Modeling Long Term Investment Decisions in Housing and Transportation

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1 Abstract

The work presented in this paper is part of a NSF project that investigates strategies to reach the 2000 Watt Society in Zurich. Within the project, a bottom-up model is established to predict the development of energy consumption over several decades. The model consists of two agent based micro-simulations, one for the housing sector and one for private transportation.

The paper focus on the behavioral model, which determines the agents decisions concerning long term investments in energy efficiency, such as refurbishment of the house or the purchase of a more efficient car. The main question in this context is whether homeowners treat their energy consumption, or the financial expenses related to it, of the two mentioned sectors as one single budget silo or as two separates.

A survey among homeowner (owner-occupier) was conducted to establish a database, including information about household, house, car fleet also featuring a Stated Preference part. The Survey was conducted as a paper and pen survey and was distributed by mail. The Stated Preference survey consists of nine experiments which are determined by variable energy prices. The resulting (personalized) energy costs are shown to the respondents along with four offered alternatives to lower them. The alternatives are: Insulate the House (1), install a heat pump (2), buy a more efficient car (3) and switch to public transport (4). The alternatives differ in investment sum, expected savings, CO_2 reduction and annual mileage.

The data gathered through the SP experiments are used to estimate a Multinomial Logit Model to predict Investment decisions of homeowners regarding energy efficiency and private transport habits. The model includes not only socioeconomic variables, but also variables of the condition of the house, the composition of the private transport fleet as well as the energy prices. The ratio between the parameters for the savings and for the investment reveals the underlying mean payback time of the homeowners, which corresponds to the explicitly asked expected payback time in the first part of the survey of about 10 years.

2 Introduction

2.1 Research Context

The Intergovernmental Panel on Climate Change states that global warming - caused by increasing emission of carbon dioxide and other green house 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 percent of all energy consumption(Swiss Federal Office of Energy (SFOE), 2009), but cannot be produced inside the country. Switzerland is fully dependent on oil exporting countries and on the highly volatile global market for crude oil, with its possible price spikes like that occurring in summer 2008 (Smith, 2009).

To cope with these kinds of problems, "The 2000 Watt Society" concept was developed at the Eidgenössische Technische Hochschule (ETH) in Zurich. The 2000-Watt Society envisions a society and economic system with an average energy consumption of 2000 watts per person instead of the current 6300 watts (Novatlantis, 2010). The work presented is embedded in a project aimed at simulating the urban metabolism of the city of Zurich using a bottom-up approach. This model will be used in developing strategies to reach the goals of a 2000-watt society. In this bottom-up model, a long-term investment behavioral model is necessary to account for changes in energy consumption over the longer term.

2.2 Research Question

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. 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.

No literature specifically comparing these two energy sectors - in terms of consumer behavior - was found. The survey presented in this paper addresses this issue for the first time, offering a direct choice between these major energy sectors.

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, 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?

As in the bottom - up model, both economic and policy scenarios will be addressed. The question then arises: how do people react to financial incentives (e.g. monetary savings due to reduced fuel consumption) and what are differences in behavior if people are forced to reduce energy consumption (e.g. laws restricting carbon output)?

2.3 Research Project

The modeling framework of the bottom up model consists of three main modules, based on agent-based micro-simulation.

The first module is a long-term investment decision model determining the development of energy-consuming infrastructure and appliances, such as houses, furnaces, cars, transit systems, air conditioner, electric appliances, etc. over a time span of 20 to 40 years. It calculates, for every year, the decisions agents make for buying, replacing, or selling energy-consuming appliances. For housing, this includes renovation of roof, windows, facade, installation of solar panels and replacement of the heating system. In transportation it is the private car and/or season tickets for public transport.

Once the agents are equipped with mobility tools and the condition of their houses and flats/apartments are defined, the second module calculates travel demand. MATSim, an agent-based micro-simulation tool, is used to estimate the total demand of private transport in the city of Zurich (Balmer, 2007; Meister *et al.*, 2009; Balmer *et al.*, 2008).

Dependent on this, the third module, a micro-simulation of all buildings in Zurich called CitySim (Robinson *et al.*, 2009) (Kämpf and Robinson, 2009), calculates energy demand of the housing sector.

Together, these three modules will be able to derive energy demand the housing and transport sectors in different scenarios given by the researcher. In the context of the 2000 Watt project, various strategies for reaching the society's goals in the city of Zurich are evaluated and assessed.

3 Data Collection: Survey

The key data used by the model comes from a survey conducted specially for this purpose. The participants, homeowners of the canton of Zurich, are asked hypothetical questions about investment decisions and possible changes in behavior. The survey is divided in three parts: first, general questions about household members, cars, house, financial situation and attitude are asked. Second, a Stated Preference part where 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. The Paper presented focuses on the models derived from data of the second, Stated Preference, part of the survey.

