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The cost of food consumption across socioeconomic groups in Switzerland: estimation of the price of a healthier diet and its impact on nutritional inequality

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Executive summary

Aim of the study

The principal objective of the project is to estimate the relationship between the financial cost of food con-sumption and nutritional quality of diets across socio-economic groups in Switzerland.

Material and methods

We first conducted a systematic overview of the scientific literature (Medline, Embase and Econlit from 1990 to January 2018) on the relationship between diet quality and diet cost in the fields of public health, nutrition science and health economics.

We estimated the cost of diets using data from the Consumer Price Index Retail Scanner dataset (CPI) and the Swiss Household Budget Expenditure Survey (SHBES), linked these data to menuCH dietary intake data and subsequently analyzed the relationship between food expenditures and nutritional quality across socioeconom-ic status (SES) groups in Switzerland. We assessed diet quality using the Swiss Food Pyramid Score and the Healthy Eating Index (HEI).

Using menuCH, CPI and SHBES datasets, we conducted a policy simulation for a sugar-sweetened beverage (SSBs) tax in Switzerland. We exploited annual fluctuations in prices and associated demand responses in consumption to estimate the price elasticity of demand of SSBs amongst Swiss households.

We exploited the large exchange rate shock that occurred on January 15th, 2015 following a decision by the Swiss National Bank as a natural experiment to investigate the causal relationship of an increase in purchasing power on changes in individual food consumption and on the nutritional quality of diets. A large proportion of the Swiss population lives near the border hence cross border shopping is relatively easy. We exploited individual-level dietary data collected before and after the shock within menuCH in a regression-discontinuity design framework with time to the exchange rate shock as the running variable.

Results and significance

The systematic overview of the literature (based on 139 articles) showed that there is a positive association between diet cost and diet quality in the public health literature, with evidence coming mainly from observa-tional studies conducted in high-income countries and with substantial heterogeneity across studies. This find-ing, combined with the body of evidence coming from economics, in particular the results of quasi-experimental studies, suggests a causal relationship. Studies in economics provide a broader view of cost than just food prices and consider time costs of searching for and preparing foods, as well as availability barriers, as important factors influencing food choices.

We found a non-linear relationship between food expenditure and diet quality in Switzerland when combin-ing menuCH data with CPI and SHBES datasets. At lower levels of daily expenditure, there is significant scope to increase daily expenditure and time cost on food to improve diet quality. We find that close to 40% of the population would increase the quality of their diet by increasing their daily expenditure over to 17 CHF per day, using the HEI as diet quality measure. After the turning point, at higher levels of daily ex-penditure, increasing daily expenditure on food

has a detrimental impact on diet quality. We found that household net income had no direct impact on diet quality and that larger households tended to have lower daily food expenditure.

A tax on SSBs in Switzerland would substantially reduce SSBs consumption. Our results suggest that a rel-atively large increase of 25 percentage points may have a substantial effect on population weight. While such tax would be perceived as affecting the whole population, heavy consumers of SSBs would be the ones that would benefit the most from the reduction of SSBs intake.

The exchange rate shock had mixed effects on diet quality. Sodium intake was significantly lower, but the other changes in dietary intakes were not statistically significant (decreases in total calories fiber, vegetable and processed meat intakes, increases in SBB consumption, red meat intake and healthy eating index) like-ly due to a lack of power. A significant price reduction across all foods did not appear to significantly in-crease the consumption of healthier foods. These results therefore suggest that multi-sectoral policies may be required to improve nutritional quality in Switzerland.

Our results suggest that the relationship between food cost and diet quality is complex and that there might not be a one-size fits all policy option to address the public health and equity consequences of unhealthy diets.

Key words: food consumption, diet costs, nutritional value, socio-economic status

0 Introduction

Evidence that a healthy diet is important to human health has long been established.[1] In 2017, globally, nearly 20% of all deaths (i.e. 11 million) and 255 million disability-adjusted life years were attributable to dietary risk factors.[2] In the last 30 years, there has been a rapid increase in obesity prevalence in high income countries, with lower income countries experiencing similar trends.[3, 4]

Diet cost has been identified as an important barrier to healthy eating.[5] Relative food costs between more nutritious and nutrient poor food has been increasing, along with rising time costs for food preparation relative to prepared foods.[6] It is therefore important to quantify the differences in prices of healthy relative to unhealthier diets. The relationship between diet cost and diet quality has been summarized in prior reviews.[7, 8] A meta-analysis, found that the healthiest diets cost, on average, approximately $1.50 more per person per day to consume than unhealthier diets.[8] More nutritious products have a higher cost relative to calorie-dense, nutrient-poor foods.[7] Hence, food costs and financial affordability may represent a significant barrier to healthy eating, which may exacerbate socio-economic inequalities in health and increase the prevalence of diet-related diseases in low-income communities, which spend less, but consume proportionately more of their income on food.[9]

Many important public health and policy implications can be gained from the study of the cost of healthier diets. As growing evidence indicates, even small dietary changes could have significant impacts in reducing the prevalence of non-communicable diseases.[10] Furthermore, there is increasing interest in policy interventions aiming at changing relative prices of selected foods through carefully designed tax or subsidy policies as well as providing consumers with better information to improve their dietary choices.[11]

While these issues are well-documented in the international litterature, there is a lack of evidence for Switzerland. In this report, we present findings from four studies on the relationship between food price and quality, with empirical applications in Switzerland. In the first chapter, we provide a systematic overview of the international literature from public health and economics and present results of a meta-analysis. In the second chapter, we use data from the first national nutritional survey menuCH to explore the association between diet cost and quality in Switzerland as well as the potential differences between socioeconomic groups in terms of food expenditures and diet quality. In the third chapter, we discuss the potential impact of a specific fiscal policy (i.e. tax on sugar-sweetened beverages) on consumption, including equity considerations. Finally, the fourth chapter exploits an exogenous shock on food prices following the abrupt change in the EUR/CHF exchange rate decided by the Swiss National Bank in 2015 using detailed individual-level dietary data collected before and after the shock in a regression discontinuity design.

1 Relationship between diet cost and nutritional quality: evidence from the public health, nutrition science, and economics literature

1.1 Introduction

In this first chapter we review the multidisciplinary evidence on the relationship between diet cost and quality. Specifically, we broaden the search strategy employed by past reviews by screening the scientific literature from public health, nutrition science and health economics. These distinct research fields explore the cost-quality relationship using different methods and perspectives, which offer a variety of insights useful to inform policy.

In a first step, we conduct a meta-analysis of studies from the public health literature that analyze the association between diet cost and quality and we assess the robustness of the findings, in particular with respect to methodological choices. We then review findings from studies not included in the meta-analysis in a narrative style, including those from the economics literature. Studies in the field typically explore mechanisms that drive the observed associations and attempt to uncover causal relationships. Hence, this research can provide not only insights for public policy interventions aimed at reducing the cost of healthier foods or more generally at altering the relative prices of food items, but also knowledge on the broader economic and behavioral constraints faced by consumers.

1.2 Methods

1.2.1 Search strategy and selection criteria

Systematic searches were conducted using Medline, Embase (via Ovid) and Econlit from 1990 to January 2018. Additional studies were identified by reviewing reference lists of all articles included after full text review. We focused our search on literature analyzing the relationship between the cost of food and measures of the nutritional quality or composition of reported diets, enabling an assessment of the healthiness of the diets (see appendixThe cost of food consumption across socioeconomic groups in Switzerland

Table 6.3 for search strings, terms and sequences used in the Ovid interface). Studies were included if they reported any measure of food cost and any specified measure of food healthfulness. Reviews, letters, editorials and commentaries, were excluded. Studies evaluating policy interventions were excluded because they often directly alter the price of foods pre-identified as of poor or higher nutritional quality. We distinguish studies from the public health literature from studies from economics throughout the chapter. We define economic studies as studies drawn from the application of economic theory, models and empirical techniques that analyze individuals' dietary decisions in relation to economic constraints influencing the quality of food consumption. For the meta-analysis, we included only studies studies that report on the relationship between food cost and quality of diets with sufficient details for a formal quantitative analysis (in particular regarding uncertainty around point estimates). All other studies were included in the narrative summary of the literature review.

1.2.2 Data extraction

For all studies included in the meta-analysis, we extracted information on country, setting, time period, target population, measures of diet quality and cost, and study design. Each study was then assigned a discipline (i.e. public health vs. economics) and its suitability for inclusion in the meta-analysis was assessed.

1.2.3 Meta-analysis

Studies reporting on price differences between healthy and unhealthy dietary patterns were grouped to perform the meta-analysis. We include in this group both studies reporting extreme nutritional quality differences (e.g. between the lowest and highest quality quantiles), as well as studies reporting on the cost implications of the changes from population average diets necessary to meet nutritional recommendations (including in some cases disease-specific diets).

Studies which reported nutritional quality differences between food items were grouped separately across six food groups, including fat, sugar, fruits and vegetables, grains, protein and dairy. Other studies reporting diet cost in quantiles did not provide information on cost differences between dietary patterns. However it was possible to aggregate this studies using dietary nutritional differences between food items as outcomes.

Study outcomes were transformed into response ratios by combining costlier with less costly diets/food items. For studies that reported dietary nutritional outcomes, response ratios were combined using higher and lower quality diets. The response ratio is commonly used as an effect measure because it quantifies the proportionate difference between two groups.[12, 13] We combined response ratios by estimating a restricted maximum-likelihood random effects model (REML).[14, 15] Random-effects models do not underestimate the standard error and thus adequately reflect uncertainty.[16] Heterogeneity was assessed using Q-statistic with a p-value, I^2, H^2 and τ^2.

We then conducted a meta-regression analysis with a limited number of moderators due a relatively small number of observations. We restrict the analysis to explanatory variables including country, type of cost data used in the study, measure of nutritional quality and dummy variables explaining the type of dietary comparison and study type. The dependent variable is the response ratio. Finally publication bias was assessed using a contour-enhanced funnel plot.[17] All analyses were undertaken using Stata V.16 (StataCorp, College Station, Texas, USA).

1.3 Results

1.3.1 Included studies

The search yielded 4803 potential articles from which 1093 were duplicates, yielding 3710 articles to review. After review for title, 678 were selected by abstract, of which 147 were full-text reviewed for inclusion by a single reviewer. Following careful review of full texts, 102 were included in the review. An additional 37 articles were identified from hand-searches of references listed in the full-text articles. The corresponding PRISMA flow chart is shown in Figure 6.1.

In total, we therefore included 139 articles on the relationship between diet cost and nutritional quality conducted in 28 different countries. Of these, 43 articles have been reported in previous systematic reviews.[7, 8] Among the 139 articles, 39 studies fulfilled the criteria to be included in the meta-analysis. The remaining 100 articles were included in the narrative review.

1.3.2 Main findings from the public health literature

Observational studies using self-reported food intake constitute the highest proportion (49.5%) of research on the cost of healthier diets. The most frequent dietary assessment methods in epidemiological studies include the 24-hour dietary recall, dietary record, dietary history, and food frequency questionnaires.[18-33] Differences between dietary assessment methods as well as their strengths and limitations were already discussed elsewhere.[34] Most studies found a positive and significant association between diet cost and nutritional quality (50.7%) using self-reported food intake data.[18, 19, 21, 24, 27, 28, 32, 35-61] Predominantly, studies found that high-energy dense foods were less costly than foods high in nutrient density, but with low-energy density levels.[37, 41, 58, 62, 63] Low-energy density foods such as vegetables, fruits, fish and lean meat were more expensive than energy-dense foods such as fats and oils, added sugars, and refined grains. Foods rich in added sugar, saturated fat and sodium are relatively cheaper than foods rich in vitamins, calcium, iron, magnesium, protein and/or fiber.[32, 35, 36, 47, 53, 58, 64-66] Monetary cost of vegetables was significantly positively associated with protein, potassium and sodium intake.[67] Higher food prices, such as for low-fat dairy products, were associated with increased blood sugar among people with type 2 diabetes.[68]

There is a growing interest in analyzing affordability of disease-specific diets. The current body of literature focuses on gluten-free diets for celiac disease or gluten sensitivity, specific diets for inflammatory bowel diseases, diabetes, obesity and hypercholesterolemia, cardiovascular diseases and cancers.[18, 20-28, 30-33, 50] The association between diet cost and diet quality is not clear for these disease-specific diets.

Other evidence suggests that a healthier diet may be achieved without an increase in diet costs and that other factors might pose a greater barrier to healthy eating.[50, 69] Careful budgeting, using lower cost vegetables can reduce dietary costs and satisfy dietary recommendations for fruit and vegetables intake.[70] The presence of "positive deviants", i.e. individuals able to search for, and select, foods with a higher nutritional quality to price ratio, amongst low-income groups, who are usually more price sensitive and at higher risk of poor nutritional quality, seems to confirm that a healthier diet is not necessarily more costly.[45] In Japan, studies found that diet cost was positively associated with not only healthy dietary components but also with less healthy ones.[67, 71, 72]

Several studies have evaluated the relationship between diet cost and nutritional quality using (hypothetical) market baskets of foods (29%). These studies evaluate the price differential between healthy and less healthy food baskets without the need for data on individuals' observed food intake by using a pre-determined recommended healthy diet compared with current household diets based on a list of commonly consumed foods.[9] The construction of these market baskets ranged from baskets based on national dietary guidelines [31, 73-78] to single nutrient comparisons.[79-81] The majority of the studies confirm the positive association between diet cost and diet quality.

