Norwegian School of Economics
Bergen, Spring 2021

An Analysis of Consumer Demand in Switzerland

Estimation of a Quadratic Almost Ideal Demand System with Censored Alcohol Consumption

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Master thesis, Economics and Business Administration

Major: Economics

NORWEGIAN SCHOOL OF ECONOMICS

Acknowledgements

I would like to express my gratitude to my supervisor, Professor Fred Schroyen, who guided me throughout this project. The many fruitful discussions, active correspondence and exchange of ideas enabled the fulfillment of this thesis. I would also like to offer my special thanks to Jakob Roth, who provided highly appreciated comments in the final phase of this thesis. Furthermore, I am particularly grateful for the language-related assistance given by Emma Littlejohn. Lastly, I wish to acknowledge the help of Peter Bolliger from the Bundesamt für Statistik (BFS) with the provision of the data, as well as the financial support of the Department of Economics that bore the cost of the data delivery.

Norwegian School of Economics

Bergen, May 2021

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Abstract

In this thesis, I estimate a Quadratic Almost Ideal Demand System using Swiss household expenditure data from 2006-2017. To control for the censored budget share variable of alcohol, I implemented a two-step Heckman-type model for consistent estimation of the demand system. Furthermore, I computed Stone-Lewbel-like prices to increase price variation, and controlled for expenditure endogeneity with an augmented regression approach. For the estimation, I partitioned the sample into consumers and abstainers of alcohol and enhanced each demand systems with the appropriate inverse Mills ratio. The two models were then estimated with an iterated linear least squares estimator. Firstly, I find that income elasticities are in the interval of ca. 0.3 (*Food*) to 1.7 (*Recreation*). Secondly, uncompensated own-price elasticities range from -1.3 (*Others*) to -0.2 (*Alcohol*). All own-price elasticities are of a slightly lower magnitude in the compensated case due to the income effect and the fact that all commodity groups are normal goods. Lastly, theoretical restrictions are empirically tested. The results suggest that homogeneity and symmetry are rejected, while approximately one-third of households in the sample satisfy negativity.

Keywords – Quadratic Almost Ideal Demand System, QUAIDS, Swiss consumer demand, Censored dependent variable, Sample selection, Expenditure endogeneity

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1 Introduction

Applied demand analysis has been subject to extensive research throughout history. It is essential for two main reasons. Firstly, it can serve as a tool to learn about price and income effects for individuals (i.e. to quantify these effects). This is obviously of great interest for the economist and the policymaker. Finding quantifiable answers to questions such as “How do households respond to an increase in alcohol prices?” or “What is the effect of a carbon tax on the consumer demand for fossil fuels?” allows the policymaker to make optimal decisions. Furthermore, it can be the groundwork for many other types of analyses in realms like welfare analysis (e.g. welfare effects of changes in the value-added tax system) or competition analysis (e.g. merger simulations and analysis of market power abuse by dominant firms). Secondly, it allows economists to test the empirical validity of their theoretical models. Hence, questions are addressed such as “What functional form should a demand function have?” and “In what way should prices and incomes be allowed to influence demand?” (Brown and Deaton, 1972). It seems most difficult to find answers to the latter type of questions, and there has thus been a vivid, ongoing scientific debate centered around that matter. Given the considerable interest in applied demand analysis, it is not surprising that this domain is fairly old. In fact, it has already been investigated before Adam Smith (1776) laid the foundation of classical economics in “The Wealth of Nations”.

Given its importance, there has also been empirical research on consumer demand in Switzerland. While most studies focused on the demand for single goods (e.g. Kilchling et al., 2009; Boes et al., 2015; Abdulai, 2003), only a few studies estimated complete demand systems. Abdulai (2002) adopted the Quadratic Almost Ideal Demand System (QUAIDS) to study the demand for food with Swiss household expenditure data. He defined several disaggregated commodity groups for food items and one broad composite commodity consisting of non-food items. According to this procedure, consumers are assumed to allocate their budget to one of the food categories or to non-food items. His estimated uncompensated own-price elasticities for the food categories are mostly below one, while “Non-Food Items” is overall the most price-elastic commodity group. It is worthwhile to mention that in this study, zero expenditure was neither controlled for nor mentioned. It seems likely that there are some categories where a significant fraction of households do not spend money on (for instance, vegetarian households that do not purchase fish and meat). Not controlling for this with a censored regression approach most probably gives biased results.

Aepli (2014a) devoted his PhD-thesis to the study of consumer demand in Switzerland. In particular, he published two essays analysing demand for food and alcoholic beverages using complete demand systems. In Chapter III, he implemented a three-stage budgeting QUAIDS to study the demand for meat and dairy products. He found that most of the product groups are necessary goods and concluded that most meat and milk-based commodity groups are substitutes.

Aepli (2014b), which was featured as Chapter IV in Aepli (2014a), estimated a two-stage QUAIDS to analyse the demand for alcoholic beverages. He first estimated a QUAIDS to determine the demand for broad commodity groups. Subsequently, he examined the demand for alcohol in more detail by employing another QUAIDS in a second step. The main finding of this study is that moderate and heavy drinkers are less price-sensitive with respect to wine and beer than light drinking households. However, there seems to be no difference when considering spirits. Both Aepli (2014a, Chapter III) and Aepli (2014b) featured a two-step Heckman-type estimation procedure to control for zero consumption of some alcohol categories.

In this thesis, I apply the QUAIDS model to Swiss household expenditure data from 2006 to 2017. The goal of the thesis is to learn about household's demand reaction to changes in consumer prices and income. In particular, the goal is to estimate own- and cross-price as well as income elasticities of households, which can serve as a foundation for policymakers' decisions. Furthermore, I test and discuss the empirical validity of the theoretical restrictions homogeneity, symmetry and negativity.[1] Generally, I adopt a

[1] Homogeneity is the property that demand functions are homogeneous of degree zero in prices and income. Hence, a proportional change in prices and income does not affect the demand. Symmetry means that the substitution matrix (Slutsky matrix) with the price derivatives of compensated demands as its elements is symmetric. Equivalently, the change in the compensated demand for good i after a marginal price change of good j must be equal to the change in the compensated demand for good j after a marginal price increase of good i. By Shephard's lemma, the substitution matrix is equal to the Hessian of the expenditure function, and, therefore, the symmetry property follows from Young's theorem. The negativity condition states that the substitution matrix is negative semidefinite. It results from the fact that the Hessian of a concave function (in this case the expenditure function, which is concave in prices) must be negative semidefinite. Negativity implies that all diagonal elements of the Slutsky matrix are non-positive, i.e. that the compensated demand for a specific good decreases or remains unchanged as its price rises. The fourth condition is adding-up (sometimes also referred to as additivity or aggregation restriction), and states that budget shares must add up to one, which results directly from the budget constraint. Similarly, a reallocation of the budget due to price and income changes must continue to

similar empirical approach as Aepli (2014b). Other than Aepli (2014b), I only estimate the QUAIDS for broad commodity groups (the first stage of his approach). One main difference is that I will use Stone-Lewbel-like household-specific price indices derived from national price index data. To my knowledge, this has not been done before in the context of QUAIDS estimation with Swiss data. The strength of this approach is that one can estimate price coefficients with superior precision (see, as a comparison, Table S12 in "Additional file 1" of Aepli, 2014b).[2] Moreover, there are two main challenges that I will tackle in the analysis. Firstly, there is a significant fraction of households that do not report any expenditure on alcohol. As I argue, this is due to a selection decision made by households. Estimating the demand system without controlling for this sample selection would lead to biased results. This thesis adopts a two-stage approach to correct this bias. The second challenge is expenditure endogeneity, which I address with instrument variable technique.

The thesis is structured as follows. Section 2 reviews the historical background of applied demand analysis and the most important demand systems. Section 3 describes the data used in this thesis, while Section 4 introduces the AIDS model and the methodological extensions applied in this thesis. In Section 5, I present the empirical results of the analysis, which are then discussed in Section 6. Section 7 concludes.

exhaust total income. Since this restriction is mechanically satisfied in the QUAIDS model, I do not further investigate it. For a more rigorous discussion of these conditions and their relevance in applied demand analysis, see, among others, Brown and Deaton (1972).

[2]The file can be retrieved from this website: https://agrifoodecon.springeropen.com/articles/10.1186/s40100-014-0015-0. Accessed 06.05.2021.

2 Background

The first documented predecessor of empirical demand analysis dates back to the late 17th century when Davenant (1699) published an article analysing the balance of trade. Part of this work was a numerical tabulation of different defects in crop harvest and price changes. He wrote: "'Tis observ'd, That but 1/10 defect in the Harvest [of wheat] may raise the Price 3/10, [...]", which shows the early interest in the (over-proportional) relationship between quantities and prices. More rigorous studies have been conducted and theories developed in subsequent years, mostly attempting to disentangle the effects of supply and demand on prices (see for instance Smith (1776), Book I, Chapter VII). A critical contribution of Adam Smith was his suggestion of assuming the demand curve to be downward sloping. However, the development of the empirical analysis of demand curves stagnated in the 18th and 19th centuries. The main reason for this is that correlation and regression techniques were not yet developed until the late 19th century (Brown and Deaton, 1972).

Despite this stagnation, Ernst Engel presented an empirical finding in 1857, which later came to be known as Engel's law (Perthel, 1975). He analysed and described the relationship between food share of household expenditure and income. His finding was a negative relationship between those variables, implying that the income elasticity of households for food is below unity. This observation was confirmed in numerous studies (hence the term Engel's law) and has proven to be highly relevant. Nowadays, many countries determine poverty lines in terms of food share of household expenditure (Anker, 2011).

In the early 20th century, regression methodology became an attractive tool to fit demand equations. Benini (1907), for instance, estimated a multiple regression model to describe the demand for coffee using the price of coffee and the price of sugar as explanatory variables. These single-equation models have been subject to early econometric research to describe demand. In many practical settings, the estimation of a set of single-equation models was considered satisfactory. However, in the fifties, economists like Richard Stone began to centre their research around the estimation of complete demand systems, which are more attractive from a theoretical point of view (Brown and Deaton, 1972).

In 1954, Stone presented the Linear Expenditure System, which was the first full demand

system, and applied it to British household expenditure data from 1920 to 1938. In the following decades, numerous other demand systems have been developed, the most notable of which were the Rotterdam model developed by Theil (1965) and Barten (1968), as well as Deaton and Muellbauer (1980)'s Almost Ideal Demand System (AIDS). All these three demand systems have been extensively studied and applied, and each has its strengths and weaknesses. The most widely used, however, is arguably the AIDS model thanks to some desirable properties. The AIDS model has been extended by Banks et al. (1997), who suggested adding a term to the model that allows for quadratic income effects. Their extension came to be known as the Quadratic Almost Ideal Demand System and is well-established in practice nowadays.
Since the 1990s, there has been a change in the data used for demand analysis (Heien and Wessells, 1990). While earlier studies estimated empirical models with time-series data, increased availability of micro-data shifted demand analysis towards using cross-sectional or panel data. The latter type of data is preferable as it avoids the problem of aggregation over consumers and circumvents the endogeneity issue of price variables at the aggregate level. In addition, the statistical richness of micro-data allows for more precise estimates.

2.1 Linear Expenditure System

The Linear Expenditure System (LES) was derived by Stone (1954). He proceeded by setting up a linear relationship between expenditure on good i on the left-hand side of the equations and income and prices on the right-hand side of the expenditure system. The system is set up in a way to assume expenditure to be decomposable into two linearly separable parts. The first part represents a fixed amount of minimum outlay on each good i, while the second part can be interpreted as a super-numerary expenditure split in fixed proportions between all goods.

The model imposes adding-up, homogeneity and symmetry by construction and implicitly assumes consumers' utilities to be represented by a *Stone-Geary utility function* (see Geary, 1950). However, the linear functional form of the LES can be very restrictive and entail some undesirable properties (Brown and Deaton, 1972). In particular, inferior goods are not possible, and all price-elastic goods are substitutes with all price-inelastic goods. Another caveat is that it is only linear conditional on a set of parameters, and it cannot be estimated with standard OLS.

Despite these drawbacks, researchers used the model widely in applied demand analysis. Stone (1954) initially applied the model to British data from 1920 to 1938 and continued to use the model extensively afterwards. Parks (1969) estimated the LES and different specifications of it with Swedish data from 1861 to 1955. He further compared its performance with other demand systems such as the indirect addilog system and the Rotterdam model. His findings were somewhat ambiguous: For some criteria, the Rotterdam model seemed to outperform the others, while the LES and the indirect addilog system seemed to give superior predictions for some commodities. Pollak and Wales (1969) applied the LES model to US data from 1929 to 1965 and compared the pre- and postwar periods. Later, Lluch (1973) enhanced the LES with another parameter representing the ratio of the subjective discount rate to the interest rate. This so-called Extended Linear Expenditure System (ELES) allows studying consumption-savings decisions of households. After the introduction of the AIDS model, the LES has lost some of its appeal. However, there are some more recent studies employing the ELES to study the relationship mentioned above (see, for instance, Cao, 2013).

2.2 Rotterdam Model

In contrast to the LES, the Rotterdam model starts by decomposing infinitesimal changes in demand into marginal changes in prices and wealth (Theil, 1965). In a second step, Theil parametrised this differential equation and replaced infinitesimal changes with their finite counterparts. The result was a demand system that allows to impose or test the adding-up, homogeneity and symmetry restrictions. Barten and Geyskens (1975) showed how one could impose negativity using the Cholesky decomposition of the Slutsky substitution matrix. They further estimated the implied non-linear combination of parameters using maximum likelihood methodology. Despite this subsequent research effort, the Rotterdam model has continuously been criticised for not being derived from a well-behaved utility function. Barten (1969) argued that it instead should be regarded as the first term of a Taylor expansion of any arbitrary demand function. Still, the system only satisfies integrability locally. Integrability is an additional restriction that must be satisfied by first difference demand equations in order to be compliant with demand theory (Brown and Deaton, 1972). Global imposition of this condition would imply constant budget shares (Cobb-Douglas case). Such an extreme restriction is a severe limitation, and Brown and Deaton (1972) argued that, therefore, "the system can hardly be called a system of demand functions".

The Rotterdam model has been used a lot since its development, although it could never reach the popularity of the LES and the AIDS (Clements and Gao, 2015). Its main appeal lies in its unconventional approach to demand analysis, which for the first time allowed to test the theory of the utility-maximising consumer rigorously. Furthermore, it is notable that this workhorse of demand analysis has been developed in neither of the two Cambridges, which were arguably global leaders in economic research by that time. Instead, it was developed in Rotterdam – the second largest city in a minor European country still suffering from World War II.

Empirical results of the Rotterdam model generally show good uniformity, although some results seem to contradict each other (Brown and Deaton, 1972). Some studies (e.g. Barten, 1967) found that symmetry and homogeneity cannot be rejected, while others (e.g. Barten, 1969) came to opposite conclusions. More recent studies are, for instance, Tonsor et al. (2010), who used the Rotterdam model to estimate meat demand in the USA. They found that the meat categories beef, pork and poultry exhibit price-inelastic demand. Other recent studies include Barnett and Seck (2008), where the relative performance of the Rotterdam model to the AIDS model has been evaluated using Monte Carlo simulation. They found that, in general, the fully non-linear AIDS outperforms the Rotterdam model, while the latter seems to give more satisfactory results than the linearised version of the AIDS model (see Section 4.1).

2.3 Almost Ideal Demand System

The Almost Ideal Demand System has been developed by Deaton and Muellbauer (1980) and became arguably the most popular model in applied demand analysis (Clements and Gao, 2015). In contrast to the Rotterdam model, which assumes an arbitrary preference ordering, it is derived from a specific class of preferences called "price invariant generalized logarithmic" preferences ($PIGLOG$). These preferences allow for exact aggregation over consumers implying that market demands can be regarded as the outcome of a single rational and representative consumer (Deaton and Muellbauer, 1980). From these *PIGLOG* preferences, budget share equations can be derived with some desirable properties, which I discuss in greater detail in Section 4.1. The main drawback of the AIDS model is that it does not allow for testing or imposing the Slutsky negativity condition, a problem that has largely remained unsolved in applied demand analysis.[3] Moreover, it is only linear in parameters conditional on the income term of the budget share equations. Hence, it either has to be approximated linearly or estimated with non-linear estimation techniques. Another approach is to estimate the demand system iteratively, which is possible thanks to its conditional linearity.

The AIDS model and its variants have experienced widespread adoption. The model is used for two main types of demand analysis. Firstly, it is applied to study the demand for broad commodity groups as done in this thesis. And secondly, competition economists implement it to study product differentiation, such as brand differentiation on a disaggregated level (see, among others, Baltas, 2002). The AIDS model has proven to capture substitution patterns reasonably well compared to, for instance, the LES or discrete choice models. This property is especially interesting for welfare analysis and studies in the field of competition and antitrust analysis (Davis and Garcés, 2010, Chapter 9).

[3]There have been attempts to impose Slutsky negativity locally in the context of AIDS models. I discuss this further in Section 5.5.

3 Data

This section presents the data used in this thesis. Section 3.1 describes the household expenditure data set, while Section 3.2 introduces the price data used. Finally, I explain how variation of the price data was increased in Section 3.3.

3.1 Household Budget Survey

The main data set used in this thesis is provided by the Federal Statistical Office of Switzerland (FSO). The data is gathered in the Household Budget Survey (HBS). Approximately 250 households are randomly selected each month to take part in this survey. The participating households then have to keep track of their income and expenditure in a very detailed manner for one month. In addition to that, they have to report socio-demographic information, including household size, the composition of the household, and more (BFS, 2013).

One data set consists of five files with different data types and represents a period of three years. The first file contains general information about the households, such as households' identification numbers, income, transfers, expenditure on aggregate commodity groups and savings. Furthermore, it provides details about household size, the composition of the household, region and year. The second file contains detailed data about consumption expenditure at four different levels of aggregation. The third file reports quantities purchased for food, alcohol and fuel, measured in kilograms for food and litres for liquids. The fourth file contains information about durable goods that the households possess. Lastly, the fifth file provides information about individuals living in the household. In this thesis, I use four of these data sets, each of which consists of data for three consecutive years. The four data sets provided by the FSO cover the years 2006-2017, inclusive. As a result, the total number of observations is equal to 38'975.