3.1 Sample Size

The survey investigating these questions uses a sample of 400 homeowners, (owner-occupier), from the canton of Zurich, out of a total canton population of 100,000 (Statistical Office of the Canton Zurich, 2010). All homeowners 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.

For this project, the behavior of homeowners of the city of Zurich is significant. According to the Zurich statistics office, 9,899 single-family homes exist in the city (Bau, 2010). To achieve a sample of 500 people, a large portion of all addresses in the city itself would have been needed. To get a wider sample representation, participants are recruited among people living in the 112,644 single-family homes of the canton of Zurich.

3.2 Protocol

In the first step, an announcement letter was sent. From the persons that have received the letter, participants were recruited through telephone if they agreed to participate and met the requirements of being the owner of the home and at least one car and having a different heating system than a heat pump. During the recruitment phone call, additional information of the participants that were needed for the SP experiments like energy consumption of car and heating system and annual mileage of the car.

The recruited participants were sent the paper and pen questionnaire with the socioeconomic part and the personalized SP experiments that are used for this paper. A CHF 20 incentive was

Figure 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

sent along with the questionnaire to increase response rate. A third, internet based part was conducted after the paper and pen survey was completed and return. For a detailed description of the whole survey please see (Jäggi Axhausen 2010).

3.2.1 SP Scenarios

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 benefit 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).

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.
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 imposed. 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 kilometers 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 kilometers driven remain unchanged.

More efficient 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 in the house and savings in variable mobility costs depend on annual kilometers driven. Savings in heating costs are zero and the annual kilometers driven remain unchanged.

Car Sharing and Public Transport This alternative involves selling the car and reducing annual kilometers driven. Public transport would be the primary means of mobility and the remaining annual kilometers of private transport would be traveled 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.

Table 1: Survey Response Rate

		of Sample	of Valid Adresses	of Participation
	[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

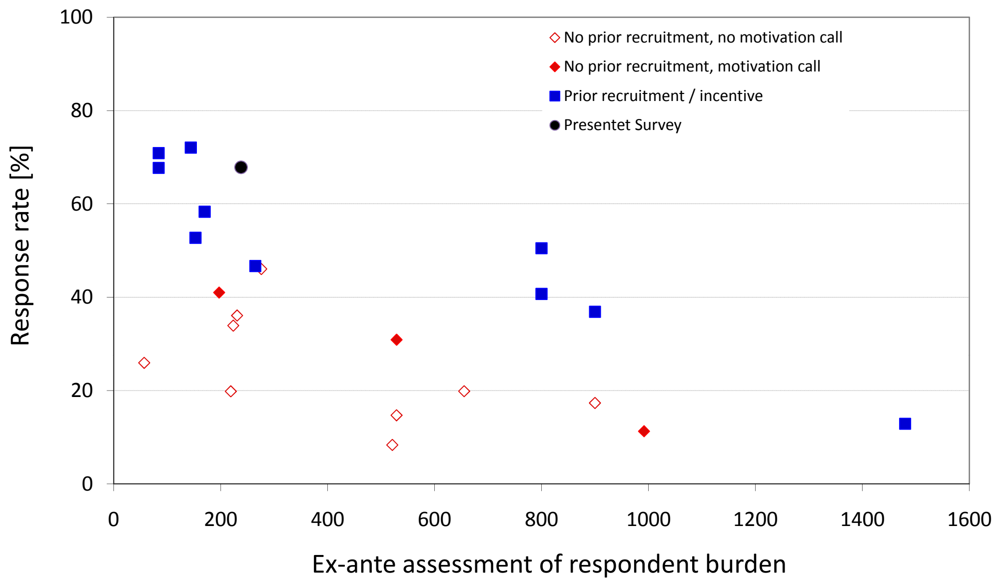
4 Data Overview

4.1 Response Rate and Completion Rate

The Response Rate of the survey is shown in table 1.

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, the correlation between the response burden and the response rate is shown.

Figure 2: Response Rate of ex-ante assessed surveys



Source: Axhausen and Weis (2010)

4.2 Data Overview

This section gives a short overview of the data used for the modeling. In 2, a summary of the analyzed data of the involved persons is given. Head of household is the person that filled in the questionnaire and it is assumed that that is the person that usually deals with issues concerning house or fleet and therefore is defined as owner of the house for this survey. The numbers are not directly comparable with statistical data because the survey includes only homeowner and their families. For example are more than 80% of heads of households male, the persons are equally distributed. Also ownership of drivers licence is over represented because only households with cars are recruited.