The scope of the analyses varies from national [6, 26, 33, 76-78, 81-93], local [20, 23, 25, 42, 62-65, 73-75, 79, 80, 94-105] and specific populations [31, 106-108], including disease specific diets. Several studies constructed hypothetical households, which represent families from low socioeconomic status, to examine the affordability of healthy food choices.[44, 61, 70, 73, 75, 98]

Spatial analyses show that the cost of healthier market baskets vary by socio-economic groups and geographic location. Rural and remote locations have limited access to healthier products, which can constitute a barrier to healthy eating together with higher costs for healthy food items.[99, 103] Diet cost also varies by type of retail store. Findings suggest that bulk retailers provide the best ratio of diet healthiness to cost and access to healthier options is driven by the availability and characteristics of food retailers.[42, 64, 73, 75, 79] However, other studies find conflicting results as to whether lower availability and higher costs of low-energy density, but nutrient rich foods might lead low-income individuals to consume unhealthier diets.[91, 100] School canteens are also an important food environment. School menus meeting the dietary guidelines were relatively more expensive than other less healthy food choices.[77, 93]

While previous studies analyzed the cost differences across various dietary patterns, linear programming models offer a mathematical optimization approach to derive affordable diets that meet pre-specified food constraints while resembling local eating habits and locally available foods (21.5%). These approaches can identify diets and specific foods that are cost-effective but may require significant dietary changes from existing food preferences.[40, 61, 74, 78, 82, 85, 88, 90, 92, 96, 97, 106, 109-111] The introduction of budget constraint, showed that decreased the energy provided by meat, fresh vegetables, fresh fruits, vegetable fat, and yogurts and increased the energy from processed meat, eggs, offal, mixed grains, nuts and seeds.[61, 74]

1.3.2.1 Methodological differences: Nutritional quality indicators

Studies often (36.2%) use indices or nutrition quality scores to evaluate the healthiness of diets/foods compared to their cost.[19, 27, 31, 35, 36, 39, 40, 45, 47, 49-51, 54-57, 59, 66, 73, 76, 112] The studies included in this review used various nutritional quality metrics such as the Healthy Eating Index (HEI) and the Healthy Diet Indicator (HDI); individual intakes of nutrients, Mean Adequacy Ratio (MAR) and Mean Excess Ratio (MER); and various metrics on adherence to healthy dietary patterns, such as the Mediterranean Diet Score (MDS/ KIDMED) or national nutritional guidelines. However, many studies compared the nutritional quality within and between food groups, such as fruits and vegetables or/and fats and oils, refined or whole grain breads, with their cost, thereby increasing the range of nutritional quality indicators.[24, 32, 40, 42, 44, 53, 78-81]

1.3.2.2 Methodological differences: Diet cost

Time series and survey data taken from cross-sectional household expenditure surveys, with representative food prices are often derived by national agencies. These data are widely available and make it easier to map food prices.[6, 19, 37-40, 43, 49, 51, 52, 56, 57, 66, 67, 71, 72, 74, 77, 83, 85, 87, 92, 102, 107, 111-127] However, national food cost databases average prices across populations over a relatively short period of time, which does not allow for seasonality or spatial variation and often do not represent the prices faced by certain populations, masking significant price heterogeneity even within similar products.[65]

Studies have often used retail scanner data (13.8%) from commercial providers that track super-market transactions at the retailer as well as household/consumer level.[61, 66, 68, 76] Although, it allows for assessment of household purchasing behavior it is costlier and more difficult to access. Recent studies combine both methods to ensure an extensive coverage of products' prices.[37, 117]

Food prices were also collected by retailer store checks of prices in-store or through retailers' internet websites.[18, 20-23, 25-33, 35, 36, 42, 44, 47, 48, 50, 53, 55, 58-60, 62-65, 69, 73, 75, 78-82, 84, 88, 89, 94-101, 103-106, 108, 128-132] Relatively more time consuming, this approach overcomes some of the biases inherent to the use of other data types, such as food price sampling bias, seasonal effects and aggregation of food items. The first, can be due to price collection methods as purchases receipts, that provide only the prices paid by consumers, and may lack information on the entire price distribution as the prices collected are dependent on the consumption habits of the sampled population. Seasonal effects, refer to the regular intra-annual variability at predetermined time periods. Both seasonality in production and demand might impact the actual prices faced by consumers. The basic assumption of the aggregation bias hypothesis is that the individual food items from which the aggregated data is composed may be heterogenous in terms of their individual characteristics. Using average national prices, for example, might suffer from these two types of bias.

Collection of receipts at point of sale have the ability to overcome the misreporting from self-reported diet assessment methods but do not correspond to actual food consumption. Furthermore, actual prices paid can include discounts and reflect consumer search and choice behavior. It is feasible for participants to maintain good records of food receipts but processing time for research is longer.[24, 45, 90, 93, 109, 133-139]

1.3.2.3 Meta-analysis and meta-regression

From the 139 studies included in the literature review, 39 were included in the meta-analysis. One hundred of these were excluded from the meta-analysis, 12 because of insufficient data and 88 because they did not report clear effect sizes in either diet costs or quality (see Appendix A Table 6.2 for a summary of all included articles and other relevant information). Among the final studies, 11 were market-basket surveys with the number of food items compared ranging from 2 to 7,575. Twenty-eight studies were dietary assessment surveys including between 13 to 78,191 participants. The market studies including multiple price and food item comparisons as well as multiple participants' groups, contribute more than one observation to this analysis.

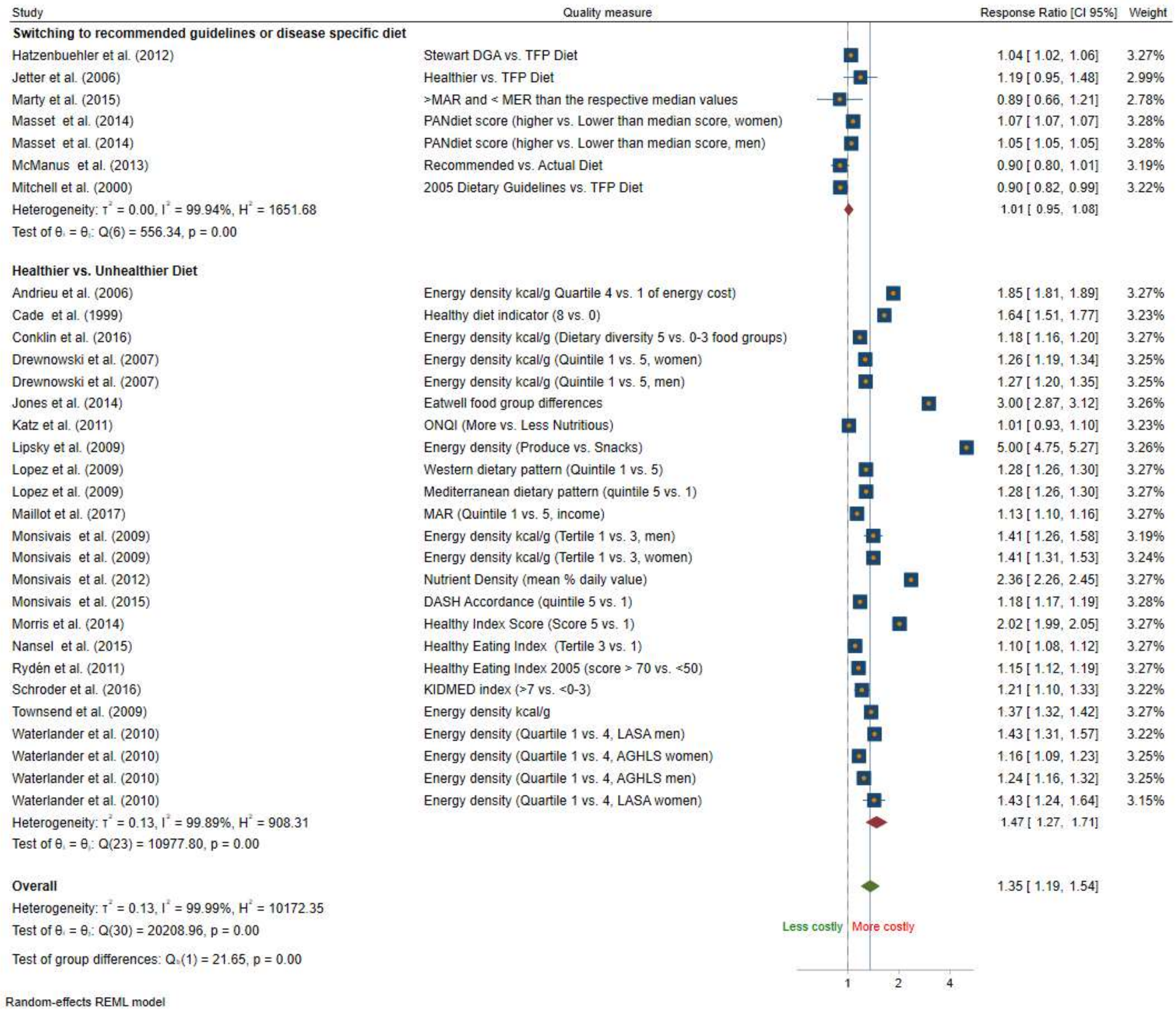
Analysis of price differences between diets of differing nutritional quality were aggregated in different groups. The first group, corresponds to diets meeting dietary guidelines or disease specific recommendations compared to departures from average diet patterns or past previously recommended diet guidelines. The second group, corresponds to studies comparing opposite quantiles of diet quality (high vs low diet quality).

The pooled random effects response ratio across all studies was 1.35 (95% CI 1.19 to 1.54); with healthier dietary patterns costing on average 35% more than their lower quality counterparts (Figure 1.1). In this analysis, effect heterogeneity was high (Figure 1.1). Studies that compared costs of observed diet to the recommended guidelines or disease-specific diets found no significantly difference of diet cost.

The pooled random effects response ratio of food items was 1.25 (95% CI 1.19 to 1.42); suggesting that healthier food options would cost 25% more, on average, than their unhealthier counterparts. Animal protein exhibited the highest proportional difference by healthfulness followed by whole grains and fruits and vegetables (Figure 1.2). However, the grains group contains a unique study that evaluated price differences across different retailer types. On average, the healthier protein choice was 76% more expensive than the unhealthier choice. Confidence intervals for fats, fruits and vegetables, grains and sugar do not allow for null hypothesis exclusion. There are a high heterogeneity across studies (Figure 1.2)

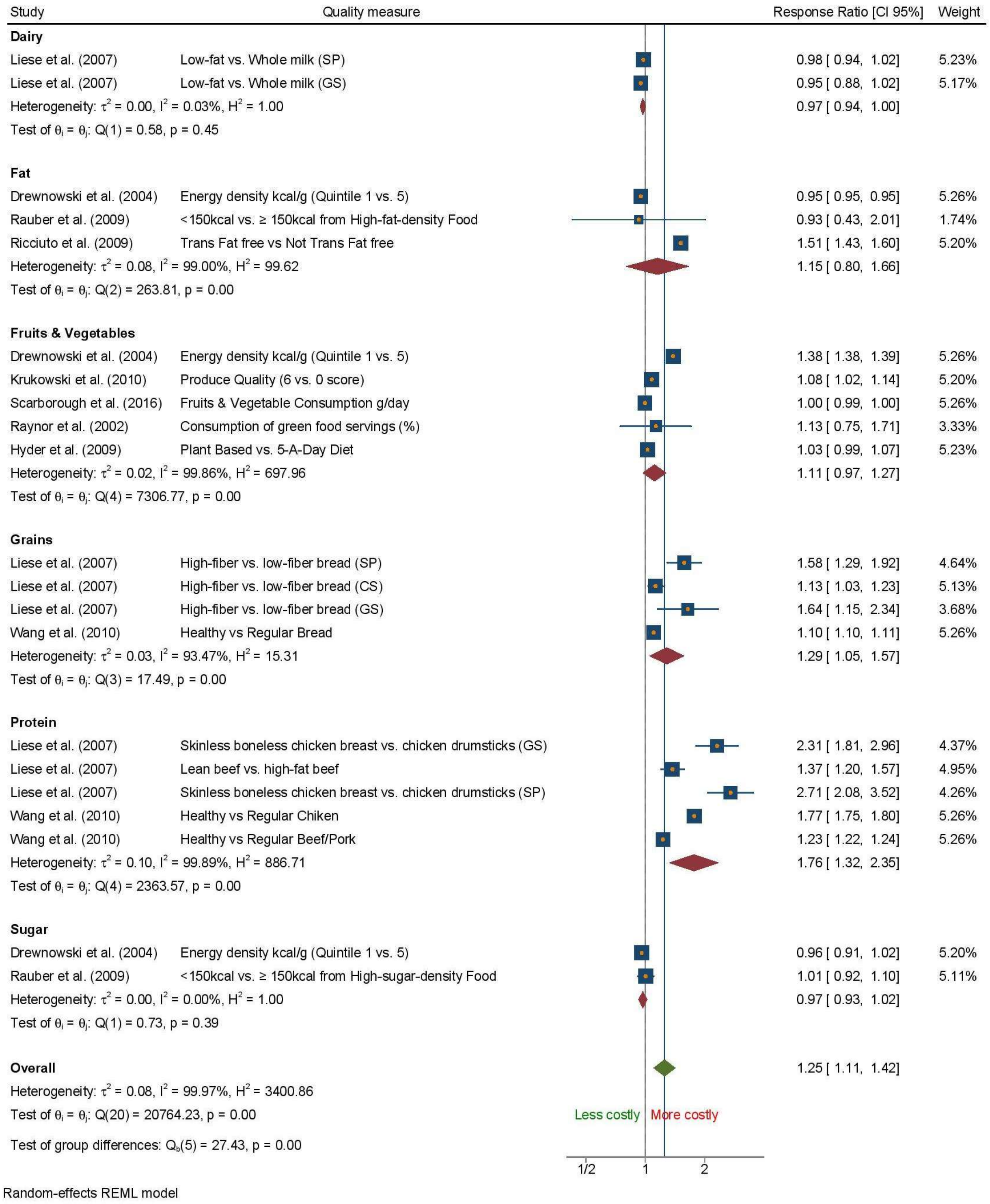
More expensive diets provide, on average, higher nutritional quality than cheaper diets (Figure 1.3). Quality differences between extreme expenditure quantiles (most vs least expensive diets) were assessed as the treatment effect. The pooled random effects response ratio for the six included studies was 1.45 (95% CI 1.18 to 1.79). This suggests that, when comparing the highest to the lowest price quantiles, nutritional quality is on average 45% higher for the most expensive diet. As in the group of studies studied above, heterogeneity was high (Figure 1.3).

Figure 1.1 : Price differences of relatively healthier patterns – Random Effects



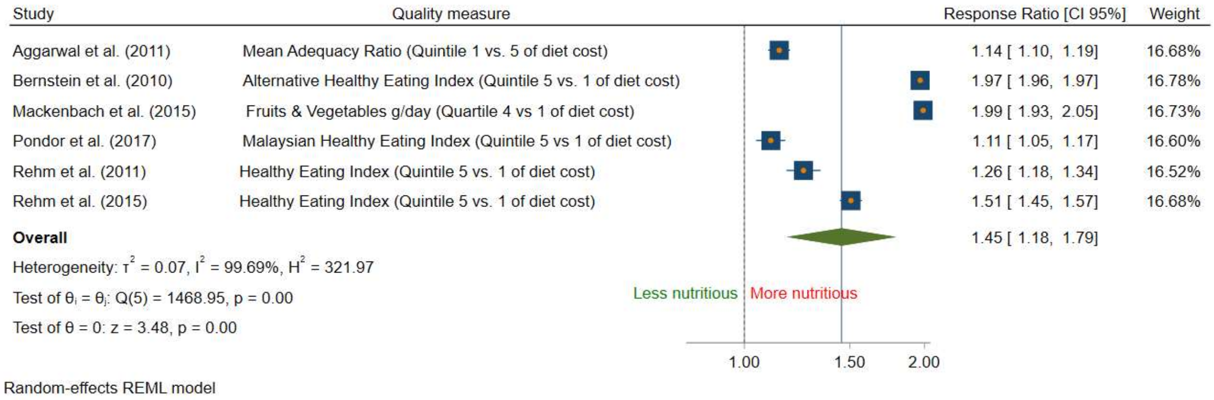
Notes: Price differences between dietary patterns are summarized by mean price ratio with healthier diet price as the numerator. Summary estimates were generated using a restricted maximum likelihood (REML) random effects model. Effect sizes were estimated according to diet comparison. Healthier vs. Unhealthier diet relates to extreme nutritional quality comparisons, whereas the other group compares smaller departures from average diets to disease specific or recommended diets. Q-statistic refers to Cochrane's overall Q. τ^2 is the variance of the true effect sizes and τ the actual standard deviation of those ($\sqrt{\tau^2} = \tau$). I^2 index reflects the proportion of observed variance that reflects real differences in effect sizes. H^2 index estimates the ratio of the total amount of variability (heterogeneity plus sampling variance) to the amount of sampling variance. Heterogeneity statistics were calculated on the log scale.