Table 3.1: Descriptive statistics of the key variables in the sample.

	Mean	SD	Min	Max
Labor income	7'794	5'868	0	30'697
Gross income	9'849	4'947	1'912	30'772
Disposable income	7'095	3'528	1'183	21'085
Total expenditure	5'620	2'819	297	75'774
Total consumption expenditure	3'955	2'184	200	73'255
Number of household members	2.40	1.25	1	14
Number of adults	1.67	1.02	0	7
Number of children	0.48	0.86	0	8
Number of pensioners	0.26	0.58	0	3
Number of earners	1.33	0.88	0	6
Woman reference person	0.30	0.46	0	1
N	34'295			

Table 3.1 gives an overview of some key economic and socio-demographic variables of the households. I removed households from the lowest and highest percentile of the income distribution and the ones with a reference person older than 75 years from the sample. Hence, the sample becomes more homogeneous, which circumvents potential biases introduced by outliers in the subsequent analysis. Of the remaining observation, the average *Labor income* is approximately 7'800 Swiss francs (CHF) per month[4], *Gross income* (including social and other transfers, not including capital income) is on average 9'850 CHF/month. The mean of *Disposable income* (after taxes and other mandatory transfers) equals approximately 7'100 CHF/month. Households spend on average 5'620 CHF/month, 3'950 CHF/month of which is on the commodity groups considered in the analysis of this thesis. On average, a household consists of 2.4 members, 1.67 adults, 0.48 children and 0.26 pensioners. The mean number of earners per household is 1.33, and for 30 % of the households, a woman is the reference person.

[4] 1 CHF = 9.14 NOK (https://www.norges-bank.no/en/topics/Statistics/exchange_rates. Accessed 14.05.2021).

Table 3.2: Descriptive statistics of households' expenditure shares.

	Mean	Median	SD	Min	Max	Share of zeros
Food and non-alcoholic beverages	0.191	0.177	0.0970	0	0.843	0.0036
Alcoholic beverages	0.017	0.004	0.0332	0	0.575	0.4682
Clothing	0.057	0.042	0.0584	0	0.542	0.1986
Housing and energy	0.071	0.058	0.0515	0	0.740	0.0009
Restaurants and accommodation	0.142	0.126	0.0989	0	0.895	0.0471
Transport	0.226	0.205	0.1117	0	0.924	0.0005
Recreation and leisure	0.149	0.129	0.0957	0	0.878	0.0036
Other goods and services	0.147	0.127	0.1021	0	0.900	0.0090
N	34'295					

For this study, only non-durable goods have been considered. The reason for this is the intertemporal component inherent to consumption decisions when facing durable goods. A similar reasoning applies to tobacco. As tobacco is a highly addictive good, there is an intertemporal consideration involved in the consumption decision (health-related problems in the future). Consequently, tobacco[5] has also been removed from the data set. In order to theoretically justify the exclusion of durable goods, I have to assume weak separability of the individuals' utility functions (Strotz, 1959). This assumption means that the marginal rate of substitution between any two non-durable goods is assumed to be independent of the quantity demanded of any durable good excluded in this analysis. Finally, the eight commodity groups presented in Table 3.2 are used for the analysis. Table A1.1 in Appendix A1 shows the exact composition of the commodity groups.

Table 3.2 deserves more attention. First of all, the last column indicates the fraction of households that do not report expenditure on each commodity group. It is important to note that a large fraction of the sample does not purchase alcoholic beverages, which imposes some challenges in estimating the demand system later (see Section 4.4). Similarly, the commodity group *Clothing* appears to have a high zero consumption share. However, as I will argue, the reason for this is different from the case of alcoholic beverages and will therefore not be dealt with in the estimation strategy. Nevertheless, the share of zero expenditure on *Clothing* will have implications for the interpretation of the elasticities

[5]I hereafter include tobacco in my definition of durable goods.

involving *Clothing*. Next, it might seem surprising that the mean budget share of the category "Housing and energy" (hereafter referred to as *Housing*) is only 0.075. The reason for this seemingly low number can be found when considering how the category is defined. As all durable goods have been excluded from the analysis, so have rent and mortgage payments. Consequently, the category only consists of household maintenance, insurance and energy expenditure (discretionary expenses on housing), which results in the low mean expenditure share of this category.

3.2 Price Data

A drawback of the HBS is that no price data is reported. Therefore, I have to rely on national price index data for the estimation, which the FSO provides on their website.[6] The data set contains yearly price indices on a very disaggregated level. Furthermore, a second data set is available containing the weights of the different sub-category price indices used for computing the aggregate national price index. Thus, one can calculate precise price indices for the custom defined commodity groups. For instance, the commodity group "Alcoholic beverages" (hereafter referred to as *Alcohol*) that originally consisted of the sub-categories *Beers* (b), *Wines* (w), *Spirits* (s) and *Tobacco* (t). Since I removed *Tobacco* from the data set due to reasons explained in Section 3.1, I had to calculate the respective price index for the category *Alcohol* without tobacco. I applied the formula

$$p_a = \frac{\sum_i w_i p_i}{\sum_i w_i} \tag{3.1}$$

where p_a is the aggregate price index for *Alcohol* (without tobacco), w_i and p_i are the weights and the price indices for $i \in \{b, w, s\}$, respectively. Equation (3.1) allows the construction of price indices for arbitrary commodity groups.

3.3 Stone-Lewbel Prices

Unfortunately, the price indices are reported on a yearly basis in the price data set and do not contain any seasonal or regional price variation. Consequently, price data varies

[6] https://www.bfs.admin.ch/bfs/en/home/statistics/prices.html. Accessed 14.05.2021.

very little across households. Cross-sectional variation in price data can be increased *ex post* by using information about the households' budget shares. For this to be justified theoretically, I have to assume that the sub-utility functions are Cobb-Douglas (Lewbel, 1989). For each commodity group i consisting of $j = 1, \ldots, n_i$ sub-groups, the within-group sub-utility function for household h is given by

$$u_{ih}(\mathbf{q}_{ih}) = k_i \prod_{j=1}^{n_i} q_{ijh}^{w_{ijh}} \tag{3.2}$$

where $\mathbf{q}_{ih}$ is a vector[7] of all sub-group quantities q_{ijh}. k_i is a scaling factor defined as

$$k_i = \prod_{j=1}^{n_i} \overline{w}_{ij}^{-\overline{w}_{ij}} \tag{3.3}$$

where $\overline{w}_{ij}$ represents the within-group budget share of good j in category i of a representative household (in this case the average of all budget shares w_{ijh}). Then, Lewbel (1989) showed that household-specific prices can be calculated with the formula

$$v_{ih}(p_{ij}, w_{ijh}) = \frac{1}{k_i} \prod_{j=1}^{n_i} \left(\frac{p_{ij}}{w_{ijh}} \right)^{w_{ijh}} \tag{3.4}$$

where p_{ij} is the national price index for good j in category i. The function $v_{ih}(p_{ij}, w_{ijh})$ can be referred to as Stone-Lewbel price index. National price index data can be replaced by $v_{ih}(p_{ij}, w_{ijh})$ for the analysis. For households that do not spend money on a specific sub-group, i.e. $w_{ijh} = 0$ for any j, Stone-Lewbel prices cannot be calculated. In this case, I replaced the missing price data by the average Stone-Lewbel price across households for category i, which was done in other studies such as García-Enríquez and Echevarría (2016). Table 3.3 presents the descriptive statistics of the Stone-Lewbel prices. It becomes clear that price variation increased considerably in the case of Stone-Lewbel prices compared to the unmodified national price index data. This is achieved by introducing cross-sectional variation to the time-varying national price indices. Hoderlein and Mihaleva (2008) showed that the use of Stone-Lewbel prices makes estimates more plausible and robust.

[7] Throughout this thesis, vectors and matrices are printed in bold in mathematical expressions.

Table 3.3: Descriptive statistics of national price indices and Stone-Lewbel prices.

	Mean	Median	Min	Max	SD	Avg. SD within year
National price indices						
Food and non-alcoholic beverages	102.57	102.10	99.90	105.90	1.78	0
Alcoholic beverages	101.86	102.10	99.40	103.70	1.20	0
Clothing	101.11	99.00	96.80	108.10	3.81	0
Housing and energy	104.43	103.10	96.70	111.60	5.44	0
Restaurants and accommodation	97.85	98.80	91.40	101.10	3.28	0
Transport	104.19	105.10	99.50	107.70	2.88	0
Recreation and leisure	105.32	104.80	100.30	110.80	3.82	0
Other goods and services	99.37	99.60	97.10	100.80	1.16	0
Stone-Lewbel prices						
Food and non-alcoholic beverages	100.33	97.97	73.93	157.97	16.71	16.61
Alcoholic beverages	57.03	56.89	39.94	132.05	15.46	15.31
Clothing	81.16	80.62	56.25	129.50	21.91	21.45
Housing and energy	94.29	97.50	47.90	106.85	11.59	11.28
Restaurants and accommodation	86.56	71.64	64.53	148.66	27.33	26.34
Transport	90.00	95.32	49.50	108.04	16.18	16.87
Recreation and leisure	87.93	93.39	45.57	106.83	16.24	16.24
Other goods and services	83.48	87.68	49.84	104.24	16.94	17.12
N	34'295					

4 Methodology

This section presents the methodology applied in this thesis. Firstly, I formally introduce the AIDS model in Section 4.1 and its quadratic extension in Section 4.2. Next, Section 4.3 explains how demographic variation can enter the model. In Section 4.4, I discuss how I address sample selection, and I explain how expenditure endogeneity is controlled for in Section 4.5. Finally, Section 4.6 presents the estimator used in the analysis.

4.1 AIDS Model

In this thesis, I base my analysis of consumer demand in Switzerland on the Almost Ideal Demand System introduced by Deaton and Muellbauer (1980). In this model, it is assumed that consumers follow *PIGLOG* preferences. These preferences are represented by the minimum expenditure function for household h that takes the form

$$\log e(\mathbf{p}, u) = (1 - u) \log a(\mathbf{p}) + u \log b(\mathbf{p}) \tag{4.1}$$

with utility $u \in [0, 1]$ and where log stands for the natural logarithm and $\mathbf{p}$ is a vector of prices. Note that subscript h has been avoided to simplify notation. In equation (4.1), the second term reduces to zero if $u = 0$ and hence, $a(\mathbf{p})$ can be interpreted as the cost of subsistence. Similarly, if $u = 1$ the expenditure function will represent the cost of bliss. In a next step, Deaton and Muellbauer (1980) replaced $\log a(\mathbf{p})$ and $\log b(\mathbf{p})$ by flexible functional forms such that the first and second partial derivatives of the expenditure function are equal to the ones of any arbitrary expenditure function. They proposed

$$\log a(\mathbf{p}) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \log p_j + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij}^{*} \log p_i \log p_i \tag{4.2}$$

$$\log b(\mathbf{p}) = \log a(\mathbf{p}) + \beta_0 \prod_{i=1}^{n} p_i^{\beta_i} \tag{4.3}$$

where i and j are indices for specific goods and n is the number of goods, and α_i, β_i

and γ^*_{ij} are parameters. By plugging these expressions into equation (4.1) one gets the expenditure function

$$\log e(\mathbf{p}, u) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \log p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma^*_{ij} \log p_i \log p_j + u\beta_0 \prod_{i=1}^{n} p_i^{\beta_i} \tag{4.4}$$

Taking the partial derivatives of this expenditure function with respect to the logarithm of the prices gives directly the budget share equations. This is true because

$$\frac{\partial \log e(\mathbf{p}, u)}{\partial \log p_i} = \frac{1}{e(\mathbf{p}, u)} \frac{\partial e(\mathbf{p}, u)}{\partial p_i} \frac{\partial p_i}{\partial \log p_i} \tag{4.5}$$

where the second fraction is, by Shephard's lemma, equal to the compensated (Hicksian) demand q_i for good i and the third fraction equals p_i. Thus,

$$\frac{\partial \log e(\mathbf{p}, u)}{\partial \log p_i} = \frac{p_i q_i(\mathbf{p}, u)}{e(\mathbf{p}, u)} \stackrel{\text{def}}{=} w_i(\mathbf{p}, u). \tag{4.6}$$

Consequently, following these steps, the budget share equation for good i can be written as

$$w_i(\mathbf{p}, u) = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \log p_j + \beta_i u \beta_0 \prod_{i=1}^{n} p_i^{\beta_i} \tag{4.7}$$

where $\gamma_{ij} = 1/2(\gamma^*_{ij} + \gamma^*_{ji})$. Note that since this equation is derived with Shephard's lemma, $w_i(\mathbf{p}, u)$ represents the budget share in terms of compensated demands. To get the uncompensated budget share equation, total expenditure $e(\mathbf{p}, u)$ has to be set equal to income m, which is true for standard utility maximising consumers. Hence, $e(\mathbf{p}, u)$ can be inverted to get the indirect utility function. Plugging this into equation (4.7) gives the uncompensated budget shares

$$w_i(\mathbf{p}, m) = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \log p_j + \beta_i \log \left(\frac{m}{a(\mathbf{p})} \right) \tag{4.8}$$

where m is income/total expenditure. This system of budget share equations is called the Almost Ideal Demand System. From equation (4.8) follows that if

$$\sum_{i=1}^{n} \alpha_i = 1 \quad \sum_{i=1}^{n} \gamma_{ij} = 0 \quad \sum_{i=1}^{n} \beta_i = 0 \tag{4.9}$$

$$\sum_{j=1}^{n} \gamma_{ij} = 0 \tag{4.10}$$

$$\gamma_{ij} = \gamma_{ji} \tag{4.11}$$

hold, the demand system satisfies the properties of adding up (4.9), homogeneity of degree zero in prices and income (4.10) as well as the Slutsky symmetry (4.11) implied by utility maximisation.

The expressions for uncompensated price elasticities can then be found by logarithmic differentiation of the budget share equation. Let

$$\epsilon_{ij}^{u} \stackrel{\text{def}}{=} \frac{\partial q_i(\mathbf{p}, m)}{\partial p_j} \frac{p_j}{q_i(\mathbf{p}, m)} = \frac{\partial \log\left(w_i(\mathbf{p}, m)\right)}{\partial \log p_j} - \delta_{ij} \tag{4.12}$$

where ϵ_{ij}^{u} is the uncompensated price elasticity of demand for good i with respect to the price of good j and δ_{ij} is the Kronecker delta that takes the value 1 if $i = j$ and 0 otherwise.

Similarly, the income elasticity can be found as

$$\epsilon_i \stackrel{\text{def}}{=} \frac{\partial q_i(\mathbf{p}, m)}{\partial m} \frac{m}{q_i(\mathbf{p}, m)} = \frac{\partial \log\left(w_i(\mathbf{p}, m)\right)}{\partial \log m} + 1 \tag{4.13}$$

One can derive the compensated price elasticities of demand by making use of the Slutsky equations for elasticities. ϵ_{ij}^{c} is then defined as

$$\epsilon_{ij}^{c} = \epsilon_{ij}^{u} + w_j \epsilon_i \tag{4.14}$$

Finally, expressions (4.12), (4.13) and (4.14) can be written as

$$\epsilon_{ij}^{u} = \frac{\gamma_{ij} - \beta_i \left(w_j - \beta_j \log \left(\frac{m}{a(\mathbf{p})} \right) \right)}{w_i} - \delta_{ij} \tag{4.15}$$

$$\epsilon_i = \frac{\beta_i}{w_i} + 1 \tag{4.16}$$

$$\epsilon_{ij}^{c} = \frac{\gamma_{ij} + \beta_i \beta_j \log \left(\frac{m}{a(\mathbf{p})} \right) + w_i w_j}{w_i} - \delta_{ij} \tag{4.17}$$

to get explicit expressions for all the three types of elasticities in the context of the AIDS model.

The first advantage of the AIDS model is its great generality. Thanks to the flexible functional forms proposed in equations (4.2) and (4.3), it serves as an arbitrary first-order approximation to any demand system. This property holds if utility maximising behavior is assumed but also for any other demand system that is represented by continuous functions. Such generality, however, comes at the cost of having to estimate a large number of parameters. This problem can be mitigated by imposing restrictions on the demand system such as the ones given by equations (4.9), (4.10) and (4.11).

Secondly, it satisfies a certain form of aggregation over households. Deaton and Muellbauer (1980) show how household-level budget shares can be aggregated to market budget shares. They do so by first scaling down the budget shares to a *per capita* level. Next, the resulting equations can be aggregated to give market budget shares with an identical form as equation (4.8). Consequently, aggregate budget shares correspond to the budget share of a rational representative household with a representative budget level. This property is essential because of the aggregate time-series data used at that time (Heien and Wessells, 1990).

Thirdly, as the linear restrictions in equations (4.9), (4.10) and (4.11) are only imposed on parameters, the demand system satisfies adding-up, homogeneity and symmetry without loss of flexibility.

Furthermore, the AIDS is a linear function of the logarithm of income deflated by the price index $a(\mathbf{p})$, which can be interpreted as the logarithm of real income. The sign of β_i determines whether commodities are classified as necessary or luxury goods. A negative sign of β_i (i is a necessary good) conforms to Engel's law, which says that the budget share devoted to a commodity group like food, for instance, declines as income rises. However, this does not allow for non-linear Engel curves, an empirical observation made by, among others, Banks et al. (1997), Hausman et al. (1995) and Kedir and Girma (2007).

Another drawback of the model is that the Slutsky negativity condition cannot be imposed when estimating demands. Slutsky negativity requires that the Slutsky substitution matrix with price derivatives of the Hicksian demands as its elements is negative semidefinite. Since this matrix involves the optimal demands by definition, which depend on parameters *and* the right-hand side variables, it cannot be imposed as a restriction on the parameters alone. However, given the estimated parameters and optimal demands, it can be verified by calculating the eigenvalues of the Slutsky matrix.

