284.81	*-1.74*	-52.15	*-0.36*	67.93	*0.6*
Comu	118.07	*0.93*	-136.26	*-0.78*	-117.49	*-0.73*	262.35	*1.55*
Dec	83.86	*4.62*	113.58	*4.37*	95.97	*2.48*	52.97	*1.13*
Jan	-85.2	*-4.58*	-60.59	*-2.59*	-121.14	*-3.08*	-133.31	*-2.89*
Year 02	-4.13	*-0.21*	1.17	*0.04*	-4.46	*-0.11*	-6.73	*-0.13*
Year 03	-36	*-1.77*	-8.01	*-0.3*	38.3	*0.96*	85.15	*1.63*
Year 04	-25.56	*-1.31*	-30.51	*-1.18*	-25.54	*-0.62*	-61.03	*-1.22*
Year 05	-44.9	*-2.26*	-33.31	*-1.26*	-37.03	*-0.92*	17.47	*0.35*
Year 06	-58.96	*-3*	-10.19	*-0.37*	-40.1	*-0.98*	-95.21	*-1.73*
Year 07	-23.74	*-1.19*	-21.45	*-0.8*	-89.96	*-2.1*	-97.63	*-1.8*
Year 08	-21.13	*-1.06*	-29.75	*-1.12*	-28.32	*-0.71*	-35.94	*-0.69*
Adj. R^2	0.48		0.29		0.18		0.37	

Figure 7.17: Influence of income on food



only consisting of an intercept, income and income squared. The more or less flat lines for all the household types are clear visualization of the negligible effect income has on food spending.

7.7.3 Eating Out, Alcohol and Tobacco

7.7.3.1 Observed Households

Table 7.44 shows the multivariate linear regression model for the "Eating Out, Alcohol and Tobacco" (EAT) expenditure category. Expenditure for luxurious food and tobacco is influenced significantly by income (with a slight satiation) and average age. For every year of higher mean age, the household spends CHF 11 more for eating out. The number of persons in a household has a negative influence, which could be because larger households provide more social interaction within the house or the apartment and decreasing the need for going out as well as for substances like alcohol or tobacco which often are used for their psychological effect on mood and emotions. The significant influence of household type (already controlled for household size) are that couples, retired or working, spend more money for this category, and single parents spend significantly less. This points in the direction that this category may be linked to time use and time availability more then with other categories. Single parents have the highest ratio of housework per capita (one adult making housekeeping and education for several persons) and thus the least time to go out or enjoy alcohol, and couples have the smallest ratio, as they are two adults to share the housework and have no children to look after, freeing time to enjoy luxurious food. Residential municipality type where the household is located has a relatively significant influence. Households from higher income classes spend almost CHF 60 more and from middle income classes 20 more per month when they are located in a city compared to a suburb. Households in suburban, peri-urban and commuter municipalities spend less than in cities or industrial municipalities. In agrarian municipalities, households spend the least. There is also a seasonal effect that can be observed, as expenditure in Summer is higher than during the rest of the year.

7.7.3.2 Pseudo Panel

Tables 7.45 and 7.46 show the multivariate linear regression models for all nine pseudo panels for the "EAT" expenditure category. For the single households and families with two or more children, income does not have a significant influence, but for couples and single parents and families with one child the coefficients for income are significant. Residential location has a substantial effect, with living in a urban area with a generally negative effect and living in a commuter town with a positive effect (except for retired couples). The Christmas effect can also be observed

Table 7.44: Coefficients of the linear model for eating out, alcohol and tobacco (observed households)

Variable	Type	Estimate	Std. Error	T - Value
Intercept		23.02	38.40	0.60
Income [/ 10^3 CHF]	c	36.56	1.19	30.69
Income^2 [/ 10^6 CHF]	c	-0.19	0.01	-13.09
No. Pers.	c	-23.92	8.58	-2.79
Age	c	10.64	1.06	10.04
Age^2	c	-0.14	0.01	-11.36
Retired Single	d	25.65	26.74	0.96
Working Age Single	d	-18.27	23.03	-0.79
Single Parent	d	-43.07	19.77	-2.18
Retired Couple	d	93.27	21.39	4.36
Working Age Couple	d	75.06	17.69	4.24
Familiy w/1	d	-6.82	16.80	-0.41
Familiy w/2	d	13.44	18.72	0.72
Familiy w/3+	d	23.27	26.59	0.87
Centre Mid	d	45.87	8.67	5.29
Centre High	d	125.92	19.83	6.35
Subu Mid	d	29.09	8.19	3.55
Subu High	d	64.22	18.02	3.56
Peri Mid	d	24.06	10.96	2.20
Peri High	d	99.49	23.08	4.31
Comu Mid	d	25.09	13.52	1.86
Comu High	d	99.18	33.65	2.95
Indu Mid	d	36.42	10.68	3.41
Indu High	d	115.26	27.88	4.13
Summer	d	39.78	5.75	6.92

c = continuous, d = dummy
Adjusted R^2 0.194

in the significant and negative coefficient for January for all household types. Some effects for the influence of time can be observed for families, where the dummies for the later years from 2006 to 2008 are higher than for the previous years. However, the effects are not very clear and significant and interpretation is not obvious. The explanatory power for all household types, and especially for retired singles, are much lower than for normal food, indicating the that this category depends more on personal preferences and choices than on systemic variables or income.

The scatter plots and extrapolation of the income model in figure 7.18 shows a clear correlation with income, but also the higher level for working age singles and working aged couples compared to single parents

Table 7.45: Coefficients of the linear model for eating out, alcohol and tobacco (pseudo panel)

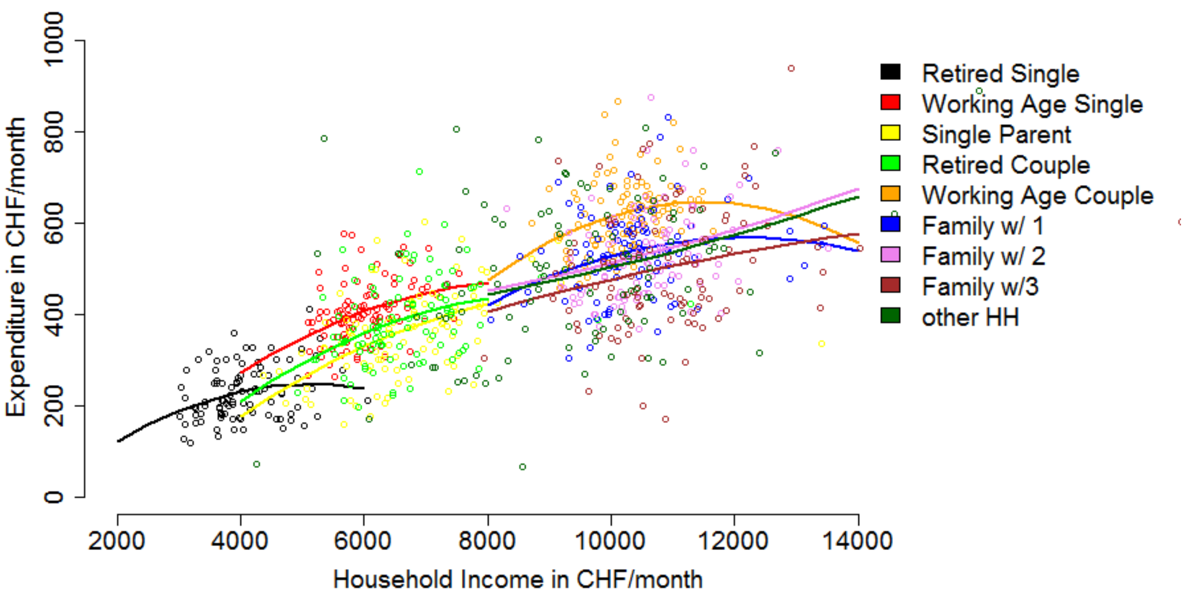
Variable	**RS**		**WAS**		**SP**		**WAC**		**RC**	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	181.44	*0.41*	349.74	*0.5*	-338.08	*-1.6*	366.36	*0.55*	-2815.38	*-1.59*
Inc.	67.38	*0.64*	0.27	*0*	155.46	*3.7*	212.52	*2.91*	643.29	*1.89*
Inc.^{2}	-5.44	*-0.44*	2.76	*0.16*	-8.19	*-3.16*	-12.08	*-2.52*	-29.36	*-1.76*
Age	-1.23	*-0.28*	-1.52	*-0.33*	2.53	*0.72*	-9.97	*-1.19*	-1.27	*-0.31*
Centre	-46.47	*-0.52*	111.78	*0.86*	-50.48	*-0.53*	-43.38	*-0.27*	26.01	*0.15*
Subu	-4.4	*-0.05*	-2.46	*-0.02*	2.48	*0.03*	-164.07	*-1.3*	13.08	*0.08*
Peri	-170.57	*-1.42*	16.39	*0.09*	-27.56	*-0.22*	-220.78	*-1.32*	-79.36	*-0.39*
Comu	-72.5	*-0.5*	418.86	*1.73*	-91.16	*-0.62*	120.95	*0.57*	-232.18	*-0.87*
Jan	-21.34	*-1*	-33.11	*-1.45*	-32.81	*-1*	-98.34	*-3.08*	-7.38	*-0.29*
Jun	21.48	*1*	-53.63	*-2.27*	-38.55	*-1.19*	26.24	*0.82*	33.37	*1.34*
Oct	6.4	*0.3*	30.85	*1.35*	34.95	*1.02*	7.37	*0.22*	-20.99	*-0.82*
Year 02	-17.71	*-0.78*	-34.97	*-1.43*	20.37	*0.58*	-60.67	*-1.75*	2.67	*0.1*
Year 03	-11.34	*-0.48*	-15.14	*-0.6*	-16.56	*-0.47*	-49.86	*-1.41*	-35.87	*-1.24*
Year 04	16.08	*0.67*	-61.62	*-2.47*	-43.75	*-1.22*	-39.72	*-1.12*	-22.92	*-0.83*
Year 05	-39.61	*-1.63*	-33.94	*-1.35*	-9.95	*-0.28*	-52.44	*-1.47*	-33.02	*-1.21*
Year 06	-25.38	*-1.05*	-39.67	*-1.51*	6.37	*0.17*	-59.54	*-1.65*	70.74	*2.52*
Year 07	21.53	*0.92*	-59.77	*-2.39*	17.21	*0.48*	-18.71	*-0.5*	90.78	*3.23*
Year 08	-16.97	*-0.74*	-66.28	*-2.7*	-26.11	*-0.64*	-4.28	*-0.12*	15.43	*0.56*
Adj. R^2	0.08		0.22		0.22		0.21		0.29	

and families. Between the families, the number of children makes not a big impact. The picture for luxurious food (EAT) however is distinctively different from the one for normal food.

Table 7.46: Coefficients of the linear model for eating out, alcohol and tobacco (pseudo panel)

Variable	Fam1		Fam2		Fam3		oth	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	-698	*-1.05*	605	*0.66*	67	*0.17*	500	*1.93*
Inc.	235	*1.91*	-88	*-0.51*	68	*1.2*	-5	*-0.1*
Inc.^{2}	-10	*-1.72*	5	*0.63*	-1	*-0.54*	2	*0.84*
Age	-6	*-1.14*	1	*0.12*	-3	*-0.29*	-1	*-0.23*
Centre	-7	*-0.05*	235	*1.32*	-146	*-0.91*	-108	*-1.01*
Subu	54	*0.42*	306	*1.77*	-44	*-0.33*	-182	*-1.86*
Peri	95	*0.49*	354	*1.65*	-123	*-0.64*	-407	*-3.16*
Comu	464	*2.1*	555	*2.45*	161	*0.8*	306	*1.55*
Jan	-93	*-2.87*	-74	*-2.41*	-98	*-2.01*	-98	*-1.8*
Jun	0	*0*	-33	*-1.04*	-32	*-0.68*	-100	*-1.84*
Oct	23	*0.72*	-2	*-0.07*	-14	*-0.28*	112	*1.95*
Year 02	-26	*-0.75*	2	*0.06*	-83	*-1.6*	-10	*-0.16*
Year 03	-64	*-1.83*	-36	*-1.06*	-80	*-1.61*	-22	*-0.37*
Year 04	-25	*-0.74*	31	*0.92*	-63	*-1.23*	43	*0.74*
Year 05	-45	*-1.3*	-19	*-0.55*	-134	*-2.71*	-32	*-0.56*
Year 06	24	*0.7*	79	*2.17*	27	*0.54*	-21	*-0.33*
Year 07	46	*1.32*	92	*2.59*	57	*1.07*	-91	*-1.44*
Year 08	25	*0.73*	70	*2.02*	7	*0.14*	-4	*-0.07*
Adj. R^2	0.22		0.28		0.19		0.27	

Figure 7.18: Influence of income on eating out, alcohol and tobacco



7.7.4 Housing Rent, Interest and Mortgage Payments

7.7.4.1 Observed Households

Table 7.47 shows the multivariate linear regression model for the "Housing: Rent and Mortgage interest" expenditure category. Spending for this category is relatively hard to predict given the information available. The best model we could find, only explains 13% of the variance of the data. Income does not have a big effect, especially considering that the absolute amount households spend on housing is relatively high. The number of persons living in the household has no influence when controlled for household type. Age however has substantial negative effect of CHF -8 per year of age difference. A Household that is 40 years older on average pays around CHF 320 less for housing. That fact reflects the increase in land prices in Switzerland where rents and house prices are higher every year for the recent past, which affects households who move into a new place much more as they have to make a new contract, whether they buy a house or rent a flat. Increasing the rent of a tenant is very difficult for the landlord and only possible if major improvements and renovations are made. The longer one lives in the same home, the cheaper it is compared to the average. Car ownership is negatively correlated with housing cost, however the impact is relatively small. Considering household types, it is interesting to see that families spend less for housing than couples or singles. In Switzerland, subsidised and cooperative non-profit housing is relatively common and its guidelines favour families with children. Another explanation is that families need the money for other things and as their budget is tighter, housing costs are optimized. As for residential location, it is very interesting to see that households in suburbs spend considerably more than in other municipality types. Here we have to consider that the municipality type "Regional Centre" includes much more than the usually more expensive inner cities of Zurich, Basel and Geneva, but also much smaller cities. Living in the Zurich area (or in central Switzerland) also increases housing costs substantially, while Ticino is the cheapest region to live. Combining both regional influences, the contribution can get substantial. The difference for the same upper income household located either in the suburbs of Zurich or in a commuter town in Ticino is 200 + 215 -(-54-72) = CHF 541 per month or almost CHF 6.500 per year according to the model.