Figure 1.2 : Price differences of healthier food items – Random Effects



Notes: Price differences between food items are summarized by mean price ratio with healthier food item price as the numerator. Summary estimates were generated using a restricted maximum likelihood (REML) random effects model. Effect sizes were estimated according to food item group. Q-statistic refers to Cochrane's overall Q. τ^2 is the variance of the true effect sizes and τ the actual standard deviation of those ($\sqrt{\tau^2} = \tau$). I^2 index reflects the proportion of observed variance that reflects real differences in effect sizes. H^2 index estimates the ratio of the total amount of variability (heterogeneity plus sampling variance) to the amount of sampling variance. Heterogeneity statistics were calculated on the log scale.

Figure 1.3 : Nutritional quality across price quantiles – Random effects



Notes: Quality differences between food items are summarized by mean quality ration index with the more expensive dietary pattern as the numerator. Summary estimates were generated using a restricted maximum likelihood (REML) random effects model. Effect sizes were estimated according to the dietary quality index. Studies reported nutritional quality across price quantiles. The most extreme quantile comparison was selected for meta-analysis. Q-statistic refers to Cochrane's overall Q. τ^2 is the variance of the true effect sizes and τ the actual standard deviation of those ($\sqrt{\tau^2} = \tau$). I^2 index reflects the proportion of observed variance that reflects real differences in effect sizes. H^2 index estimates the ratio of the total amount of variability (heterogeneity plus sampling variance) to the amount of sampling variance. Heterogeneity statistics were calculated on the log scale

Results of the meta-regression analysis focusing on the magnitude of quality differences of more expensive diets, suggest that heterogeneity in the dietary patterns group can be partially explained by covariates as shown by Table 1.1 (R^2=67.08%). Studies relying on marked basket show that studies using market baskets were found to be positively and significantly associated with price differences of relatively healthier diets. No significant impact was found regarding the cost data used in these studies. Moreover, the choice of diet quality measure was found to be limited, as only the Overall Nutrition Quality Index has shown a positive and significant impact relatively to energy density measure. The model F-statistic indicates that the estimated meta-regression coefficients are jointly significant. Meta-regression results of studies focusing on price differences of healthier food items, suggest that the model could not account for the observed heterogeneity (Table 1.2).

Table 1.1 : Multivariate Meta-Regression model – Price differences of relatively healthier patterns

Dependent variable: Effect Size					
Covariates	Coef.	Std. Err.	t	p-value	[95% Conf. Interval]
Constant	1.581	0.181	3.99	0.003	[1.224,2.041]
Comparison (Healthier vs. Unhealthier diet)					
Recommended guidelines/Disease specific diet	0.570	0.138	-2.32	0.043	[0.333, 0.977]
Study Type (Dietary Assessment)					
Market Basket	2.203	0.394	4.42	0.001	[1.479, 3.28]
Costing data					
National Price Data	1.705	0.663	1.37	0.200	[0.718, 4.057]
Shopping Receipts	1.447	0.700	0.76	0.462	[0.493, 4.253]
Scanner Data	1.126	0.515	0.26	0.800	[0.407, 3.122]
Diet Quality Measure (Energy Density)					
DASH diet	1.003	0.294	0.01	0.992	[0.522, 1.927]
Dietary Guidelines	0.678	0.186	-1.42	0.187	[0.368, 1.248]
Healthy Diet Indicator	0.816	0.319	-0.52	0.615	[0.342, 1.951}
Healthy Eating Index	0.697	0.165	-1.52	0.159	[0.411, 1.182]
Healthy Index Score	1.001	0.391	0.01	0.990	[0.423, 2.391]
KIDMED Index	0.448	0.208	-1.73	0.114	[0.159, 1.259]
Mediterranean dietary pattern	0.475	0.219	-1.61	0.138	[0.170, 1.328]
Nutrient Density	1.490	0.354	1.68	0.124	[0.878,2.531]
Overall Nutritional Quality Index	0.291	0.079	-4.55	0.001	[0.159, 0.533]
PANdiet Score	1.523	0.468	1.37	0.201	[0.768, 3.020]
Western dietary pattern	0.474	0.219	-1.62	0.137	[0.170,1.326]
Country (United States)					
France	0.686	0.3176	-0.82	0.433	[0.245, 1.918]
Netherlands	0.827	0.129	-1.21	0.253	[0.584, 1.172]
Sweden	1.047092	.3073098	0.16	0.879	[0.544, 2.014]
United Kingdom	0.744	0.176	-1.25	0.240	[0.439, 1.261]

Model diagnostics

Number of Obs. = 31
τ^2 = 0. 043
I^2 res. =99.6%
R^2 = 67.08%
Model F(20,10) = 3.94
Prob>F = 0.015

Notes: Mean Adequacy Ratio and Spain were excluded due to collinearity. DASH diet: Dietary Approaches to Stop Hypertension

Table 1.2 : Multivariate Meta-Regression model - Price differences of healthier food items

Dependent variable: Effect Size

Covariates	Coef.	Std. Err.	t	p-value	[95% Conf. Interval]
Constant	1.581	0.181	3.99	0.003	[1.224,2.041]
Comparison (Departure from average diet)					
Extreme comparison	0.570	0.138	-2.32	0.043	[0.333, 0.977]
Study Type (Dietary Assessment)					
Market Basket	1.052	0.332	0.16	0.876	[0.5313, 2.082]
Costing data					
National Price Data	0.935	0.399	-0.16	0.878	[0.372, 2.353]
Reported Expenditure	0.935	0.351	-0.18	0.860	[0.416, 2.102]
Country					
Brazil	0.896	0.310	-0.32	0.757	[0.424, 1.894]
New Zealand	0.930	0.189	-0.36	0.726	[0.600, 1.441]
United Kingdom	0.691	0.218	-1.17	0.261	[0.350, 1.363]

Model diagnostics

Number of Obs. = 21
τ^2 = 0. 077
I^2 res. = 99.96%
R^2 = 0.00%
Model F(7,13) = 0.74
Prob>F = 0.645

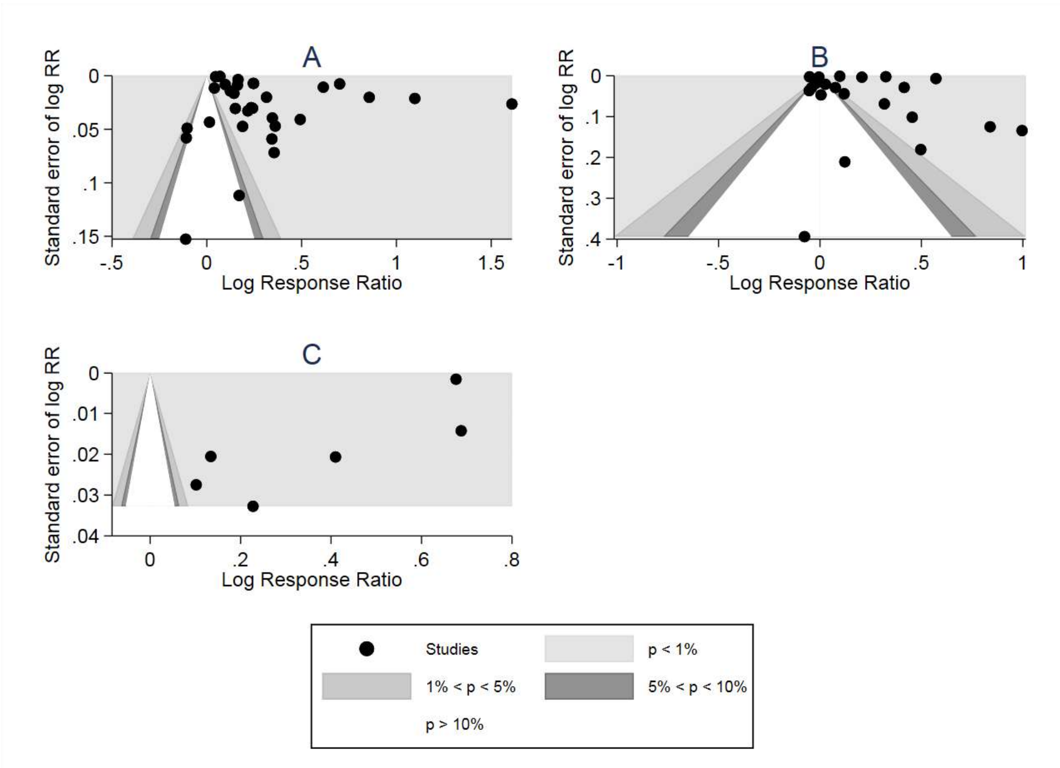
Notes: Country: Canada and France were excluded due to collinearity. Scanner Data and Shopping Receipts cost data did not enter this model since no study in this group used this cost data source.

1.3.2.4 Publication bias

The contour-enhanced funnel plots showed marked asymmetry with a concentration of studies to the top right of the plot in the light grey area where associations were large and standard errors are smaller. The presence of fewer studies with small or negative effects when standard errors were increasing suggests that publication bias is of concern, however, there were not many studies with large standard errors, but large and significant associations. Published studies with insignificant or negative associations tended to have smaller associations and larger standard errors.

Contour-enhanced funnel plots showed that few studies for price differences of relatively healthier patterns found insignificant or negative associations (Figure 1.4, A). Most of the studies had results overcoming the statistical threshold of $p < 0.05$, with a higher proportion of these even significant at the more conservative level $p < 0.01$. Results were similar for price differences of healthier food items group, though the number of effect sizes was smaller and a higher proportion of lower significance studies or negative associations are present (Figure 1.4, B). Finally, considering the nutritional quality across price quantiles contour-enhanced funnel plot, there seems to be few studies with high standard errors in the lower white area as compared to the number of studies with small standard errors in the upper grey area in order to create more balance in Figure 1.4, C, suggesting publication bias.

Figure 1.4 : Contour-enhanced funnel plots



Notes: Contour-enhanced funnel plots for (A) Price differences of relatively healthier patterns; (B) Price differences of healthier food items; and (C) Nutritional quality across price quantiles.

1.3.3 Main findings from the economics literature

Individuals do not choose their diet only to maximize health. Differences in diet quality are due to a complex sets of factors, such as financial constraints but also nutrition knowledge and information costs, the opportunity cost of time, access and search barriers. Furthermore, preferences are important in terms of how individuals value their health now and in the future compared to the short term gratification of (less healthy) food consumption. Hence, the observed associations between diet quality and diet cost found in the public health literature could reflect bias from omitted confounding factors or an inability to capture the complexity of the observed determinants of diet quality. Failure to appropriately model differences in other factors, such as preferences, food knowledge and availability of healthy products, can lead to biased estimates of the impact of prices on dietary choices. The goal of most empirical economic research is to estimate key parameters explaining how economic circumstances influence dietary choices, and to find data and study designs that mitigate selection bias and therefore identify causal effects. It is not always possible to run large scale randomized controlled experiments that can change the relative nutritional quality or affordability of foods for an intervention group along, that would hold constant other confounders.[140] Instead, empirical economics research has sought to exploit natural experiments in which the relative prices of food, household incomes or other constraints vary exogenously in order to estimate the impact of diet cost on diet healthiness.[141, 142]

1.3.3.1 Structural modelling

Economic theory allows researchers to specify how the behavior or outcome of interest could be influenced by the different economic conditions, which provides a structure for formalizing empirical analysis to estimate the relationships. Structural models allow for the estimation of the important economic or behavioral parameters from non-experimental data and to remove bias from unobserved factors. These models can be validated by out-of-sample predictions and used to infer counterfactual outcomes or undertake policy simulations.

Economists have used a rational model of household production that treats households both as producers and as consumers whose objective is to choose marketable goods (e.g. time) to produce nonmarketable goods (e.g. health; food preparation) to maximize utility by consuming food and other goods, subject to a budget and time constraint as well as the cost of food, time and other consumer goods.[115, 120, 143, 144] Knowledge about nutrition and education affects the efficiency by which individuals purchase a basket of food items, combine them with cooking skills and other kitchen appliances to minimize the time and costs necessary to produce a healthy meal.

The relationship between diet cost and diet quality was estimated using multivariate regression analysis controlling for potential factors influencing food choices.[145] They found that consumers preferred the taste of less healthy products, but those products were not necessarily cheaper. Moreover, low education and household size were negatively associated with healthier choices. It seems that income does not provide the best explanation for the heterogeneity of food behaviors.[145, 146] In fact, consumers displaying healthier behaviors, such as regular physical exercise and not smoking, tend to have healthier diets while also spending more on food.[59]

Hedonic price modelling has been used to investigate the relationship between nutritional quality and diet cost.[52] Hedonic price models infer individuals' willingness to pay for improved nutrition from food prices that are determined by their constituent characteristics, both intrinsic (nutrients) and extrinsic (taste, appearance) factors affecting it.[147] Foods with nutrient profiles associated with dietary health improvements were found to be valued by consumers and are associated with increased food expenditures.

A household production model was applied to systematically estimate consumer demand for nutritional quality measured by the HEI.[120] Consumers were found to prefer to spend more on improving food taste, appearance, social image/perception, convenience, degree of processing and food variety.

Demand systems approaches have been pervasive in the economics literature, especially when evaluating the impact of prices, income, and other factors on food demand. These studies typically estimate price elasticities from demand curves, which are conceptually derived from constrained utility maximization, given prices and a budget constraint. Using nutrient and energy conversion matrices, it is easy to evaluate the impact of price policies on nutrient and energy intakes of consumers.[148] A demand system framework was used to make cross-country comparisons in diets, namely between France, United States and United Kingdom, and found that nutritional differences between countries couldn't be fully explained by prices, incomes and nutritional composition of available foods on the market.[149] Preferences and tastes for product characteristics play a role in driving differences in food purchasing patterns across countries. A new approach to identify diets that comply with dietary recommendations and consumer preferences also measured the "taste cost" of complying with those recommendations as well as time and money constraints.[110] It speaks for the difficulty of adhering to dietary recommendations, which impose significant "taste costs" on consumers.