The AIDS model given in equation (4.8) is linear conditional on the last term involving $a(\mathbf{p})$. This non-linearity of the income term complicates estimation. However, $a(\mathbf{p})$ can be replaced by a price index at hand, which reduces the AIDS to a linear approximation of the AIDS, and can be estimated easily with OLS. Blanciforti and Green (1983) proposed replacing $a(\mathbf{p})$ by the so-called Stone price index, which is defined as

$$\log P^* = \sum_i w_i \log p_i \tag{4.18}$$

This linear approximation can be made if prices are closely collinear ($a(\mathbf{p}) \simeq \phi P^*$). The variation of the AIDS model with the Stone price index as an approximation for $a(\mathbf{p})$ came to be known as the Linear Approximate AIDS or LA/AIDS.

4.2 Non-Linear Engel Curves and Quadratic Extension

In the AIDS model, Engel curves for good i are represented by the parameter β_i, as $\partial w_i / \partial \log m = \beta_i$. Thus, the AIDS model assumes parallel linear Engel curves. However, Banks et al. (1997) suggested that Engel curves appear to be non-linear for some commodity groups. For both alcohol and clothing, they observed a $\cap$-shaped functional form. Their argument was supported by both non-parametric kernel regressions as well as quadratic polynomial regressions. Hence, according to this finding, the budget shares of alcohol and clothing are expected to be increasing at a low income level, while they decrease after peaking at a higher income level. To account for these non-linear Engel curves, they proposed to extend Deaton and Muellbauer (1980)'s AIDS model by a quadratic term. Banks et al. (1997) started by assuming the indirect utility function to be given by

$$\log V(\mathbf{p}, m) = \left(\left(\frac{\log m - \log a(\mathbf{p})}{b(\mathbf{p})} \right)^{-1} + \lambda(\mathbf{p}) \right)^{-1} \tag{4.19}$$

where $(\log m - \log a(\mathbf{p}))/b(\mathbf{p})$ is equal to the indirect utility function of the AIDS model and $\lambda(\mathbf{p})$ is differentiable and homogeneous of degree zero in $\mathbf{p}$. Banks et al. (1997) defined $a(\mathbf{p})$ and $b(\mathbf{p})$ as in equations (4.2) and (4.3) following Deaton and Muellbauer (1980)'s approach. However, $\lambda(\mathbf{p})$ is given by

$$\lambda(\mathbf{p}) = \sum_{i=1}^{n} \lambda_i \log p_i \tag{4.20}$$

where $\sum_i \lambda_i = 0$. If $\lambda(\mathbf{p}) = 0$, equation (4.19) collapses to the indirect utility function of the AIDS and the model reduces to the one proposed by Deaton and Muellbauer (1980). To derive the budget share equations, one can apply Roy's identity

$$-\frac{\frac{\partial V(\mathbf{p},m)}{\partial p_i}}{\frac{\partial V(\mathbf{p},m)}{\partial m}} = -\frac{\frac{\partial \log V(\mathbf{p},m)}{\partial \log p_i} \frac{V(\mathbf{p},m)}{p_i}}{\frac{\partial \log V(\mathbf{p},m)}{\partial \log m} \frac{V(\mathbf{p},m)}{m}} = q_i(\mathbf{p}, m)$$

rearranging gives

$$-\frac{\frac{\partial \log V(\mathbf{p},m)}{\partial \log p_i}}{\frac{\partial \log V(\mathbf{p},m)}{\partial \log m}} = \frac{p_i q_i(\mathbf{p}, m)}{m} = w_i(\mathbf{p}, m) \tag{4.21}$$

Plugging equations (4.2), (4.3) and (4.20) into equation (4.19) and applying Roy's identity as in equation (4.21) gives

$$w_i(\mathbf{p}, m) = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \log p_j + \beta_i \log\left(\frac{m}{a(\mathbf{p})}\right) + \frac{\lambda_i}{b(\mathbf{p})}\left(\log\left(\frac{m}{a(\mathbf{p})}\right)\right)^2 \tag{4.22}$$

This equation system is called the Quadratic Almost Ideal Demand System. The "quadratic" qualifier comes from the last term, which is quadratic in the logarithm of real income. Again, if $\lambda_i = 0$, the system reduces to the AIDS model. Therefore, the QUAIDS serves as a generalisation of the AIDS, where the original AIDS is contained in the QUAIDS as a special case. In order for the QUAIDS to satisfy the restrictions imposed by utility maximisation, the following condition must hold in addition to conditions (4.9), (4.10) and (4.11)

$$\sum_{i=1}^{n} \lambda_i = 0 \tag{4.23}$$

If conditions (4.9), (4.10), (4.11) and (4.23) hold, the demand system satisfies adding-up, homogeneity of degree zero in prices and income, as well as symmetry of the Slutsky substitution matrix. However, similar to the case of the AIDS model, negative semidefiniteness of the Slutsky substitution matrix can neither be tested nor imposed. Here again, it can be checked *ex post* by calculating the eigenvalues of the Slutsky matrix.

In a next step, price elasticities of demand can be derived following the formulas given by equations (4.12), (4.13) and (4.14). Consequently, they are defined as

$$\begin{aligned}
\epsilon_{ij}^{u} = \frac{1}{w_i}\Bigg[\gamma_{ij} - \left(\beta_i + \frac{2\lambda_i}{b(\mathbf{p})}\left(\log\left(\frac{m}{a(\mathbf{p})}\right)\right)\right) \\
\times \left(w_j - \beta_j \log\left(\frac{m}{a(\mathbf{p})}\right) - \frac{\lambda_j}{b(\mathbf{p})} \log\left(\frac{m}{a(\mathbf{p})}\right)^2\right) \\
- \beta_i \frac{\lambda_i}{b(\mathbf{p})} \log\left(\frac{m}{a(\mathbf{p})}\right)^2\Bigg] - \delta_{ij}
\end{aligned} \tag{4.24}$$

$$\epsilon_i = \frac{\beta_i + \frac{2\lambda_i}{b(\mathbf{p})} \log\left(\frac{m}{a(\mathbf{p})}\right)}{w_i} + 1 \tag{4.25}$$

$$\epsilon_{ij}^{c} = \epsilon_{ij}^{u} + w_j \epsilon_i \tag{4.26}$$

Equation (4.26) is written in this general form in order to save space.

The QUAIDS exhibits the same flexible functional form as the AIDS model. But in addition to this, it allows for budget shares to be increasing/decreasing in income up to a certain level and decreasing/increasing afterwards (quadratic Engel curves). The model is furthermore linear in its parameters conditional on $a(\mathbf{p})$ and $b(\mathbf{p})$. Also, the number of additional parameters to be estimated is kept to a minimum compared with the AIDS. Thanks to these advantages, the QUAIDS model has arguably become the most popular model for estimating full demand systems.

4.3 Demographic Shifters

The QUAIDS defined in equation (4.22) can be enhanced by socio-demographic variables. These variables enter the equation system linearly and cause the constant term α_i to be shifted up- or downwards, which allows for these variables to influence the budget shares of households. Consider the vector of socio-demographic variables $\mathbf{s}$ with elements s_l for $l = 1, \ldots, L$. Thus,

$$\alpha_i = \xi_{i0} + \sum_{l=1}^{L} \xi_{il} s_l \tag{4.27}$$

where ξ_i's are the socio-demographic parameters for the ith budget share equation. Equation (4.27) can then be combined with the QUAIDS from equation (4.22).

4.4 Censored Dependent Variable

The dependent variables in this analysis are the budget shares. Households choose to allocate between none ($w_i = 0$) and all of their budget ($w_i = 1$) to commodity i. As a consequence, the dependent variables inherently take only values between 0 and 1. Table 3.2 reveals that none of the households allocate their entire budget to any category. However, the minimum in each category is zero, implying that there is *at least* one household in each category that reported zero consumption. Therefore, the dependent variables are censored at their lower limit zero. Tobin (1958) first showed that estimating an equation with a censored dependent variable using standard OLS results in biased and inconsistent estimates. His approach to solving the problem can be extended to the case of truncated and other non-randomly selected samples. The first work on sample selection in economics was done by Roy (1951), who discusses the issue in the context of workers selecting their occupation. Heckman (1979) proposed a two-step estimator to correct for the resulting bias from non-random sample selection.

In the data set used in this thesis, many observations report zero consumption for the commodity group *Alcohol*. They might desist from purchasing alcoholic beverages for several reasons, including health-related concerns, religious considerations or personal rationales. All of these reasons have in common that they imply an *ex ante* decision of households. According to this argument, individuals first face the decision whether to consume or not (i.e. whether to spend money on the good or not). If they decide to allocate parts of their budget to the good, they will subsequently choose *how much* of the good they will purchase. Hence, this can be regarded as a sample selection process affecting the budget share equation for *Alcohol*. In this thesis, I will follow the approach of Heien and Wessells (1990) who applied a two-stage Heckman-type procedure to correct for sample selection in the context of the AIDS model.[8] Let

$$w_{ih} = f_i(\mathbf{p}_h, m_h, \mathbf{s}_h) + u_{ih} \qquad (i = 1, \dots, n) \tag{4.28}$$

where w_{ih} is the budget share of household $h = 1, \dots, H$ for good i, $\mathbf{p}_h$ is a vector of prices, m_h is income, $\mathbf{s}_h$ is a vector of socio-demographic variables, and u_{ih} is the random error term. Furthermore, let

$$d_h = \begin{cases} 1, \text{ if } d_h^* = \mathbf{z}_h' \boldsymbol{\pi} + \nu_h > 0 \\ 0, \text{ if } d_h^* = \mathbf{z}_h' \boldsymbol{\pi} + \nu_h \leq 0 \end{cases} \tag{4.29}$$

where d_h is a dummy for household h that takes the value 1 if positive expenditure on the n^{th} good (*Alcohol*, in this case) is observed ("consumer") and 0 otherwise ("abstainer"). d_h^* is the latent variable, $\mathbf{z}_h'$ is a vector of exogenous independent variables, $\boldsymbol{\pi}$ is the corresponding vector of parameters and ν_h is the random error term. Hence, equation

[8] The same logic can directly be translated to the QUAIDS model.

(4.28) can be changed to the demand system

$$w_{ih}^c = f_i^c(\mathbf{p}_h, m_h, \mathbf{s}_h) + u_{ih}^c \qquad (i = 1, \ldots, n) \tag{4.30}$$

if h is a consumer of n (indicated by the superscript c), and to the demand system

$$w_{ih}^a = f_i^a(\mathbf{p}_h, m_h, \mathbf{s}_h) + u_{ih}^a \qquad (i = 1, \ldots, n-1) \tag{4.31}$$

if h is an abstainer (superscript a). If there is sample selection, both ν_h and $\mathbf{u}_h^c$, as well as ν_h and $\mathbf{u}_h^a$ are possibly correlated. Assuming that the error terms are jointly normally distributed, after normalizing $\sigma_{\nu_h}^2 = 1$, their joint distribution is given by

$$\begin{pmatrix} \nu_h \\ \mathbf{u}_h^c \end{pmatrix} \sim N \left[\begin{pmatrix} 0 \\ \mathbf{0}_n \end{pmatrix}, \begin{pmatrix} 1 & \boldsymbol{\sigma}_{\nu u^c} \\ \boldsymbol{\sigma}_{\nu u^c} & \boldsymbol{\sigma}_{u^c}^2 \end{pmatrix} \right] \tag{4.32}$$

for consumers, and

$$\begin{pmatrix} \nu_h \\ \mathbf{u}_h^a \end{pmatrix} \sim N \left[\begin{pmatrix} 0 \\ \mathbf{0}_{n-1} \end{pmatrix}, \begin{pmatrix} 1 & \boldsymbol{\sigma}_{\nu u^a} \\ \boldsymbol{\sigma}_{\nu u^a} & \boldsymbol{\sigma}_{u^a}^2 \end{pmatrix} \right] \tag{4.33}$$

for abstainers. Under these assumptions, one can derive the conditional expectation function for budget share equation i for consumers of n by applying the rules for conditional expectations of normally distributed random variables.

$$\begin{aligned} \mathbf{E}(w_{ih}^c \mid \mathbf{p}_h, m_h, \mathbf{s}_h, d_h = 1) &= f_i^c(\mathbf{p}_h, m_h, \mathbf{s}_h) + \mathbf{E}(u_{ih}^c \mid d_h = 1) \\ &= f_i^c(\mathbf{p}_h, m_h, \mathbf{s}_h) + \mathbf{E}(u_{ih}^c) + \sigma_{\nu u_i^c} \mathbf{E}(\nu_h \mid d_h = 1) \\ &= f_i^c(\mathbf{p}_h, m_h, \mathbf{s}_h) + \sigma_{\nu u_i^c} \mathbf{E}(\nu_h \mid \nu_h > -\mathbf{z}_h' \boldsymbol{\pi}) \\ &= f_i^c(\mathbf{p}_h, m_h, \mathbf{s}_h) + \sigma_{\nu u_i^c} \lambda(\mathbf{z}_h' \boldsymbol{\pi}) \qquad (i = 1, \ldots, n) \end{aligned} \tag{4.34}$$

The conditional expectation function for budget share equation i for abstainers of n can be derived similarly.

$$\begin{aligned}
\mathbf{E}(w_{ih}^a \mid \mathbf{p}_h, m_h, \mathbf{s}_h, d_h = 0) &= f_i^a(\mathbf{p}_h, m_h, \mathbf{s}_h) + \mathbf{E}(u_{ih}^a \mid d_h = 0) \\
&= f_i^a(\mathbf{p}_h, m_h, \mathbf{s}_h) + \mathbf{E}(u_{ih}^a) + \sigma_{\nu u_i^a}\mathbf{E}(\nu_h \mid d_h = 0) \\
&= f_i^a(\mathbf{p}_h, m_h, \mathbf{s}_h) + \sigma_{\nu u_i^a}\mathbf{E}(\nu_h \mid \nu_h < -\mathbf{z}_h'\boldsymbol{\pi}) \\
&= f_i^a(\mathbf{p}_h, m_h, \mathbf{s}_h) - \sigma_{\nu u_i^a}\lambda(-\mathbf{z}_h'\boldsymbol{\pi}) \qquad (i = 1, \ldots, n-1)
\end{aligned} \tag{4.35}$$

In equations (4.34) and (4.35), $\lambda(\cdot) = \frac{\phi(\cdot)}{\Phi(\cdot)}$, where $\phi(\cdot)$ is the standard normal density function and $\Phi(\cdot)$ is the standard normal cumulative distribution function. This quotient is referred to as the inverse Mills ratio (IMR). Since the vector $\mathbf{z}_h$ consists of observed variables, the probability of a household being a consumer can be written as

$$P(d_h = 1 \mid \mathbf{z}_h) = \Phi(\mathbf{z}_h'\boldsymbol{\pi}) \tag{4.36}$$

This probit model is estimated with maximum likelihood (ML) method. Given the estimated parameters $\widehat{\boldsymbol{\pi}}$, $\lambda(\cdot)$ can be calculated as

$$\lambda(\mathbf{z}_h'\widehat{\boldsymbol{\pi}}) = \frac{\phi(\mathbf{z}_h'\widehat{\boldsymbol{\pi}})}{\Phi(\mathbf{z}_h'\widehat{\boldsymbol{\pi}})} \tag{4.37}$$

for consumers, and

$$\lambda(-\mathbf{z}_h'\widehat{\boldsymbol{\pi}}) = \frac{\phi(-\mathbf{z}_h'\widehat{\boldsymbol{\pi}})}{\Phi(-\mathbf{z}_h'\widehat{\boldsymbol{\pi}})} = \frac{\phi(\mathbf{z}_h'\widehat{\boldsymbol{\pi}})}{1 - \Phi(\mathbf{z}_h'\widehat{\boldsymbol{\pi}})} \tag{4.38}$$

for abstainers. For the estimation, I partitioned the sample into consumers and abstainers, and a QUAIDS is estimated for each group. The IMRs enter the QUAIDS linearly in a similar way as described in Section 4.3. For consumers, I included the IMR given by (4.37), while for abstainers, (4.38) is used instead.

4.5 Endogeneity of Total Expenditure

When estimating the demand system, total expenditure is likely to be endogenous (Blundell and Robin, 1999). Since total expenditure is defined as the sum of the (endogenous) expenditures on each commodity group, one must expect total expenditure to be jointly endogenous. It seems plausible that there are unobservable characteristics of households that affect both their total expenditure and their demand behavior. An example could be a household's wealth (which is unobserved) and presumably affects both expenditure shares and total expenditure. It seems plausible that a wealthier household spends more money in total, but also more on luxury goods and less on essentials. Hence, both total expenditure and the expenditures on each commodity group correlate with the error terms in the budget share equations. Similarly, we have to suspect that a common shock will determine both total expenditure and expenditure shares. A sudden wealth increase of a household (e.g. due to inheritance) is likely to affect both the household's total expenditure and the individual budget shares. Again, this would imply that total expenditure correlates with the error terms, and there are likely to be endogeneity problems.

If total expenditure m_h in the QUAIDS model is endogenous, it could possibly be fixed using an instrument variable r_h. Such a variable has to satisfy the following restrictions in order to be valid:

1. **Relevance** $\quad \mathrm{Cov}(m_h, r_h) \neq 0$
2. **Exogeneity** $\quad \mathrm{Cov}(r_h, u_{ih}) = 0$

In other words, the instrument r_h must be correlated with total expenditure while being uncorrelated with the error term of the outcome equation(s) u_{ih}. The most commonly used candidate to correct for expenditure endogeneity is (log) disposable household income (see, among many, Blundell and Robin (1999)), which I adopt in my analysis. The argument is the following: *Log disposable income* is assumed to be a positive determinant of total expenditure in the sense that higher income leads to higher expenditure, which seems plausible. However, it is less clear whether the instrument is, in fact, exogenous. It might be questionable to assume that disposable income is uncorrelated with unobservable factors determining the budget shares as income itself is – to some extent – a decision variable by households. If a given household has an inherently strong preference for luxury goods, its members might seek better-paid jobs to satisfy these needs. Similarly, a household without such preference might be happy with less money and thus could experience a weaker incentive to seek jobs with a high salary. If this example were true, the exogeneity assumption would be violated and the instrument *Log disposable income* would correlate with the error terms of the budget share equations.