Table 7.47: Coefficients of the linear model for housing Rent, interest and mortgage (observed households)

Variable	Type	Estimate	Std. Error	T - Value
Intercept		916.7	66.62	13.76
Income [/ 10^3 CHF]	c	51.4	2.45	20.99
Income^2 [/ 10^6 CHF]	c	-0.2	0.03	-6.7
No. Pers.	c	1.34	17.35	0.08
Age	c	-8.24	0.51	-16.02
New Cars	c	-35.51	9.69	-3.66
Used Cars	c	-57.23	8.79	-6.51
FunGoods	c	22.68	4.36	5.2
HH Goods	c	6.07	2.41	2.51
Retired Single	d	272.79	50.81	5.37
Working Age Single	d	87.05	46.63	1.87
Single Parent	d	90.03	40.04	2.25
Working Age Couple	d	70.16	40.53	1.73
Retired Couple	d	101.34	35.81	2.83
Familiy w/1	d	26.03	33.98	0.77
Familiy w/2	d	18.3	37.87	0.48
Familiy w/3+	d	-23.3	53.75	-0.43
Centre Mid	d	85.12	17.71	4.81
Centre High	d	80.21	40.27	1.99
Subu Mid	d	108.08	16.73	6.46
Subu High	d	215.13	36.58	5.88
Peri Mid	d	94.86	22.4	4.23
Peri High	d	39.71	46.81	0.85
Comu Mid	d	-2.66	27.53	-0.1
Comu High	d	-72.54	68.07	-1.07
Indu Mid	d	-52.02	21.64	-2.4
Indu High	d	-37.5	56.37	-0.67
Zurich	d	199.81	14.32	13.96
CS	d	114.89	18.09	6.35
NWS	d	96.08	15.61	6.16
TI	d	-54.51	18.51	-2.95
Oct	f	54.28	18.18	2.99

c = continuous, d = dummy

Adjusted R^2 0.141

7.7.4.2 Pseudo Panel

Tables 7.48 and 7.49 show the multivariate linear regression models for all nine pseudo panels for the "Housing: Rent, Interest and Mortgage" expenditure category. The explanatory power of the models is generally very poor, for retired singles and working age couple almost in-existent. Working age singles, single parents and families with three or more children have a better adjusted R^2 of between 23% and 29%. The model also contains a negative coefficient for the number of cars. The negative influence of age is also consistent throughout all the household types. A clear pattern of changing housing cost over the year however can not be observed, even with several years having a significant coefficient for some household types.

Figure 7.19 shows the differences between the household types in the pseudo panel better. While Families and working age couples with (aggregated average) incomes above CHF 8.000/month are mixed together in the same space, working age and retired singles, working age couples and single parents, each have their own cluster. Retired couples spend significantly less on housing than working age singles and single parents, single parents with even higher expenses than working age singles. Another interesting finding is that retired and working age singles (the black and red dots) form a continuous cluster with the same correlation together, while there is a step between retired and working age couples with working age couples having a steeper correlation between income and housing expenditure. The main conclusion from the models is that housing expenditure is only slightly dependent on income and much more on personal preferences, regions, special arrangements and exceptions and how long a household already has occupied the home. Single parents are over- and retired couples under paying relative to their income.

Table 7.48: Coefficients of the linear model for housing rent, interest and mortgage (pseudo panel)

Variable	**RS**		**WAS**		**SP**		**WAC**		**RC**	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	1557	*1.15*	1105	*1.43*	1509	*4.47*	2055	*1.41*	7946	*2.61*
Inc.	212	*0.66*	-140	*-0.6*	32	*0.49*	86	*0.57*	-1088	*-1.89*
Inc.^{2}	-17	*-0.45*	15	*0.79*	1	*0.23*	-3	*-0.29*	55	*1.96*
Age	-16	*-1.16*	-1	*-0.16*	-15	*-2.64*	-18	*-1.01*	-20	*-2.83*
NewC	-99	*-0.55*	-1	*-0.01*	127	*1*	-262	*-1.37*	79	*0.42*
UsedC	-100	*-0.51*	-13	*-0.12*	-22	*-0.22*	-158	*-0.8*	-89	*-0.56*
FuGood	-47	*-0.49*	61	*1.4*	29	*0.87*	-78	*-0.88*	-109	*-1.43*
Centre	-44	*-0.16*	170	*1.16*	-347	*-2.33*	216	*0.67*	-74	*-0.26*
Subu	-12	*-0.04*	228	*1.69*	-126	*-0.82*	-62	*-0.25*	-1	*0*
Peri	438	*1.19*	546	*2.77*	79	*0.41*	245	*0.75*	-203	*-0.58*
Comu	-66	*-0.15*	-17	*-0.06*	-519	*-2.32*	-310	*-0.73*	-381	*-0.82*
Oct	92	*1.37*	-12	*-0.48*	-28	*-0.5*	-67	*-1.03*	2	*0.04*
Year 02	-46	*-0.66*	45	*1.67*	22	*0.39*	18	*0.25*	-24	*-0.52*
Year 03	95	*1.3*	32	*1.18*	-40	*-0.72*	7	*0.1*	27	*0.54*
Year 04	-56	*-0.75*	3	*0.12*	-78	*-1.38*	-110	*-1.54*	-73	*-1.49*
Year 05	110	*1.44*	36	*1.26*	-22	*-0.39*	-67	*-0.9*	-44	*-0.93*
Year 06	61	*0.82*	-10	*-0.33*	-109	*-1.88*	49	*0.64*	-123	*-2.46*
Year 07	32	*0.44*	2	*0.07*	-120	*-2.09*	49	*0.61*	-77	*-1.44*
Year 08	36	*0.5*	56	*1.83*	-92	*-1.43*	38	*0.48*	-56	*-1.08*
Adj. R^2	0.03		0.23		0.27		0.03		0.14	

Figure 7.19: Influence of income on housing rent, interest and mortgage

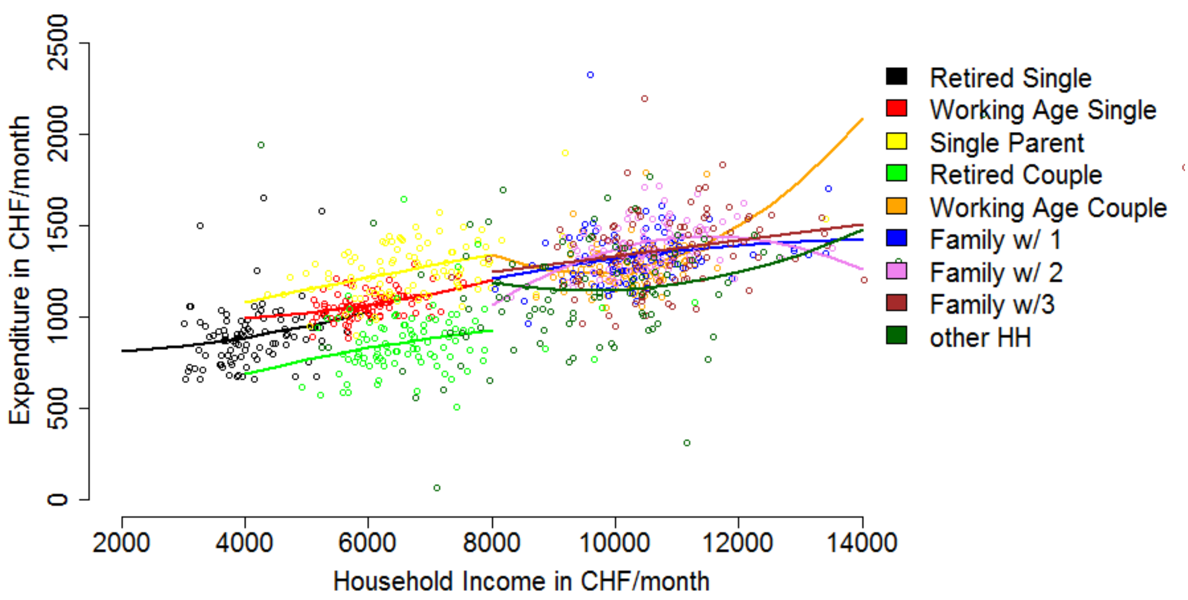


Table 7.49: Coefficients of the linear model for housing rent, interest and mortgage (pseudo panel)

Variable	Fam1		Fam2		Fam3		oth	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	1173	*0.92*	-1400	*-0.67*	2120	*3.63*	4145	*3.27*
Inc.	25	*0.1*	730	*1.81*	-10	*-0.12*	-162	*-0.64*
Inc.^{2}	0	*0*	-31	*-1.67*	3	*0.89*	10	*0.79*
Age	-14	*-1.46*	-43	*-1.78*	-31	*-1.87*	-31	*-2.41*
NewC	-9	*-0.06*	-113	*-0.43*	-185	*-1.27*	-684	*-2.05*
UsedC	-30	*-0.17*	-110	*-0.5*	-314	*-2.26*	-304	*-0.91*
FuGood	10	*0.16*	51	*0.63*	39	*0.8*	-57	*-0.44*
Centre	653	*2.04*	-522	*-1.24*	-7	*-0.03*	-56	*-0.1*
Subu	474	*1.76*	-510	*-1.29*	236	*1.19*	552	*1.15*
Peri	706	*1.89*	-315	*-0.63*	-271	*-1*	-199	*-0.31*
Comu	178	*0.43*	-265	*-0.51*	360	*1.23*	249	*0.25*
Oct	32	*0.55*	196	*2.66*	153	*2.18*	-16	*-0.06*
Year 02	-16	*-0.24*	-27	*-0.33*	-101	*-1.32*	-372	*-1.24*
Year 03	-64	*-0.97*	-42	*-0.51*	-67	*-0.92*	-525	*-1.66*
Year 04	-114	*-1.77*	13	*0.16*	-101	*-1.35*	-551	*-1.94*
Year 05	-153	*-2.19*	-99	*-1.2*	-132	*-1.83*	-407	*-1.39*
Year 06	-139	*-2.15*	-69	*-0.79*	-236	*-3.13*	-558	*-1.77*
Year 07	-64	*-0.86*	-85	*-0.92*	-131	*-1.57*	-528	*-1.71*
Year 08	-95	*-1.38*	-75	*-0.8*	-134	*-1.77*	-501	*-1.7*
Adj. R^2	0.12		0.13		0.29		0.15	