1.3.3.2 Causal inference and econometrics

When randomized experiments are not feasible, quasi-experimental designs can be used to evaluate causal treatment effects. Treatment-effect models focus on identifying a specific causal effect of a policy or intervention without specifying a complete structural model linked to a specific economic theory, but instead the evidence can be used to validate theoretical predictions.

Economic shocks such as falling incomes, unemployment, changes in exchange rates or increases in energy costs that impact food prices can lead to quasi-experimental variation in changes in consumers purchasing behavior and thereby allow the estimation of their causal effects on diet quality.[137, 139, 150] The treatment-effect model will isolate the causal impact of the shock on any outcome of interest without informing on the mechanism by which it occurs without further research. For instance, inflation leads to decreased consumption of high-nutrient and low-energy density foods [121] and longer-run economic growth was found to be associated with greater energy intake, increased adult weight and child height.[125]

Research using a differences-in-differences approach on the relationship between the risk of unemployment and healthiness of diets during business cycles found countercyclical, although mostly insignificant, effects for unhealthy foods and significant pro-cyclical effects for healthy food consumption.[134] Unemployment status had a negative impact on households' food consumption in both the boom and crisis periods. This effect was intensified in times of economic crisis, particularly in socioeconomically disadvantaged households. Expenditures on protein, fruits and vegetables decreased while expenditure on fats and sugars remained constant for unemployed individuals.[151]

The duration of such economic shocks might also play an important role on household food intake with negative transitory shocks having smaller effects than positive ones, suggesting that households use temporary gains in income to buy more nutritious or expensive foods, although, increasing income after the crisis led to increases in both low and high quality food consumption.[127, 136]

Recent studies provide evidence that households can cope with economic headwinds by changing food choices and preferences, using discount retailers, increasing shopping time, and frequency, to find lower cost items and therefore maintaining calorie intake without dramatically lowering the nutritional quality of their diets.[37, 133, 149, 152] These strategies can however, prove insufficient in different settings and impose greater time, search and taste costs.[122]

1.3.4 Discussion and policy implications

This paper presents an update and expansion of earlier systematic reviews discussing the relationship between diet quality and diet cost.[7-9] This review found a multiplicity of methods addressing the relationship between diet quality and diet cost. Public health studies mainly leverage on multivariable analysis to identify the latter although simulation of the potential impact of dietary changes from current diet to a diet meeting nutritional guidelines are also common. Traditionally, only randomized trials were considered reliable enough for causal inference.[153] Although, the existing public health literature finds positive and significant association between diet cost and diet quality it is challenging to disentangle the true "effect size" of diet cost on diet quality from observational studies. Biased estimates, in particular due to endogeneity, can preclude a causal interpretation. Quasi-experiments can generate evidence of similar strength to randomized trials and can be applied to research questions for which randomized trials are not possible.[154]

Economic shocks provide a quasi-experimental setting and we find that studies with this design, although supportive of a positive association between diet quality and diet cost, provided a broader view of costs. Time costs of searching for, and preparing foods as well as information and availability barriers were found to be important factors influencing food choices. Income constraints and other economic shocks were shown to reduce diet quality. Purchasing cheaper alternatives, increasing search effort for discounts, home production and changing the composition of diets to limit the loss of nutritional quality were valuable coping mechanisms to protect against economic headwinds. A concentration of retailers offering better quality and more expensive foods in wealthier neighborhoods was also thought to explain the observed positive diet quality and cost relationship, however, evidence that most households could travel to access higher quality retailers, implies that so called 'food deserts' may not explain the observed association. Preferences and tastes as well as education and other related health behaviors were found to be important factors for individual's dietary decisions, which suggest that some of the association reflects a higher willingness to pay for healthier food and a greater valuation of health, as opposed to a reluctance to renounce tastier food that is cheaper, provides instant gratification, but with low nutritional value and elevated future health risks.

From a behavioral economics perspective, several studies argue for the importance of cognitive ability, loss aversion and time discounting, which may inhibit individuals in making rational choices in evaluating the relative costs and health benefits of foods consumed.[155, 156]

A number of methodological differences among studies were noted and their implications for the research and potential improvements for future research is discussed. First, a multitude of diet quality indices were used to measure the healthiness of dietary patterns. The choice of an appropriate nutritional quality measure should be motivated by its empirical validation with health outcomes.[157, 158]

Second, the choice of method for measuring food cost depends on the research question and setting and the feasibility of obtaining high quality data. Evidence suggests that receipt collection and food purchase records provide detailed information on household food quantities and prices.[159] However, researchers should consider whether information on food store purchases (e.g. retail scanner data) provide the best picture for what is consumed by individual members of the household because of their inability to capture foods purchased from outside catering sources and their inability to capture what has been consumed or not.

Third, the meta-analysis of findings from public health studies confirms a positive association between diet cost and nutritional quality. The size of the association is larger when extreme comparisons of diet quality are considered (diet cost is on average 35% higher). The results are consistent when examining this association using food items. More expensive diets were found to be 45% healthier than the cheapest diets.

Fourth, heterogeneity between studies was large in all groups considered. In meta-regression analyses, the associations between studies were substantially altered by study type considered (p=0.001) and, in the analyses of extreme diet quality comparisons (p=0.004) when dietary patterns group was considered. Moreover, there is evidence of publication bias, due to asymmetry in contour-enhanced plots in the predicted direction, with a relative lack of low accuracy (i.e., small) studies indicating no significant effect or a direction of effect opposite to those with higher accuracy.

Fifth, the treatment-effect approach says very little on its own on the mechanisms by which outcomes are influenced by economic shocks. This limits the understanding of a particular experiment that are generalizable to other populations or circumstances. However, more insights into the mechanisms underlying the observed response can be obtained by exploring heterogeneity across sub-groups of the population whose circumstances may have mitigated the impacts of the economic shock.

Evidence from quasi-experimental methods can be combined with formal structural models of household behavior and data on observed food consumption, prices and other household characteristics to see how changing key policies could change the distribution of diets and expenditures.[160]

There are some limitations to this study that must be considered. The meta-analysis is heavily dependent on the inclusion of observational studies, which are susceptible to confounding and problems of comparability between populations with differing exposure levels. There were very few evaluations carried out in low- and middle-income countries and the recommendations made in this article may not address all methodological differences and requirements of such evaluations. Moreover, even though we employed an extensive search strategy covering all potentially useful information sources, it remains possible that not all relevant articles have been identified.

This paper in no way suggests that diet cost is not a relevant barrier for healthier diets. We believe that the large and significant positive association between diet cost and diet quality combined with the body of evidence from economics provides good evidence of a causal relation.

The potential of price changes to influence individuals' dietary behavior has become evident as several national and regional governments have introduced targeted fiscal policies to influence dietary behavior, such as taxes on sugar sweetened beverages.[161] Pricing policies aimed at favoring healthy dietary patterns have been considered in several studies[148, 162-164], with results of a recent systematic review of the effects of fiscal policies on diets and their related chronic disease risk suggesting that food taxes and subsidies can influence food consumption.[11] However, the literature review suggests that eating behaviors are modifiable by economic factors, therefore the importance of considering measures that take a broader view of costs such as search and time costs of accessing healthier foods, information on nutrition quality or targeted subsidies as well as regulations to ensure affordability and availability of healthier diets to individuals at higher risk.

2 The cost of food consumption across socioeconomic groups in Switzerland

2.1 Introduction

The evidence that a healthy diet is important to human health has been extensively investigated.[165-169] In 2017, 11 million deaths and 255 million DALYs worldwide were attributable to dietary risk factors as modifiable causes of chronic diseases such as cardiovascular disease, type 2 diabetes and cancer.[2, 170] Diets which score high on diet quality indices are associated with a lower risk of chronic diseases and a lower risk of death.[171] Worldwide public health interventions aim at improving the quality of diets via national recommendations for a range of food products and nutrients to improve population health. A variety of instruments have been used for this purpose, for whom relative price changing policies are the most common.[172]

The high cost of healthy foods has been identified as an important barrier to healthy eating.[5, 173] Improvement of diet quality might therefore be constrained by the affordability of the diet. In Chapter 1, healthier diets were found to cost 35% more on average than less healthy diets when comparing the lowest and highest quintiles of nutritional quality. When quantiles of diet cost were considered, more expensive diets were 45% healthier on average than cheaper diets.[174]

Public health literature has long established a positive association between diet cost and nutritional quality and that this association is likely to be stronger inr selected population groups, such as people with a lower income.[174, 175] Studies usually leverage on monetary cost of food to explain this relationship. However, the cost of a diet is not limited to the monetary cost of food items. Individuals make their food choices based on dietary preferences, taste, socioeconomic and demographic circumstances, nutrition knowledge, cultural factors as well as time and information constraints. Not accounting for this broad range of factors can render any policy aiming at improving diet quality ineffective and yield possible unintended consequences.[176, 177]

Public health policies that are appropriate in one country may be less relevant in other countries. The underlying mechanisms linking food consumption to socioeconomic status might be significantly different. Each policy therefore needs to be tailored to a given regional, socio-economic and cultural setting and sequenced carefully to ensure success. A better adherence of dietary intakes with nutrition recommendations in Switzerland could lead to population health benefits and potential healthcare savings. However, such recommended healthy diets might also cost more for consumers. Understanding the relationship between diet cost and nutritional quality is of paramount importance for policymaking. Moreover, the role of nutrition in contributing to socioeconomic inequalities in health has been receiving increasing attention from policymakers, hence analyzing the differences in nutritional quality across socioeconomic groups and the contribution of food costs, households income, education, work status but also preferences for food choices and time cost is of relevance. Also, beyond simply characterizing the diets in relation to their nutritional quality, it is important to assess the extent to which dietary adherence to national nutrition recommendations may be associated with higher food costs for consumers.

In this Chapter, we estimated the cost of diets using data from the Consumer Price Index Retail Scanner dataset (CPI) and the Swiss Household Budget Expenditure Survey (SHBES), linked these data to menuCH dietary intake data and subsequently analyzed the relationship between food expenditures and nutritional quality across socioeconomic status (SES) groups in Switzerland. We assessed diet quality using the Swiss Food Pyramid Score, which evaluates compliance with national nutritional recommendations, and the

Healthy Eating Index. Moreover, we extend our analyses by exploring the impact of time cost, nutritional knowledge and food preferences on diet quality.

2.2 Data

The analyses were based on data from multiple sources. To evaluate diet quality, we rely on data from the first national nutrition survey, menuCH. The dataset includes two non-consecutive 24-hour dietary recalls (first by face-to-face interview and the second by telephone interview, both with a certified dietician) from more than 2000 participants aged 18 to 75 years from the three main linguistic regions of Switzerland.[178]

Participants were recruited from the national sampling frame for person and household surveys. The survey population was intended to be representative of the Swiss population in terms of age and place of residency across all seven major areas of Switzerland, but did not survey people from every canton. A total of 5496 eligible people reachable by phone were invited to participate, of whom 2086 (38%) responded [179]. Participants and non-participants had similar age and marital status but participants were more frequently women and Swiss nationals than non-participants. Survey sampling weights were derived to adjust statistical analysis to be more representative of the Swiss adult population aged 18 to 75 years and to account for non-response.

Very detailed data is provided by menuCH dataset on food consumption in terms of the exact items and quantities consumed. However, it does not provide any information on food prices and food expenditures by participants. In order to assign food prices and derive daily food expenditures for participants, we obtained and integrated data on food prices as well as food expenditures from two different datasets to estimate the cost of Swiss diets.

The first dataset is the Federal Statistical Office (FSO) of Statistics Consumer Price Index Retail Scanner dataset (CPI). It is a national survey of food retail prices for a large basket of food items most frequently consumed by the Swiss population. The retail price data is collected monthly from electronic retail scanner data from the major supermarket retailers across Switzerland (i.e., Coop, Migros, Denner) as well as from smaller retailers across Switzerland by fieldworkers.[180] Information on the prices of different prepared foods and meals purchased outside the home from canteens, self-service restaurants, take-away food, cafes or restaurants was also available. Data is collected on a regional basis with the country split into 12 regions. The scanner data does not identify specific brands but provides significant detailed information on a generic product level. The data was structured hierarchically with food items grouped in up to four product category levels. In total around 554 generic food items and their prices were provided at the lowest level.

This data provides detailed price variation within food item categories by region and month. We obtained data on all the collected prices from the different retailers per quantity (kg, liter) grouped within the generic food item classifications defined by the FSO for each region and month for the years 2013 to 2015 and utilized these data to attribute prices to the menuCH data. Some 840'000 prices are collected every year. Decisive for calculating the CPI are transaction prices, i.e. the price paid by consumers for a specific good or service, including indirect taxes (chiefly VAT and incentive fees), customs duties, environmental taxes and subsidies. Credit or interest costs are not taken into account. Price reductions (special offers, promotions, discounts, sales) are taken into account. Overall, approximately 2,700 sales outlets participate in the successive surveys. The data collection procedure and further information were already discussed elsewhere.[180]

The second dataset is composed by the individual household level data from the Swiss Household Budget Expenditure Survey (SHBES) for the years 2008 to 2015 collected by the FSO.[181] It is an annual nationwide household survey to obtain information on household expenditure patterns from 3'300 individuals aged 15 and over (from 2012 data on children over 6 years was also collected). The data was stratified by the seven large Swiss regions consisting of private households permanently resident in Switzerland. Additional information was collected on the labor market situation and on the social and educational background of the household members. The survey contains itemized food expenditures during the survey period (quantity and cost) as well as major expenditures in past 5 months, and household mobility with a travel diary with information of all trips within and outside of Switzerland during the survey period including reasons for travel, geographic coordinates of destination and expenditures.

The survey contains 14 broad food categories and additional 7 additional categories for external catering or food gifts. These groups nest a further 120 food item classifications. For each household, the total monthly quantity purchased in kilograms or liters and the amount spent for each item is recorded.

Furthermore, the SHBES has comparable income, socioeconomic and geographic information to menuCH, hence it was possible to match food prices stratified by socioeconomic characteristics and geographic area. The limitation of the data is that the 120 food items, while covering the majority of most frequently consumed foods, contains a number of aggregate and general categories – it is a fraction of the generic food items in menuCH (964 or approx. 10%). The SHBES data, however, enabled to predict individuals' likelihoods of purchasing foods at discount (below the 25% of prices) or premium prices (above the 75%). This information was used to estimate food prices and the costs of domestic food preparation as explained in the methods below. It also enabled us to compare food expenditures derived from the menuCH data and the linked CPI data.