3 shows information on the houses of the participants and their cars. The average mileage per car is 11’635 km (Homeowner Canton ZH) and according to the Microzensus (Swiss Federal Statistical Office, 2006) the average mileage in Switzerland is 12’580 km. More half of all cars are younger than 6 years and were bought as new cars. For the houses one can see that 58.1% and 23.6% use oil and gas respectively for heating which concur with the numbers from

Table 2: Personal Data

Variable	All Persons	Head of Households
Adults	80.1%	100.0%
Males	51.3%	81.4%
Age Groups		
younger than 26 years	29.6%	0.0%
26 to 45 years	16.8%	18.6%
46 to 65 years	33.1%	48.9%
older than 65 years	20.5%	32.5%
Highest Education		
Up to Apprenticeship	56.6%	40.3%
Matura	6.6%	4.7%
Higher Secondary Education	24.3%	41.7%
University Degree	8.9%	12.8%
Drivers Licence 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	33.6%	7.2%
often/always	66.4%	92.8%

Statistical Office of the Canton Zurich (2011b) for apartments (including single family homes) being 58.4% and 22.9% respectively. Most of the participants consider their insulation as good or very good. We couldn't collect data on the actual condition of insulation because that would include an major assessment by professionals. We only ask how the participants would estimate it by themselves. The age of the the house differ somewhat from the data from the statistical office of Zurich (Statistical Office of the Canton Zurich, 2011a). In the survey we have to little houses built after 1990, 18.82% compared to 24.7%, and to many built before. The biggest difference is in the period between 1971 and 1980 with 18.3% compared to 13.9%.

4 and 5 show income and wealth distribution of the participating households and **??** shows the age distribution of the homeowners.

Table 3: House and Car Data

House		Car	
Year of Construction		Year of manufacture	
previous 1946	28.9%	previous 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 to 2007	27.1%
1991 to 2000	12.9%	2008 to present	30.5%
2001 to present	5.9%	Used Car	48.7%
Detached	48.2%	Mileage	11'635 km/y
Double	24.6%	Engine Fuel	
Row	19.1%	Gasoline	81.1%
Attached	8.1%	Diesel	17.7%
Insulation Roof		Hybrid	0.9%
Good, Very Good	64.5%	other	4.3%
Medium, Bad	35.5%	Engine Size	
Insulation Facade		$<1400cm^3$	16.7%
Good, Very Good	63.5%	1401 to $1900cm^3$	32.5%
Medium, Bad	36.5%	1901 to $2400cm^3$	28.6%
Solar Panels	6.3 %	2401 to $2900cm^3$	9.0%
Ventilation System	2.3 %	$>2900cm^3$	12.1%
Warm Water Generation			
With Heating	56.2 %		
Boiler	38.9 %		
Other	2.8 %		
Solar	2.0 %		
Heating System			
Oil	58.1 %		
Gas	23.6 %		
Electricity	7.9 %		
Wood	7.9 %		
District	2.3 %		