7.7.5 Entertainment

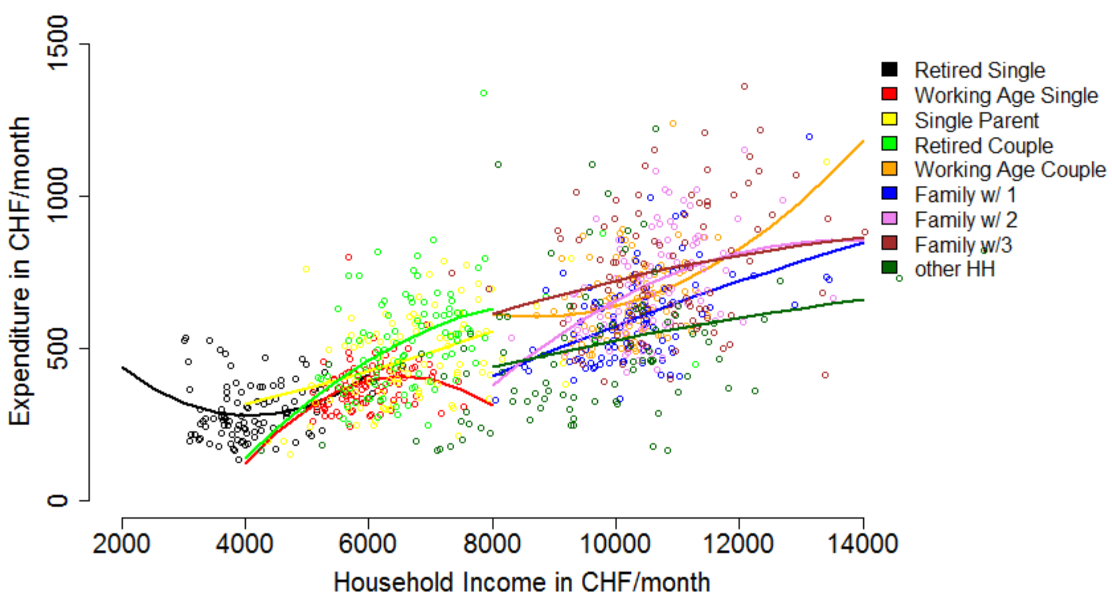
7.7.5.1 Observed Households

Table 7.50 shows the multivariate linear regression model for the "Entertainment" expenditure category. The explanatory power is somewhat better than for the housing category but still weaker than for savings or food. Influence of income is very significant and with a significant satiation. The number of persons decreases entertainment spending, maybe because more persons in a household provide more in home entertainment and therefore reducing the need to buy entertainment. However, looking at the dummies for household type shows that households with more persons, like families, spend substantially more. The difference between the effect of being family with 3 or more children and a being a retired single on entertainment is equivalent to the effect of almost CHF 4.000/month of income per month, regarding entertainment expenditure. Durable goods for housekeeping and for entertainment, washing machine or a television, also increase entertainment spending. Residential location municipality type has a significant but limited impact. Households in cities or suburbs or peri-urban areas spend more than commuter or industrial areas. The Christmas effect is can also be observed with about CHF 80 difference between December and January.

Table 7.50: Coefficients of the linear model for entertainment (observed households)

Variable	**Type**	**Estimate**	**Std. Error**	**T - Value**
Intercept		-176.27	54.23	-3.25
Income [/ 10^3 CHF]	c	56.69	1.99	28.52
Income^2 [/ 10^6 CHF]	c	-0.26	0.02	-10.77
No. Pers.	c	-18.12	14.15	-1.28
Age	c	2.13	0.42	5.08
New Cars	c	1.57	7.83	0.2
Used Cars	c	-31.45	7.14	-4.4
HH Goods	c	12.7	3.55	3.58
FunGoods	c	17.38	1.97	8.83
Retired Single	d	42.57	41.4	1.03
Working Age Single	d	76.67	38.01	2.02
Single Parent	d	150.5	32.65	4.61
Working Age Couple	d	123.1	33	3.73
Retired Couple	d	94.64	29.19	3.24
Familiy w/1	d	59.46	27.72	2.14
Familiy w/2	d	162.54	30.89	5.26
Familiy w/3+	d	240.18	43.84	5.48
Centre Mid	d	45.26	14.41	3.14
Centre High	d	105.42	32.8	3.21
Subu Mid	d	15.43	13.54	1.14
Subu High	d	129.01	29.74	4.34
Peri Mid	d	21.74	18.14	1.2
Peri High	d	118.88	38.08	3.12
Comu Mid	d	-1.7	22.35	-0.08
Comu High	d	84.89	55.49	1.53
Indu Mid	d	-15.75	17.62	-0.89
Indu High	d	144.73	45.97	3.15
Dec	d	52.76	15.21	3.47
Jan	d	-33.12	14.9	-2.22
Jun	d	-32.31	15.04	-2.15
Jul	d	25.07	15.08	1.66
c = continuous, d = dummy				
Adjusted R^2	0.167			

Figure 7.20: Influence of income on entertainment



7.7.5.2 Pseudo Panel

Tables 7.51 and 7.52 show the multivariate linear regression models for all nine pseudo panels for the "Entertainment" category. Income has a significant influence on entertainment spending for all household types except for retired singles. The models for working age and retired singles have no explanatory power, indicating that for these two household types, expenditure for entertainment is solely based on personal preferences. The coefficients for the different municipality types show a positive influence of commuter areas for families with one or three or more children as well as for working age couples. Families with 2 children and single parents have higher spending in cities and suburbs. The Christmas effect can be observed with all household types except singles. The coefficients for the years show slightly higher spendings for the most recent years. Generally the results from the pseudo panel models are lacking clear patterns and are hard to interpret. Figure 7.20 depicting entertainment spending as a function of income also show some rather chaotic scatter plots with high variances and a slight correlation of about CHF 50 per CHF 1.000/month of income. The conclusion is that expenditure for entertainment is mainly a personal preference.

Table 7.51: Coefficients of the linear model for entertainment (pseudo panel)

Variable	RS		WAS		SP		WAC		RC	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	261	*0.42*	78	*0.24*	-115	*-0.51*	771	*0.63*	-283	*-0.65*
Inc.	11	*0.66*	48	*2.83*	67	*4.98*	53	*2.88*	73	*3.87*
Age	-1	*-0.14*	-2	*-0.31*	-4	*-0.74*	-13	*-0.77*	0	*0.07*
FuGood	0	*0.01*	-25	*-0.46*	36	*1.07*	37	*0.44*	55	*0.79*
Centre	36	*0.23*	185	*1.05*	162	*1.09*	192	*0.65*	62	*0.23*
Subu	132	*0.89*	115	*0.69*	127	*0.83*	141	*0.6*	17	*0.06*
Peri	257	*1.23*	32	*0.13*	208	*1.08*	457	*1.48*	-91	*-0.29*
Comu	145	*0.58*	-69	*-0.21*	-253	*-1.09*	409	*1*	14	*0.03*
Dec	74	*1.9*	15	*0.48*	35	*0.69*	57	*0.91*	85	*2.11*
Jan	6	*0.16*	22	*0.72*	-6	*-0.12*	-26	*-0.42*	-11	*-0.29*
Year 02	-36	*-0.9*	18	*0.55*	53	*0.95*	23	*0.34*	-78	*-1.8*
Year 03	-39	*-0.98*	16	*0.47*	-16	*-0.28*	-10	*-0.15*	-67	*-1.49*
Year 04	-17	*-0.42*	42	*1.22*	-29	*-0.52*	12	*0.17*	-14	*-0.33*
Year 05	-23	*-0.58*	34	*0.99*	54	*0.95*	-1	*-0.01*	67	*1.58*
Year 06	-28	*-0.69*	61	*1.59*	100	*1.72*	135	*1.95*	117	*2.55*
Year 07	-20	*-0.51*	50	*1.38*	63	*1.1*	118	*1.65*	130	*2.69*
Year 08	-17	*-0.44*	14	*0.39*	67	*1.05*	116	*1.65*	42	*0.89*
Adj. R^2	-0.07		-0.01		0.3		0.11		0.31	

Table 7.52: Coefficients of the linear model for entertainment (pseudo panel)

Variable	**Fam1**		**Fam2**		**Fam3**		**oth**	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	-462	*-1.54*	246	*0.56*	-26	*-0.06*	-90	*-0.33*
Inc.	61	*4.21*	79	*3.65*	47	*2.57*	49	*3.52*
Age	3	*0.34*	-19	*-1.13*	5	*0.28*	-4	*-0.97*
FuGood	72	*1.52*	-58	*-1.07*	-45	*-0.87*	36	*0.87*
Centre	-74	*-0.37*	347	*1.24*	168	*0.65*	176	*1.04*
Subu	87	*0.46*	497	*1.84*	234	*1.13*	117	*0.72*
Peri	227	*0.82*	116	*0.34*	701	*2.43*	-151	*-0.71*
Comu	803	*2.62*	131	*0.36*	528	*1.67*	406	*1.26*
Dec	62	*1.38*	31	*0.57*	81	*1.03*	48	*0.54*
Jan	-116	*-2.52*	-100	*-2.01*	-151	*-1.94*	-120	*-1.38*
Year 02	-10	*-0.2*	-49	*-0.89*	-80	*-0.97*	20	*0.2*
Year 03	-55	*-1.11*	-30	*-0.53*	55	*0.7*	-46	*-0.45*
Year 04	-14	*-0.28*	-3	*-0.06*	8	*0.11*	344	*3.64*
Year 05	123	*2.49*	-14	*-0.26*	23	*0.29*	25	*0.26*
Year 06	88	*1.78*	175	*3*	136	*1.68*	112	*1.09*
Year 07	122	*2.28*	135	*2.23*	135	*1.58*	202	*2.04*
Year 08	94	*1.79*	60	*0.96*	176	*2.17*	139	*1.45*
Adj. R^2	0.39		0.35		0.17		0.25	

7.7.6 Consumer Goods

7.7.6.1 Observed Households

Table 7.53 shows the multivariate linear regression model for the "Consumer Goods" Category. Income has a similar significant effect like entertainment and housing with about CHF 50 for every CHF 1.000/month more in income. The impact of age is significant but very small. The number of cars and of household goods influence spending for this category, but also with a limited impact. The possession of 2 housekeeping appliances more increases spending for consumer goods by CHF 37 per month. A more substantial impact comes from household type, where being a family or a single parent household contributes to consumer goods expenditure. A working age single household with in the same location and with the same income as a family with 3 or more children spends about CHF 141 less. Households located in cities and suburbs also spend more on consumer goods than households in commuter or industrial villages. The Christmas effect adds another CHF 149 to spending in December.

7.7.6.2 Pseudo Panel

Tables 7.54 and 7.55 show the multivariate linear regression models for all nine pseudo panels for the "Consumer Goods" category. For this category, the explanatory power in the pseudo panel model is much higher than for the model using the original households. Especially couples, single parent households and families up to two children have a decent explanatory power of between 41% and 52%. Income has the most substantial impact, but also the number of durable goods for the purposes of housekeeping and entertainment have some limited and mixed influence. Durable goods for entertainment, such as televisions, DVD players or cameras, positively influence spending for consumer goods in working aged couple households but decreasing it for families, while it is the other way around for housekeeping appliances. Looking at the dummies for the year of observation gives also mixed results for the influence of time, but in general, the spending in the more recent years was higher. The scatter plots in figure 7.21 show the variance of the data points, the almost zero influence of income for retired singles but also that households with children like single parents and families have significantly higher expenses for consumer goods than household types of the same income level. As a conclusion we can state that expenditure for consumer goods is dependent on the presence of children in the household and on income, more so than other categories.