2.2.1 Data Linkage

In order to estimate diet costs of daily food consumption at the individual level, we attributed food prices for each of the recorded items consumed for each individual and 24-hour recall period.

We started by mapping menuCH food items consumed with generic product category names in the CPI. The CPI data are nested in a hierarchical structure of at least four different levels. The classification and coding systems are different across the two databases, but each food code has an associated name in both datasets, that can be used to identify the best correspondence. The wording of the food descriptions, however is not exact and neither are the hierarchical structures, although they are not too dissimilar, permitting the use of semi-automated data linkage methods. The scanner data, however, often grouped several related products in to a single category (e.g. sugary drinks with flavors would include Coke, or Sprite/7UP, Orangina, etc.). Fortunately, the CPI data provided a list of the main products included within each generic category so that we were able to create a lowest product level that closely resembled the names recorded in the menuCH data to improve the record linkage.

Hence, we performed a matching procedure involving a combination of exact hierarchical matching and probabilistic record linkage using word-pattern-recognition algorithms that estimate the probability of a match between nested items. An iterative procedure was required to first derive a higher level-grouping common to all datasets, and to reformat food item names in a standardized way across food price and consumption datasets in order to reduce avoidable matching errors due to simple differences in syntax. Additional rounds of sequential matching were still needed, continually refining the linking to ensure that the remaining unmatched items can be linked. This process required 'hand' review of items with multiple matches to indicate the most flagging unmatched items for the best link. We use the Stata commands reclink2 with clrevmatch to performs these tasks.[182]

We first used the food category upper level and subcategory level groupings already defined in menuCH to ensure all the highest-level food grouping identifiers exactly matched across the CPI and menuCH in the hierarchical linkage. Within these matched categories, we then performed probabilistic matching on all lowest level food items. A probability of an exact match was given for all potential pairings (one item can have more than one possible pairing). We set the exact record linkage score threshold to 99% (true match), for which matches were automatically accepted. Hand review of matches was required to ensure reliability of the matches below this threshold. Hand review then coded matches (1) to be definitely a match, (2) highly likely to be a match or (3) definitely not a match, with definitely or highly likely matches integrated into the matched database. The probabilistic linkage yielded 82% true matches between food classification in menuCH and CPI datasets. After hand reviewing the non-matched products, we were able to increase the correspondence between food items in the two datasets to 91%. For, the remaining 9% of food items in menuCH without a match, we attributed a weighted average price of similar products (subcategory level). However, this remaining 9% of products represent less than 1% of the total food items consumed in menuCH. We exclude tap water and ice cubes from the linkage because we were not able to find a proper estimation of the price.

The CPI data provided a distribution of prices, that is a list of all prices recorded within a given generic food item group for a given month and region. As we do not know the exact product and location chosen by the individual in menuCH, we have to attribute a representative price of the product within each matched group. To improve the representativeness of the matched prices we used the specific region and month prices corresponding to the survey date and responder location. A merge between the menuCH and the SHBES food categories allowed to estimate the cut-offs that define if the households in the SHBS paid three possible price ranges, discount (the lower 25th percentile price), standard price (the median 50th percentual price) and premium product prices (75th percentile price). The lowest quartile and the highest quartile of prices can therefore be calculated for each menuCH food categories. Hence, the price paid by the households in Swiss Francs (CHF) is transformed into a categorical variable. The model is estimated as a function of observed individual and household characteristics using the SHBES and the main food sub-categories as an ordered probit for each food category *g* with the following specification:

$$
\begin{aligned}
Price_{ig} = \ & \beta_0 + \beta_1 Age_i + \beta_2 Sex_i + \beta_3 Smoker_i + \beta_4 Civil\ status_i + \beta_5 Nationality_i \\
& + \beta_6 StudentORRetiree + \beta_7 Works\ for\ money_i + \beta_8 Receive\ a\ pension_i \\
& + \beta_9 Number\ of\ cars_i + \beta_{10} Net\ Income_i + \beta_{11} Household\ status_i \\
& + \beta_{12} Language\ Region_i + \beta_{13} Region_i + \beta_{14} Household\ Size_i \\
& + \beta_{15} Period\ observed_i + \epsilon_i
\end{aligned}
$$

The goal is to model the probability of paying a discount, median or premium price. Thanks to the data linkage between the CPI and menuCH, we have a distribution of prices for each menuCH categories *g*. The model then predicts on the sample of the SHBES the probability of paying one of the three price categories based on the same socioeconomic characteristics used in the SHBES to model the willingness/probability to pay that can also be found in menuCH.

2.3 Diet cost

2.3.1 Daily food expenditures

Food expenditures were calculated as the cost of foods consumed per day in Swiss Francs (CHF). These were obtained by multiplying the quantity of food consumed by its standardized unit price in grams (CPI included different measures including Kg/L/unit). These were all converted into grams, in particular, average weights were obtained for products that had only reported prices per unit (e.g. 1 egg was estimated to weigh 50 grams on average; cervelas sausages were estimated to weight 100 grams on average). Restaurant meals' prices were not converted as the price paid by the consumer is the full price. Prices varied by region, month and price category where the price category with the highest predicted probability within a main food category was assigned in order to better reflect the actual price an individual was likely to have paid, being a discount price, median price and premium price. The price-weighted quantities were then aggregated for each individual's food consumption during the day to calculate daily food expenditure by individual in each dietary recall date, hence we have two observations of daily expenditure for each individual.

2.3.2 Time cost

Time cost refers to the economic cost corresponding to the time each individual allocates to cooking at home. Therefore, when calculating the time cost, we calculated the economic cost per unit time. Time cost is proxied using the wage rate, estimated by the ratio between the monthly individual net income and the monthly number of hours worked. In menuCH, we have only the net income of the households in a categorical variable and it required two adjustments to reflect an individual expected hour wage rate. First, each income category is transformed into single income value in Swiss Francs based on the income distribution of the SHBES that is representative of the Swiss population. We assigned the median income observed in the SHBES within each menuCH income category, for the household's reported income, we applied the OECD-modified equivalence scale to transform household's net income into an individual's equivalized level income depending of the number of adults and children living in the households.[183] This measure of wage rate is not available for all individuals since some of them did not report their net income or their hours worked or they are not working (zero working hours). Hence, this value is imputed for the non-working and the working population with less than 20 hours work per week. The model is estimated for men and women separately. The sample contains individuals reporting more than 20 hours of work per week. A generalized linear model with a Gaussian family and a log link function is used:

$$\begin{aligned} WageRate_i = {} & \beta_0 + \beta_1 Age_i + \beta_2 Nationality_i + \beta_3 Health\ status_i + \beta_4 Civil\ status_i \\ & + \beta_5 Household\ status_i + \beta_6 Education_i + \beta_7 Function_i + \beta_8 Occupation_i \\ & + \gamma Region + \epsilon_i \end{aligned}$$

Some individuals had no work occupation or function reported or simple did not have one. Hence, a second model without those covariates is computed for the latter. The real hourly wage rate is used for the estimation sample and the estimated wage rate for the remaining.

To estimate the expected daily time an individual allocated to cooking, we used two questions in the menuCH survey that related to the number of times per week that an individual cooked (extensive margin) and their estimated time spent cooking when they did so (intensive margin). We were then able to estimate their expected daily hours spent cooking per day by dividing total weekly hours by seven, which was then costed by multiplying by the wage rate.

2.4 Diet quality assessment

To measure diet quality, we derived two nutritional quality indices namely the Swiss Food Pyramid Score and Health Eating Index (HEI). The OSAV communicates nutrition recommendations through the Swiss Food Pyramid that was derived together with the Swiss Society for Nutrition. The six-stage Swiss Food Pyramid consists of recommendations based on different food categories. We chose seven food categories with quantitative cut-offs for daily consumption to assess whether the diet met the Food-based dietary guidelines, namely (1) non-caloric beverages; (2) fruit and vegetables; (3) cereal products and potatoes; (4) dairy products meat, fish, eggs and tofu; (5) added fats and nuts; (6) sweets and salty snacks and (7) alcohol.[184] Scoring compliance with recommendations attributes a score of 0 or 1 if the individual's diet does not comply or complies with the recommendations, respectively. Where compliance is defined as eating 'adequate' portions of food items in each category as recommended by the Swiss Food Pyramid. Therefore, the score has a minimum of 0 and a maximum of 7 points.[178]

The HEI, a diet quality index that measures alignment with the Dietary Guidelines for Americans, developed by the United States Department of Agriculture Center for Nutrition Policy and Promotion (CNPP), was updated with the 2015-2020 Dietary Guidelines for Americans. The HEI is the most common measure of diet nutritional quality in the literature and it has been validated by evidence supportive of construct validity, reliability, and criterion validity.[168, 185] Relatively higher HEI scores have been associated with reduced relative risks for diet-related illnesses.[186] A key feature of the HEI is that the scoring separates dietary quality from quantity using a density approach. Hence, for each diet quality component, a maximum number of points are attributed to full compliance, which are then weighted according to the degree (proportion) of compliance. The components are generally calculated as a food group amount per 1,000 calories in the total mix of foods. The Fatty Acids component is an exception; it is scored as a ratio of unsaturated to saturated fatty acids (Figure 2.23. The component scores are then summed to give an overall score ranging from 0 to 100. Figure 2.24 presents a brief graphical description of the scoring process.

2.5 Descriptive analysis

We present univariable graphs and summary statistics of the distributions of diet quality and diet costs variables. We also look at their distributions across socio-economic groups, namely income and education. We also provide a table of summary statistics for all the covariates used in our subsequent regression model analyses.

2.6 Multivariable regression analysis

We estimated multivariate regression models of the observed association between our two outcome measures of diet quality (dependent variable) and diet cost, namely an individual's daily expenditure and time cost they incurred on cooking. We also estimated whether socio-economic status is associated with diet quality, and included a large set of other explanatory variables that are likely to be correlated with observed food expenditures and time costs as well as being associated with diet quality. We use both 24h dietary recall assessments for each individual as our unit of observation, hence we have more than 4000 potential observations. In economic terms, the model is considered a health (diet quality) production function with diet expenditures and time costs the amount of inputs consumed by individuals in order to produce a desired level of diet quality. Socio-economic status and other food knowledge variables reflect their ability to choose and transform these inputs efficiently i.e. to achieve the healthiest diet possible for the least amount of diet cost. Other variables in the model are included to capture preferences for healthy eating, cultural or demographic influences on diet quality.

We estimated the impact of diet cost on diet quality using a Poisson regression model for count dependent variables for the Pyramid Score. We also estimated a random effects or mixed-effects Poisson regression that allows for unobserved variation between individuals and included sampling weights. For the HEI-2015, we estimated an ordinary least squares (OLS) regression and a random-effects model. All models included sampling weights and allowed for cluster/robust standard errors for the models without random-effect between surveyed individuals for whom we have repeated observations.

Our baseline model specification included all covariates in a linear specification, The linear model assumes a monotonic (constantly increasing or decreasing) association between diet cost and diet quality. The linear base model is presented as follows:

$$Diet\ Quality_{ij} = \beta_0 + log\ \beta_1 log\ (Exp)_{ij} + \beta_2 T_i + \beta_3 SES_i + \beta_4 H_i + \beta_5 DEM_i + \beta_6 F_i + \beta_7 X_i + \varepsilon_{ij}$$

The dependent variable is diet quality (as measured by the Swiss Food Pyramid score or the HEI-2015), and the independent variables are the logarithm of daily expenditure on food $log\ log\ (Exp)$ and time cost (T). Logarithmic transformation of the food expenditure variable was a convenient means of transforming a highly skewed variable into one that is more approximately normal. It also implies that the estimated association between diet quality and expenditure is a proportionate one, so that the underlying relationship between increases in actual expenditure and diet quality is a non-linear relationship (diminishing absolute marginal effects with increasing expenditures), while still preserving the log-linear specification of the model.

Apart from the two measures of diet cost, the model included the socioeconomic status variables (**SES**) net household income, education level and work status to test for significant inequalities in diet quality across SES groups. Income is likely to determine expenditure on food, but in the model that already included food expenditure it indicates if there are stronger preferences for healthier diets between richer and poorer households. Education is a proxy for individuals health literacy, cognitive ability, and, along with work status, is a measure of their degree of social capital.[187] We included smoking status, perceived health status and physical activity as proxies for healthy behaviors and preferences (**H**). We included as demographic factors (**DEM**) gender, ge and language region, which is a proxy for cultural differences within Switzerland. Further explanatory variables (**F**) closely related to dietary choices and nutritional knowledge, specifically being on a diet or being a vegetarian as well as awareness of either the food pyramid or the 5-a-day recommendation or both. Summary statistics of all the covariates used in the regression please are listed in Table 6.3. Finally, we controlled for the methods used for survey data collection (face-to-face or telephone interviews) and for seasonality using monthly indicator variables. Moreover, in the random effects model only, there is an individual specific error term ε_i to control for unobserved heterogeneity that is persistent within individuals over time and is assumed independent of the other explanatory variables. The random error term is represented by ε_{ij}.

We tested if the log-linear specification for the relationship between diet cost and diet quality holds by using both a visual approach, namely the augmented residuals plot with a non-parametric kernel density line plot, as well as a regression model with a quadratic specification for food expenditures and time costs with the Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) to test for goodness-of-fit.[188] The intuition for the quadratic specification is that the association between diet quality and diet costs is non-linear, in the sense that increases in diet expenditure may not be associated with the same degree of improvement in diet quality at all levels of expenditure. Instead, it could be hypothesized that there is initially a larger positive association at lower levels of expenditure, but that at higher levels of expenditure additional expenditure may be associated with a smaller increase or even a decrease in diet quality.

For instance, at low levels of diet expenditure or time costs, individuals may face significant financial or time constraints to eating healthier, so that any additional increase in diet costs will improve diet quality. However, as the diet cost increases the additional benefits to diet quality diminish and, beyond a certain level of expenditure, diet quality could decline. This is because, either individuals overconsume relative to their daily caloric needs or there is a substitution from more necessity foods to more expensive foods that, while providing greater enjoyment from eating, do not necessarily improve nutritional quality.

We specified the following model with quadratic terms in the logarithm of food expenditures and the level values of time costs to examine the existence of non-linearity between diet cost and diet quality:

$$Diet\ Quality_{ij} = \beta_0 + log\ \beta_1 log\ (Exp)_{ij} + log\ \beta_2 log\ (Exp)^2_{ij} + \beta_3 T_i + \beta_4 T_i^2 + \beta_5 SES_i + \beta_6 H_i + \beta_7 DEM_i + \beta_8 F_i + \beta_9 X_i + \varepsilon_{ij}$$

Where all variables except $log\ log\ (Exp)^2$ and T^2 are similar to the variables used in the previous model specifications and the random individual effect ε_i is estimated only in the random/mixed effects models. The non-linear relationship is reflected by the coefficients β_1, β_2 and β_3, β_4 for daily expenditure and time cost, respectively. As a robustness check, we estimated the linear model with quintiles of $log\ log\ (Exp)$ and quintiles of T. AIC and BIC were used to determine model goodness-of-fit between the alternative linear and non-linear specifications. Statistical significance was set to 5%.