Figure 3: Income Distribution of Participants

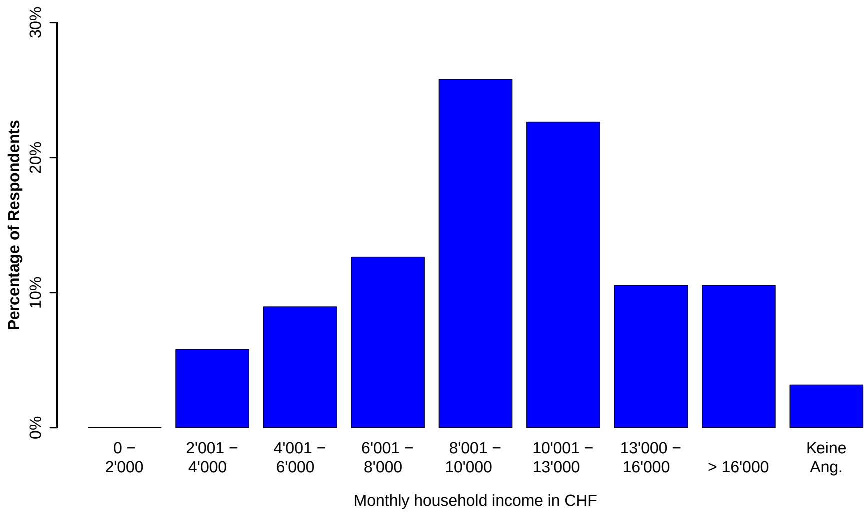


Figure 4: Age Distribution of Participants

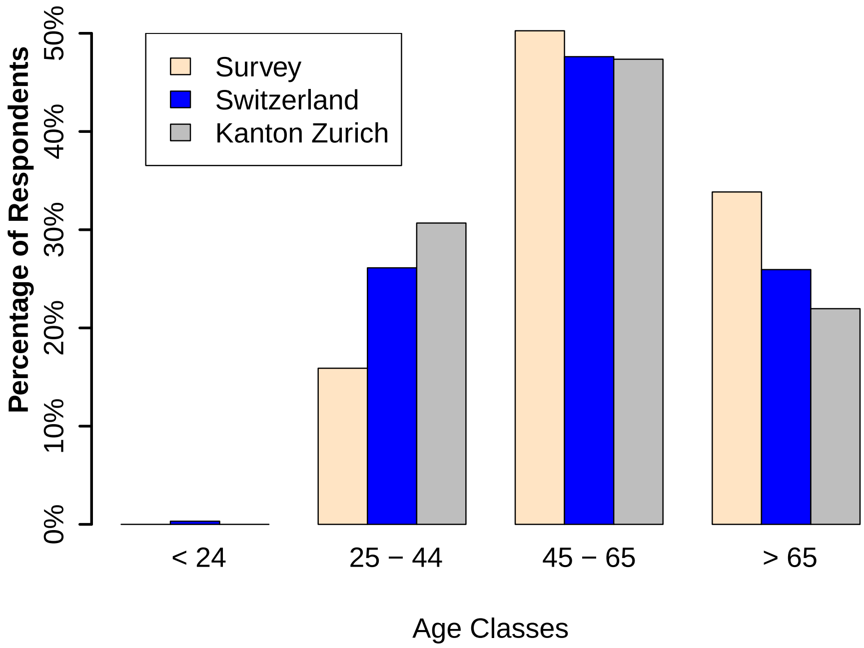
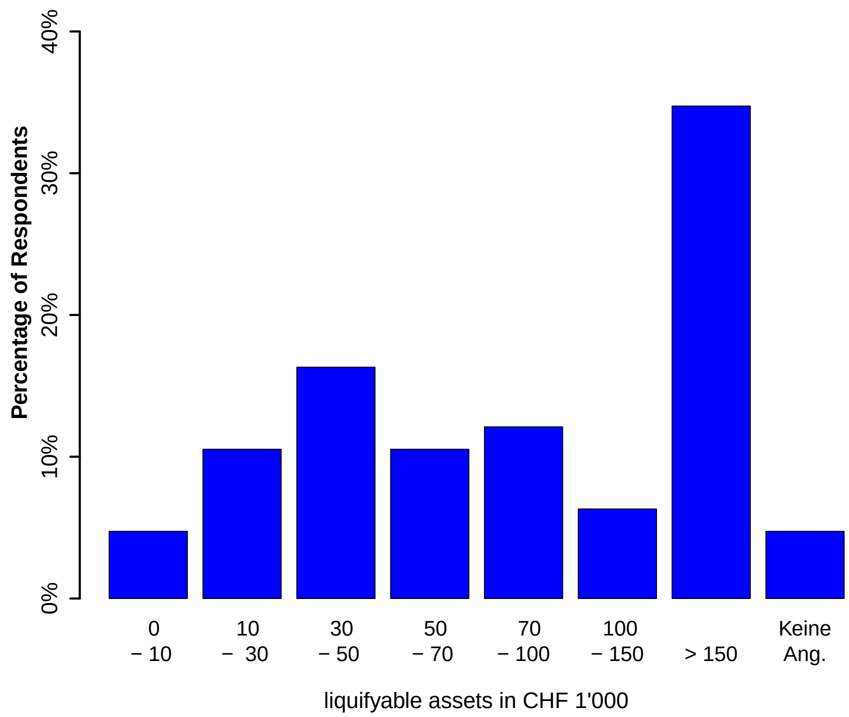


Figure 5: Wealth Distribution of Participants



5 Methodology

5.1 Stated Preference

To design the second part of the study, the 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 a 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.

5.2 Multinomial Logit Models (MNL)

The econometric models used in the present work is standard and nested multinomial logit models (MNL). MNL models are discrete choice models that predict the choice of one alternative among a limited number of also available alternatives, called choice set. The models are based on the utility theory of the standard microeconomic theory. It is assumed that the alternative with the greatest utility is preferred. The utility of an alternative is defined as:

$$U(A) = V(A) + \epsilon \tag{1}$$

where V(A) is the utility described by the model and ϵ the random utility that cannot be describable by the model. Calculating the probability for one agent to choose an alternative using a gumbel distribution for ϵ and assuming that the alternative with the higher utility U(A) is chosen, one becomes the probability function (for alternative i) of the following form:

$$P_i = \frac{e^{V_i}}{\sum_{i=1}^{K} e^{V_i}} \tag{2}$$

A detailed deduction and explanations of the probability function are given by Louviere *et al.* (2000); Train (2003) The utility function for the alternatives in a basic model presented 3.2.1 are the followings:

$$V_{Insulation} = ASC_{Ins} + \beta_{InvIns} \cdot Inv_{Ins} + \beta_{SavIns} \cdot Sav_{Ins} + \beta_{CO2Ins} \cdot CO2_{Ins} + \beta_{FuelpriceIns} \cdot Fuelprice \tag{3}$$

$$V_{HeatPump} = ASC_{HP} + \beta_{InvHP} \cdot Inv_{HP} + \beta_{SavHP} \cdot Sav_{HP} + \beta_{CO2HP} \cdot CO2_{HP} + \beta_{FuelpriceHP} \cdot Fuelprice \tag{4}$$

$$V_{NewCar} = ASC_{NC} + \beta_{InvNC} \cdot Inv_{NC} + \beta_{SavNC} \cdot Sav_{NC} + \beta_{CO2NC} \cdot CO2_{NC} + \beta_{GasPriceNC} \cdot Gasolineprice \tag{5}$$

$$V_{CarSharing} = ASC_{CS} + \beta_{SavCS} \cdot Sav_{CS} + \beta_{CO2CS} \cdot CO2_{CS} + \beta_{GasPriceCS} \cdot Gasolineprice \tag{6}$$

$$V_{DoNothing} = 0 \tag{7}$$

This model only includes variables of given in the SP scenarios and is meant to be basic model that is further developed using socioeconomic as well as house, household and car specific variables. ASC means Alternative Specific Constant and is estimated as well as the β parameter for each alternative and each Variable. The Variables of the basic model are the investment sum, the projected savings and the stated CO_2 reduction. Additional linear terms in the utility function are used for different models.

Nested MNL models assume that similar alternatives are gathered in nests. An individual first makes the choice between the nests (e.g between housing and transportation) and as a second step the choice between the alternatives inside the nest (e.g. between insulation and heat pump). With this model structure similarities between alternatives can be captured and estimated. The Utility in a nested model for alternative A in nest N is therefore defined as:

$$U(A, N) = V_N + V_{A|N} + \mu_N + \epsilon_{A|N} \tag{8}$$

where V_N (μ_N) denotes the observed (unobserved) utility of the nest N and $V_{A|N}$ ($\epsilon_{A|N}$) the utility of the alternative A given the choice of nest N.

The probability function for the choice of a nested alternative i is:

$$P_{ni} = \frac{e^{V_i/\lambda_k}(\sum_{j \in B_k} e^{V_{nj}/\lambda_k})^{\lambda_k - 1}}{\sum_{l=1}^{K}(\sum_{j \in B_l} e^{V_{nj}/\lambda_l})^{\lambda_l - 1}} \tag{9}$$

in which λ_k is an estimated parameter for the K nests (B_1, B_2, ..., B_K). V_i is the utility of the alternative and $V_n j$ is the utility of the alternatives within the same nest. For a more intuitive understanding one can look at it it this way: In the numerator its e to the power of the utility of the considered alternative times the sum of it over all alternatives within the same nest. In the denominator its the sum of e to the power of the utility of all alternatives over all sets.

6 Results

6.1 Standard MNL Model

6.1.1 Basic Model

The Basic Model an MNL model with the utility functions given by (3), (4), (5), (6) and (7) in chapter 5.2. These utility functions only include variables from the SP design without socioeconomic variables. The estimated Parameters of this Model is shown in 4 (**bold** Parameters are significant at 95% level).

We can see that the parameters for the expected financial savings are significant for all alternatives involving investment. The parameters for the investment costs are highly significant for the alternatives of the house. The signs of the parameters, negative for investments and positive for savings, are the same as expected. One can see that the required lump sum and the expected savings play a major role in the decision for investment in energy efficiency of the home, especially compared with the investment in a more efficient car. By calculating the ratio between the parameters for savings [$\frac{1}{CHF/year}$] and for investment [$\frac{1}{CHF}$] one gets the average expected payback period [y] of an investment for the sample. For an insulation of the house, it is 0.25/0.03 = 8 years and for a heat pump it is 0.25/0.05 = 5 years. The average payback period for energy efficiency given from the explicit question of the questionnaire is 10 years. That means that the respondents did not answer the SP consistent with the questionnaire and that faced with a concrete sum of money (as in the SP) they tend to request a higher interest rate for their money than if they think about energy efficiency in general (as in the explicit question).

Another finding is that more savings are requested from a heat pump than from an insulation. However, looking at the constants, that are all significant, it is obvious that no investment or changes in habits is preferred over all alternatives, but the heat pump is the least rejected among the investments. The most rejected (by a factor of 3 compared to the other alternatives) is the Car Sharing alternative which implies a behavioral change.