Table 7.53: Coefficients of the linear model for consumer goods (observed households)

Variable	Type	Estimate	Std. Error	T - Value
Intercept		14.35	28.07	0.51
Income [/ 10^3 CHF]	c	49.51	1.67	29.64
Income^2 [/ 10^6 CHF]	c	-0.14	0.02	-6.85
Age	c	-1.01	0.35	-2.88
New Cars	c	32.53	6.47	5.03
Used Cars	c	-21	5.93	-3.54
HH Goods	d	18.41	2.94	6.27
Retired Single	d	111.15	27.44	4.05
Working Age Single	d	58.75	22.56	2.6
Single Parent	d	189.3	27.15	6.97
Working Age Couple	d	118.37	25.91	4.57
Retired Couple	d	93.19	21.97	4.24
Familiy w/1	d	167.5	23.37	7.17
Familiy w/2	d	181.94	23.22	7.84
Familiy w/3+	d	199.76	25.72	7.77
Centre Mid	d	46.23	12.12	3.81
Centre High	d	144.36	27.64	5.22
Subu Mid	d	21.83	11.38	1.92
Subu High	d	168.41	25.05	6.72
Peri Mid	d	26.14	15.28	1.71
Peri High	d	131.64	32.08	4.1
Comu Mid	d	-5.62	18.84	-0.3
Comu High	d	144.61	46.77	3.09
Indu Mid	d	-14.58	14.86	-0.98
Indu High	d	98.02	38.74	2.53
Dec	d	148.63	12.68	11.72
Jun	d	26.8	12.54	2.14

c = continuous, d = dummy, n = number

Adjusted R^2 0.227

Table 7.54: Coefficients of the linear model for consumer goods (pseudo panel)

Variable	**RS**		**WAS**		**SP**		**WAC**		**RC**	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	75	*0.16*	-23	*-0.09*	-288	*-0.87*	1235	*1.66*	264	*0.86*
Inc.	20	*1.54*	51	*4.15*	135	*7.54*	30	*2.65*	45	*3.57*
Age	-2	*-0.3*	1	*0.23*	4	*0.57*	-16	*-1.68*	-3	*-0.72*
NewC	-13	*-0.16*	-5	*-0.05*	-39	*-0.24*	114	*1.14*	-65	*-0.56*
UsedC	-74	*-0.9*	-211	*-2.22*	-157	*-1.18*	6	*0.06*	-146	*-1.48*
FuGood	-10	*-0.24*	15	*0.41*	-41	*-0.91*	102	*2.08*	68	*1.46*
HHGood	53	*1.53*	-14	*-0.36*	36	*0.56*	-87	*-1.7*	47	*0.93*
Centre	234	*1.99*	155	*1.22*	-89	*-0.46*	67	*0.39*	-142	*-0.79*
Subu	312	*2.82*	103	*0.88*	8	*0.04*	124	*0.96*	-14	*-0.07*
Peri	243	*1.58*	23	*0.13*	-167	*-0.68*	143	*0.86*	-322	*-1.52*
Comu	307	*1.65*	287	*1.26*	388	*1.31*	100	*0.43*	-183	*-0.63*
Dec	39	*1.33*	41	*1.93*	162	*2.44*	110	*3.19*	138	*5.17*
Jan	-12	*-0.44*	-70	*-3.39*	-68	*-1.02*	-21	*-0.61*	-86	*-3.22*
Aug	-9	*-0.33*	-45	*-2.14*	-63	*-0.89*	-64	*-1.83*	-91	*-3.52*
Year 02	-29	*-0.98*	-7	*-0.33*	-71	*-1*	11	*0.3*	-7	*-0.26*
Year 03	-31	*-1.02*	-16	*-0.67*	-73	*-1.01*	-39	*-1.02*	-15	*-0.52*
Year 04	-15	*-0.49*	-10	*-0.42*	-85	*-1.16*	-13	*-0.34*	31	*1.07*
Year 05	12	*0.39*	-1	*-0.04*	-86	*-1.15*	2	*0.05*	-33	*-1.16*
Year 06	-50	*-1.43*	41	*1.21*	1	*0.01*	53	*1.27*	26	*0.74*
Year 07	48	*1.61*	38	*1.48*	53	*0.72*	151	*3.63*	73	*2.25*
Year 08	-1	*-0.04*	29	*1.12*	97	*1.16*	96	*2.34*	18	*0.56*
Adj. R^2	0.12		0.37		0.48		0.41		0.46	

Figure 7.21: Influence of income on consumer goods

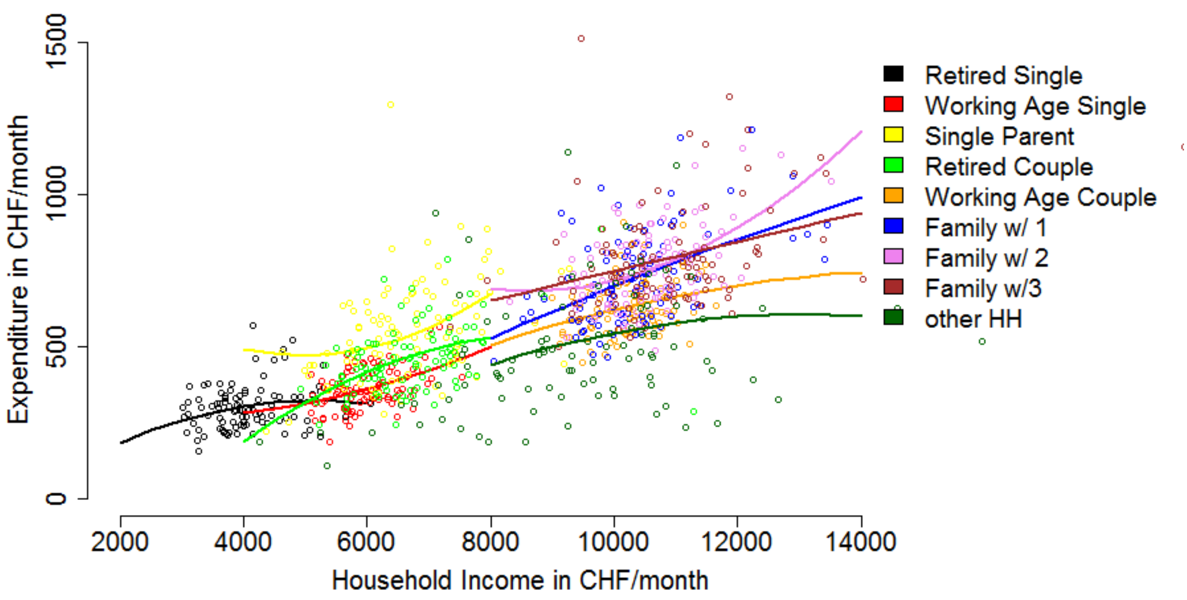


Table 7.55: Coefficients of the linear model for consumer goods (pseudo panel)

Variable	**Fam1**		**Fam2**		**Fam3**		**oth**	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	106	*0.32*	794	*2.44*	415	*1.19*	488	*1.86*
Inc.	76	*5.48*	58	*3.85*	44	*2.89*	47	*3.36*
Age	-8	*-1.21*	-31	*-2.61*	-3	*-0.2*	-7	*-1.6*
NewC	-174	*-1.41*	-54	*-0.41*	19	*0.15*	323	*3.07*
UsedC	12	*0.1*	33	*0.3*	-112	*-1.01*	331	*3.19*
FuGood	-54	*-1.21*	-14	*-0.36*	-11	*-0.24*	-66	*-1.58*
HHGood	133	*2.19*	19	*0.29*	72	*1.06*	-38	*-0.66*
Centre	-114	*-0.53*	306	*1.51*	9	*0.04*	-98	*-0.55*
Subu	159	*0.83*	71	*0.38*	-163	*-0.97*	-445	*-2.79*
Peri	214	*0.81*	-71	*-0.29*	-365	*-1.63*	-649	*-3.18*
Comu	10	*0.03*	476	*1.93*	-46	*-0.19*	-200	*-0.65*
Dec	127	*3*	150	*4.08*	209	*3.43*	265	*3.15*
Jan	-69	*-1.59*	-129	*-3.63*	-148	*-2.6*	-48	*-0.57*
Aug	-67	*-1.63*	-28	*-0.82*	-113	*-2.02*	-47	*-0.56*
Year 02	-95	*-2.07*	-1	*-0.03*	-60	*-0.93*	-112	*-1.19*
Year 03	-131	*-2.81*	-22	*-0.55*	-66	*-1.09*	-155	*-1.59*
Year 04	-117	*-2.53*	-35	*-0.93*	-50	*-0.79*	-7	*-0.08*
Year 05	-58	*-1.17*	-48	*-1.2*	-112	*-1.85*	-64	*-0.7*
Year 06	-32	*-0.67*	100	*2.21*	-112	*-1.75*	4	*0.04*
Year 07	-27	*-0.5*	86	*1.9*	-6	*-0.08*	-130	*-1.4*
Year 08	47	*0.94*	25	*0.56*	48	*0.74*	-36	*-0.39*
Adj. R^2	0.50		0.52		0.33		0.25	

7.7.7 Communication

7.7.7.1 Observed Households

Table 7.56 shows the multivariate linear regression model for the "Communication" category. Expenditure for communication is relatively independent of household income. Number of persons and age have a much higher impact. The by far most significant and greatest impact however has the number of mobile phones in the household. Every mobile phone increases communication spending by about CHF 38. Printers and computers also have a positive influence on communication spending. Controlled for the number of mobile phones, families with children spend less on communication than couples or singles. Differences among municipality type are significant, but not very substantial, in that households in cities and suburban municipalities have slightly higher expenses than households from other types.

7.7.7.2 Pseudo Panel

Tables 7.57 and 7.58 show the multivariate linear regression models for all nine pseudo panels for the "Communication" category. The explanatory power for single households and single parent households is considerably smaller than for couples and families. Single households usually have only one mobile phone which does not explain the variance in communication expenses. Internet expenses are usually flat rate fixed cost per household and thus only dependent on personal preferences about speed and the local availability of providers. The dummies for the years do not show a clear pattern for time, although the years of observation from 2001 to 2008 experienced a rapid change in mobile telephone technology and availability. The spending patterns however seem to be fully represented by the possession of a mobile phone device.

Figure 7.22 gives the pseudo panel scatter plots with the regression model for income. Retired couples and retired singles spend almost the same level for communication, while working age singles spend more, independent of income. Single parent households spend substantially more than other households, especially considering the lower income level. A possible explanation for that would be the greater need for coordination between the divorced parents. Another interpretation could lie in the fact that single parents use a much greater share of their time for working and caring for their children, so that direct social interaction relies more on telecommunication than on direct personal contact. Single parent households spend even more on communication than families. To sum

Table 7.56: Coefficients of the linear model for communication (observed households)

Variable	Type	Estimate	Std. Error	T - Value
Intercept		94.74	8.25	11.49
Income [/ 10^3 CHF]	c	3.44	0.25	13.63
Income^2 [/ 10^6 CHF]	c	-0.02	0	-5.55
No. Pers.	c	4.57	2.15	2.12
Age	c	-0.88	0.06	-14.11
Computer	c	3.93	1	3.93
CellPh	c	38.42	0.76	50.72
Printer	c	11.43	1.44	7.96
Retired Single	d	-2.74	6.28	-0.44
Working Age Single	d	-4.18	5.77	-0.72
Single Parent	d	-19.49	5.01	-3.89
Working Age Couple	d	-15.36	4.43	-3.47
Retired Couple	d	4.65	4.95	0.94
Familiy w/1	d	-13.96	4.21	-3.32
Familiy w/2	d	-39.75	4.68	-8.49
Familiy w/3+	d	-48.16	6.66	-7.23
Centre Low	d	7.11	2.49	2.86
Centre Mid	d	9.47	1.88	5.03
Centre High	d	12.16	4.3	2.83
Subu Low	d	8.65	2.52	3.44
Subu Mid	d	6.42	1.69	3.79
Subu High	d	13.94	3.72	3.75
Adjusted R^2	0.2586			

c = continuous, d = dummy

up, expenditure for communication is largely determined by household type and the possession of a mobile telephone device and independent of income.

Table 7.57: Coefficients of the linear model for communication (pseudo panel)

Variable	RS		WAS		SP		WAC		RC	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	-13	*-0.19*	116	*1.75*	48	*0.93*	-1	*-0.01*	77	*1.61*
Inc.	2	*0.8*	1	*0.21*	9	*2.85*	5	*2.68*	6	*2.78*
Age	1	*0.73*	-1	*-0.5*	0	*-0.15*	0	*0.24*	-1	*-0.95*
CellPh	26	*2.21*	46	*1.78*	18	*1.36*	37	*3.31*	40	*3.24*
Centre	17	*0.89*	-4	*-0.12*	68	*1.96*	3	*0.13*	2	*0.08*
Subu	14	*0.8*	-10	*-0.3*	71	*1.97*	7	*0.32*	-36	*-1.29*
Peri	65	*2.69*	-40	*-0.81*	50	*1.11*	35	*1.25*	-37	*-1.11*
Comu	49	*1.68*	88	*1.34*	-20	*-0.36*	1	*0.04*	17	*0.39*
Feb	2	*0.48*	3	*0.58*	-12	*-0.99*	0	*0.04*	-9	*-2.19*
Year 02	-1	*-0.12*	-5	*-0.78*	2	*0.16*	-3	*-0.45*	5	*1*
Year 03	-4	*-0.76*	-5	*-0.71*	7	*0.49*	-6	*-0.89*	0	*-0.03*
Year 04	5	*0.96*	-4	*-0.51*	19	*1.36*	-20	*-2.73*	19	*3.4*
Year 05	-2	*-0.3*	2	*0.25*	11	*0.76*	-6	*-0.73*	19	*2.96*
Year 06	1	*0.24*	-1	*-0.15*	22	*1.33*	-9	*-1.01*	16	*2.22*
Year 07	0	*0.04*	-1	*-0.06*	-2	*-0.1*	-5	*-0.49*	19	*2.28*
Year 08	0	*0*	-6	*-0.59*	17	*1*	-14	*-1.22*	10	*1.16*
Adj. R^2	0.16		0.04		0.18		0.38		0.69	