The endogeneity issue is traditionally addressed with a Two-Stage Least Squares (2SLS) estimator. However, Blundell and Robin (1999) suggested testing and correcting for this endogeneity in the conditionally linear demand system by implementing an augmented regression approach proposed by Hausman (1978). They showed that this approach is equivalent to the 2SLS estimator but has the significant advantage of providing a test for endogeneity of m_h. The augmented regression approach relies on the assumption that the error terms u_{ih} have the orthogonal decomposition

$$u_{ih} = \rho_i \widehat{v}_h + \varepsilon_{ih} \tag{4.39}$$

where $\widehat{v}_h$ are the residuals computed from the first stage regression of m_h on the exogenous explanatory variables as well as the instrument r_h. The independent variables are the demographic shifters, the logarithms of the price variables as well as the identifying instrument. Then, by assuming $\mathbf{E}(\varepsilon_{ih} \mid \mathbf{p}_h, m_h, \mathbf{s}_h, \widehat{v}_h) = 0$, the parameters of the QUAIDS model are successfully identified.

Finally, by combining the adjustments to the QUAIDS discussed in Sections 4.3, 4.4 and 4.5, the two models that I estimate can be written as

$$\begin{aligned} w_i^c(\cdot) = \xi_{i0} + \sum_{l=1}^{L} \xi_{il} s_l + \sum_{j=1}^{n} \gamma_{ij} \log p_j + \beta_i \log\left(\frac{m}{a(\mathbf{p})}\right) + \frac{\lambda_i}{b(\mathbf{p})}\left(\log\left(\frac{m}{a(\mathbf{p})}\right)\right)^2 \\ + \sigma_{\nu u_i^c} \frac{\phi(\mathbf{z}_h' \widehat{\boldsymbol{\pi}})}{\Phi(\mathbf{z}_h' \widehat{\boldsymbol{\pi}})} + \rho_i \widehat{v} + \varepsilon_i \qquad (i = 1, \ldots, n) \end{aligned} \tag{4.40}$$

for consumers, and

$$
\begin{aligned}
w_i^a(\cdot) = \xi_{i0} + \sum_{l=1}^{L} \xi_{il} s_l + \sum_{j=1}^{n} \gamma_{ij} \log p_j + \beta_i \log\left(\frac{m}{a(\mathbf{p})}\right) + \frac{\lambda_i}{b(\mathbf{p})}\left(\log\left(\frac{m}{a(\mathbf{p})}\right)\right)^2 \\
- \sigma_{\nu u_i^a} \frac{\phi(\mathbf{z}_h'\widehat{\boldsymbol{\pi}})}{1-\Phi(\mathbf{z}_h'\widehat{\boldsymbol{\pi}})} + \rho_i \widehat{v} + \varepsilon_i \qquad (i = 1, \ldots, n-1)
\end{aligned}
\tag{4.41}
$$

for abstainers.

4.6 Iterated Linear Least Squares Estimator

In this analysis, I applied an iterated linear least squares estimator (ILLE) proposed by Blundell and Robin (1999) for conditionally linear demand systems to estimate the equation systems (4.40) and (4.41). The use of this estimator is possible because the AIDS model is linear in parameters conditional on the translog price index $\log(a(\mathbf{p}, \boldsymbol{\theta}))$.[9] The estimator then consists of the following series of iterations: It takes a starting value for $\boldsymbol{\theta}^{(p)}$, estimates the demand system using a linear moment estimator to get updated estimates $\boldsymbol{\theta}^{(p+1)}$. Given $\boldsymbol{\theta}^{(p+1)}$, an updated price index $\log a(\mathbf{p}, \boldsymbol{\theta}^{(p+1)})$ can be calculated. Subsequently, it repeats the estimation using $\log a(\mathbf{p}, \boldsymbol{\theta}^{(p+1)})$ instead of $\log a(\mathbf{p}, \boldsymbol{\theta}^{(p)})$ until numerical convergence is reached. Blundell and Robin (1999) argue that this approach has a significant computational advantage over estimating the demand system simultaneously. They further show that the estimator fully identifies the parameters of the non-linear AIDS model and that it exhibits consistency and asymptotic normality. In addition, they prove that the ILLE $\widehat{\theta}$ is asymptotically equivalent to the Non-Linear Three-Stage Least Square (NL3S) estimator $\tilde{\theta}$. The ILLE has been implemented in Stata software by Lecocq and Robin (2015) in the user-written Stata command `aidsills`. If the number of iterations in the `aidsills` command is set to one, the model is equal to the LA/AIDS model that takes the Stone price index to deflate income.

[9] $\boldsymbol{\theta}$ represents the parameters of the translog price index.

5 Analysis

In this section, I proceed by presenting the estimation results. In Section 5.1, I discuss the selection model and the estimates from the probit model. Section 5.2 will subsequently be devoted to the first stage regression of the augmented regression approach, while Section 5.3 discusses estimation results of the QUAIDS model for both consumers and abstainers of alcohol. Section 5.4 covers the empirical validity of the postulates imposed by traditional demand theory. Finally, Section 5.5 discusses a possible approach to imposing negativity.

5.1 Selection Model

First, I estimated the selection model to determine the probability of household h to be a consumer of alcohol. I proceed according to the approach discussed in Section 4.4. The set of independent variables is chosen similarly to the ones in the QUAIDS model. There are, however, some differences.

1. I included a dummy variable indicating whether a household smokes as an explanatory variable. Smoking is potentially an essential factor explaining alcohol consumption, and I expect households that smoke to be more likely to consume alcohol. Cameron and Trivedi (2009, p. 546) discuss the importance of not using the same set of independent variables in the selection model as in the outcome model. They argue that an excluded "instrument" can help prevent the inverse Mills ratio from being collinear with the regressors of the outcome model. Hence, following this logic, I argue that being a smoker does not affect the budget allocation decision but is indeed a predictor of a household being a consumer of alcohol. Of course, this assumption is debatable, as households that spend money on tobacco have less money available for other goods and have to adjust the optimal allocation of their money.

2. Following the reasoning from Section 4.5, I assume total expenditure to be endogenous. Therefore, I did not use total expenditure as an explanatory variable but rather log of real disposable income and log of real disposable income squared. Of course, the exogeneity assumption of income is also debatable in this case. However, I assume it to be at least closer to exogeneity than total expenditure.

3. Due to some issues related to the collinearity of the inverse Mills ratio and the regressors in the outcome model (see bullet point 1.), I included the (real) national price indices for each commodity group instead of the Stone-Lewbel prices.

4. Yearly dummies have been dropped from the selection model because of multicollinearity between the dummy variables and the real price index variables.

The independent variables in the selection model were thus: A dummy indicating whether the household spent money on tobacco, a dummy for whether a woman is the reference person of the household, the number of children, the number of adults, the number of pensioners, the number of earners, real income and real income squared, regional dummies and real price indices for the eight commodity groups. The dependent variable is a dummy for whether household h reported positive expenditure on alcohol.

It can be seen that most of the variables are statistically significant. Most importantly, the variable *Smoker*, which is the excluded variable from the outcome model, is very precisely estimated. Its sign is also in line with what one would expect – being a smoker makes a household more likely to consume alcohol. Furthermore, if a woman is the households' reference person, the household is less likely to consume alcohol. Similarly, a higher number of children seems to decrease the likelihood of consuming alcohol. If there are more adults or more pensioners in a given household, it is more likely to be a consumer of alcohol, while the sign for the number of earners is negative, however. Real income is less significant than the other variables, and real income squared does not have any statistical significance. However, the signs of those variables are as expected, and the selection model seems reasonable. Given the estimates in Table 5.1, I calculated the linear predictions of the probit model. Next, these fitted values can be used to calculate the IMR for each household.

Table 5.1: Selection model (probit estimation).

	Alcohol consumer
Smoker	0.224***
	(0.016)
Woman reference person	-0.115***
	(0.017)
Number of children	-0.064***
	(0.008)
Number of adults	0.096***
	(0.012)
Number of pensioners	0.244***
	(0.016)
Number of earners	-0.068***
	(0.013)
Real income	0.159
	(0.158)
Real income squared	0.017
	(0.020)
N	34'295
Yearly dummies	No
Regional dummies	Yes
Prices	Yes (real price indices)

Note: Standard errors in parentheses.
* p<0.05, ** p<0.01, *** p<0.001.

5.2 First Stage Regressions

For the estimation of the QUAIDS, the sample has been partitioned into consumers of alcohol and abstainers of alcohol. The same reasoning applies to the respective IV estimations, and I estimated two different models for consumers and abstainers. The independent variables used in the first stages are the same as those used in the second stages, i.e. in the demand system. The only difference is that *Log disposable income* is added to the model as an instrument. The dependent variable is the log of total expenditure. The OLS estimates of the two first stages are displayed in Table 5.2.

Firstly, notice that apart from *Number of earners*, the estimated coefficients have the same signs in both models. This finding is in line with what one would expect, as there is no specific reason to believe that any of the explanatory variables would affect total expenditure differently for one of the groups. Secondly, most of the coefficients are rather precisely estimated (except for the coefficient of *Woman reference person* for consumers). Most importantly, the estimated coefficients of *Log disposable income* is highly statistically significant, supporting the relevance hypothesis ($\text{Cov}(m_h, r_h) \neq 0$). The magnitude suggesting that an 1 % increase in disposable income leads to a 0.52 % (consumers) and a 0.54 % (abstainers) increase in total expenditure also seems plausible.

If we consider the other estimates, we see that the variable *Woman reference person* leads to a lower total expenditure (2.5 % for consumers and 0.1 % for abstainers). Furthermore, one additional child is estimated to increase total expenditure by 3.8 % (consumers) and 4.8 % (abstainers), respectively. Similarly, the number of adults and the number of pensioners are estimated to lead to higher total expenditures. It seems surprising that the number of earners has a negative sign for both groups. One might think that an additional earner should lead to higher total expenses as it is an extra household member that consumes goods and services. However, the fact that the additional earner is also an additional (consuming) household member is already captured by the variable *Number of adults* (if the earner is also an adult). Similarly, the higher income induced by additional earners is controlled for by the income variable. The "remaining" effect of an additional earner could indeed be negative since a working person has less time to consume goods and services. Therefore, the negative coefficient is, in fact, not counterintuitive.

Table 5.2: First stage regressions for consumers and abstainers of alcohol.

	Log total expenditure	
	Consumers	Abstainers
Log disposable income	0.521***	0.535***
	(0.010)	(0.013)
Woman reference person	-0.025***	-0.001
	(0.007)	(0.009)
Number of children	0.038***	0.048***
	(0.004)	(0.005)
Number of adults	0.133***	0.106***
	(0.005)	(0.007)
Number of pensioners	0.198***	0.189***
	(0.008)	(0.012)
Number of earners	-0.034***	-0.004
	(0.005)	(0.007)
Inverse Mills ratio	0.133**	0.038
	(0.045)	(0.052)
N	20’194	14’101
R^2	0.522	0.535
Yearly dummies	Yes	Yes
Regional dummies	Yes	Yes
Prices	Yes (Stone-Lewbel)	Yes (Stone-Lewbel)

Note: Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001.

5.3 QUAIDS Estimation

As mentioned in Section 4.4, I estimated the two QUAIDS models for consumers and abstainers given by equations (4.40) and (4.41). The dependent variables are the budget shares of all commodity groups. The regressors are the logs of Stone-Lewbel prices, the log of real total expenditure and its respective quadratic term, and the predicted residuals from the first stage regressions. Furthermore, the following socio-demographic variables enter the demand system linearly: *Woman reference person*, *Number of children*, *Number of adults*, *Number of pensioners*, *Number of earners*, regional dummies[10] as well as yearly dummies[11]. For each group (consumers and abstainers), the appropriate inverse Mills ratio was added as an additional regressor. Lastly, I set the parameter α_0 to 5.99, which is the minimum value of the log of total expenditure in the sample for the base year. In doing so, I followed Deaton and Muellbauer (1980) and Banks et al. (1997), who argued that α_0 can be interpreted as outlay required for a minimum standard of living. In the estimation procedure, homogeneity was imposed by considering only $n-1$ relative prices (Deaton and Muellbauer, 1980, p. 318). After the occurrence of numerical convergence of the estimated parameters, one last iteration was performed imposing symmetry (Lecocq and Robin, 2015).

Due to the large number of estimated coefficients, it is unfortunately impracticable to present all estimation results in this section. Table A1.2 and A1.3 in Appendix A1 present the raw estimates for the interested reader. These tables demonstrate that all commodities except *Food* and *Others* have statistically significant coefficients of the quadratic income terms – both for consumers and abstainers. This supports the use of the QUAIDS rather than the AIDS.

Arguably the most meaningful results of the QUAIDS estimation, however, are the different elasticities of demand that can be computed with equations (4.24), (4.25) and (4.26). I calculated the elasticities on a household level for all households in the sample, given that they had positive predicted budget shares.

[10]The regions are: Geneva, Northwest, Plateau, Zürich, East, Central and Ticino. Ticino has been omitted and is therefore the reference category.

[11]The time period is 2006-2017. 2006 is omitted and thus the reference category.

Table 5.3: Predicted budget shares ($\widehat{w}_i$), observed budget shares ($\overline{w}_i$) and income elasticities (ϵ_i) for consumers and abstainers of alcohol (sample averages).

	Consumers			Abstainers		
	$\widehat{w}_i$	$\overline{w}_i$	ϵ_i	$\widehat{w}_i$	$\overline{w}_i$	ϵ_i
Food	0.192***	0.193	0.313***	0.186***	0.189	0.280***
	(0.001)	–	(0.021)	(0.001)	–	(0.028)
Alcohol	0.028***	0.029	0.755***			
	(0.000)	–	(0.068)			
Clothing	0.059***	0.057	1.567***	0.060***	0.057	1.607***
	(0.000)	–	(0.045)	(0.001)	–	(0.056)
Housing	0.067***	0.069	0.641***	0.072***	0.074	0.579***
	(0.000)	–	(0.034)	(0.001)	–	(0.042)
Restaurants	0.148***	0.142	1.224***	0.147***	0.140	1.315***
	(0.001)	–	(0.028)	(0.001)	–	(0.037)
Transport	0.212***	0.215	0.770***	0.238***	0.241	0.726***
	(0.001)	–	(0.023)	(0.001)	–	(0.027)
Recreation	0.147***	0.149	1.645***	0.147***	0.149	1.719***
	(0.001)	–	(0.030)	(0.001)	–	(0.037)
Others	0.147***	0.146	1.345***	0.150***	0.149	1.273***
	(0.001)	–	(0.031)	(0.001)	–	(0.038)

Note: Standard errors in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table 5.3 summarises the predicted budget shares, the observed budget shares, and the average income elasticities for consumers and abstainers. Firstly, none of the groups categorises as an inferior good, as all income elasticities are positive. On the one hand, *Food*, *Alcohol*, *Housing* and *Transport* appear to be necessary goods with income elasticities less than unity. On the other hand, *Clothing*, *Restaurants*, *Recreation*, and *Others* are luxury goods, with increasing demand as their consumers' income rise. Note, however, that the elasticity of *Clothing* is possibly underestimated. As can be seen in Table 3.2, *Clothing* exhibits a large share of zero expenditure. I did not control for the zero consumption share of *Clothing* since this is due to the infrequency of purchases rather than sample selection. If households were observed for a more extended period, more households would report positive expenditure. The fact that many households did not purchase clothes in the survey period might cause the estimated elasticity to be biased towards zero.

The averages of the predicted budget shares are very close to the observed averages suggesting a relatively good overall fit of the models. Finally, all of these estimates exhibit low standard errors and are rather precisely estimated.

Next, Table 5.4 shows the mean of all individual elasticities computed in the sample. The table is divided into uncompensated and compensated price elasticities of demand.

All diagonal elements (own-price elasticities) have a negative sign. This finding is in line with what one would expect from economic theory under the assumption that none of these commodity groups exhibits the properties of a Giffen good. *Food*, *Alcohol*, *Clothing* *Restaurants*, *Transport*, and *Recreation* have on average estimated elasticities less than unity while *Housing* and *Others* have on average elastic demand. All of these own-price elasticities are rather precisely estimated, with relatively low standard errors. Again, it is important to keep in mind that the elasticities involving *Clothing* should be interpreted with caution.

The estimates for the compensated price elasticities of demand are, in general, very similar to the uncompensated price elasticities of demand discussed in the paragraph above. Almost all compensated elasticities have the same sign as their uncompensated counterpart. The only exceptions are some cross-price elasticities that have previously been estimated to be close to zero. It seems, however, that the compensated elasticities are less negative than the uncompensated ones. This result makes sense: If a household is financially compensated for a price increase (to keep utility constant), it will adjust its demand for any normal good to a lesser extent than in the absence of financial reimbursement. Hence, this empirical finding is in line with the theoretical fact that compensated demand only reflects the substitution effect, while uncompensated demand both represents substitution and income effect. Furthermore, the same commodity groups have elastic and inelastic demand as in the uncompensated case. However, the own-price elasticity of housing is closer to unity, and it is probably more appropriate to classify it as a unit elastic good, given its standard errors.

Table 5.4: Uncompensated and compensated price elasticities of demand for consumers of alcohol (sample averages).