2.7 Results

2.7.1 Descriptive data analysis

The mean values for our diet quality scores were 2.17 (upper bound 7) for the Food Pyramid Score and 47.5 (upper bound 100) for the HEI. Average daily food expenditure was 20.07 CHF and average expected daily time cost from preparing meals at home was 20.87 CHF.

Figure 2.1 and Figure 2.2 show the distributions of the Food Pyramid Score and HEI. There is less variation in the Food Pyramid score as it can only take on 7 values, and most individuals achieve scores of 2 and 3 with few individuals achieving scores above 4. There is more variation in the HEI, which is quite symmetrically distributed around a score of 50. Few individuals achieve scores above 75 or below 25.

The distribution of daily expenditure is heavily rightly skewed (Figure 2.3) with a small but non-negligible number of individuals with estimated daily expenditures above 50 CHF and even over 100 CHF (over 5 times the mean). After having applied the natural logarithm to the transform the variable (see

Figure 2.4) the distribution is now close to that of the normal distribution. Taking the natural logarithm of daily expenditures reduces the influence of the unusually large daily expenditures while dispersing the concentration of expenditures at the lower end of the scale.

Figure 2.1 : Food Pyramid Score Distribution

Figure 2.2 : Healthy Eating Index Distribution

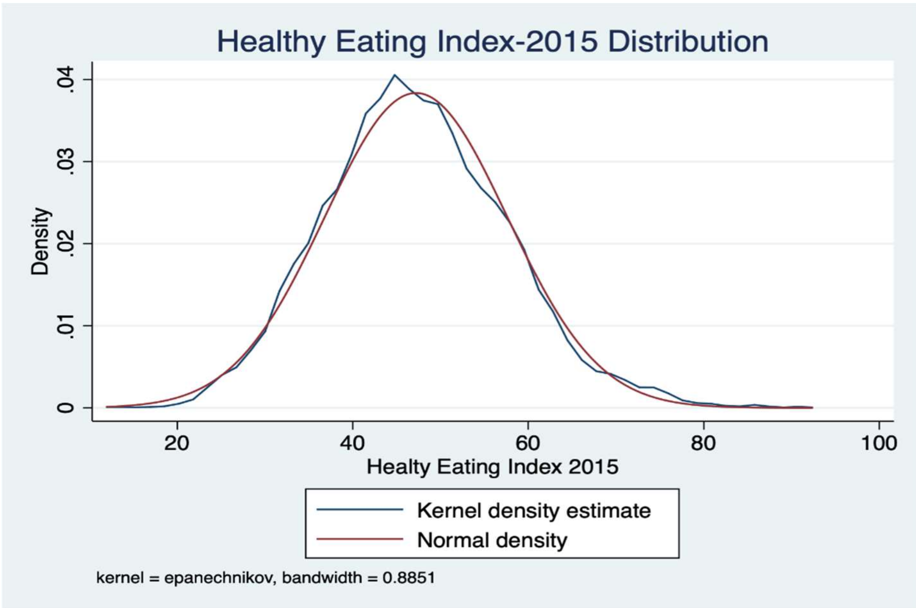


Figure 2.3 : Distribution of Daily Expenditure (CHF/day)

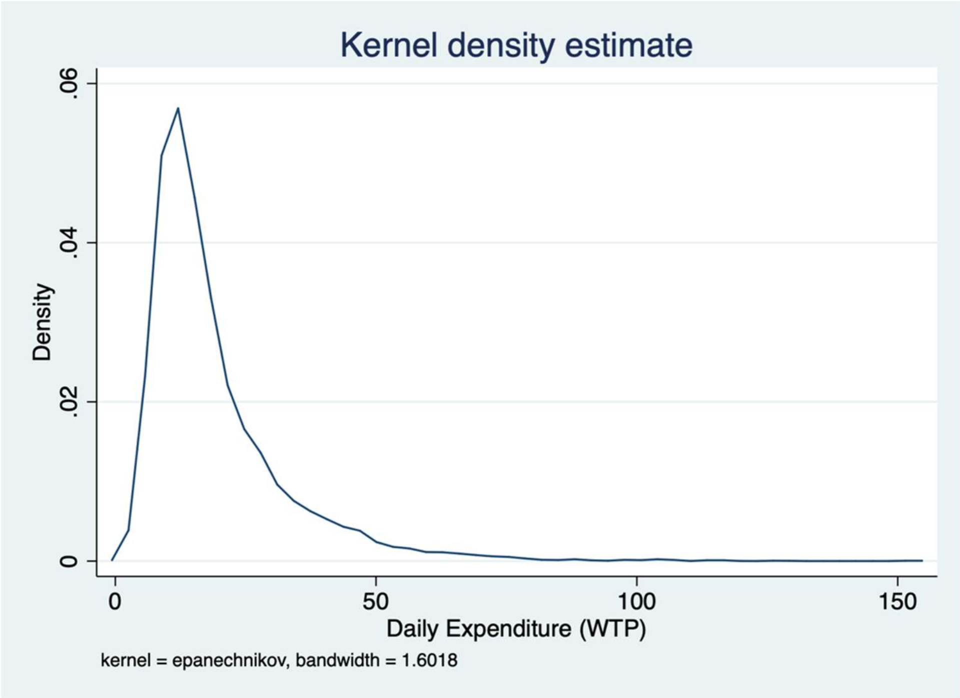


Figure 2.4 : Distribution of the logarithm of Daily Expenditure

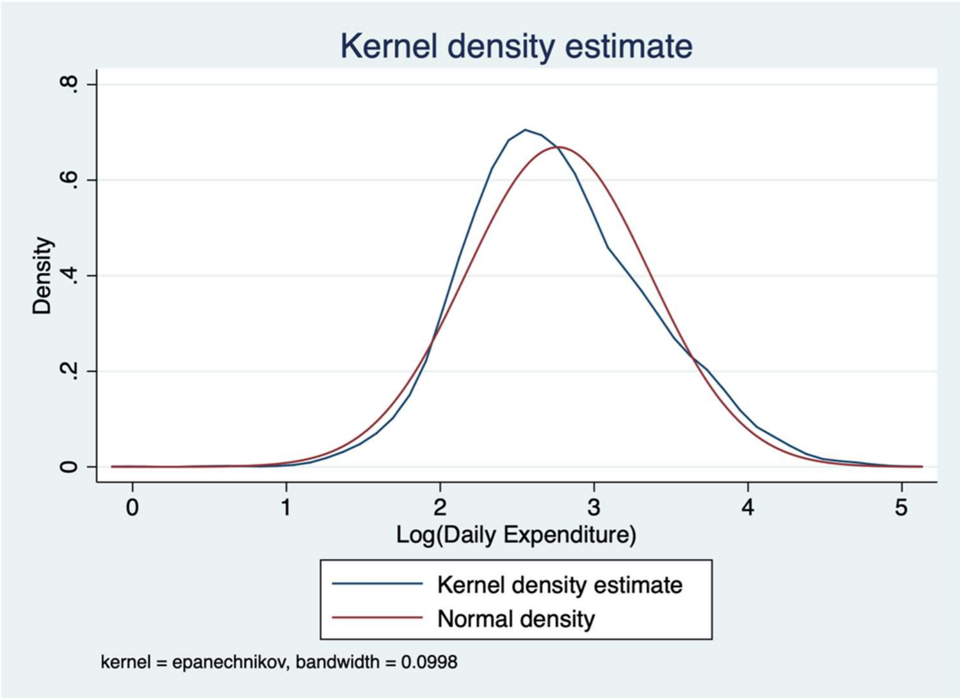
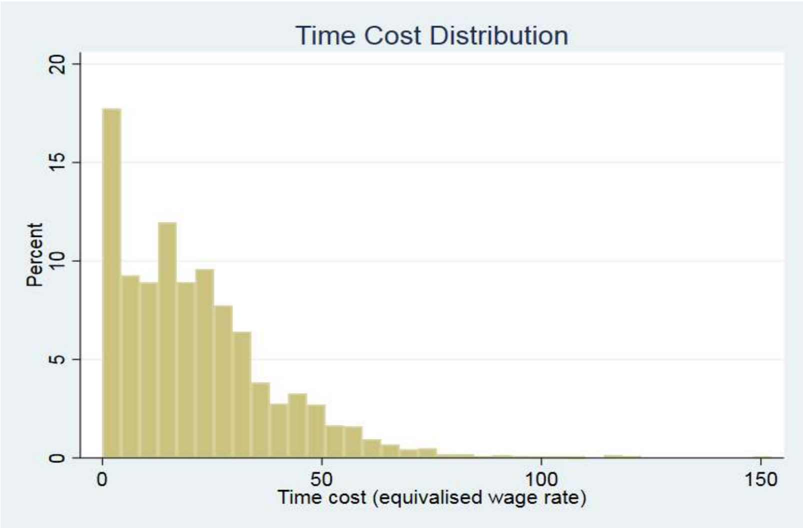


Figure 2.5 depicts the distribution of estimated time cost across the population surveyed in menuCH. Interestingly, a large proportion of participants report no time costs (around 17% with values of 0) reflecting people who did not report cooking meals at home.

Figure 2.5 : Time cost distribution



In Figure 2.6 to Figure 2.9, we present the mean values of the Food Pyramid score and HEI across education and income categories defined in menuCH. There appears to be a small difference in favor of better-educated individuals and wealthier individuals who have slightly larger Pyramid Scores on average (2.3 for University educated and household incomes > 13,000 CHF compared to 2.0 for only Mandatory schooling and 2.1 for incomes below 3,000 CHF). However, there was no such gradient for the mean HEI across education and net income categories..

By contrast, the socio-economic gradient in daily food expenditures is more noticeable. Figure 2.10 and Figure 2.11 show average expenditures by education and income categories. University educated individuals are spending 22.3 CHF per day compared to 16 and 17 CHF for individuals with only incomplete professional or mandatory schooling, respectively. In terms of income the wealthiest individuals with income about 13,000 CHF are spending nearly 30% more on food per day compared to individuals with household income less than 3,000 (23.4 compared to 18.1 CHF).