Figure 7.22: Influence of income on communication

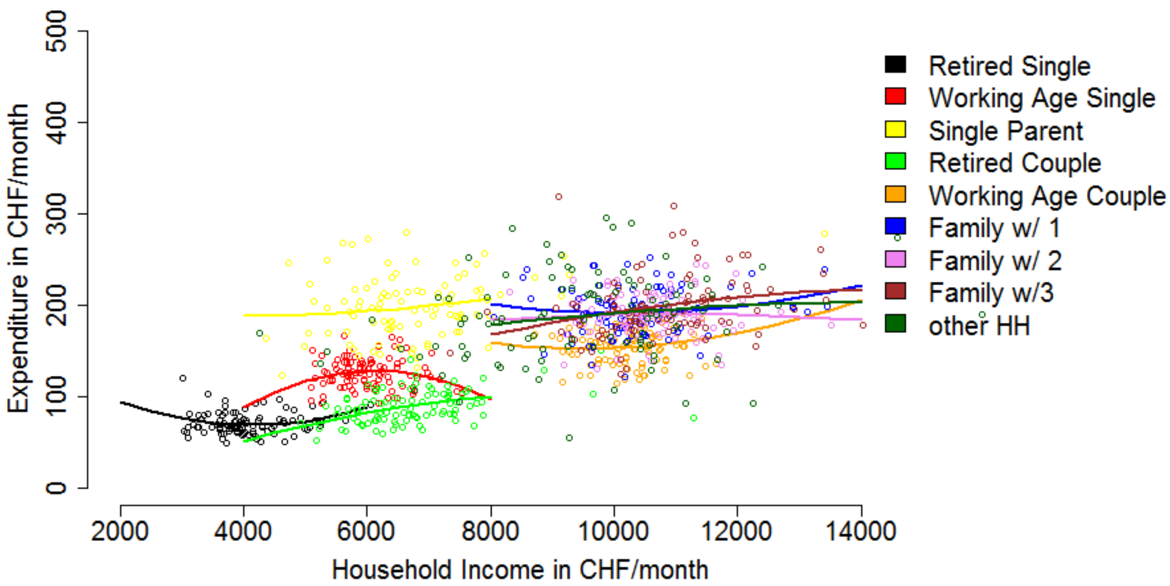


Table 7.58: Coefficients of the linear model for communication (pseudo panel)

Variable	Fam1		Fam2		Fam3		oth	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	25	*0.49*	64	*1.14*	94	*1.28*	183	*3.66*
Inc.	1	*0.36*	-3	*-1.25*	4	*1.56*	7	*2.76*
Age	1	*1.16*	2	*0.87*	0	*-0.11*	-2	*-2.08*
CellPh	58	*4.26*	49	*4.28*	36	*2.61*	18	*1.46*
Centre	-1	*-0.02*	30	*0.85*	1	*0.02*	-75	*-2.36*
Subu	0	*0.01*	2	*0.05*	42	*1.21*	-73	*-2.38*
Peri	-1	*-0.03*	114	*2.61*	-40	*-0.85*	-89	*-2.24*
Comu	51	*0.95*	-40	*-0.89*	-43	*-0.79*	32	*0.54*
Feb	1	*0.09*	-6	*-1.02*	14	*1.14*	-45	*-2.65*
Year 02	6	*0.63*	-23	*-2.96*	-20	*-1.43*	62	*3.21*
Year 03	-8	*-0.81*	-6	*-0.68*	-31	*-2.07*	34	*1.66*
Year 04	-1	*-0.09*	-6	*-0.67*	-2	*-0.11*	32	*1.73*
Year 05	-2	*-0.18*	-18	*-1.62*	-23	*-1.25*	31	*1.51*
Year 06	3	*0.21*	-19	*-1.44*	-42	*-2.02*	11	*0.49*
Year 07	-8	*-0.59*	-17	*-1.34*	-40	*-1.76*	44	*2.13*
Year 08	-15	*-1.04*	-36	*-2.71*	-35	*-1.52*	30	*1.5*
Adj. R^2	0.35		0.49		0.17		0.21	

7.7.8 Public Transportation

Table 7.59 shows the multivariate linear regression model for the "Public Transport" category. Household expenditure for public transportation is almost independent from income. For every CHF 1.000/month more in income, the household spends in average only CHF 8 more for public transportation. A rich household with an income of CHF 20.000/month spends about CHF 136 more on public transportation than a poor household with an income of CHF 4.000/month, which is a very small difference. Public transport expenses is also almost completely independent of household type. The number of persons in the household has a significant influence, but with less than CHF 10 per person, it is also very small. The biggest impact comes from car ownership, reducing monthly expenses in the amount of CHF 40 per month. The other major influence is residential location municipality, where being located in a regional centre means higher expenses of about CHF 25 compared to suburban municipalities and 30 compared to all other municipalities. The month from November to May have a significant coefficient, but an explanation or interpretation seems difficult. It could mean that people make more activities in Summer and therefore spend more for public transportation, but that does not necessarily hold since winter sports like skiing are widespread and very common. The explanatory power of 0.12% of explained variance is the lowest value for all presented expenditure categories. Unfortunately, the data set does not contain information about the ownership of mobility tools such as season tickets, half-fare cards or general abonnements (GA).

7.7.8.1 Observed Households

7.7.8.2 Pseudo Panel

Tables 7.60 and 7.61 show the multivariate linear regression models for all nine pseudo panels for the "Public Transport" category. As in the model showed in table 7.59, income has minor influence and is only significant for retired couples and other households. The models for retired singles, single parents and working age couples have almost no explanatory power at all. For the other categories, car ownership is the main influence, especially for families with children. Living in an urban area however has more impact for working aged singles or families with only one child. There seams to be threshold for families between having one or two children. With one child residential location determines how much to spend on public transport, independent of car ownership, while with 2 or more children its only car ownership with a significant influence (and a higher explanatory power). It seems that families with one child still frequently use public transport in spite of having a car. With more than one child, families tend to strongly reduce public transport expenses if they have a car, regardless of their residential location. Coefficients for time are significant for working age couples and singles and for families, where they reveal a weak trend of slightly increases spending for the later years.

Figure 7.23 shows the chaotic nature of public transport spending with no influence of income and no differences among household types. Expenditure for public transportation is either depending almost entirely on personal preferences or on situational characteristics that are on a higher level of detail then the information available in the present study.

Table 7.59: Coefficients of the linear model for public transportation (observed households)

Variable	Type	Estimate	Std. Error	T - Value
Intercept		10.9	9.76	1.12
Income [/ 10^3 CHF]	c	8.46	0.35	24.21
Income^2 [/ 10^6 CHF]	c	-0.07	0	-16.04
No. Pers	c	9.45	2.41	3.92
Age	c	0.38	0.07	5.38
New Cars	c	-42.48	1.28	-33.15
Used Cars	c	-36.61	1.19	-30.83
Retired Single	d	-14.79	7.07	-2.09
Working Age Single	d	-2.47	6.49	-0.38
Single Parent	d	3.33	5.57	0.6
Working Age Couple	d	-7.17	5.62	-1.28
Retired Couple	d	-1.12	4.98	-0.23
Familiy w/1	d	-5.32	4.73	-1.13
Familiy w/2	d	-13.3	5.27	-2.52
Familiy w/3+	d	-9.95	7.48	-1.33
Centre Low	d	29.07	3.76	7.73
Centre Mid	d	36.87	3.24	11.39
Centre High	d	60.68	5.76	10.53
Subu Low	d	13.1	3.76	3.48
Subu Mid	d	14.21	3.09	4.6
Subu High	d	26.27	5.24	5.01
Peri Low	d	2.11	5.13	0.41
Peri Mid	d	8.5	3.68	2.31
Peri High	d	29.89	6.62	4.51
Comu Low	d	-1.02	6.2	-0.16
Comu Mid	d	-2.84	4.3	-0.66
Comu High	d	34.46	9.56	3.6
Indu Low	d	0.43	4.64	0.09
Indu Mid	d	-0.8	3.63	-0.22
Indu High	d	30.56	7.96	3.84
Nov	d	-9.16	2.73	-3.35
Dec	d	-5.03	2.74	-1.84
Jan	d	-10.31	2.69	-3.84
Feb	d	-12.46	2.61	-4.77
Mar	d	-6.06	2.68	-2.26
Apr	d	-10.45	2.71	-3.86
May	d	-4.77	2.72	-1.76
Jul	d	0.67	2.72	0.25
Adjusted R^2	0.1295			

c = continuous, d = dummy

Table 7.60: Coefficients of the linear model for public transportation (pseudo panel)

Variable	**RS**		**WAS**		**SP**		**WAC**		**RC**	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	198	*1.71*	-48	*-0.85*	79	*1.41*	408	*1.81*	183	*2.64*
Inc.	7	*2.23*	5	*1.88*	8	*2.34*	-4	*-1.17*	3	*1.13*
Age	-2	*-1.51*	1	*1.38*	0	*0.17*	-4	*-1.47*	-2	*-1.9*
NewC	-25	*-1.37*	-38	*-1.51*	-88	*-2.76*	-25	*-0.77*	-45	*-1.66*
UsedC	-22	*-1.2*	-59	*-2.66*	-77	*-2.94*	-52	*-1.52*	-36	*-1.6*
Centre	15	*0.49*	76	*2.6*	17	*0.45*	57	*1.06*	19	*0.46*
Subu	-8	*-0.27*	42	*1.57*	0	*0*	6	*0.15*	18	*0.41*
Peri	9	*0.23*	-17	*-0.44*	-46	*-0.93*	19	*0.34*	7	*0.14*
Comu	16	*0.34*	30	*0.57*	-17	*-0.3*	67	*0.93*	-75	*-1.14*
Year 02	-5	*-0.65*	0	*0.09*	10	*0.71*	6	*0.52*	1	*0.1*
Year 03	-5	*-0.61*	7	*1.26*	11	*0.78*	19	*1.57*	-1	*-0.11*
Year 04	-5	*-0.64*	9	*1.67*	16	*1.09*	18	*1.43*	3	*0.38*
Year 05	-3	*-0.35*	11	*1.89*	-5	*-0.31*	9	*0.74*	-1	*-0.15*
Year 06	8	*1*	21	*3.72*	15	*1.03*	30	*2.24*	18	*2.65*
Year 07	-1	*-0.08*	16	*2.81*	24	*1.65*	40	*2.97*	23	*3.26*
Year 08	11	*1.52*	24	*4.29*	1	*0.04*	25	*1.87*	21	*3.1*
Adj. R^2	0.05		0.38		0.07		-0.01		0.26	

Figure 7.23: Influence of income on public transportation

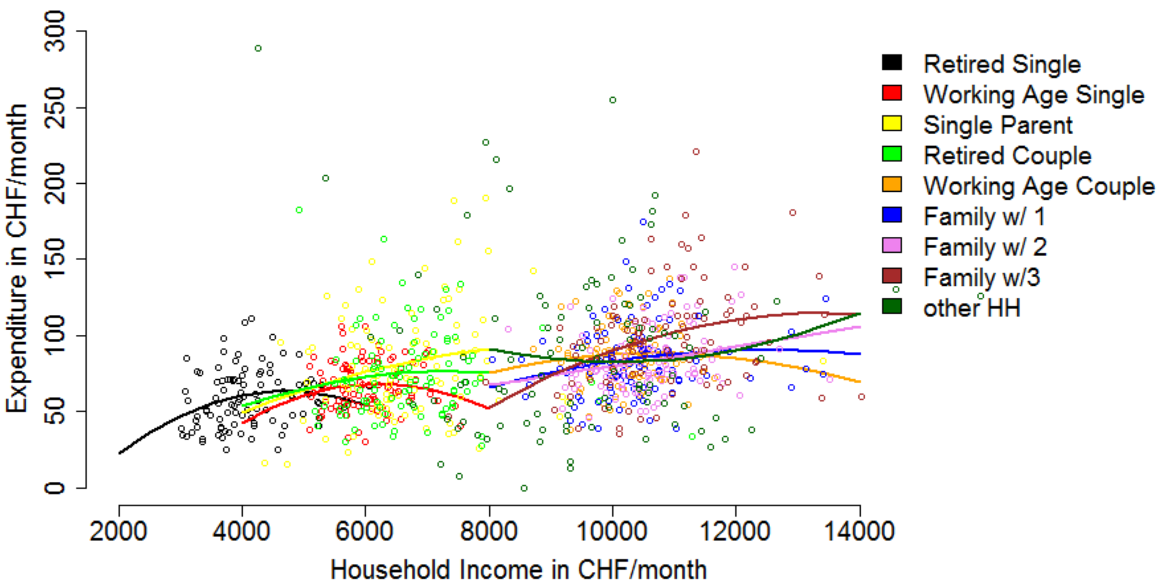


Table 7.61: Coefficients of the linear model for public transportation (pseudo panel)