Comparing the "Car" alternatives with the "House" alternatives confirms an expected difference regarding the influence variables. While for the "House" variables the dominating influence variables are the investment sum and the savings, for the car alternatives the investment has no influence and the expected savings matter only for the buying of a new car. However, the influence of the gasoline price is much bigger 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 gasoline price is $5.5 \cdot 0.51 = 2.8$. That means that the respondents orientate their decision for a more efficient car more on the gasoline price visible at the gas station than on the financial consequences. This is a very interesting fact and is to be considered in policy

Table 4: Parameters of 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			

making, especially because it suggests that a change in the fleet can easier be achieved (and estimated) than expected. Even more determined by the gasoline price itself than by the financial consequences is the decision to sell the car, reduce annual mileage and switch to car sharing.

The energy prices for heating fuel has also a significant influence on the decisions for a renovation that is higher than the expected savings and the investment sum, similar to the "Car" alternatives.

These findings imply that also for investments in the house involving a big sum of money, people are influenced equally by the communicated prices and the real financial consequences. However, they have to interpreted with caution. The effect could also come from the high complexity of the task in the SP experiments that made people more likely to consider one figure (fuel price) than two ore more (investment and savings).

An interesting finding is also the influence of CO_2 output reduction representing consideration towards the environment. In the SP design the stated values of the output reduction is not correlated to any other variable. It shows that for all alternatives besides insulation, the reduction of CO_2 has a significant influence on the decision. That suggests that the current communication and marketing efforts accompanying policy making for energy efficiency, which points out the benefits for the environment (e.g. CO_2 reduction) is justified. However it is important to note that the goodness of fit (adjusted $\rho^2 = 0.18$) is low .Given the the complexity of the task and the fact that a trade of between the two sectors, as required in the SP, is something that for most people is new point of view and they have no experience in this kind of decisions, it is acceptable.

6.1.2 Advanced Model

The estimation results of the advanced model, consisting of the basic model plus various other variables, are shown in 5 and 6. The parameters are all linear additive and include socioeconomic variables, house variables and car variables.

The parameters adopted from the basic model did not change substantially and are also equally significant. From the socioeconomic variables the different effects of income and assets on the different measures. While income has a fair influence on the decisions for heat pump or a new, efficient car, it has much lower and not significant influence on insulation. That can be interpreted that people with high income favor new technological solutions over a renovation of the house. The influence of liquefiable assets is only significant for insulation meaning that wealthier people tend to insulate more than less wealthier, but are not more willing to install a heat pump. Although the influence on the utility is smaller than the ones from the basic models, it reveals differences in behavior due to socioeconomic background. The influence of age of the homeowner is not included in the model because it was not found to be significant even using different age classes.

Looking at the parameters for the dummy variables for a higher education (tertiary education without university) or university degree (= master) gives interesting insights. A high education level has a significant negative influence on all energy efficiency measures. This is somewhat surprising and contradicts the assumption that more educated persons are more environmentally

Table 5: Parameters of Advanced Model (Design and socioeconomic)

Parameter	Value	Robust Std. Err.	Robust t-Test	p - Value
ASC				
Insulation	**-2.99**	**0.73**	**-4.11**	**0.00**
Heat Pump	**-2.20**	**0.52**	**-4.26**	**0.00**
New Car	**-2.31**	**0.32**	**-7.25**	**0.00**
Car Sharing	**-4.10**	**0.43**	**-9.51**	**0.00**
β - Investment [in CHF 10^3]				
Insulation	**-0.03**	**0.00**	**-7.43**	**0.00**
Heat Pump	**-0.04**	**0.01**	**-6.01**	**0.00**
New Car	0.01	0.01	0.43	0.66
β - Savings [in CHF 10^3 / y]				
Insulation	**0.22**	**0.08**	**2.64**	**0.01**
Heat Pump	**0.31**	**0.10**	**3.20**	**0.00**
New Car	**0.26**	**0.10**	**2.58**	**0.01**
Car Sharing	0.08	0.11	0.75	0.46
β - Energy Price [in CHF/kWh]				
Insulation	**0.08**	**0.01**	**6.8**	**0.00**
Heat Pump	**0.08**	**0.01**	**6.59**	**0.00**
β - Gasoline Price [in CHF/l]				
New Car	**0.49**	**0.09**	**5.12**	**0.00**
Car Sharing	**1.15**	**0.12**	**9.92**	**0.00**
β - CO_2 Reduction				
Insulation	**0.28**	**0.07**	**4.12**	**0.00**
Heat Pump	**0.25**	**0.10**	**2.58**	**0.01**
New Car	-0.08	0.17	-0.47	0.64
Car Sharing	-0.02	0.20	-0.08	0.93
β - Income [in 10^4 / m]				
Insulation	0.43	0.28	1.51	0.13
Heat Pump	**0.90**	**0.25**	**3.66**	**0.00**
New Car	**0.89**	**0.21**	**4.25**	**0.00**
Car Sharing	-0.10	0.28	-0.35	0.73
β - Asset [in 10^6]				
Insulation	**4.26**	**1.78**	**2.39**	**0.02**
Heat Pump	0.47	1.53	0.31	0.76
New Car	0.80	1.29	0.62	0.54
Car Sharing	-1.99	1.64	-1.21	0.22
Adjusted ρ^2	0.21			
Number of Observations	2'158			