Figure 2.6 : Food Pyramid Score by education group

Figure 2.7 : Food Pyramid Score by net income group

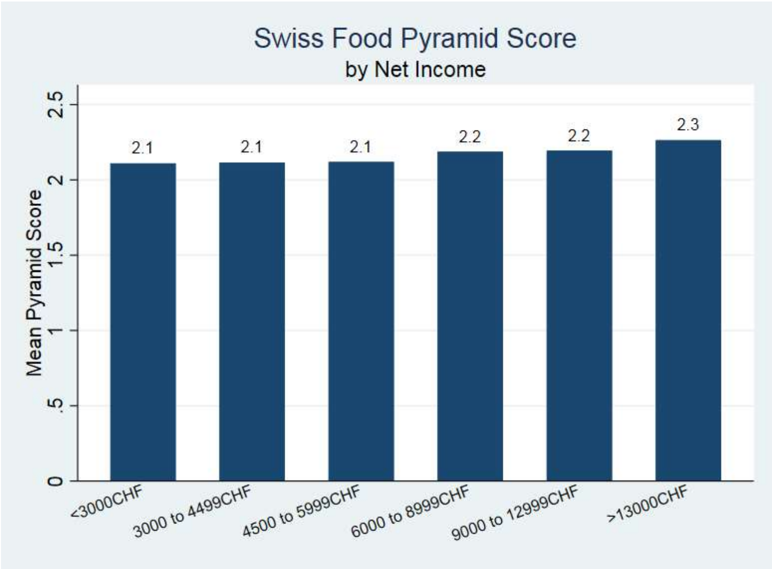


Figure 2.8 : Mean Healthy Eating Index Score by education group

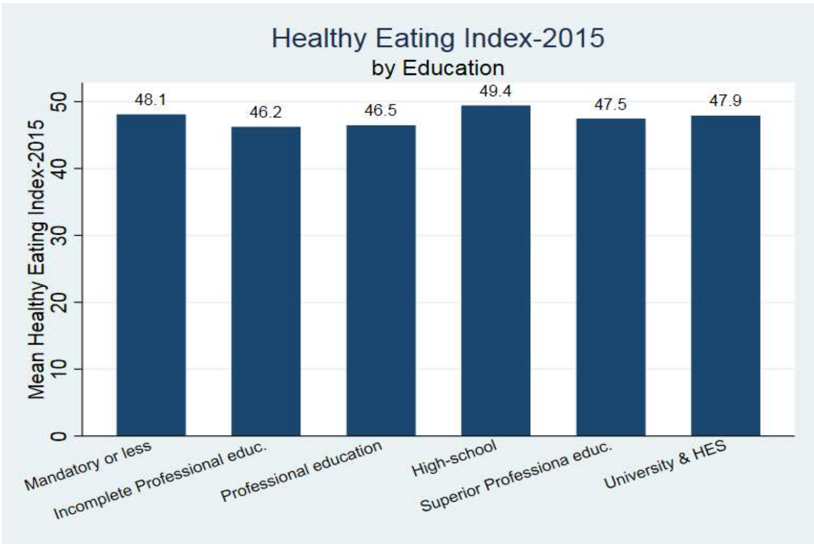


Figure 2.9 : Mean Healthy Eating Score by net income group

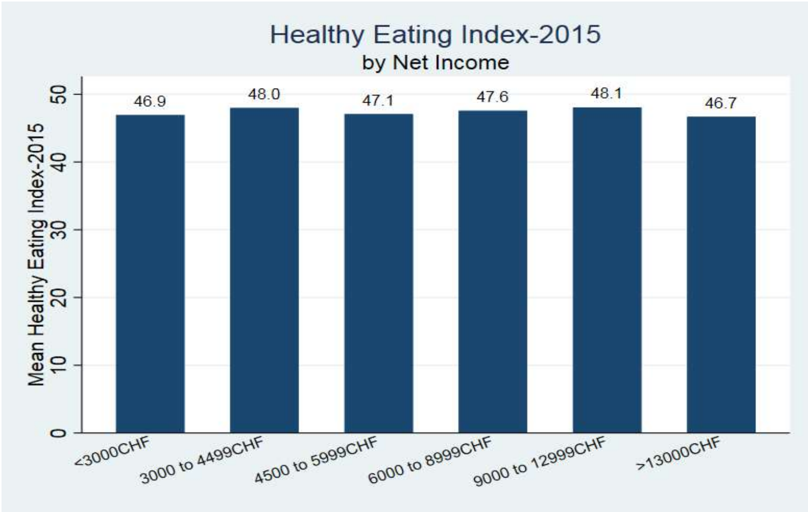


Figure 2.10 : Mean daily expenditure by education group

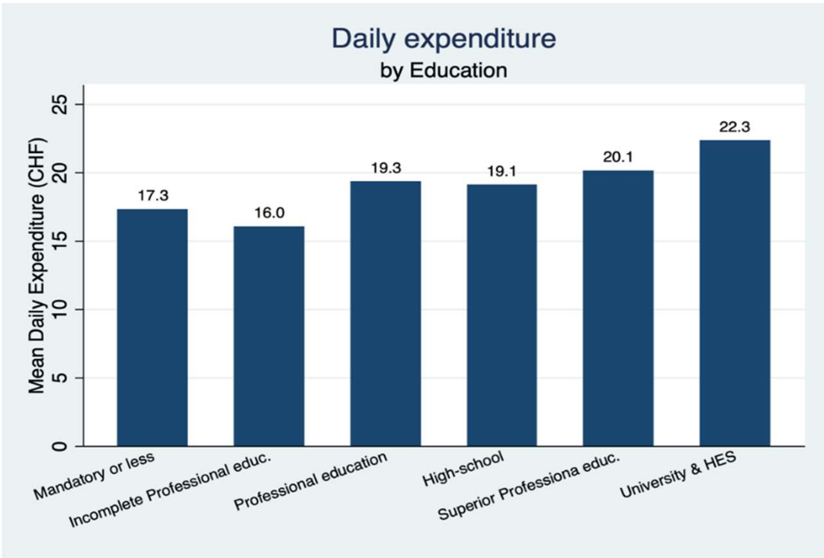
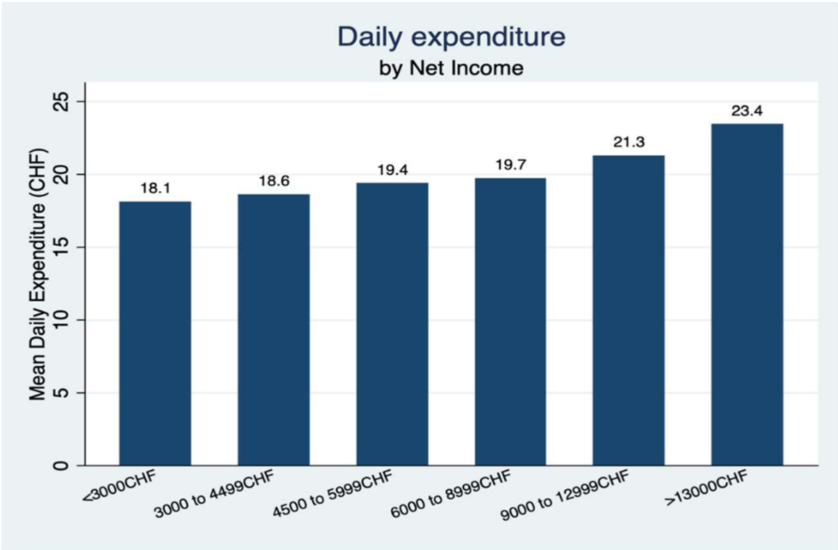


Figure 2.11 : Mean daily expenditure by net income group



Below we present bar graphs of the mean time cost across education and income categories defined in menuCH. There are significant differences on time cost in favor of better-educated individuals (University educated have a 48% higher time cost compared with those with Mandatory or less education), with the exception of incomplete Professional education category. Conversely, in terms of income, the wealthiest individuals with income about 13,000 CHF have a lower time cost compared to individuals with household income less than 3,000 (20.5 compared to 19.4 CHF). As the cost of time of higher income individuals is higher, this indicates that lower income individuals spend more time cooking.

Figure 2.12 : Mean time cost by education group

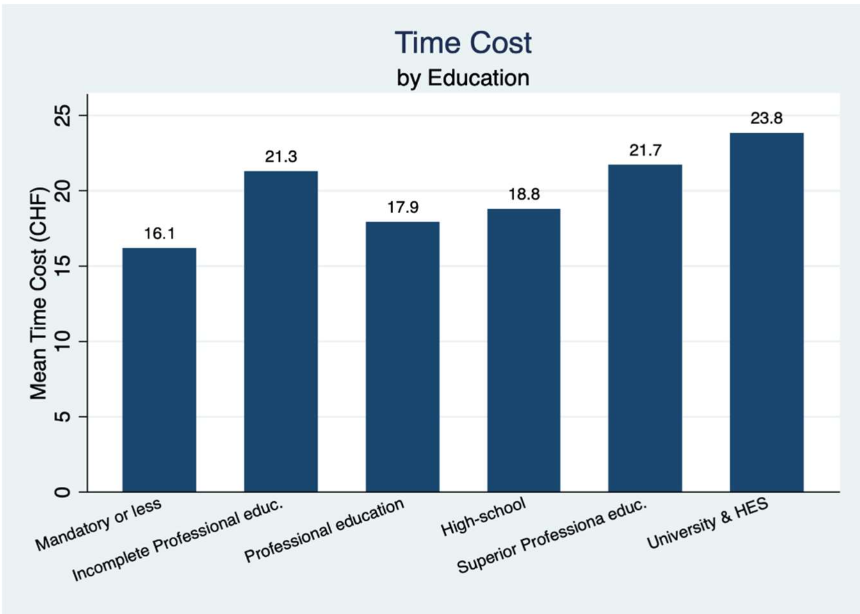
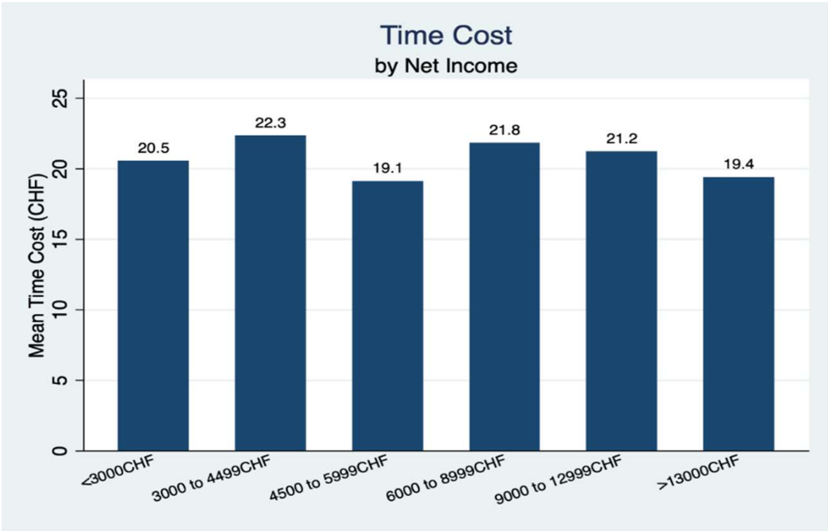


Figure 2.13 : Mean time cost by net income group



2.7.2 Association between diet quality and costs

The results of the estimated associations between diet quality and diet costs are reported for both the Food Pyramid Score and HEI in Table 2.1. Poisson regression models for the linear specification (column 1) and quadratic forms for the Poisson and mixed/random-effects Poisson regression are presented in (columns 2 and 3) for the Food Pyramid Score, with ordinary least-squares (OLS) linear specification and quadratic speciation without and with random-effects are presented in columns 4, 5 and 6 respectively for the HEI-2015 diet quality outcome variable.

The logarithm of daily food expenditure is associated non-linearly with the Swiss Food Pyramid and the HEI . The results imply the existence of a non-linear inverted-U-shape relationship between diet quality and diet cost, which is confirmed by the smaller AIC and BIC statistics for the quadratic compared to the linear model specifications. The inverted-U-shape relationship implies that diet quality increases with additional food expenditures from low initial levels of expenditure, but additional expenditures from higher levels do not improve quality as much, and beyond an 'optimum' level of expenditure, additional expenditures could be associated with a reduction in diet quality.

The association of time costs is non-linear with the Food Pyramid score and linear (positive) with HEI.

Whereas for time cost the coefficient for the linear term is positive, the squared term coefficient is negative but very small for Pyramid Score and non-significant when considering HEI-2015 as diet quality measure. This suggests that additional costs from investing more time preparing meals at home is associated with improvements in diet quality, but there are significant diminishing returns and a plateau is reached after a certain amount of time.

The random-effects results confirm the non-linear relationship between diet quality and diet cost when using HEI-2015 as diet quality measure (column 6). The daily expenditure coefficients of the positive linear and negative squared terms are highly significant. The time cost linear term is positive and statistically significant in the random-effects model, and the non-linear term negative but not statistically significant suggesting that there are not substantial diminishing returns in diet quality from additional time costs.

We can estimate the observed 'optimum' level of daily expenditure i.e. the amount of expenditure where additional food expenditures are associated with reductions in diet quality. We estimate the threshold or turning point of the parabolic relationship, which is shown as follows:

$$log\ log\ (Exp)^{*} = -\frac{\beta_1}{2\beta_2}$$

Where $log(Exp)^{*}$ is the turning point level of daily expenditure, and β_1 and β_2 are the coefficients of linear and quadratic term of $log(Exp)$, respectively. Taking the exponential of the ratio of the $log(Exp)$) coefficients gives 'optimum' amounts of daily food expenditures points of 18.3 CHF and 17.0 CHF, considering the Food Pyramid Score and HEI-2015 as diet quality measures, respectively. This is above the median daily food expenditure value of 15.84, hence less than half of the surveyed population is spending the amount estimated to achieve the highest observed levels of diet quality, on average. However, there are also a substantial number of individuals who are spending more than would appear 'optimum', and associated with reductions in diet quality.

To facilitate the interpretation of the non-linear relationship between diet costs and quality we plotted the average marginal effects for the logarithm of daily expenditures and time cost for each measure of diet quality using the estimated coefficients from regressions 2 and 4 of Table 2.1. The marginal effects for the logarithm of daily food expenditure are expressed as elasticities for both the HEI and Pyramid scores that is the percentage change in the HEI given a 1% increase in the actual amount of food expenditure. For time costs marginal effects are expressed in absolute values of the HEI and Pyramid Scores In Figure 2.14 and Figure 2.15, graph marginal effects confirms the non-linear relationship between diet quality and daily expenditure. For the Pyramid score significant improvements in diet quality with elasticities ranging from above 0.2 to around 0.05 were estimated for individuals with logarithm daily expenditures below 2 or about less than 8 CHF per day. Expenditures above logarithm of 3 CHF (around 20 CHF) were associated with reductions in diet quality with elasticities between -0.01 and -0.19 but these were not statistically significant.

Table 2.1 : Relationship between diet quality and diet cost

Covariates	Food Pyramid Score			Healthy Eating Index -2015		
	Poisson Model (1)	Poisson Quadratic Model (2)	Random-Effects Model (3)	Linear Model (4)	Quadratic Model (5)	Random-Effects Model (6)
Log (Daily Expenditure)	-0.001 (0.017)	0.250* (0.121)	0.164 (0.133)	-0.176 (0.381)	7.933*** (2.363)	9.215*** (2.355)
Log(Daily Expenditure)^2		-0.043* (0.022)	-0.031 (0.023)		-1.401*** (0.414)	-1.600*** (0.409)
Time cost	0.001 (0.001)	0.004** (0.001)	0.003 (0.001)	0.035* (0.017)	0.074* (0.032)	0.069* (0.034)
Time cost^2		-0.000** (0.000)	-0.000 (0.000)		-0.001 (0.000)	-0.000 (0.001)
Education						
Mandatory or less	-0.043 (0.084)	-0.046 (0.084)	-0.024 (0.063)	1.192 (1.511)	1.161 (1.507)	1.175 (1.500)
Incomplete Professional education	-0.121** (0.046)	-0.131** (0.046)	-0.098* (0.048)	-1.091 (1.012)	-1.295 (1.007)	-1.311 (1.002)
Professional education	-0.085** (0.033)	-0.086** (0.032)	-0.084* (0.035)	-1.005 (0.698)	-1.013 (0.691)	-1.020 (0.686)

High-school	-0.005	-0.009	-0.024	1.790	1.672	1.677
	(0.042)	(0.042)	(0.042)	(0.936)	(0.934)	(0.931)
Superior Professional education	-0.017	-0.017	-0.049	0.354	0.341	0.352
	(0.033)	(0.033)	(0.034)	(0.667)	(0.660)	(0.657)
Net Income						
<3000CHF	-0.022	-0.020	-0.018	-0.020	0.040	0.022
	(0.054)	(0.054)	(0.053)	(1.228)	(1.239)	(1.235)
3000 to 4499CHF	-0.019	-0.023	0.001	-0.640	-0.704	-0.762
	(0.045)	(0.044)	(0.041)	(0.908)	(0.910)	(0.911)
4500 to 5999CHF	-0.006	-0.004	0.002	-0.535	-0.511	-0.538
	(0.033)	(0.033)	(0.033)	(0.684)	(0.686)	(0.685)
9000 to 12999CHF	0.006	0.006	0.019	1.001	0.953	0.889
	(0.030)	(0.030)	(0.033)	(0.717)	(0.708)	(0.708)
>13000CHF	0.018	0.016	0.003	-0.605	-0.641	-0.643
	(0.040)	(0.040)	(0.043)	(0.926)	(0.912)	(0.906)
Work Status						
Retirement	-0.043	-0.041	-0.031	0.113	0.162	0.239
	(0.050)	(0.050)	(0.050)	(1.029)	(1.025)	(1.023)
Full-time mom/dad	0.114*	0.137**	0.062	1.186	1.531	1.722
	(0.052)	(0.051)	(0.062)	(1.683)	(1.618)	(1.660)
Student	0.059	0.064	0.030	1.057	1.177	1.230
	(0.094)	(0.091)	(0.069)	(1.381)	(1.379)	(1.365)
Unemployed	-0.013	-0.020	0.057	5.690**	5.473**	5.352**
	(0.101)	(0.102)	(0.085)	(1.883)	(1.857)	(1.838)
AI or CNA/SUVA	0.096	0.091	0.027	-1.079	-1.192	-1.214
	(0.081)	(0.082)	(0.133)	(2.104)	(2.093)	(2.073)
Other situation	0.023	0.020	-0.015	-1.979	-1.999	-1.972
	(0.075)	(0.075)	(0.098)	(1.922)	(1.926)	(1.913)
Labourer	-0.017	-0.009	-0.016	-0.309	-0.172	-0.192
	(0.051)	(0.052)	(0.054)	(1.137)	(1.155)	(1.150)
Skilled worker	-0.015	-0.013	-0.029	3.054**	3.041**	3.037**
	(0.046)	(0.046)	(0.052)	(1.136)	(1.136)	(1.127)
Farmer	0.056	0.064	0.007	1.197	1.301	1.272
	(0.092)	(0.091)	(0.133)	(1.729)	(1.714)	(1.735)
Worker without post-secondary education	0.032	0.041	-0.010	1.513	1.696	1.775
	(0.061)	(0.061)	(0.069)	(1.257)	(1.274)	(1.274)
Middle management	0.038	0.037	0.036	-0.909	-0.924	-0.968
	(0.036)	(0.036)	(0.039)	(0.763)	(0.756)	(0.750)
Small shop owner. artisan	-0.009	-0.013	-0.014	-2.200	-2.282	-2.373
	(0.051)	(0.050)	(0.060)	(1.322)	(1.324)	(1.309)
Senior management	0.084	0.085	0.058	1.590	1.616	1.477
	(0.061)	(0.060)	(0.059)	(1.588)	(1.570)	(1.549)
Liberal profession	0.046	0.041	0.006	0.258	0.168	0.113
	(0.077)	(0.076)	(0.072)	(1.214)	(1.212)	(1.205)
Director	0.038	0.041	0.058	2.211	2.309	2.282
	(0.073)	(0.072)	(0.065)	(1.716)	(1.683)	(1.669)
AIC	25505780	254865093	11595.464	27834.93	27816.233	$6.13e^{+7}$
BIC	25506177	25486503	12005.33	28232.38	28226.1	$6.13e^{+7}$
N	3678	3678	3678	3678	3678	3678

Notes: * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$. Standard Errors in parenthesis. Reference categories are chosen for highest frequency and include University and HES for Education; 6000 to 7999CHF for Net Income; and Qualified Worker for Work Status. Akaike's information criteria (AIC). Bayesian information criteria (BIC).