Variable	Fam1		Fam2		Fam3		oth	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	-20	*-0.31*	-25	*-0.39*	-98	*-1.79*	191	*3.74*
Inc.	2	*0.89*	6	*2.21*	8	*3.19*	4	*1.38*
Age	1	*0.63*	4	*1.83*	9	*3.81*	-2	*-2.56*
NewC	14	*0.59*	-55	*-2.3*	-67	*-3.24*	-64	*-2.8*
UsedC	-22	*-0.88*	-55	*-2.63*	-90	*-4.78*	-58	*-2.51*
Centre	83	*1.92*	6	*0.15*	-9	*-0.24*	2	*0.05*
Subu	31	*0.8*	-13	*-0.34*	-17	*-0.56*	-20	*-0.6*
Peri	123	*2.27*	51	*1.06*	-25	*-0.63*	-22	*-0.47*
Comu	20	*0.35*	-35	*-0.71*	47	*1.07*	1	*0.01*
Year 02	-3	*-0.28*	2	*0.27*	-9	*-0.75*	44	*2.08*
Year 03	8	*0.78*	2	*0.24*	-5	*-0.48*	33	*1.56*
Year 04	1	*0.1*	9	*1.16*	13	*1.19*	39	*1.93*
Year 05	8	*0.77*	7	*0.9*	27	*2.52*	18	*0.88*
Year 06	0	*0.04*	17	*2.08*	-3	*-0.31*	47	*2.11*
Year 07	14	*1.38*	19	*2.42*	34	*2.76*	55	*2.6*
Year 08	30	*3.05*	30	*3.72*	12	*1.07*	51	*2.48*
Adj. R^2	0.13		0.29		0.41		0.26	

7.7.9 Private Transportation

7.7.9.1 Observed Households

Table 7.62 shows the multivariate linear regression model for the "Public Transport" category. While car ownership is a function of income as shown in figure 2.14, expenditure for private transportation is not, when controlled for the number of car possessed by the household. That means, that richer households have more cars, but they do not spend more money per car! Since a big part of transportation expenses are for fuel, that means that richer households do not drive more kilometres per years per vehicle than poorer ones, indicating a very low fuel price elasticity. This supports the findings in chapter 5, where households revealed in a stated preference survey, that in the case of very high fuel prices, they would rather buy a more efficient car to spend less on fuel than to reduce actual annual mileage. The present model also shows a negative influence of age, with CHF 3 less per year of average age. Number of persons has no significant influence. Car ownership however has the main influence: Every newly bought car provokes expenses of CHF 187/month, a used car CHF 116. Household type however is remarkably insignificant once controlled for car ownership. Also residential location municipality does not have that much of an impact as could be assumed. For low income household, the difference between living in a city and in a commuter town is 22.9 -1.2 = CHF 21.7/month. For high income household it is much higher with 112.8 - (-35.5) = CHF 148/month. Household living in the city therefore even if they have the same number of cars used them much less than household in a commuter municipality. Seasonal effects are significant but not very strong and of the form of higher spending in summer than in winter. The explanatory power of the model is higher than for the public transport category.

7.7.9.2 Pseudo Panel

Tables 7.63 and 7.64 show the multivariate linear regression models for all nine pseudo panels for the "Private Transport" category. As in the previous models, the model fit represented by the adjusted R^2 value differs much among household types. While retired singles, couples and families with up to 2 children can be modelled comparably well, the other types are much more chaotic. For retired singles, car ownership is very determining, residential location is not. Retired singles tend to use their car if they have one, regardless where they live. The pattern is similar for the other household types, but less clear.Interestingly the three most recent years, 2006 to 2008 have a significant and substantial impact on transportation spending of around CHF 50 to 100 compared to the earlier years. The could come from the higher fuel prices. Fuel prices for the end consumer in Switzerland where about CHF 0.30 more expensive between 2006 and 2008 than in the previous years. This effect is more substantial for families and retired couples than for the other household types, as their lifestyle makes them more dependent on car use.

Figure 7.24 shows the still somewhat chaotic scatter plot for private transport spending. Influence of income and different patterns among household types can bee seen clearly. Retired single households spend much less than other household types. While income has no big influence within each household types, its influence comes through car ownership. Household types with higher income have higher car ownership and thus higher expenses for private transportation. Interestingly, number of persons in the household has no effect at all. Especially when comparing it with food or consumer goods, where families with children have significantly higher expenditures than couples. That indicates that car use depends on affordability of car ownership and comes with enough economies of scale, making it much more interesting for families.

Table 7.62: Coefficients of the linear model for private transportation (observed households)

Variable	Type	Estimate	Std. Error	T - Value
Intercept		197.91	32.24	6.14
Income [/ 10^3 CHF]	c	17.79	1.1	16.17
Income^2 [/ 10^6 CHF]	c	-0.11	0.01	-7.73
No. Pers	c	-6.63	8.28	-0.8
Age	c	-2.96	0.24	-12.21
New Cars	c	187.16	4.4	42.5
Used Cars	c	115.66	4.08	28.36
Retired Single	d	-17.33	24.28	-0.71
Working Age Single	d	-25.49	22.3	-1.14
Single Parent	d	-80.82	19.13	-4.22
Working Age Couple	d	-23.63	19.32	-1.22
Retired Couple	d	-3.27	17.11	-0.19
Familiy w/1	d	-17.61	16.25	-1.08
Familiy w/2	d	-55.09	18.1	-3.04
Familiy w/3+	d	-54.84	25.71	-2.13
Centre Low	d	-22.93	10.45	-2.19
Centre Mid	d	-14.51	8.31	-1.75
Centre High	d	-35.46	17.82	-1.99
Subu Low	d	-0.5	10.5	-0.05
Subu Mid	d	1.15	7.63	0.15
Subu High	d	-5.27	15.75	-0.33
Peri Low	d	-15.26	15.95	-0.96
Peri Mid	d	11.19	10.28	1.09
Peri High	d	50.43	21.06	2.39
Comu Low	d	-1.2	19.93	-0.06
Comu Mid	d	-10.5	12.84	-0.82
Comu High	d	112.79	31.76	3.55
Dec	d	-15.14	8.87	-1.71
Jan	d	-25.11	8.69	-2.89
Jul	d	28.32	8.79	3.22
Adjusted R^2	0.1733			

c = continuous, d = dummy

Figure 7.25 shows the much clearer relationship between average number of cars in the household and private transportation expenditures. More cars in the household generate more expenditure, as assumed. The higher the number of cars however, the higher also variation in the data.

Table 7.63: Coefficients of the linear model for private transportation (pseudo panel)

Variable	RS		WAS		SP		WAC		RC	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	340	*1.87*	95	*0.5*	-9	*-0.06*	571	*1.21*	70	*0.3*
Inc.	5	*1.04*	29	*3.06*	4	*0.44*	9	*1.29*	21	*2.04*
Age	-5	*-2.14*	-2	*-0.44*	-1	*-0.27*	-8	*-1.3*	0	*-0.03*
NewC	170	*5.93*	112	*1.34*	193	*2.32*	115	*1.66*	9	*0.1*
UsedC	126	*4.4*	111	*1.49*	184	*2.68*	129	*1.81*	30	*0.39*
Centre	-6	*-0.12*	-44	*-0.45*	142	*1.41*	87	*0.77*	80	*0.58*
Subu	23	*0.51*	-64	*-0.71*	111	*1.08*	-38	*-0.43*	154	*1.05*
Peri	43	*0.7*	-87	*-0.67*	69	*0.54*	199	*1.72*	-79	*-0.48*
Comu	19	*0.26*	-240	*-1.37*	116	*0.77*	61	*0.4*	44	*0.2*
Year 02	8	*0.7*	-6	*-0.32*	-10	*-0.28*	-42	*-1.66*	2	*0.09*
Year 03	-4	*-0.37*	-17	*-0.9*	0	*0.01*	-14	*-0.53*	-23	*-0.97*
Year 04	-12	*-0.99*	3	*0.16*	-17	*-0.46*	8	*0.32*	-15	*-0.63*
Year 05	14	*1.13*	8	*0.44*	3	*0.07*	-19	*-0.7*	7	*0.3*
Year 06	4	*0.36*	53	*2.77*	27	*0.68*	20	*0.73*	106	*4.58*
Year 07	35	*2.88*	46	*2.46*	27	*0.72*	70	*2.44*	79	*3.33*
Year 08	-1	*-0.1*	31	*1.64*	18	*0.42*	34	*1.2*	69	*3.07*
Adj. R^2	0.5		0.19		0		0.29		0.37	

Figure 7.24: Influence of income on private transportation

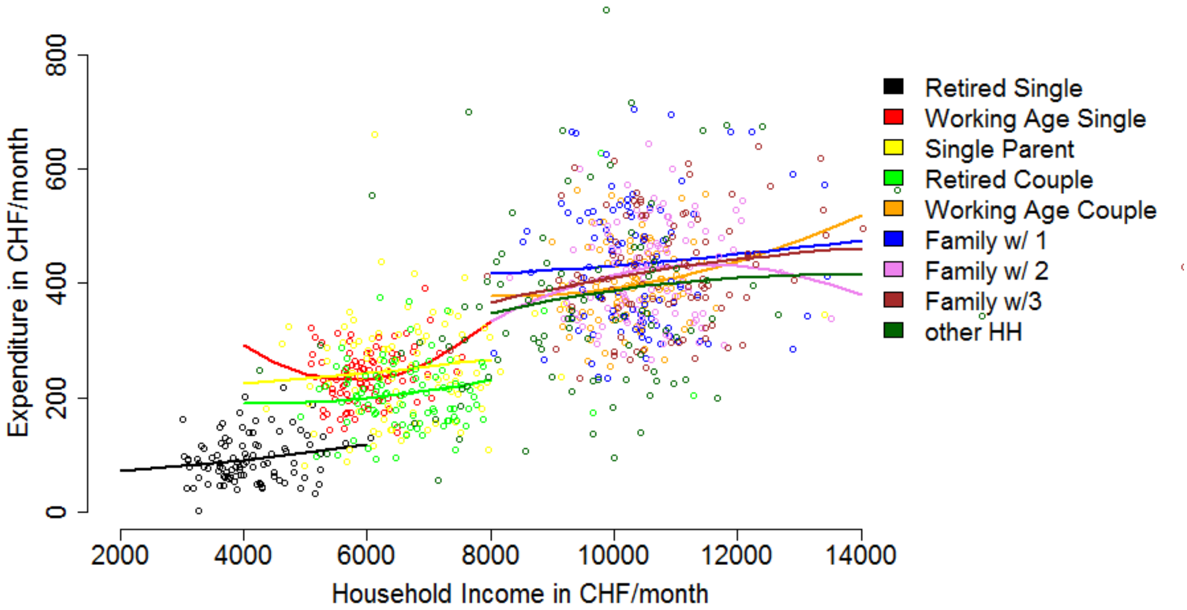
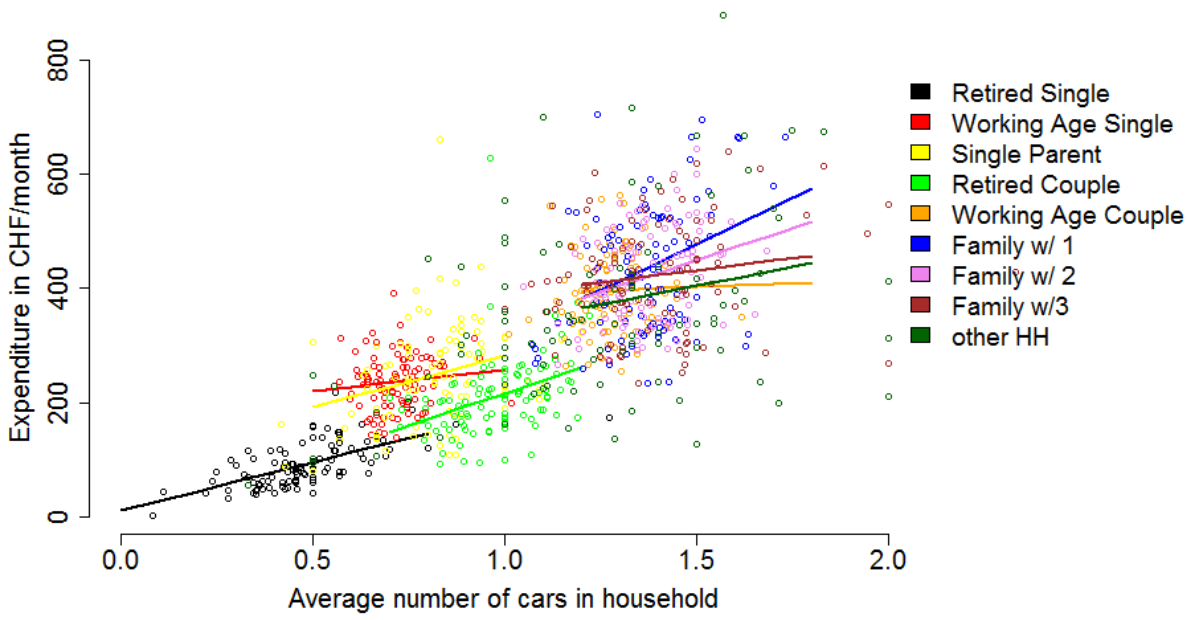