	Food	Alcohol	Clothing	Housing	Restaurants	Transport	Recreation	Others
Uncompensated								
Food	-0.886***	0.030**	0.005	0.062***	-0.001	0.146***	0.173***	0.157***
	(0.017)	(0.009)	(0.011)	(0.019)	(0.013)	(0.015)	(0.016)	(0.014)
Alcohol	0.124*	-0.216***	-0.203***	-0.060	-0.131**	0.029	-0.120*	-0.177***
	(0.056)	(0.032)	(0.037)	(0.062)	(0.043)	(0.050)	(0.053)	(0.046)
Clothing	-0.225***	-0.120***	-0.317***	-0.182***	-0.278***	-0.348***	-0.203***	0.106***
	(0.038)	(0.020)	(0.025)	(0.042)	(0.028)	(0.034)	(0.035)	(0.031)
Housing	0.114***	-0.022	-0.104***	-1.127***	-0.130***	0.329***	0.211***	0.088***
	(0.028)	(0.015)	(0.018)	(0.031)	(0.021)	(0.025)	(0.026)	(0.023)
Restaurants	-0.176***	-0.038**	-0.090***	-0.099***	-0.325***	-0.163***	-0.285***	-0.050*
	(0.024)	(0.013)	(0.015)	(0.026)	(0.018)	(0.021)	(0.022)	(0.019)
Transport	0.044*	0.003	-0.049***	0.096***	-0.046**	-0.750***	-0.065***	-0.003
	(0.019)	(0.010)	(0.012)	(0.021)	(0.014)	(0.017)	(0.018)	(0.016)
Recreation	-0.030	-0.048***	-0.086***	0.029	-0.350***	-0.280***	-0.983***	0.102***
	(0.025)	(0.014)	(0.016)	(0.028)	(0.019)	(0.023)	(0.023)	(0.021)
Others	0.007	-0.050***	0.055***	-0.007	-0.068***	-0.127***	0.146***	-1.302***
	(0.026)	(0.014)	(0.017)	(0.029)	(0.020)	(0.023)	(0.024)	(0.021)
Compensated								
Food	-0.826***	0.039***	0.023*	0.084***	0.046***	0.213***	0.219***	0.203***
	(0.018)	(0.009)	(0.011)	(0.019)	(0.011)	(0.014)	(0.015)	(0.013)
Alcohol	0.269***	-0.195***	-0.159***	-0.009	-0.019	0.189***	-0.009	-0.066
	(0.061)	(0.032)	(0.036)	(0.063)	(0.038)	(0.047)	(0.049)	(0.045)
Clothing	0.076	-0.076***	-0.225***	-0.077	-0.046	-0.015	0.027	0.336***
	(0.041)	(0.020)	(0.025)	(0.042)	(0.025)	(0.031)	(0.033)	(0.030)
Housing	0.237***	-0.004	-0.067***	-1.084***	-0.035	0.465***	0.305***	0.182***
	(0.030)	(0.015)	(0.018)	(0.031)	(0.019)	(0.023)	(0.024)	(0.022)
Restaurants	0.059*	-0.004	-0.018	-0.016	-0.144***	0.098***	-0.105***	0.130***
	(0.025)	(0.013)	(0.015)	(0.026)	(0.016)	(0.020)	(0.021)	(0.019)
Transport	0.192***	0.025*	-0.004	0.148***	0.068***	-0.586***	0.048**	0.110***
	(0.021)	(0.010)	(0.012)	(0.021)	(0.013)	(0.016)	(0.017)	(0.015)
Recreation	0.286***	-0.002	0.011	0.140***	-0.106***	0.070***	-0.742***	0.343***
	(0.027)	(0.014)	(0.016)	(0.028)	(0.017)	(0.021)	(0.022)	(0.020)
Others	0.266***	-0.013	0.134***	0.084**	0.131***	0.159***	0.344***	-1.105***
	(0.028)	(0.014)	(0.017)	(0.029)	(0.017)	(0.022)	(0.023)	(0.020)

Note: Standard errors in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

The estimated uncompensated elasticities for abstainers of alcohol are presented in the top panel of Table 5.5. Only seven commodity groups are observed for abstainers, as the budget share of *Alcohol* is inherently equal to zero for these observations. The average of the own-price elasticities is negative for all commodity groups. The estimates are generally very similar to the ones obtained for consumers and are in line with what could be expected. All commodity groups appear to have inelastic demand except for *Others*, which has an estimated own-price elasticity lower than -1. The uncompensated elasticities for abstainers seem to compare to those obtained for alcohol consumers regarding their estimated magnitude.

Table 5.5: Uncompensated and compensated price elasticities of demand for abstainers of alcohol (sample averages).

	Food	Clothing	Housing	Restaurants	Transport	Recreation	Others
Uncompensated							
Food	-0.827***	0.004	0.069**	0.006	0.094***	0.185***	0.190***
	(0.022)	(0.016)	(0.023)	(0.019)	(0.020)	(0.020)	(0.018)
Clothing	-0.235***	-0.404***	-0.203***	-0.272***	-0.417***	-0.160***	0.084*
	(0.045)	(0.033)	(0.048)	(0.038)	(0.041)	(0.041)	(0.038)
Housing	0.124***	-0.109***	-0.887***	-0.144***	0.290***	0.071*	0.075**
	(0.033)	(0.024)	(0.035)	(0.028)	(0.030)	(0.030)	(0.028)
Restaurants	-0.186***	-0.094***	-0.123***	-0.342***	-0.210***	-0.318***	-0.043
	(0.029)	(0.021)	(0.031)	(0.025)	(0.027)	(0.027)	(0.025)
Transport	-0.009	-0.052***	0.077***	-0.043*	-0.603***	-0.073***	-0.023
	(0.022)	(0.015)	(0.023)	(0.018)	(0.020)	(0.020)	(0.018)
Recreation	-0.034	-0.073***	-0.047	-0.376***	-0.354***	-0.816***	-0.019
	(0.030)	(0.022)	(0.032)	(0.025)	(0.027)	(0.027)	(0.025)
Others	0.051	0.054*	-0.014	-0.036	-0.166***	0.047	-1.209***
	(0.030)	(0.022)	(0.032)	(0.026)	(0.027)	(0.028)	(0.025)
Compensated							
Food	-0.775***	0.021	0.089***	0.047**	0.161***	0.226***	0.231***
	(0.024)	(0.016)	(0.024)	(0.017)	(0.018)	(0.018)	(0.017)
Clothing	0.064	-0.307***	-0.088	-0.036	-0.034	0.076*	0.324***
	(0.049)	(0.033)	(0.048)	(0.034)	(0.038)	(0.038)	(0.036)
Housing	0.232***	-0.074**	-0.845***	-0.059*	0.428***	0.156***	0.162***
	(0.036)	(0.024)	(0.035)	(0.025)	(0.027)	(0.028)	(0.026)
Restaurants	0.059	-0.015	-0.029	-0.149***	0.103***	-0.124***	0.154***
	(0.032)	(0.021)	(0.032)	(0.023)	(0.025)	(0.025)	(0.024)
Transport	0.126***	-0.009	0.129***	0.064***	-0.430***	0.034	0.086***
	(0.023)	(0.016)	(0.023)	(0.016)	(0.018)	(0.018)	(0.017)
Recreation	0.286***	0.031	0.076*	-0.124***	0.055*	-0.563***	0.238***
	(0.033)	(0.022)	(0.032)	(0.023)	(0.025)	(0.025)	(0.024)
Others	0.288***	0.131***	0.077*	0.151***	0.137***	0.234***	-1.019***
	(0.033)	(0.022)	(0.032)	(0.023)	(0.025)	(0.026)	(0.024)

Note: Standard errors in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

The compensated elasticities appear to follow a similar pattern as observed for consumers. Most compensated elasticities are less negative than the uncompensated ones, again indicating that demand for normal goods is less responsive to price changes if households are financially compensated for the welfare loss associated with these price changes. Similar to the case of consumers, most uncompensated and compensated elasticities have the same sign, and their magnitudes do generally not differ dramatically from each other.

5.4 Testing Postulates from Demand Theory

As mentioned in the introduction, one of the purposes of applied demand analysis is to test the empirical validity of economic theory using real-world data. The four postulates of interest are (i) adding-up, (ii) homogeneity, (iii) symmetry and (iv) negativity. Since adding-up is satisfied by construction, I will focus on the remaining three restrictions.

The Wald statistic for the general test of the linear null hypotheses $H_0 : \mathbf{R}\boldsymbol{\vartheta} - \mathbf{r} = \mathbf{0}$ with h linear hypotheses is given by

$$W = (\mathbf{R}\widehat{\boldsymbol{\vartheta}} - \mathbf{r})'\left\{\mathbf{R}\widehat{\mathbf{V}}(\widehat{\boldsymbol{\vartheta}})\mathbf{R}'\right\}^{-1}(\mathbf{R}\widehat{\boldsymbol{\vartheta}} - \mathbf{r}) \overset{a}{\sim} \chi^2_h \tag{5.1}$$

where $\boldsymbol{\vartheta}$ is a $K \times 1$ parameter vector with its empirical counterpart $\widehat{\boldsymbol{\vartheta}}$. $\mathbf{R}$ is a $h \times K$ matrix, $\mathbf{r}$ is an $h \times 1$ vector ($h \leq K$) and $\widehat{\mathbf{V}}(\cdot)$ is an estimator for the variance-covariance matrix. The Wald statistic is then approximately χ^2_h distributed, which can be used to evaluate whether to reject H_0.

In order to test (ii) homogeneity, I estimated an unconstrained QUAIDS model. Then, the Wald statistic for the restrictions (4.10) can be calculated according to equation (5.1). In this model, the χ^2_7-statistic with seven degrees of freedom is 381.25 for consumers, and the χ^2_6-statistic with six degrees of freedom is 233.62 for abstainers. The corresponding probabilities are below any conventional significance level, and homogeneity is therefore jointly rejected in both cases. However, one cannot entirely trust the estimated χ^2-statistics. The inclusion of the IMRs in the QUAIDS models implies that the estimated variances of the coefficients are too low. Hence, the χ^2-statistics are calculated based on underestimated variances and are therefore too large. Still, given the large magnitude of the χ^2-statistics, it would be surprising if the test result changed dramatically by correcting for the wrongly estimated variances.

Similarly, I tested (iii) symmetry after running a homogeneity constrained QUAIDS model. Here again, a χ^2-test can be applied to test the joint hypothesis given in equation (4.11). For consumers of alcohol, the χ^2_{21}-statistic is 668.07, while for abstainers, the χ^2_{15}-statistic is 351.20. Hence, for both groups, symmetry is rejected at any conventional significance level. The same argument as previously suggests that the χ^2-statistics are overestimated due to wrong standard errors. It is, however, hard to believe that correcting for the standard errors would have changed the result of the χ^2-test.

These test results provide evidence that homogeneity and symmetry do not seem to hold in the unconstrained models. Due to the fundamentality of the homogeneity and symmetry restrictions, it is convenient to regard them as given rather than as evidence for non-rational behavior. Therefore, I proceeded with imposing the restrictions as explained in Section 5.3.

Lastly, and probably most interestingly, one can assess the empirical validity of (iv) negativity. Since this restriction cannot be imposed, it has to be checked *ex post*. In order to do so, I calculated the (modified) substitution matrix $\mathbf{K}$ for each household. This matrix is defined as the Slutsky matrix $\mathbf{S}$ with elements $s_{ij} = \partial h_i(p,m)/\partial p_j$ pre and post multiplied by a diagonal matrix with prices as diagonal elements and divided by total expenditure

$$\mathbf{K} = \frac{1}{m} \begin{bmatrix} p_1 & & \\ & \ddots & \\ & & p_{n-1} \end{bmatrix} \begin{bmatrix} s_{11} & \cdots & s_{1(n-1)} \\ \vdots & \ddots & \vdots \\ s_{(n-1)1} & \cdots & s_{(n-1)(n-1)} \end{bmatrix} \begin{bmatrix} p_1 & & \\ & \ddots & \\ & & p_{n-1} \end{bmatrix} \tag{5.2}$$

which can be shown to be equal to

$$\mathbf{K} = \begin{bmatrix} \epsilon^c_{11} & \cdots & \epsilon^c_{1(n-1)} \\ \vdots & \ddots & \vdots \\ \epsilon^c_{(n-1)1} & \cdots & \epsilon^c_{(n-1)(n-1)} \end{bmatrix} \begin{bmatrix} w_1 & & \\ & \ddots & \\ & & w_{n-1} \end{bmatrix} \tag{5.3}$$

This matrix has the same eigenvalues as **S** and is, in practice, more straightforward to calculate than the Slutsky matrix (Deaton and Muellbauer, 1980). I compute matrix **K** for all households in the sample and check each observation's largest eigenvalue. If this value is less than zero for a given household, the matrix is negative definite and the household has a concave expenditure function as postulated by demand theory.[12]

The result of these calculations is somewhat surprising and puzzling. I find that only 10'716 out of 34'295 households (31.2 %) in the sample have a negative definite substitution matrix (or, equivalently, a concave expenditure function). I furthermore checked the diagonal elements of the matrix for each household. The result, however, is not much more promising. Only 15'261 households (44.5 %) have a substitution matrix with solely negative diagonal elements. Hence, most observations violate the fundamental postulate of demand theory that compensated demand for good i decreases when the price for good i increases. Hoderlein and Mihaleva (2008) found that negativity cannot be rejected for 70 % of their observations when Stone-Lewbel prices are used, which is a considerably better result than what I find in this thesis. I reproduced Tables 5.3, 5.4 and 5.5 for the sample that does not violate negativity (see Tables A1.4, A1.5 and A1.6 in Appendix A1). It seems that the estimates are, in general, very similar to the ones obtained previously.

In order to learn more about what households violate Slutsky negativity, I estimated a probit model with a dummy that equals one for households that violate negativity as a dependent variable. The independent variables are the following socio-demographic variables: *Woman reference person*, *Number of children*, *Number of adults*, *Number of pensioners*, *Number of earners*, *Log disposable income* and a dummy indicating whether the household is a consumer of alcohol. Lastly, I included an indicator for whether the household was assigned a mean Stone-Lewbel price for any of the eight commodity groups (for any of the seven groups if the household is an abstainer of alcohol). The results are displayed in Table A1.7 in Appendix A1. It seems like all the independent variables are significant determinants of whether a household violates negativity.

In Figures 5.1 and 5.2, I plotted the estimated income elasticities for all consumers and abstainers who satisfy the negativity restriction against the logarithm of their total

[12] Similarly, matrix **K** could be set up as an $n \times n$ matrix. In this case, the maximum eigenvalue should be equal to zero and the remaining ones negative. Thus, considering n goods, the matrix has to be negative semidefinite for Slutsky negativity to be satisfied (Deaton and Muellbauer, 1980).

expenditure. The red line is a quadratic fit of the relationship between the two variables. This relationship is interesting because it reveals how households with different incomes are predicted to adjust the demand for the groups studied if their incomes change.

When comparing the two figures, the relationships between income elasticities and log total expenditure seem to be similar within each commodity group for consumers and abstainers (leaving aside the commodity group *Alcohol*, of course). The plots reveal some compelling insights. For instance, for none of the households is *Food* a luxury good. However, while it is a necessary good for low-income households, *Food* seems to be an inferior good for many high-income households. This finding could be explained by the fact that high-income households have a higher propensity to derive their nutrients from food services like restaurants or canteens, while lower-income households are more likely to prepare food themselves. Thus, an income increase would induce low-income households to demand more raw food, while high-income households would demand less food and more of the commodity *Restaurants*. Indeed, *Restaurants* has a positive income elasticity for all households, although it is a luxury good for low-income households and a necessary good for high-income households. The commodity groups *Clothing*, *Recreation* and *Others* are luxury goods, while *Housing* and *Transport* are necessary goods for all households. Lastly, *Alcohol* is a necessary good for low-income households and a luxury good for households with a high income.

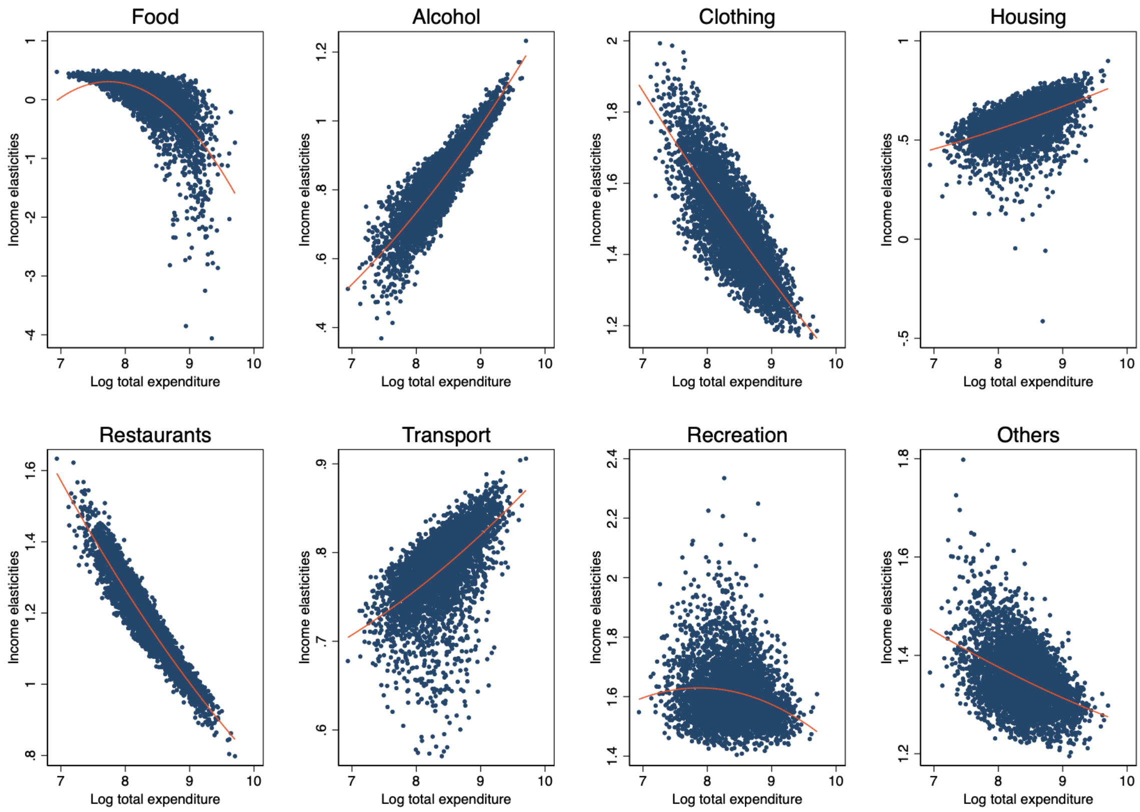

Figure 5.1: Income elasticities of consumers of alcohol.