Table 6: Parameters of Advanced Model (House and Car)

Parameter	Value	Robust Std. Err.	Robust t-Test	p - Value
β - Higher Education				
Insulation	-0.34	0.19	-1.81	0.07
Heat Pump	**-0.44**	**0.17**	**-2.65**	**0.01**
New Car	**-0.61**	**0.15**	**-4.03**	**0.00**
Car Sharing	**-0.53**	**0.20**	**-2.59**	**0.01**
β - University Degree				
Insulation	**-0.74**	**0.29**	**-2.54**	**0.01**
Heat Pump	**-1.38**	**0.26**	**-5.42**	**0.00**
New Car	**-0.99**	**0.23**	**-4.25**	**0.00**
Car Sharing	**-0.66**	**0.31**	**-2.12**	**0.03**
β - Age Car				
New Car	**0.02**	**0.01**	**2.14**	**0.03**
Car Sharing	0.01	0.01	1.02	0.31
β - Car for Business				
New Car	-0.15	0.15	-1.02	0.31
Car Sharing	**-0.40**	**0.23**	**-1.76**	**0.08**
β - Commute with Car				
New Car	0.14	0.12	1.22	0.22
Car Sharing	-0.01	0.17	-0.04	0.97
β - Big Motor Car				
New Car	0.09	0.12	0.76	0.45
Car Sharing	-0.35	0.21	-1.71	0.09
β - Good Facade Ins.				
Insulation	**-0.62**	**0.19**	**-3.32**	**0.00**
Heat Pump	-0.11	0.16	-0.69	0.49
β - Good Roof Ins.				
Insulation	**-0.35**	**0.17**	**-2.09**	**0.04**
Heat Pump	0.01	0.14	0.09	0.93
β - High Mortgage				
Insulation	0.35	0.25	1.41	0.16
Heat Pump	-0.02	0.19	-0.12	0.90
β - Wood Heating				
Insulation	**0.99**	**0.33**	**2.95**	**0.00**
Heat Pump	**-1.05**	**0.44**	**-2.38**	**0.02**

Table 7: Parameters of Advanced Model (Age House)

Parameter	Value	Robust Std. Err.	Robust t-Test	p - Value
β - House older 1947				
Insulation	0.66	0.54	1.21	0.23
Heat Pump	0.48	0.33	1.47	0.14
β - House between 1947 and 1970				
Insulation	0.916	0.555	1.65	0.1
Heat Pump	0.409	0.337	1.21	0.23
β - House between 1971 and 1980				
Insulation	0.991	0.554	1.79	0.07
Heat Pump	0.377	0.322	1.17	0.24
β - House between 1981 and 1990				
Insulation	**1.2**	**0.551**	**2.17**	**0.03**
Heat Pump	**0.767**	**0.317**	**2.42**	**0.02**
β - House between 1991 and 2000				
Insulation	0.853	0.563	1.52	0.13
Heat Pump	0.594	0.313	1.89	0.06

friendly. One explanation could be that people with higher education are more sensitive to financial investments and hesitate to invest in energy efficiency that have low monetary benefits.

All other presented variables have a relatively low influence in the model. Please note that also the age the car has a small influence. Even a 20 year old car would contribute only 0.4 utility points to the alternative of saving energy through a new, more efficient car. The condition (as given by the respondents) of the house's facade and roof have a negative influence on the probability of insulating the house, as shown by the 2 dummy variables for a good condition. This is not only logical and understandable but also quite useful for the aimed overall energy model, despite the fact that it does not include the real existing condition but rather an estimation of it by the owner. Also useful and not surprising is that the presence of a wood heating has a strong negative influence on the alternative heat pump, since a wood heating is already CO_2 neutral and fossil fuel independent (but not energy efficient). However, the positive influence on the willingness to insulate is surprising.

The age of the house is dived in six classes. The parameters for the age classes of the house are shown in 7. The only significant influence have the parameters for houses built between 1981 and 1990. The sixth (and reference) class is for houses built after 2000. All houses built before

2000 have a higher probability to be insulated or equipped with a heat pump than modern ones, which is a reasonable result. More significant influence was expected from houses built in the 70ies, which is the least energy efficient building period.