Table 7.64: Coefficients of the linear model for private transportation (pseudo panel)

Variable	**Fam1**		**Fam2**		**Fam3**		**oth**	
	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*	Est.	*T-Stat*
Interc.	69	*0.27*	241	*0.99*	176	*0.91*	103	*0.45*
Inc.	3	*0.3*	10	*0.88*	9	*0.95*	7	*0.55*
Age	-1	*-0.09*	-7	*-0.75*	-2	*-0.2*	-3	*-0.73*
NewC	205	*2.16*	79	*0.84*	142	*1.94*	153	*1.51*
UsedC	256	*2.59*	195	*2.4*	51	*0.76*	129	*1.26*
Centre	-115	*-0.66*	40	*0.25*	180	*1.45*	13	*0.08*
Subu	12	*0.08*	65	*0.45*	16	*0.15*	231	*1.51*
Peri	233	*1.07*	-17	*-0.09*	168	*1.22*	147	*0.72*
Comu	-182	*-0.77*	-98	*-0.51*	-95	*-0.62*	236	*0.77*
Year 02	-46	*-1.2*	-25	*-0.82*	-31	*-0.77*	20	*0.21*
Year 03	-45	*-1.16*	3	*0.11*	-13	*-0.33*	-14	*-0.15*
Year 04	-55	*-1.43*	20	*0.67*	-13	*-0.32*	47	*0.52*
Year 05	19	*0.46*	12	*0.38*	0	*0*	27	*0.29*
Year 06	121	*3.21*	101	*3.19*	73	*1.85*	-34	*-0.34*
Year 07	164	*3.92*	113	*3.57*	60	*1.38*	80	*0.85*
Year 08	117	*2.97*	82	*2.65*	60	*1.53*	225	*2.47*
Adj. R^2	0.47		0.32		0.07		0.06	

Figure 7.25: Influence of average number of cars on private transportation



7.8 Discussion

7.8.1 Summarized Results

The results presented in this chapter show how data from the national federal survey on income and expenditure can be used to gain insight into the budgeting process of households. To model a households budgeting process, we have to assume that the chosen amount of spending for every category depends on either characteristics of the households or the amount of spending of the other categories. In section 7.4 the correlation matrices of the expenditure categories are analysed to find mutual influences and in section 7.7 the correlation between socio-economic characteristics and the different expenditure categories are analysed with the use of linear last square regression models. The correlation matrices showed very little correlation between the respective expenditure categories, even within more homogeneous subgroups of the population. The correlation within these subgroups is assumed to be higher because of similar spending patterns among similar households, but in majority of cases rejected by the data, finding only very small differences in correlation among subgroups. The only difference between subgroups and the total of households was the correlations between the "Savings and Durable Goods" category and the other categories when separated between income classes. For lower income households, the negative correlation of savings with the other categories was higher, meaning that the lower a household's income, the more it (needs to) substitute savings with other categories. This finding is well in line with the literature on savings which finds higher savings rate for higher incomes (Dynan et al., 2004). These differences are not very pronounced, and do not tell much about interdependencies among categories. The only general pattern that could be observed was that higher income means higher spending for all categories. There is no category where this is only valid for a certain range of income.

When analysing the influence of socio economic and geographical characteristics on spending habits, a few patterns and differences between the categories could be observed. The main finding for every expenditure category is summarized in table 7.65.

Relatively luxurious goods like savings, durable goods, eating out and alcohol and tobacco are more dependent on income then the other categories. Spending on food is mainly driven by the number of persons in a household, with more spending for more persons. Spending on housing however is independent from the number of persons and almost independent of income when controlled for household type. This is

Table 7.65: Summarized main influences of category models

Category	Influence of Income	Main Influence Variable	Adj. R^2
Savings and DG	Strong	Inc. and HH Type	0.40
Food	Weak	No. Of Pers. and HH Type	0.48
EAT	Medium	Inc. and Age	0.19
Housing: R + I	Weak	HH Type, Age and Geography	0.14
Entertainment	Weak	Inc. and HH Type	0.16
Consumer Goods	Weak	Inc. and HH Type	0.23
Communication	Very Weak	Mobile phone devices	0.26
Public Transportation	Very Weak	Car Own. and Geography	0.13
Private Transportation	Weak	Car Own. and Geography	0.17

somewhat contradictory to the general impression is that rich people live in very generous houses that certainly must be more expensive. That may be true for some of the richer households, but many of the very rich households fully own their property without having to spend money on interest or they live in a housing cooperative or an apartment with relatively low rents because of their long duration of occupancy. Segregation between rich and poor neighbourhoods is very rare in Switzerland and housing costs as an entry barrier to exclude lower income households only exist on the uppermost end of the income distribution.

Entertainment and consumer goods depend on income and household type, communication spending on the number of mobile phone devices in the household. Public transport expenditure, a very important and substantial category in most developing countries, is on a very low level and also very difficult to model. Income has hardly any influence on it, only car ownership and residential location municipality type has a significant and somewhat substantial impact. Public transportation and housing expenditure are the two categories with the lowest adjusted R^2 value meaning that they correlate the least with the available information on household characteristics. Both transportation categories show a different set of significant explanatory variables: While most categories depend on income and household characteristics, transportation is largely a function of car ownership and geography, with expenditures for private transportation being slightly more correlated to income and car ownership, but also with a high variance that remains unexplained. Especially the variables for residential location municipality type, which, in spite of being significant and also with substantial impact, fails do explain a greater part of the variance in transportation spending. That would conclude that mode choice and residential location choice are indeed a matter of personal preferences or conditions in the microscopic level that cannot be observed.

We also found no typical pattern that would fit to describable and distinctive lifestyles or life-situations. A hypothetical pattern for example would be the two lifestyles of a) living in a expensive residential area that is near to ones workplace describing a typical urbanized lifestyle with reduced transportation costs and b) living in a cheap residential area further away but with higher expenditures for transportation. Such patterns could not be found in the data using the models presented.

7.8.2 Methodology

The methodologies used in the present chapter are simple statistical tools to measure correlation and significance like correlation matrices and linear least squares regression models. As these tools were not able to detect clear and strong relationship the question arises why other, more sophisticated tools were not tested. The reason is that, as the correlation matrices of the expenditure categories and the scatter plots show, the data has a high variance and randomness. If almost no simple and obvious correlation can be found with simple tools, than it is hard too choose the appropriate tool for more sophistication, because it is very unclear in which direction this sophistication would go and highly doubtful that more sophisticated methods would produce better results. Having a mismatch between the level of randomness (or not observable component) in the data and the level of sophistication of the methodology was never the intention.

For the linear least square models, the same consideration holds: As the scatter plots clearly show, the problem of the models is its high variance and not non-linearity. Having logarithmic or exponential or any other function would not give better results but instead just draw a more nicely shaped curve into a scatter plot.

7.8.3 Problems of Data Set

In sections 7.2 and 7.6, the fact that every household was only observed during one month, was suspected to be a major reason for the high variance and randomness of the data. However, even when corrected for high one time expenses (durable goods), and after the averaging out the expenses in a pseudo panel data set, the high variance and low explanatory power of the models remained to a large degree. A survey that was conducted over a whole year but with less detail would probably give somewhat more stable results but not resolve the issue of the very high level of randomness. The reason for this assumption is that even categories that are assumed to have very little change in spending over time, such as rent, interest payments, communication or private transportation, are very hard to predict with the observed set of variables and are not correlated to each other in a substantial way. A longer observation period would probably give a higher explanatory power for the public transport or the entertainment model and it would certainly give more insight about the behaviour of households regarding the purchase of durable goods, but it is doubtful that the results and the conclusion about the adequacy of such models would be fundamentally altered.

7.8.4 Conclusions

The results of this analysis of spending patterns show two very important things:

Firstly, household expenditures show very little correlation among each other and in respect to socio economic variables. Household expenditure are, apart from food that is a function of the number of people to a large degree, of a pronounced individual and random nature. Modelling household expenditures is hard enough, making predictions or forecasts would be very uncertain and only represent the few households that are grouped around the averages by chance. The findings suggest, that data on household expenditures is useful to observe average figures on household expenditure categories and general trends over a very long time period, but are vastly too noisy to be able to make predictions on an individual or microscopic household level.

Secondly, transportation expenditure, for both modes, have a very different set of explanatory variables than the other categories. Both are relatively independent of household composition and income but instead on car ownership and residential location. And the linear least squares regression models for both categories have a relatively small explanatory power. If transportation expenditure is so different from other forms of expenditures, than modelling it, or travel demand, or other transportation related behaviours on the base of household expenditure, will produce bad, unstable and insignificant results.

These two findings suggest that the original hypothesis of interdependencies between spending categories and influence of household expenditure on travel demand should be rejected. The low explanatory power, the low correlations between the categories and the highly random nature of the amount of spending for every category except food also suggest that using household expenditure data as proxy for behaviour as not recommendable, also for other categories than transportation.

The analysis shows that every household has its own lifestyle and makes decision based on personal preferences that can be very independent from each other and very different from other households. General patterns and rules are hard to detect. This finding, as problematic as it seems to be for the researcher doing modelling, can be viewed as being comforting for the Swiss society, as it would indicate that households in Switzerland have some freedom and a disposable income that they can use the way they want, every household in its individual way.

However, one has to be aware that the direct, transportation related findings of the chapter do not bring new and not already well established relations. The motivation to analyse and model household expenditures was justified in section 7.1.1 with the possibility of such a model being able to be used as part of a long term demand model. As the results of the models suggest that such a use would not be fruitful, the main contribution of this chapter is that a model only including household expenditure without a time use model (derived from sufficient and appropriate time use data) is not a sensible path to be pursued when forecasting long term travel demand.

Chapter 8

Discussion

8.1 General Insights

8.1.1 Energy Consumption

A lot of the decisions that influence travel behaviour of individuals are made on the household level and are typically not represented in standard transportation models. Car ownership is the best example: Only very seldom an individual decides to own a car without coordinating the needs and wishes of the other individuals in the household. Buying or owning a car is essentially a household's decision, but affects, through car availability, the travel behaviour of all members of the household on a daily basis. The same is true when speaking of energy consumption in general. To perform energy consuming activities, we all need the respective appliances and infrastructure. As for an individual to drive a car it is necessary that previously a household has decided to purchase a car, it is also necessary that a household owns a TV or a computer or another home appliance to consume electricity and of course a household needs a heating system to consume heating energy.

The decision of which heating system and which car a home or household wants to use is crucial for the subsequent actions and consumption patterns of the individual. The impacts of such decisions are substantial and when modelling total energy consumption, it is thus very important to do so at the household level and to reconstruct the decisions in energy consuming infrastructure on a household level.

This dissertation looked at household fleet choice in chapter 5, heating systems and reciprocal effects between fleet choice and heating systems in chapter 3 and total energy consumption in chapter 4. In all of these decisions, the long term commitments have substantial effects and are of much greater importance than our attitude towards environmental friendliness or our how much we like to ride bicycles instead of driving when considering energy consumption.

The problems with such decisions tend to be, that they usually involve a much longer time horizon, and usually tend to be more difficult to comprehend. Fleet choice and car ownership are topics fairly common to households and therefore stated preference experiments regarding these topics are normally understood well by the respondents. That means that decision models in this area not only have more stable results and a better explanatory power, but also, that interpretation is straight forward and reasonably understandable.

When dealing with total energy consumption, heating systems and insulation, a lot of very specific and personal factors play an important role, such as complicated ownership structures, building conservation agencies, personal health conditions, family issues etc. That makes household decisions to one or more orders of magnitude more complex than decisions of individuals.

Nevertheless, some insights can be gained from the models shown here: We learn that in the case of energy consumption households do not (or not yet) think in terms of energy consumption, they think in financial terms, in terms of what they need (for work or leisure) and what they want (as a symbol of status), what kind of home they want to live in and how comfortable it is. When households make decisions, they weigh financial costs against comfort or against each other, but not against an abstract, hypothetical good like energy consumption.

When energy consumption is translated in to financial costs via high energy prices, households strongly prefer technological improvements and solutions like new, more efficient, cars or cleaner heating systems. Solutions that would mean a change in lifestyle or habits, such as organising ones life with less driving or without car ownership, are largely rejected. The trade-off households make, is between the financial costs of keeping the familiar lifestyle with a high energy consumption and older technology (usually higher running costs) and the financial costs and risk of a change of technology (high investment costs).

Policy proposals that seek to increase awareness of negative effects of energy consumption or increase environmental friendliness are expected to have very little effect on households decisions, if financially viable alternatives that can hold or increase comfort and lifestyle levels do not exist.