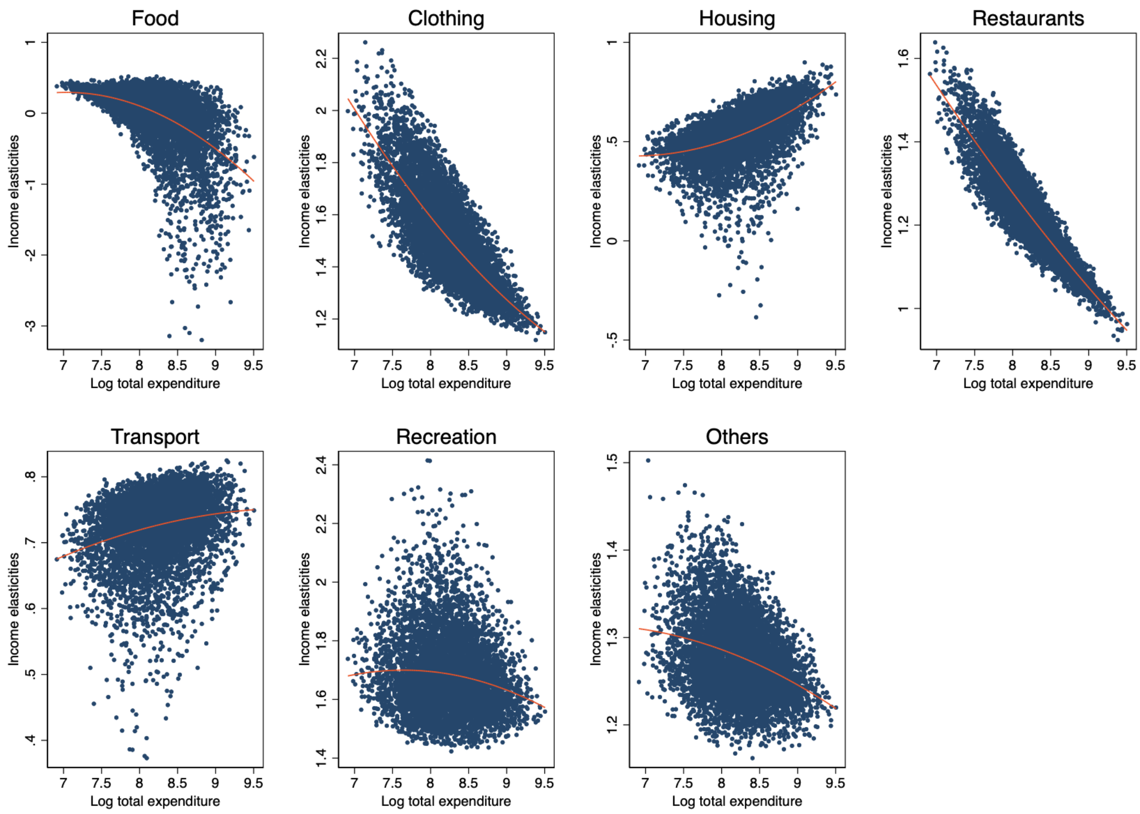

Figure 5.2: Income elasticities of abstainers of alcohol.

Figures 5.3 – 5.6 are similar to Figures 5.1 and 5.2, but plot own-price elasticities instead of income elasticities, along with a quadratic fit. Since the plots depict only elasticities of rational households (according to the model's prediction), none of the observations has a positive own-price elasticity, neither in the uncompensated nor in the compensated case. It is interesting to note that for both consumers (Figures 5.3 and 5.4) and abstainers (Figures 5.5 and 5.6), the relationship between the uncompensated elasticities and log total expenditure of each group appears similar to the respective relationship in the uncompensated case. The only exception is *Recreation*. For this group, there is no clear relationship between uncompensated elasticities and the income of alcohol-consuming households. However, if these households are financially compensated for the price change, there is a clear positive linear relationship between the elasticities and log total expenditure. This difference implies that higher-income households decrease their demand for *Recreation* to a lesser extent than lower-income households. For abstaining households, there is a negative predicted relationship between uncompensated own-price elasticities of *Recreation*. Again, if these households are financially compensated, the relationship becomes positive. This observed pattern most likely reflects that higher-income households spend a higher fraction of their income on *Recreation*. Furthermore, income elasticities of *Recreation* are generally high, making it a luxury good. Given that compensated elasticities are calculated as $\varepsilon_{ij}^{c} = \varepsilon_{ij}^{u} + w_j \varepsilon_i$, these observations could imply that the compensated own-price elasticities of *Recreation* change more for higher-income households.

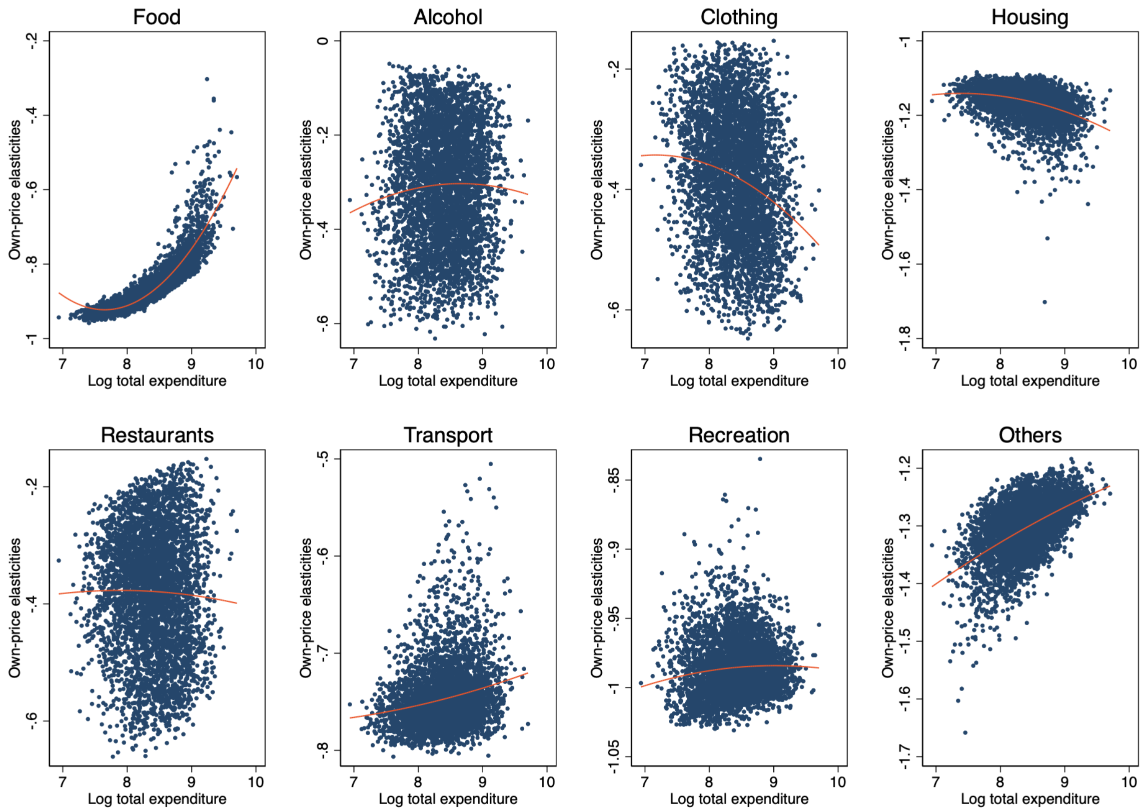

Figure 5.3: Uncompensated own-price elasticities of consumers of alcohol.

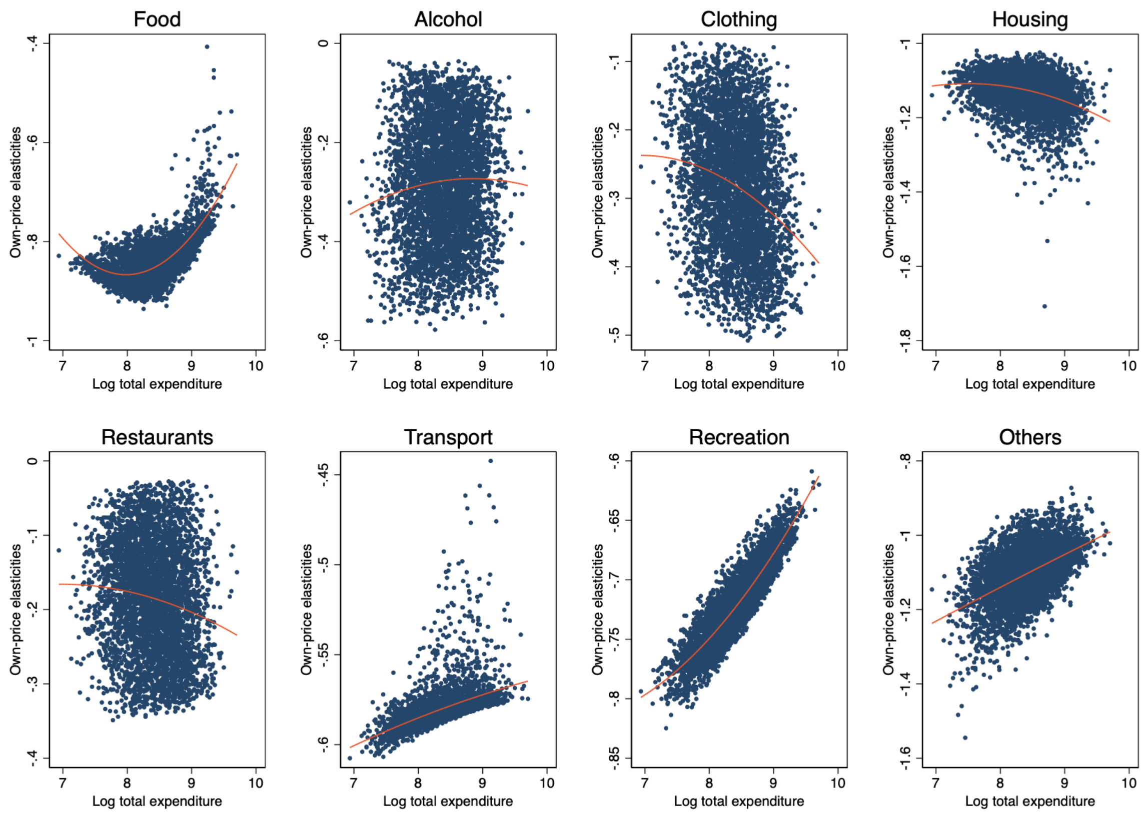

Figure 5.4: Compensated own-price elasticities of consumers of alcohol.

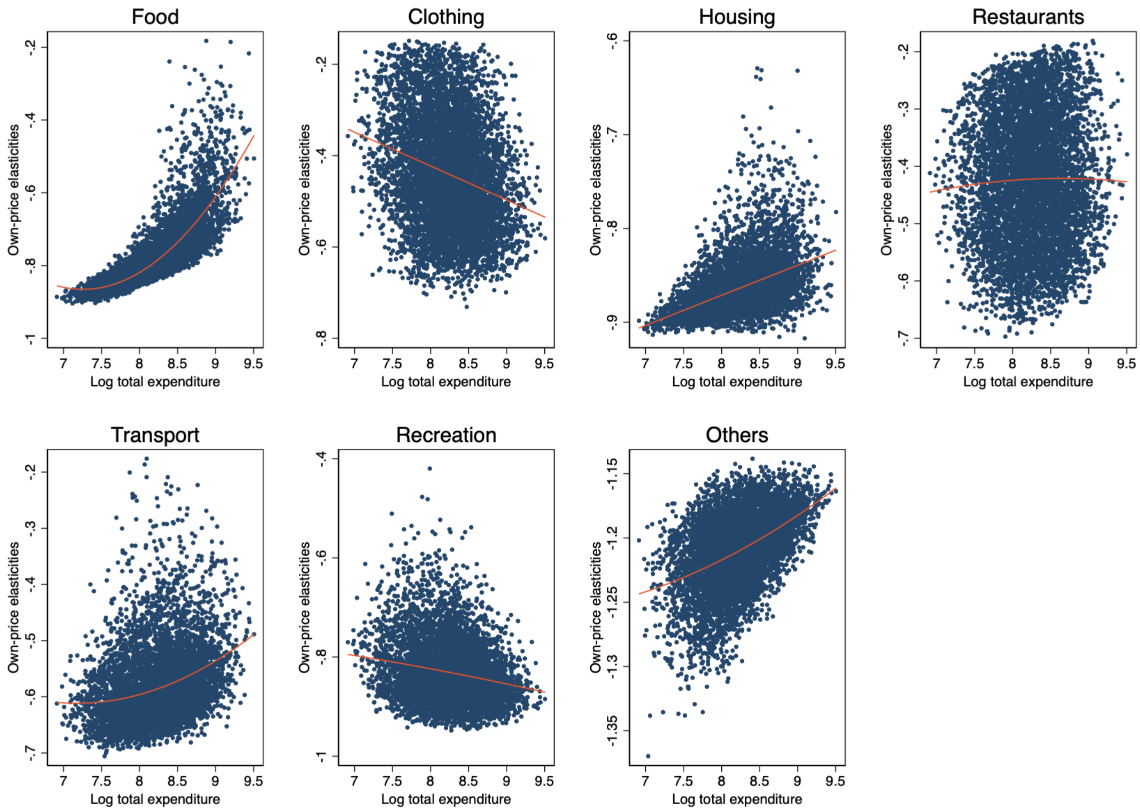

Figure 5.5: Uncompensated own-price elasticities of abstainers of alcohol.

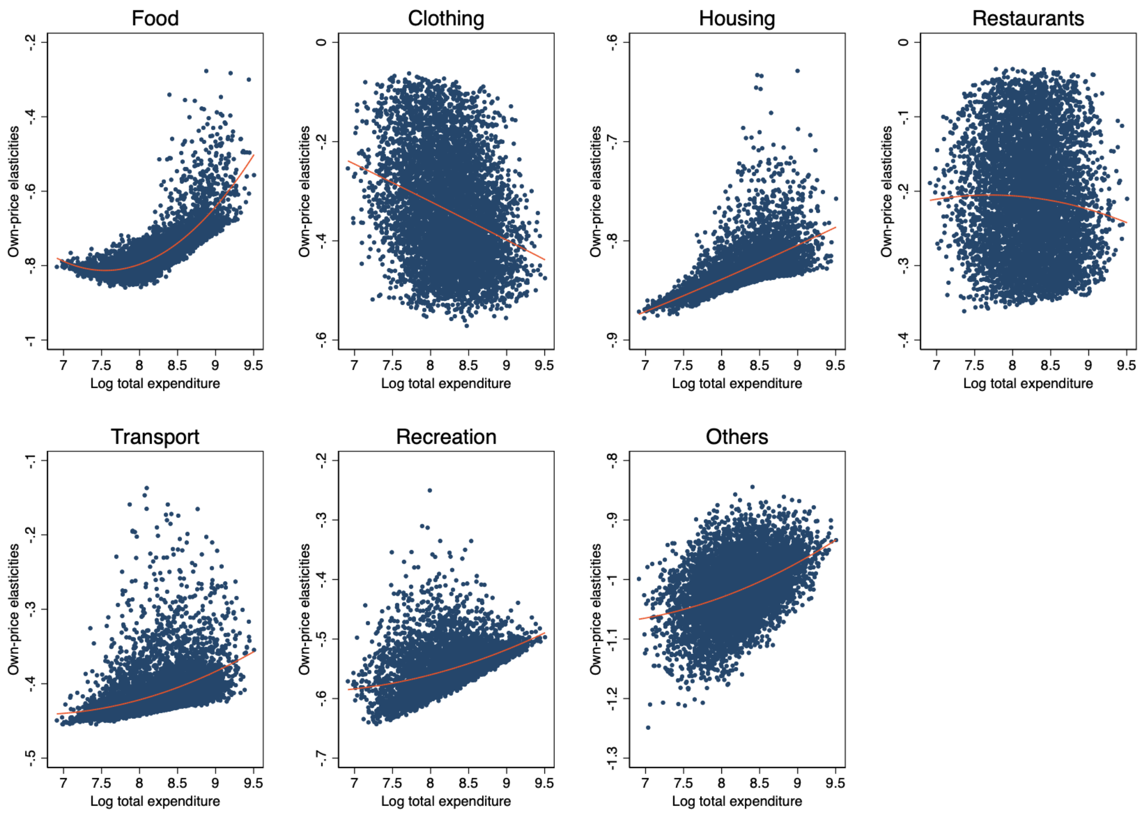

Figure 5.6: Compensated own-price elasticities of abstainers of alcohol.