7 Conclusion and Outlook

7.1 Conclusion

To establish a decision model for investment in energy efficiency in the case of unprecedented fuel prices and for two such different energy sectors is difficult, given that revealed preference data about the subject is inexistent. The stated preference data collected with the survey can substitute for this lack, but the problem of the rather complex and unfamiliar decision between two different energy sectors remains. The presented model tries to predict in which financial conditions homeowners make However, the established model gives achieves to predict in which financial conditions homeowners are willing to invest in energy efficiency and accounts for the trade-off between housing and transportation. It can quantify the expected pay back period for energy investments as well as general preferences between different measures. A very interesting finding is the role of the available assets of the household, which seem to have a big influence in the decision for renovation of the house, but much less for the acquisition of a heat pump. That the level of mortgage has no significant influence is also an interesting finding suggesting that financing energy efficiency is a secondary problem.

7.2 Outlook

To asses the model presented is important in order to now how well the model performs when implemented. An aggregate as well as a disaggregate validation of the model will be necessary before implementing it into the overall framework. An aggregate validation means, that the market shares of the model and the raw data are compared. In the disaggregate validation, the residual of every observation is calculated and it is looked at how many choices are correctly predicted and how the residuals differ between the stated alternatives. In a final step, the model will be modified if necessary and then implemented in the overall framework to predict the changes in the energy consuming infrastructure for the homeowners of the city of Zurich.

8 References

(2010) Bau- und Wohnungswesen (Jahrbuch 2010 Kapitel 9) , *Technical Report*, Zurich.

Axhausen, K. W. and C. Weis (2010) Predicting response rate: A natural experiment, *Survey Practice*, **3** (2).

Balmer, M. (2007) Travel demand modeling for multi-agent traffic simulations: Algorithms and systems, Ph.D. Thesis, ETH Zurich, Zurich, May 2007.

Balmer, M., K. Meister, M. Rieser, K. Nagel and K. W. Axhausen (2008) Agent-based simulation of travel demand: Structure and computational performance of MATSim-T, paper presented at the *Innovations in Travel Modeling (ITM'08)*, Portland, June 2008.

Kämpf, J. and R. Robinson (2009) Optimisation of urban Energy Demand using an evolutionary Algorithm, paper presented at the *Eleventh International IBPSA Conference*, Glasgow, July 2009.

Louviere, J. J., D. A. Hensher and J. Swait (2000) *Stated Choice Methods - Analysis and Application*, Cambridge University Press, Cambridge.

Meister, K., M. Rieser, F. Ciari, A. Horni, M. Balmer and K. W. Axhausen (2009) Anwendung eines agentenbasierten Modells der Verkehrsnachfrage auf die Schweiz, *Straßenverkehrstechnik*, **53** (5) 269–280.

Novatlantis (2010) Nachhaltigkeit im ETH Bereich, webpage, `http://www.novatlantis.ch/`.

Pachauri, R. K. and A. Reisinger (eds.) (2007) *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Intergovernmental Panel on Climate Change, Geneva.

Robinson, D., F. Haldi, P. Leroux, D. Perez, U. Wilke and A. Rasheed (2009) CitySim: comprehensivemicro-siumation of Resource Flows for sustainable urban Planning, paper presented at the *Eleventh International IBPSA Conference*, Glasgow, July 2009.

Smith, J. L. (2009) World oil: Market or mayhem, *Journal of Economic Perspectives*, **23** (3) 145–164.

Statistical Office of the Canton Zurich (2010) Wohnungen nach Eigentumsverhältnissen, webpage, `http://www.statistik.zh.ch/themenportal/themen/daten_detail.php?id=610&tb=3&mt=2`.

Statistical Office of the Canton Zurich (2011a) Wohnungen nach bauperiode, webpage, http://www.statistik.zh.ch/themenportal/themen/daten_detail.php?id=609&tb=3&mt=2.

Statistical Office of the Canton Zurich (2011b) Wohnungsbestand nach energieträger, webpage, http://www.statistik.zh.ch/themenportal/themen/daten_detail.php?id=579&tb=3&mt=2.

Swiss Federal Office of Energy (SFOE) (2009) Schweizerische Gesamtenergiestatistik 2008, *Technical Report*, Swiss Federal Office of Energy (SFOE), Berne.

Swiss Federal Statistical Office (2006) *Ergebnisse des Mikrozensus 2005 zum Verkehrsverhalten*, Swiss Federal Statistical Office, Neuchatel.

Train, K. E. (2003) *Discrete Choice Methods with Simulation*, Cambridge University Press, New York.