The same is observed when energy consumption is not directly addressed, but when fleet choice is observed in a stated preference experiment in the situation of very high fuel prices. Households choose the best and most cost effective option to maintain their level of mobility, comfort and status, which is mostly to switch to newer, cleaner technology such as more efficient diesel cars to hybrid or electric drive-trains.

But also the household car choice experiment as well as the long term investment experiment has shown, that risk plays a major role in the decision. Household are, even in hypothetical experiments, very reluctant in choosing unknown or little known options. The survey described in section 2.2 about household fleet choice was conducted in the year 2009, when hybrid and electric cars were available on the market but still more expensive and not widely enough used to be accepted as a valid alternative to a conventional car. The survey described in section 2.1.6 about total energy consumption was conducted in the years 2010 to 2011. Heat pumps were already well known and appreciated by home owners and chosen frequently when the financial conditions were acceptable.

8.1.2 Household Expenditures

In the case of the budgeting process of household expenditures as analysed and discussed in chapter 7, the conclusions are different. Expenditures have to be analysed on the household level instead of the level of the individual because in many households, especially in families with children, earning opportunities and spending habits are optimized between all members of the household. In a family, the parent with the higher earning job usually works more in exchange for less housework while spending is for the whole family. Among married couples all income belongs to both spouses equally and even between non married couples, individuals usually spend money on goods for collective use they otherwise would not buy for themselves alone. Furthermore, income statistics are done on a household level anyway.

The hypothesis that household expenditures follow a pattern, that they are dependent on measurable socio-economic characteristics and are subject to interdependencies cannot be verified by the data presented and models. For savings and for food, expenditures correlate enough with measurable variables to draw a distinctive but fairly obvious conclusion: Higher income leads in most cases to higher savings and higher spendings on durable goods, and with more persons in a household, more is spent on food.

For other categories, correlations are weak and not unambiguous so that no clear statements can be made that would go further than higher income leads to slightly higher spending or the relatively tautological conclusion that car ownership positively influences spending on private transportation.

Especially the hypothesis that spending categories are interdependent and influence each other should be rejected for Switzerland, as no evidence for such a mechanism was found let alone a clear and strong one. Also within fairly homogeneous subgroups of the population, such interdependencies could not be detected. The fact that in the two transportation categories, private and public transportation, the correlation with other categories as well as with socio-economic variables is even weaker than with other categories, means that the approach of using household expenditure data for travel demand forecasts is not worthy of being pursued further. The lack of correlation suggests that even with data covering a longer period than one month and including seemingly crucial variables presently not included in the models like education, reliable models for travel demand on the basis of household expenditures are very unlikely, at least for Switzerland.

Looking at the findings presented in this thesis, one is given the impression of the expenditures being individualistic and depending upon personal preferences. From a certain point of view, this could be a comforting finding, because it would mean that the inhabitants of Switzerland, even members of lower income and social classes, have a certain degree of freedom of choice when organizing everyday life. However, this impression only comes from the lack of patterns found, but cannot be confirmed or verified by the data, and thus remains speculation. The hypothesis that, like we assume it to be in many developing countries, expenditures of low income households are are pre-determined by the need to survive and budgets are reserved for housing, food and transportation, could not be confirmed.

The income equality in Switzerland, as represented by the data set used, seems to be comparatively low. However, one should be aware of the fact that the survey did not capture the highest class of society. In the 8 surveys between 2001 and 2008 only 5 households were reported with a income of CHF 1 Million or more annually and the maximum was CHF 1.8 Million. That means, that very highest income groups (the owner class, CEOs of multinational corporations etc.) are not represented in the data. Nevertheless, the bottom 99.9 % of household incomes in Switzerland share a not immensely unequal society with no clear distinguishable spending patterns.

What would be interesting research to be done, is similar analysis in other, less equal countries and to test the hypothesis that less equal societies show more pre-determined and interdependent spending patterns than more equal ones. However, while certainly of great use in economics or sociology, such research would contribute less directly to the field of transportation.

8.2 Discussion of Methodologies

8.2.1 Random Utility Models

The methodologies used in this dissertation to analyse and understand household decisions about energy consumption and household car fleet are utility based decision models. That means, that by applying these models several assumptions are made:

1. We assume that households make consciously optimization processes regarding energy consumption.
2. We assume that the variables observed and the ones used in stated choice experiments are crucial in influencing the decision.
3. We assume that household are able to simultaneously quantify and trade-off benefits, costs and discomfort of several different alternatives.
4. We assume that households not only state but also make decision based on reason that are theoretically reproducible when applying under the same circumstances.

When looking at the above assumption it is clear that with some of them it is hard to imagine that these assumption always hold in the case of energy consumption. A household may very likely be environmentally friendly with a existing desire to reduce energy consumption. That desire is manifested maybe in a situation when the purchase of an energy consuming appliance or a refurbishment is needed and the household is willing to pay more for the less energy consuming option. The models presented in chapters 3 and 4 however assume that a household makes the decision whether to actively invest (or change its behaviour) to reduce energy consumption at all. In that case, a household would have to quantify and monetize things like insecurity about future fuel prices, discomfort of refurbishment construction, personal desire to save energy, the fact that ones home changes its face, mobility needs, social status etc. and trade them off against each other in a rational thought process. It is very doubtful that households manage to make rational decision under such circumstances.

The difficulties in explaining parameter estimates and in reproducing the observed decisions reflect the problems with the assumptions mentioned above. In chapter 6, the Multiple Discrete-Continuous Choice Models about total household energy consumption described in chapter 4 and about household fleet choice described in chapter 5 are applied and tested analysed regarding their accuracy. The model parameters were used to simulate the model and reproduce the initial decisions of the households. The results of the analysis of residuals show that the models very often predicted wrong outcomes, considering both the discrete decision, as well as the continuous amount associated with the decision. We also can see that the simulated decisions for the total household energy demand were much harder (more often wrongly) to predict than the household car fleet model. This corresponds to the much more abstract nature of the concept of total household energy optimization compared to the purchase of a car. But in both cases, the share of failed predictions was higher.

Generally, parameter estimates of decision models give indications of what influences a decisions, but looking at the results from simulations it comes clear that there are many unobserved things that matter more. The sign of the parameter tells us the direction in which a observed variable may influences the decision process, significance tells us whether a variable has an influence at all and the parameter value relative to the unit used in variable indicates its impact in the decision. But first and foremost, the models tell us that decisions are largely influenced by variables or processes which are not, or cannot be observed.

The question then remains what the models are missing if they are not able to explain at least 50% of the decision. Four options are conceivable:

1. The wrong variables are observed.
2. The theoretical background with its assumptions does not accurately reflect the decision process.
3. The decisions are highly random and it is impossible to reproduce them.
4. The model specifications are chosen badly.

I find it possible that with different variables the used models could predict more accurately, admittedly with two caveats: a) The variables used and/or tested in the models are standard socio-economic variables. Other variables that may are of greater influences would first need to be found and thought of and survey tools to record them would need to be developed. b) Such newly found variables would need to be also recorded in future data sets and statistics that would be used to apply the model.

The problems with the assumption and the theoretical framework suggest that utility based methods are not optimal when reconstructing the decision process. Heuristics, based on findings of other fields studying the behaviour of people such as psychology, sociology or anthropology may offer alternative frameworks worth testing with existing or future data. Obviously, such heuristics would first have to be developed, studied and tested as well as the survey methods needed to gather appropriate data. Given the results of the disaggregate simulations of choice models as shown in chapter 6 and the general lack of simulation, validation and application of choice models an disaggregate level leads us to the suggestion, that a deeper analysis of the applicability of choice models and the performance of simulations compared to the original data would be a rewarding way to progress in our field. If indeed the low accuracy of decision models, as reported in chapter 6, will be confirmed, a search for alternative, not utility based methodologies would be necessary. The field of choice psychology is rich in literature on the thought processes of choice and proposed heuristics. Payne (1982) for example distinguishes between cost benefit principles (to which utility maximization belongs), perceptual principals like the "Elimination by Aspects" theory of Tversky (1972) and "Production Systems" (Pitz, 1977). Pitz and Sachs (1984) gives a good overview.

It is however possible that the decisions dealt in this thesis are of such random nature that no methodology whatsoever would be able capture the process. In this case, or until a better model is developed, policy proposal should less focus on vaguely advising about the behaviour of households and instead concentrate on a holistic approach in planning. Instead of trying to find out which decisions the inhabitants of a research area would make under proposed conditions, the policy maker should try to plan a desired, functional environment including transportation, energy supply, spatial planning etc. and evaluate the results of the planning process through surveys and referenda. If the inhabitants are content with the proposed infrastructure and intent to use it they would approve it. It is very well possible that to try to discover the one true decision making mechanism that explains the behaviour of persons would fail, because it does not exist but always only reflects the reaction of persons with a certain learned mindset under certain conditions.

8.2.2 Pseudo Panel

The pseudo panel formation, designed to give more stable results because of the averaging out of unexplainable variation in consumption, failed, in as far as the model using aggregated pseudo panels did not give better results. The negative effect on explanatory power from the reduction in number of observations outweighed the supposed gains from averaging. That suggests that variation does not come from the short time period of observation (as previously assumed) but from the fact that spending patterns are extremely individual and random.

Further study on household budgeting in Switzerland would thus not necessary try to cover longer time periods. However, a real panel data set would be very interesting to gain insight on the development of household budget. A study that would track spending of the same household, in the same month, to avoid seasonal effects, over a time period of many years would deliver information about general changes over time as well as consistency in spending patterns for one household. The pseudo panel formation used in chapter 7 could not show consistency within household types.

8.2.3 Linear Regressions

Linear least square regressions are a simple but good enough way to detect statistical correlations and quantify the fit. Contrary to utility based decision models they do not assume nor try to describe behaviour, and solely report correlations. When correlations are found and the results indicate more complex relations among the observed variable, other, more complicated tools are justified. In this case, where only weak correlations and patterns were found, the use of linear regressions as the definitive method is justified.

8.3 Used Data Sets

In this section we briefly discuss the used data sets regarding their usability, problems and advantages and how similar data sets should be improved in the case of future work in the area.

8.3.1 Total Energy Consumption Data

The data about total energy consumption of home-owners described in section 2.1 was gathered using a survey specifically designed to address the question how households view the abstract concept of energy consumption and whether that concept is viewed differently in different sectors, namely housing and transportation.

The households involved had ot be home and car owners because otherwise they would not have the control over the consumption these two major energy sectors. This makes the data set suitable to answering the specific question but carries the disadvantage of not being representative of Swiss population.

The Stated Preference experiments and even more so the Priority Evaluator Experiment asked the household to make decisions that were not only hypothetical in quantitative terms (e.g. in a hypothetically high fuel price) but also hypothetical in it's whole set up of having to choose between the housing sector and the transportation sector. For that, the above mentioned concept of energy consumption was attributed a transmissive aspect that normally is only related to money or time. The task to allocate energy consumption the same way people allocate time or money was very challenging for the respondents and resulted in inconsistent data. So while the results suggest that the original question can be answered with no, it also indicates that we as researchers should not assume that in the same abstract terms like us (e.g. energy consumption, utility) but in much more concrete, ordinary and simpler terms.

The advantage however, is that, despite the fact that the Stated Preference experiments lack realism and comprehensibility, the data set is unique regarding the nature of the reported decisions.

8.3.2 Car Fleet Choice Data

The data set about household fleet choice contains decisions of household under the (hypothetical) assumption of very high fuel prices. The fuel prices stated in the experiments were exceptionally high and specifically chosen to simulate a medium to distant future. The respondents were interviewed face to face and had the support of a computer software showing them all available cars in Switzerland including their characteristics. The task of the experiment, to choose an annual mileage and a specific car type for a given fuel price can be viewed as reasonable and it is safe to assume that the answers represent real life decisions. The purpose of the data set was to asses fuel price elasticity and fleet choice, which it fulfilled. The main disadvantage of the data set is that the data was gathered in a time when car types with alternative drive-trains were uncommon and were not viewed as a real alternative in the respondents minds. If a similar study was conducted, a greater focus on electric cars and under which fuel price they will be chosen by households to keep their required annual mileage, is recommended.

8.3.3 Household Expenditure Survey

The Swiss National Statistics on Income and Expenditure, from which the data set was taken, was designed to have a representative overview of household expenditures (and incomes) on a very detailed level. The data used is impressive in size and detail and covers a relatively long time period. The data set was not tailored to be used in decision models nor did it include questions or variable regarding interdependencies or connection to transportation other than expenditure for this category. However, as the analysis in chapter 7 has shown, household expenditures have very weak patterns and correlations and are highly individual. Therefore, it is doubtful that a more specific data set including stated experiments or similar techniques would have given different results or conclusions. What certainly would be of great interest are similar analysis for national expenditure statistic from other countries.

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PAPERS & PUBLICATIONS

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