5.5 Imposing Negativity

There has been some research on how negativity could be imposed when estimating the AIDS model. In the context of the AIDS model, the elements of the Slutsky matrix can be written as

$$s_{ij} = \frac{m}{p_i p_j} \left(\gamma_{ij} + w_i w_j - \delta_{ij} w_i + \beta_i \beta_j \log \left(\frac{m}{a(\mathbf{p})} \right) \right) \tag{5.4}$$

From this, it can be inferred that the Slutsky matrix $\mathbf{S}$ is globally negative semidefinite (negative definite if only $n-1$ goods are considered), if and only if both $\gamma_{ij} = 0$ for $i, j = (1, \ldots, n)$ and $\beta_i = 0$ for $i = (1, \ldots, n)$ (Moschini, 1998). Imposing these restrictions, however, would lead to a constant share model, corresponding to the Cobb-Douglas case. Such a restrictive model would in turn undermine the strengths of the AIDS model. Moschini (1998) argued that negativity (or, equivalently, concavity of the expenditure function) can be imposed locally at any arbitrary data point. He proposed to use $p_i = m = 1$ and suggested scaling the data such that p_i and m correspond to 1 at sample mean. At this point, the Slutsky substitution terms in equation (5.4) can be be written as

$$\psi_{ij} = \gamma_{ij} + \alpha_i \alpha_j - \delta_{ij} \alpha_i \tag{5.5}$$

where $\alpha_i = w_i$ if $\alpha_0 = 0$ is assumed. Consequently, in order for negativity to be satisfied at this specific point, matrix $\mathbf{\Psi}$ with elements ψ_{ij} must be negative semidefinite. Moschini (1998) proceeded by reparametrising $\mathbf{\Psi}$ with the Cholesky decomposition. Diewert and Wales (1987) showed that $\mathbf{\Psi}$ can be written as $\mathbf{\Psi} = -\mathbf{T}'\mathbf{T}$ where $\mathbf{T}$ is an upper triangular matrix with elements τ_{ij}. $-\mathbf{T}'\mathbf{T}$ is then by construction a negative semidefinte matrix. Subsequently, the AIDS budget share equations can be written and estimated in terms of τ_{ij}, which satisfies negativity by construction at the point $p_i = m = 1$ for $p_i = (1, \ldots, n)$. The drawback of this approach is that the resulting demand system is highly nonlinear in the parameters (Moschini, 1998).

6 Discussion

The main goal of this thesis was to learn about households' demand responses to changes in income and prices in Switzerland. The results presented in this thesis are, in general, very plausible and seem to be in line with economic intuition. On average, the commodity groups *Food*, *Alcohol* (for consumers of alcohol), *Housing* and *Transport* are necessities while *Clothing*, *Restaurants*, *Recreation* and *Others* are luxury goods. Regarding price-elasticities, I find that *Food*, *Alcohol* (for consumers of alcohol), *Clothing*, *Restaurants*, *Transport* and *Recreation* are price-inelastic commodities. For abstainers of alcohol, *Housing* is found to be price-inelastic as well. The remaining categories are all price-elastic, both for consumers and abstainers of alcohol and both in the uncompensated and compensated cases. I furthermore found that if the restrictions of homogeneity and symmetry are not imposed, they should be rejected – a finding that contradicts the standard consumer theory but is in line with the empirical finding of many other studies.[13] Finally, checking the negative definiteness of the (modified) Slutsky matrix revealed that only 31.2 % of the households in the sample satisfy the negativity condition.

The most interesting estimates from this thesis are arguably the uncompensated and compensated own-price elasticities of demand for *Alcohol*, as well as the respective income elasticity. I implemented an elaborate empirical strategy in order to get unbiased estimates for the elasticities involving alcohol. Gallet (2007) conducted a meta-analysis of 132 studies that studied the demand for alcohol. He found the median own-price elasticities to be roughly -0.5. However, studies using AIDS models tend to have a higher estimate in terms of magnitude (-0.8), whereas the median elasticity of studies implementing a hurdle model is -0.6. Given those results, it seems surprising that I find an own-price elasticity of demand for alcohol of approximately -0.2. This estimate is much lower in magnitude than what could be expected by considering Gallet (2007)'s meta-analysis. Wagenaar et al. (2009) found in their meta-analysis that the mean own-price elasticity of alcohol is -0.51. Here again, my estimates seem to be of a different magnitude than this study suggests. The own-price elasticity estimates of *Alcohol* found in this thesis refer to the intensive margin, i.e. it gives an estimate for *how much* consumers adjust their demand to price

[13] There is, however, an example of a notable study that found opposite results and failed to reject homogeneity (see Blundell et al., 1993).

changes. However, there is also an extensive margin, that is, an effect of a price increase on whether a given household is a consumer or an abstainer of alcohol. This extensive margin is not captured by the elasticity estimate for *Alcohol* that I find in this thesis and could be one of the reasons for the difference.
Aepli (2014b) is the only study examining alcohol consumption in Switzerland with a QUAIDS model also correcting for sample selection. Unfortunately, he did not report the overall own-price elasticity of demand for alcohol. Instead, he only presented elasticities at a more disaggregated level for the commodities beer, wine, and spirits, ranging from -1 to -0.6. Aepli (2014b)'s results, however, can hardly be compared to the results found in my thesis. The reason is that different types of alcohol are arguably close substitutes. Thus, a price increase of one type of alcohol (e.g. wine) might induce people to replace it with another type of alcohol (e.g. beer). Hence, the drop in demand for wine after a price increase might be partially outweighed by an increase in demand for beer. These substitution patterns within the commodity *Alcohol* are not captured in my model. Since a broader definition of the commodity group should lead to a lower own-price elasticity (due to the lack of close substitutes), my estimates are plausible.
Gallet (2007) also analysed income elasticities of demand across the studies examined. He found the median income elasticity to be approximately 1 for the studies using AIDS models, while studies employing a hurdle model have a median income elasticity of ca. 0.3. The estimated mean income elasticity of demand for alcohol found in this thesis (approximately 0.8) is in line with the finding of Gallet (2007).

It would be interesting to compare the remaining own-price elasticities to the findings of other meta-analyses. Unfortunately, most studies define commodity groups differently, and it is challenging to find comparable results. There are, however, some commodity groups that most studies have in common, namely *Food*, *Clothing* and sometimes *Transport*. Still, meta-studies analysing price elasticities of demand for food usually investigate more disaggregated food groups rather than the overall demand for food. Furthermore, there seem to be no meta-analyses available for clothing, making it harder to put the results from this thesis into perspective. Moreover, as mentioned earlier, it is hard to trust the estimated elasticities involving *Clothing*, as I have not controlled for its relatively high share of zero consumption, rendering comparisons pointless.
Despite the lack of meta-studies, it might be interesting to compare my results to some

selected studies. Banks et al. (1997) found own-price elasticities for food equal to ca. -0.8 (compensated) and -1 (uncompensated) and an income elasticity of approximately 0.6. The own-price elasticities are very similar to those presented here, whereas the income elasticity of demand for food seems to be significantly lower in Switzerland yet not implausible. In a more recent study using aggregate time-series data from Norway, Nygård (2012) found the price elasticity of demand for food to be approximately between -0.8 and -0.7 (depending on the model specification). Similarly, income elasticity was estimated to be between 0.14 and 0.78. Another recent study from Norway found own-price and income elasticities of demand for food of similar magnitudes (Gaarder, 2018). Here again, the results from this thesis seem to be in line with those findings. Gaarder (2018) furthermore defined a *Transport* category as done in this thesis and estimates price elasticities equal to -1.1 (uncompensated) and -0.8 (compensated), as well as an income elasticity of 1.2. All these estimates are slightly lower in this thesis, making *Transport* more price-inelastic in Switzerland, as well as a necessity rather than a luxury good.

It seems that the results, in general, are very plausible, despite some minor deviations from findings from comparable studies. Many of these deviations can be intuitively explained. For instance, on average, Switzerland might have a lower price elasticity of demand for alcoholic beverages due to its higher income level relative to most other countries. Moreover, Swiss households allocate only a small share of their budget to *Alcohol* in international comparisons (Aepli, 2014b), which could also be a reason for the lower elasticity estimate.
The difference between Switzerland and Norway regarding *Transport* could be attributed to geographical differences. As Switzerland is a small country, it is simple and convenient to live in one city and work elsewhere. Indeed, as BFS (2021) wrote, "In 2019, some eight out of ten employed persons in Switzerland were commuters, [...]", which seems quite high. Hence, the relatively low price elasticity of demand for *Transport* could be explained by this observation and its classification as a necessary good.

6.1 Limitations

The primary source of scepticism for the results of this thesis is arguably the large fraction of households that appear to violate the negativity restriction. I implemented many specifications of the QUAIDS model to find the possible cause of this surprising and puzzling finding. The main attempts include: Estimating the QUAIDS on a more homogeneous sub-sample of the data, using national price index data instead of Stone-Lewbel prices, changing the control variables in the budget share equations, not controlling for expenditure endogeneity, not controlling for sample selection (dropping the IMR as a control variable), and many more. Despite this large number of attempts and different approaches, the issue has persisted. Therefore, the cause of this finding can only be speculated upon.

It seems unlikely that this result reflects the actual consumption behavior of households. Therefore, I discuss several shortcomings and problems in the analysis that could potentially question the results in general, but in particular, the strong rejection of negativity.

1. Stone-Lewbel prices: Price data was calculated using equation (3.4). The problem with this procedure is that for many sub-categories, households do not report any expenditure. Consequently, the respective sub-category budget share is equal to zero. Therefore, it is impossible to calculate Stone-Lewbel prices for a household reporting zero consumption on *any* sub-category as the sub-category budget share enters the denominator of the formula. In my approach, I overcame this problem by assigning such households the mean Stone-Lewbel price of all other households for the given commodity. Doing so, however, might be a bad approximation of the actual prices faced by households and could potentially give undesired estimation results, which might explain the empirical deviation from demand theory. I mitigated this problem by defining the sub-categories as broad as possible to minimise the number of households reporting zero expenditure on the sub-categories. Despite this effort, the significantly positive estimate for *Dummy mean price* in Table A1.7 indicates that households facing a mean Stone-Lewbel price are more likely to violate negativity. This evidence suggests that I did not succeed in counteracting this problem.
Another solution could be to impute prices. This approach estimates the missing sub-expenditure share for each households reporting zero expenditure on a sub-category. Given the estimated values, one can easily calculate Stone-Lewbel prices even for the households without any expenditure on the sub-categories. One implementation of this approach can be found in Menon et al. (2017).

2. Selection model: There are several issues regarding the selection model. Firstly, the validity of the identifying independent variable *Tobacco* might be questionable. Although it seems plausible that a smoking household is indeed more likely to be a consumer of alcohol, it could, of course, also be the other way around. If a household is a consumer of alcohol, it is also more likely to smoke. Pryce (2016) suggested using a religion variable instead of a *Tobacco* indicator to identify abstaining households. However, given the unavailability of such information, he proposed the use of an interaction term between a dummy variable for zero gambling expenditure and a dummy for zero expenditure on pork. He argued that this would successfully identify Muslim households, as gambling and pork consumption are forbidden in Islam. Unfortunately, this turns out to be a bad approximation in my analysis. 10.6 % of the households do not report expenditure on gambling or pork. Since only 5.1 % of the Swiss population are Muslims (BFS, 2018), this seems to identify Muslim households poorly. Indeed, running the probit regression as done in Section 5.1, including this interaction term, gives an estimated coefficient that is highly insignificant (p-value = 0.763). Hence, I decided to drop this variable from the selection equation.
Secondly, I followed García-Enríquez and Echevarría (2016)'s approach and used national price indices as price data in the probit model. It is debatable whether this is a good approximation of the actual prices faced by households. Replacing national price indices by Stone-Lewbel prices gives highly implausible results in the subsequent QUAIDS estimation, which could be due to collinearity between the IMR and the regressors of the QUAIDS model (see Section 5.1). Therefore, I decided to stick to García-Enríquez and Echevarría (2016)'s specification. Still, it would be interesting to see if the results turned out better when imputed Stone-Lewbel prices are used as suggested in the previous bullet point.
Lastly, I adopted a single-hurdle model to correct for sample selection. According to this model, households decide whether to be a consumer of alcohol following a selection process. Hence, zero consumption because of a corner solution resulting from utility maximisation is not allowed. Not allowing for corner solutions is highly restrictive and does not have to be true. A more realistic approach would be to assume a double-hurdle model, which allows for corner solutions. This model, however, has only been developed for single equations and can thus not be used for demand systems as applied in this thesis.

3. IV regression: As briefly discussed in Section 5.2, it is unclear whether the instrument used is valid. The main problem is that *Log disposable income* is in itself a decision variable of households. If the consequence of this were that income (the instrument) and the error terms of the budget share equations are correlated, the effect of total expenditure on the budget shares would be wrongly determined. This concern could be counteracted by using better instrument variables that are truly exogenous, which seems difficult given the limited amount of variables in the data set.

4. Omitted variable bias: Obviously, a possible shortcoming of the empirical strategy of this thesis could be an omitted variable bias in the budget share equations. One might think of many factors influencing a households' choices of how to allocate their budgets that are also correlated with other right-hand side variables. A self-evident candidate could be a household's wealth. Although wealth arguably mostly affects the consumption decision regarding durable goods, it could also influence a household's budget allocation to non-durable goods. This argument is especially true for a household consisting of pensioners who decided to take the lump-sum withdrawals from their pension funds instead of monthly payments. Given that 55 % of all newly retired individuals in 2015 chose to withdraw their pension funds (BFS, 2017), not controlling for wealth could lead to problems in the analysis. Consider *Food*, for instance: Similar to the argument presented in Section 5.4, it could be the case that wealthier households spend a higher fraction of their budget on *Restaurants* and less on *Food* than less wealthy households. This would imply that wealth is a determinant of the budget share variables of *Restaurants* and *Food*. If wealth is also correlated with one or more explanatory variables such as the number of pensioners, for instance, the fundamental zero conditional mean assumption would be violated.

5. Standard errors: The problem regarding standard errors can be traced back to the selection model. I "manually" computed the IMR for all households and included the IMR as an additional regressor in the QUAIDS model. However, the IMR itself is estimated with some uncertainty. Thus, treating the IMR as a regular dependent variable does not account for the estimation error of the IMR and therefore under-reports standard errors of the QUAIDS model. Heckman (1979) showed how correct asymptotic standard errors can be calculated in a two-stage approach. Unfortunately, the option to do this has not been implemented in the Stata command `aidsills` by Lecocq and Robin (2015). This problem could be fixed by establishing a self-written program to estimate the QUAIDS that calculates correct standard errors by accounting for the imprecisely estimated IMR. Another possible solution could be bootstrapping of standard errors. The former approach would involve extensive coding, which in itself is error-prone and therefore not desirable. Bootstrapping appears to be a more attractive solution. However, to achieve bootstrapped standard errors that are estimated precisely enough, one would have to replicate the selection model and the QUAIDS many times. Efron and Tibshirani (1993, p. 52) stated that "very seldom are more than B = 200 replications needed for estimating a standard error", while Cameron and Trivedi (2009, p. 419) suggested computing 400 replications. Given this high number of replications required, paired with the large sample and the iterative nature of the estimator, this solution seems impractical. The computational effort entailed by this would arguably exceed its benefits.

Another source of errors could be collinearity between the IMR and the explanatory variables in the QUAIDS, which again could lead to wrongly estimated standard errors (Cameron and Trivedi, 2009, p. 546). This issue, however, is especially likely to occur if the same set of regressors are used in the selection equation and the outcome equation(s). To mitigate this concern, I added the variable *Tobacco* to the selection model, which I assume to be excluded from the outcome model.

Wrongly estimated standard errors can have implications for the inference of the results. Firstly, and most apparently, the estimated elasticities have too low standard errors. This follows from the fact that they are directly computed with the estimated coefficients of the QUAIDS, which have too low standard errors. Consequently, one could interpret elasticities to be significantly positive or negative, while they are, in fact, not. Secondly, as briefly mentioned in Section 5.4, the χ^2-statistics of the homogeneity and symmetry tests are too high. Hence, it could be the case that one falsely rejects the restrictions (committing a type I/α error).

7 Conclusion

This thesis was devoted to analysing consumer demand in Switzerland employing an empirical strategy that has not yet been implemented with Swiss data. The main goal was to estimate own-price, cross-price and income elasticities of demand for eight commodity groups. Such estimates can be used as a foundation for welfare analyses or an evaluation of the indirect tax system and serve as a basis for optimal decisions of policymakers. In addition to estimating elasticities, the empirical validity of the adding-up, homogeneity, symmetry and negativity restrictions postulated from demand theory has been tested and discussed.

For the analysis, I used household expenditure data collected through the Swiss Household Budget Survey from 2006-2017. Publicly available price index data was retrieved, and custom-defined price indices have been calculated for the eight commodity groups. Next, I introduced cross-sectional variation by calculating household-specific Stone-Lewbel prices. Finally, I estimated a QUAIDS model with that data, controlling for the numerous observations reporting zero expenditure on alcohol with a two-step selection model. The selection model resembles the one originally developed by Heckman (1979) and adapted in the context of demand systems by Heien and Wessells (1990). In the first step, I estimated a probit model and calculated the IMR for all households. The IMR, which is calculated differently for consumers and abstainers of alcohol, was then added as an additional regressor to the QUAIDS models. Thus, I had to estimate two separate demand systems for the two types of households, each of which including the appropriate IMR. Lastly, I controlled for expenditure endogeneity with an augmented regression approach, allowing testing for endogeneity of the expenditure variable. The non-linear QUAIDS was estimated with an iterated linear least squares estimator developed by Blundell and Robin (1999) until numerical convergence was reached. Given the estimated parameters of the demand system, I calculated sample means of the own-price, cross-price (both uncompensated and compensated) and income elasticities at the household level for the two household types.

For consumers of alcohol, own-price elasticities of demand range from approximately -0.2 (*Alcohol*) to -1.3 (*Others*) in the uncompensated case and from -0.1 (*Restaurants*) to

-1.1 (*Others*) in the compensated case. For the same household types, income elasticities are between 0.3 (*Food*) and 1.6 (*Recreation*). For abstainers of alcohol, uncompensated own-price elasticities of demand are in the interval -0.3 (*Restaurants*) and -1.2 (*Others*) while uncompensated own-price elasticities are between -0.1 (*Restaurants*) and -1 (*Others*). The income elasticities range from 0.3 for *Food* to 1.7 for *Recreation*. The estimated elasticities seem plausible and are roughly in line with findings from comparable studies.

When testing the restrictions derived from demand theory, both homogeneity and symmetry are rejected, while adding-up is satisfied by construction. Many previous studies have confirmed this result. Negativity, however, can neither be tested nor imposed but only checked after estimation. Only approximately one-third of all households seem to satisfy this restriction, which is both surprising and puzzling. However, the elasticities for the whole sample and the households that satisfy negativity are virtually the same.

Future studies could build on this thesis and investigate one or more commodity groups in more detail. It would, for instance, be interesting to reproduce Aepli (2014b)'s study but replacing unit values, which he used, with Stone-Lewbel prices. Moreover, one could investigate the *Transport* category at a more disaggregated level. This approach would potentially allow predicting the effect of the CO2 Act, which the Swiss population will vote on in Summer 2021. Another possible extension of this thesis, which would probably be more interesting from a theoretical perspective, is to locally impose negativity at the sample mean, as discussed in Section 5.5. By doing so, the effect of imposing negativity on the estimated elasticities could be determined, and one would be able to learn more about the practical relevance of this condition.

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Appendix

A1 Tables

Table A1.1: Composition of the commodity groups.

	Sub-categories	
	Level 1	Level 2
Food and non-alcoholic beverages (*Food*)	Food	Bread and grain products; Meat; Fish; Dairy products and eggs; Fats and oils; Fruits; Vegetables; Sweets; Other food
	Non-alcoholic beverages	Coffee, tea and cacao; Mineral waters and juices
Alcoholic beverages (*Alcohol*)	Beers	–
	Wines	–
	Spirits	–
Clothing and footwear (*Clothing*)	Clothing	Clothing fabrics and accessories; Men's clothing; Women's clothing; Children's clothing; Sportswear; Dry-cleaning and repairs
	Footwear	Men's footwear; Women's footwear; Children's footwear; Shoe repairs
Housing and energy (*Housing*)	Housing	Household maintenance; Household insurance
	Energy	Energy main residence; Energy secondary residence
Restaurants and accommodation (*Restaurants*)	Restaurants	Restaurants, Cafés and bars; Self-service restaurants and take-aways; Canteens; Private invitations
	Accommodation	Hotels, Hostels and private rooms; Supplementary accommodation
Transport and communication (*Transport*)	Transport	Fuel; Maintenance of vehicles; Other vehicle services; Transport services; Car insurance
	Communication	Postal services; Telecommunication services
Recreation and leisure (*Recreation*)	Recreation	Medical products; Storage devices and contents; Games, toys and hobbies; Spots and camping; Plants and garden; Pets and veterinary services
	Leisure	Recreational and cultural services; Books and brochures; Newspapers and periodicals; Other printed matters; Package holiday
Other goods and services (*Others*)	Other goods	Education; Personal care; Personal effects
	Other services	Health services; Social protection services; Financial services; Private health insurance; Other services

Table A1.2: QUAIDS estimates for consumers of alcohol.

	Budget shares							
	Food	Alcohol	Clothing	Housing	Restaurants	Transport	Recreation	Others
Log price parameters γ_{ij}								
Food	0.037***	0.001	-0.012***	0.006**	-0.014***	0.008	-0.022***	-0.004
	(0.004)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)
Alcohol	0.001	0.022***	-0.006***	-0.002	-0.006**	0.000	-0.003	-0.006**
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Clothing	-0.012***	-0.006***	0.043***	-0.009***	-0.010***	-0.015***	-0.003	0.013***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.003)	(0.002)
Housing	0.006	-0.002	-0.009***	-0.010***	-0.013***	0.018***	0.009*	0.001
	(0.004)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)
Restaurants	-0.014***	-0.006***	-0.010***	-0.013***	0.111***	-0.018***	-0.044***	-0.004
	(0.003)	(0.001)	(0.002)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
Transport	0.008*	0.000	-0.015***	0.018***	-0.018***	0.045***	-0.027***	-0.011**
	(0.003)	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)
Recreation	-0.022***	-0.003*	-0.003	0.009***	-0.044***	-0.027***	0.048***	0.042***
	(0.004)	(0.001)	(0.002)	(0.002)	(0.003)	(0.004)	(0.004)	(0.004)
Others	-0.004	-0.006***	0.013***	0.001	-0.004	-0.011**	0.042***	-0.031***
	(0.003)	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Income parameter β_i								
Log total expenditure	-0.141***	0.013**	0.002	0.002	-0.066***	-0.006	0.143***	0.051***
	(0.008)	(0.004)	(0.006)	(0.005)	(0.009)	(0.010)	(0.009)	(0.010)
Quadratic income parameter λ_i								
Log total expenditure squared	-0.002	0.004***	-0.007***	0.006***	-0.022***	0.010***	0.011***	0.000
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Residual parameter ρ_i								
Expenditure residual first stage	0.044***	0.007***	-0.015***	-0.001	-0.020***	0.004	-0.035***	0.016**
	(0.004)	(0.002)	(0.003)	(0.002)	(0.005)	(0.005)	(0.005)	(0.005)
Socio-demographic parameters ξ_i								
Woman reference person	-0.009***	-0.002**	0.012***	-0.003***	-0.015***	-0.010***	0.005**	0.022***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Number of children	0.025***	-0.002***	0.001*	0.003***	-0.016***	-0.011***	-0.004***	0.004***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of adults	0.046***	-0.005***	-0.004***	0.006***	-0.028***	-0.009***	-0.010***	0.004**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of pensioners	0.060***	-0.006***	-0.008***	0.015***	-0.047***	-0.040***	0.000	0.026***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Number of earners	-0.008***	-0.001*	0.001	-0.004***	0.013***	0.018***	-0.007***	-0.012***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
IMR parameter $\sigma_{\nu u_i^c}$								
Inverse Mills ratio	-0.009	-0.039***	0.025***	-0.009	-0.030**	-0.084***	0.103***	0.043***
	(0.009)	(0.004)	(0.006)	(0.005)	(0.010)	(0.011)	(0.011)	(0.011)
N	20'194	20'194	20'194	20'194	20'194	20'194	20'194	20'194
R^2	0.301	0.074	0.119	0.129	0.218	0.134	0.108	0.127
Yearly dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Number of iterations until numerical convergence occurred: 7 (tolerance level: 1×10^{-5}). Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001.

Table A1.3: QUAIDS estimates for abstainers of alcohol.

	Budget shares						
	Food	Clothing	Housing	Restaurants	Transport	Recreation	Others
Log price parameters γ_{ij}							
Food	0.050***	-0.012***	0.006**	-0.017***	0.000	-0.029***	0.002
	(0.005)	(0.003)	(0.002)	(0.004)	(0.005)	(0.005)	(0.005)
Clothing	-0.012***	0.040***	-0.011***	-0.009**	-0.019***	-0.001	0.012***
	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)	(0.004)	(0.003)
Housing	0.006	-0.011***	0.007**	-0.017***	0.016**	-0.001	0.000
	(0.005)	(0.003)	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)
Restaurants	-0.017***	-0.009***	-0.017***	0.110***	-0.022***	-0.045***	0.000
	(0.004)	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)
Transport	0.000	-0.019***	0.016***	-0.022***	0.085***	-0.040***	-0.020***
	(0.004)	(0.002)	(0.002)	(0.004)	(0.005)	(0.005)	(0.004)
Recreation	-0.029***	-0.001	-0.001	-0.045***	-0.040***	0.090***	0.027***
	(0.004)	(0.002)	(0.002)	(0.004)	(0.005)	(0.006)	(0.004)
Others	0.002	0.012***	0.000	0.000	-0.020***	0.027***	-0.021***
	(0.004)	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)
Income parameter β_i							
Log total expenditure	-0.133***	-0.007	0.010	-0.055***	-0.026*	0.169***	0.042***
	(0.010)	(0.007)	(0.006)	(0.011)	(0.013)	(0.011)	(0.011)
Quadratic income parameter λ_i							
Log total expenditure squared	0.000	-0.009***	0.008***	-0.021***	0.008***	0.013***	0.000
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Residual parameter ρ_i							
Expenditure residual first stage	0.051***	-0.017***	0.001	-0.031***	0.024***	-0.058***	0.030***
	(0.005)	(0.004)	(0.003)	(0.006)	(0.007)	(0.006)	(0.006)
Socio-demographic parameters ξ_i							
Woman reference person	-0.003	0.013***	0.001	-0.032***	-0.016***	0.006**	0.031***
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)	(0.002)	(0.002)
Number of children	0.029***	0.001	0.004***	-0.021***	-0.009***	-0.010***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of adults	0.049***	-0.004***	0.010***	-0.035***	-0.011***	-0.013***	0.004*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Number of pensioners	0.069***	-0.009***	0.024***	-0.058***	-0.056***	-0.002	0.031***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)
Number of earners	-0.008***	-0.002	-0.004***	0.013***	0.019***	-0.009***	-0.010***
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
IMR parameter $\sigma_{\nu u_i^a}$							
Inverse Mills ratio	-0.024*	0.015*	-0.005	-0.021	-0.086***	0.099***	0.022
	(0.011)	(0.008)	(0.007)	(0.012)	(0.014)	(0.012)	(0.013)
N	14'101	14'101	14'101	14'101	14'101	14'101	14'101
R^2	0.286	0.106	0.144	0.212	0.145	0.111	0.127
Yearly dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Number of iterations until numerical convergence occurred: 7 (tolerance level: 1×10^{-5}). Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001.

Table A1.4: Predicted budget shares ($\widehat{w}_i$), observed budget shares ($\overline{w}_i$) and income elasticities (ϵ_i) for consumers and abstainers of alcohol (sample averages for households satisfying Slutsky negativity).

	Consumers			Abstainers		
	$\widehat{w}_i$	$\overline{w}_i$	ϵ_i	$\widehat{w}_i$	$\overline{w}_i$	ϵ_i
Food	0.148***	0.156	0.102**	0.143***	0.152	0.061
	(0.001)	–	(0.032)	(0.001)	–	(0.043)
Alcohol	0.032***	0.033	0.837***			
	(0.001)	–	(0.062)			
Clothing	0.068***	0.065	1.451***	0.069***	0.065	1.471***
	(0.001)	–	(0.037)	(0.001)	–	(0.046)
Housing	0.056***	0.057	0.604***	0.058***	0.061	0.545***
	(0.001)	–	(0.044)	(0.001)	–	(0.056)
Restaurants	0.172***	0.164	1.146***	0.179***	0.172	1.208***
	(0.001)	–	(0.024)	(0.001)	–	(0.030)
Transport	0.211***	0.219	0.785***	0.230***	0.233	0.731***
	(0.001)	–	(0.025)	(0.002)	–	(0.030)
Recreation	0.165***	0.161	1.597***	0.169***	0.162	1.661***
	(0.001)	–	(0.025)	(0.001)	–	(0.030)
Others	0.149***	0.144	1.340***	0.152***	0.155	1.269***
	(0.001)	–	(0.030)	(0.002)	–	(0.036)

Note: Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001.

Table A1.5: Uncompensated and compensated price elasticities of demand for consumers of alcohol (sample averages for households satisfying Slutsky negativity).

	Food	Alcohol	Clothing	Housing	Restaurants	Transport	Recreation	Others
Uncompensated								
Food	-0.869***	0.044***	0.010	0.075**	0.017	0.197***	0.226***	0.199***
	(0.022)	(0.012)	(0.014)	(0.025)	(0.017)	(0.020)	(0.021)	(0.018)
Alcohol	0.095	-0.318***	-0.181***	-0.056	-0.124***	0.018	-0.110*	-0.162***
	(0.049)	(0.027)	(0.032)	(0.054)	(0.037)	(0.044)	(0.046)	(0.040)
Clothing	-0.177***	-0.105***	-0.411***	-0.152***	-0.238***	-0.297***	-0.171***	0.100***
	(0.033)	(0.018)	(0.022)	(0.036)	(0.024)	(0.028)	(0.030)	(0.027)
Housing	0.123***	-0.025	-0.128***	-1.158***	-0.160***	0.394***	0.252***	0.098***
	(0.034)	(0.018)	(0.022)	(0.037)	(0.026)	(0.032)	(0.033)	(0.028)
Restaurants	-0.140***	-0.033**	-0.074***	-0.082***	-0.408***	-0.134***	-0.242***	-0.035*
	(0.021)	(0.011)	(0.013)	(0.023)	(0.018)	(0.018)	(0.019)	(0.017)
Transport	0.037	0.004	-0.051***	0.094***	-0.047**	-0.749***	-0.067***	-0.007
	(0.019)	(0.010)	(0.012)	(0.021)	(0.015)	(0.018)	(0.018)	(0.016)
Recreation	-0.019	-0.046***	-0.081***	0.030	-0.328***	-0.257***	-0.988***	0.091***
	(0.023)	(0.012)	(0.015)	(0.025)	(0.017)	(0.020)	(0.021)	(0.018)
Others	0.014	-0.051***	0.053**	-0.004	-0.073***	-0.127***	0.144***	-1.295***
	(0.026)	(0.014)	(0.017)	(0.028)	(0.020)	(0.023)	(0.025)	(0.020)
Compensated								
Food	-0.854***	0.048***	0.017	0.080**	0.034*	0.218***	0.243***	0.214***
	(0.024)	(0.012)	(0.014)	(0.025)	(0.015)	(0.018)	(0.019)	(0.017)
Alcohol	0.219***	-0.291***	-0.124***	-0.009	0.020	0.194***	0.029	-0.038
	(0.052)	(0.026)	(0.032)	(0.055)	(0.032)	(0.041)	(0.042)	(0.039)
Clothing	0.037	-0.058**	-0.312***	-0.071*	0.011	0.009	0.069*	0.316***
	(0.035)	(0.018)	(0.021)	(0.036)	(0.021)	(0.027)	(0.028)	(0.026)
Housing	0.212***	-0.005	-0.087***	-1.125***	-0.056*	0.521***	0.352***	0.188***
	(0.036)	(0.018)	(0.022)	(0.038)	(0.022)	(0.029)	(0.030)	(0.027)
Restaurants	0.030	0.004	0.004	-0.018	-0.211***	0.108***	-0.052**	0.136***
	(0.022)	(0.011)	(0.013)	(0.023)	(0.015)	(0.017)	(0.018)	(0.016)
Transport	0.153***	0.030**	0.003	0.138***	0.088***	-0.584***	0.063***	0.110***
	(0.020)	(0.010)	(0.012)	(0.021)	(0.013)	(0.016)	(0.017)	(0.015)
Recreation	0.217***	0.006	0.028	0.119***	-0.054***	0.080***	-0.724***	0.329***
	(0.024)	(0.012)	(0.014)	(0.025)	(0.015)	(0.019)	(0.019)	(0.018)
Others	0.212***	-0.008	0.145***	0.070*	0.157***	0.155***	0.365***	-1.096***
	(0.027)	(0.014)	(0.016)	(0.028)	(0.017)	(0.021)	(0.023)	(0.020)

Note: Standard errors in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table A1.6: Uncompensated and compensated price elasticities of demand for abstainers of alcohol (sample averages for households satisfying Slutsky negativity).

	Food	Clothing	Housing	Restaurants	Transport	Recreation	Others
Uncompensated							
Food	-0.788***	0.006	0.083**	0.029	0.128***	0.239***	0.241***
	(0.028)	(0.021)	(0.030)	(0.025)	(0.026)	(0.027)	(0.024)
Clothing	-0.188***	-0.476***	-0.171***	-0.233***	-0.354***	-0.133***	0.084*
	(0.039)	(0.029)	(0.041)	(0.033)	(0.034)	(0.035)	(0.033)
Housing	0.135***	-0.140***	-0.866***	-0.183***	0.347***	0.081*	0.080*
	(0.040)	(0.029)	(0.043)	(0.035)	(0.038)	(0.038)	(0.034)
Restaurants	-0.141***	-0.072***	-0.098***	-0.451***	-0.164***	-0.256***	-0.026
	(0.024)	(0.017)	(0.026)	(0.023)	(0.022)	(0.021)	(0.020)
Transport	-0.016	-0.056***	0.077**	-0.042*	-0.589***	-0.077***	-0.027
	(0.022)	(0.016)	(0.024)	(0.019)	(0.022)	(0.020)	(0.019)
Recreation	-0.026	-0.068***	-0.037	-0.352***	-0.319***	-0.841***	-0.018
	(0.026)	(0.019)	(0.028)	(0.022)	(0.023)	(0.024)	(0.022)
Others	0.054	0.053*	-0.012	-0.042	-0.165***	0.047	-1.204***
	(0.030)	(0.021)	(0.032)	(0.026)	(0.027)	(0.028)	(0.024)
Compensated							
Food	-0.780***	0.011	0.087**	0.040	0.142***	0.250***	0.251***
	(0.030)	(0.021)	(0.031)	(0.022)	(0.024)	(0.024)	(0.023)
Clothing	0.022	-0.374***	-0.086*	0.030	-0.016	0.115***	0.308***
	(0.042)	(0.028)	(0.042)	(0.029)	(0.033)	(0.032)	(0.031)
Housing	0.213***	-0.102***	-0.834***	-0.085**	0.472***	0.173***	0.163***
	(0.043)	(0.029)	(0.043)	(0.030)	(0.034)	(0.034)	(0.032)
Restaurants	0.032	0.012	-0.028	-0.235***	0.114***	-0.052**	0.158***
	(0.026)	(0.017)	(0.026)	(0.019)	(0.020)	(0.020)	(0.019)
Transport	0.088***	-0.005	0.120***	0.089***	-0.422***	0.046*	0.084***
	(0.024)	(0.016)	(0.024)	(0.017)	(0.019)	(0.018)	(0.018)
Recreation	0.211***	0.047*	0.060*	-0.055**	0.063**	-0.561***	0.235***
	(0.028)	(0.019)	(0.028)	(0.020)	(0.022)	(0.022)	(0.021)
Others	0.235***	0.141***	0.062*	0.185***	0.126***	0.261***	-1.011***
	(0.032)	(0.021)	(0.032)	(0.022)	(0.025)	(0.025)	(0.023)

Note: Standard errors in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table A1.7: Determinants of violation of Slutsky negativity.

	Dummy negativity
Woman reference person	0.186***
	(0.019)
Number of children	0.403***
	(0.011)
Number of adults	0.668***
	(0.016)
Number of pensioners	1.125***
	(0.022)
Number of earners	-0.143***
	(0.016)
Log disposable income	-0.880***
	(0.020)
Alcohol consumer	0.822***
	(0.016)
Dummy mean price	0.251***
	(0.021)
N	34’295

Note: Standard errors in parentheses.
* p<0.05, ** p<0.01, *** p<0.001.