For the HEI elasticities were of similar in magnitude, but more precisely estimated with individuals with log daily expenditures less than 2.5 (around 13 CHF) per day likely to benefit significantly from increased expenditures, while additional expenditures beyond logarithm of daily expenditure of 3.25 (above 25 CHF per day) was associated with significant reductions in diet quality.

We estimated that a significant proportion of the population (28.12% for the Pyramid Score and 39.3% for the HEI-2015) could improve their diet quality from spending more on food. Conversely, we find that about 3.75% of the population could significantly improve diet quality as measured by the Pyramid score, and using HEI-2015 we found a higher proportion of the population, 24.80%, could increase diet quality by reducing their food spending if they were spending more than approximately 49 CHF or 23CHF per day for the Pyramid Score and HEI respectively.

Figure 2.16 and Figure 2.17 present average marginal effect in absolute terms of time cost on diet quality. The magnitude of the effect is quite small compared to the high time costs incurred, for instance a 20 CHF increase in time costs from a baseline of 0 would increase the Pyramid Score by 0.15 (or 7% around the mean) and the HEI by 1.5 (or 3.2% around the mean). We find, however, that there is significant scope amongst the population to improve diet quality by incurring higher time costs with 80.67% and 85.34% of the population potentially able to increase diet quality when considering the Pyramid Score and HEI-2015, respectively. Individuals who report being on a diet at the time of the survey are positively and significantly more likely to have higher diet quality that those who do not using HEI-2015. The result does not hold when considering the Pyramid Score as a diet quality measure.

Conversely, reported vegetarianism was shown to have a positive and significant effect on diet quality in comparison to those that stated they are not vegetarians. This was not confirmed when using HEI-2015.

The interpretation of regression coefficients when there exists a non-linear relationship between dependent and independent variables might be challenging. We plotted average marginal effects for the logarithm of daily expenditure and time cost for each measure of diet quality considering regressions 2 and 4 of Table 2.1.

In Figure 2.18 and Figure 2.19, confirms the non-linear relationship between diet quality and daily expenditure. It is also relevant to point out that there is a clear benefit of increasing daily expenditure on food for a significant proportion of the population. We find that 28.12% of the population would benefit from spending more on food and that this would influence positively diet quality as measured by the Pyramid Score (Figure 2.18). If we use HEI-2015 as diet quality measure, we find that 39.29% of the population could improve their diet quality be increasing daily food expenditure. Conversely, we find that 3.75% of the population significantly reduce diet quality by increasing daily expenditure above approximately 49CHF per day when considering the Pyramid Score. However, using HEI-2015 we find that a higher proportion of the population, 24.80%, reduce significantly their diet quality after spending more than approximately 23CHF per day.

Figure 2.14 : Average marginal effects of the logarithm of daily expenditures on predicted Pyramid Score

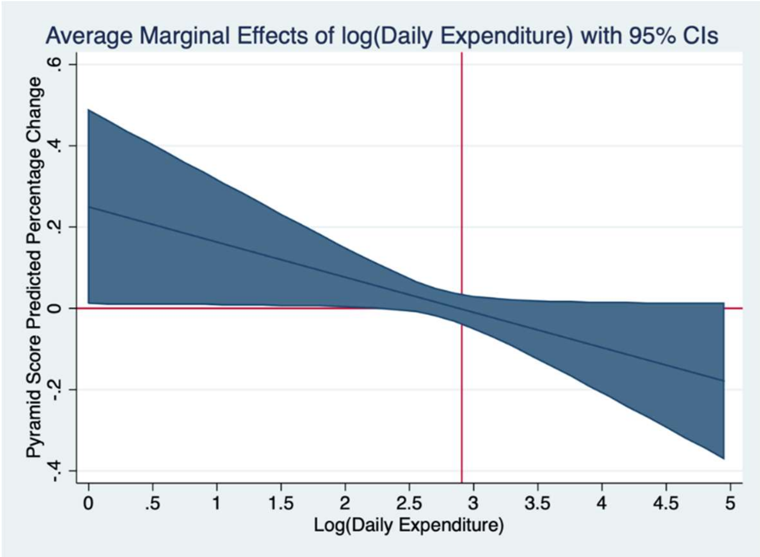


Figure 2.15 : Average marginal effects of the logarithm of daily expenditures on predicted HEI-2015 index.

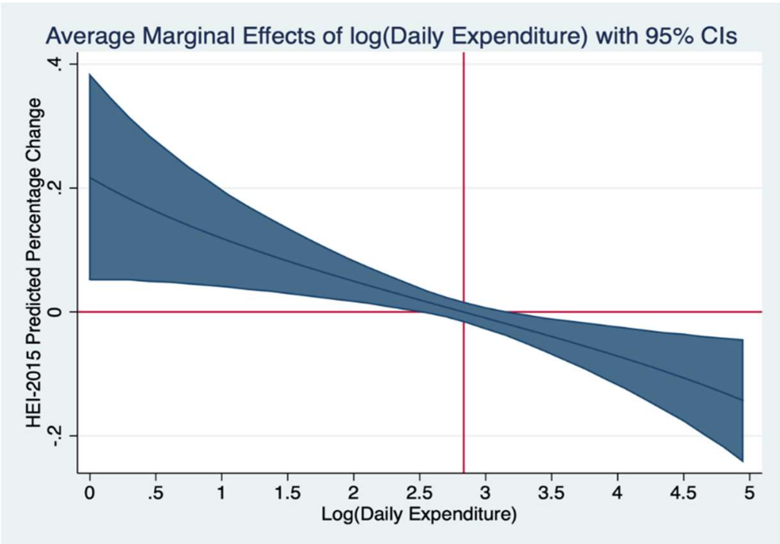


Figure 2.16 : Average marginal effects of time cost on predicted Pyramid Score

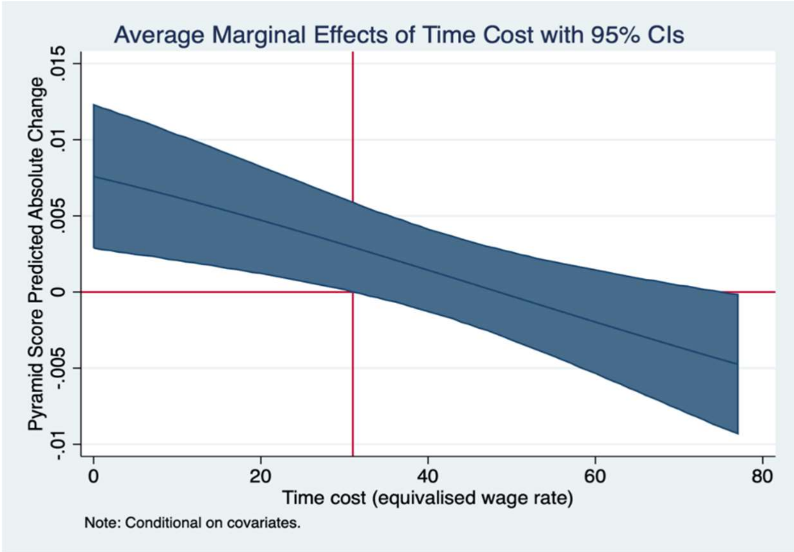
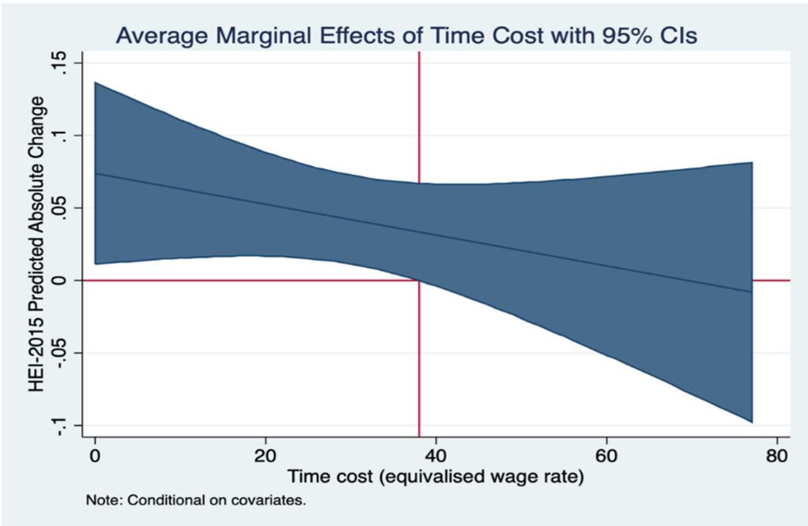


Figure 2.17 : Average marginal effects of time cost on predicted HEI-2015 index



2.7.3 Association between socio-economic status variables and diet quality

There were no significant direct associations between income and diet quality implying we could not identify a difference in preferences for healthier foods or knowledge as well as motivation for eating healthier diets amongst individuals in wealthier households. We found a significant and positive associations between food expenditures and income (Table 6.5). There is a 20% difference in food expenditure between the wealthiest and poorest households. Given that low levels of food expenditure are associated with worse diet quality, lower income would likely reduce diet quality. Therefore, the income effect is likely to indirectly impact diet quality through food expenditure. However, the non-linear association between diet costs and quality also implied that wealthier household might be spending more on foods with negative effects on diet quality. There were significant differences associated with education for the Pyramid Score in particular individuals with professional or incomplete professional education have significantly lower diet quality. Differences were not statistically significant for the HEI-2015 (Figure 2.18 and Figure 2.19). For work status, we found that individuals at home looking after the house or family had significantly better diet quality for the Pyramid Score. For the HEI-2015, unemployed individuals had higher diet quality possibly suggesting the importance of being able to allocate more time to home preparation as the opportunity costs of time are much lower (more time available and lower wage rates), which is consistent with our observed positive association with time costs. Skilled workers also had significantly higher HEI-2015. The self-employed, however, had lower diet quality although the association was not statistically significant (Figure 2.22 and Figure 2.23).

Figure 2.18 : Predicted level effects of education on predicted Pyramid Score

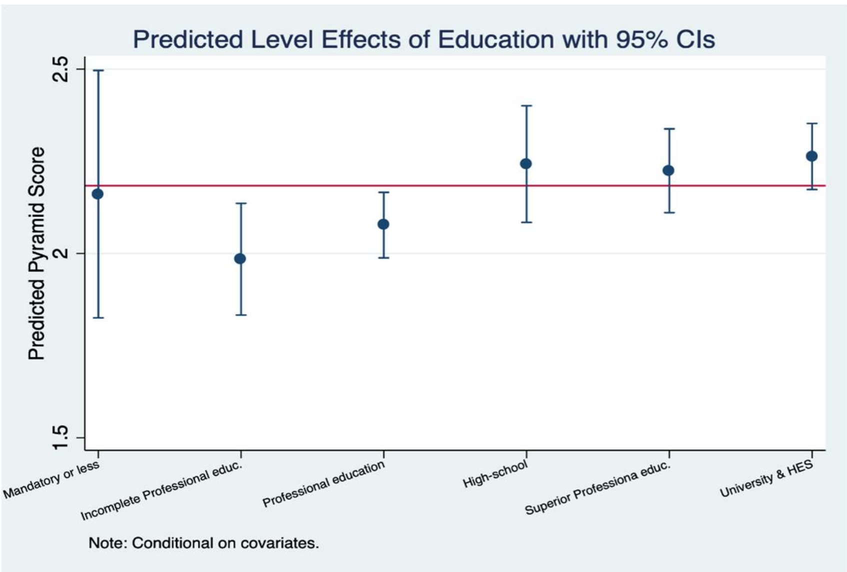


Figure 2.19 : Predicted level effects of education on predicted HEI-2015

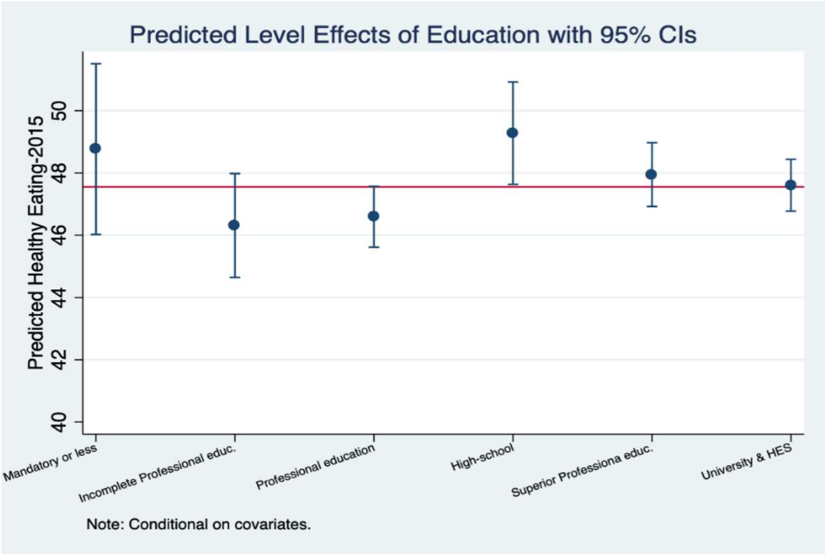


Figure 2.20 : Predicted level effects of net income on predicted Pyramid Score

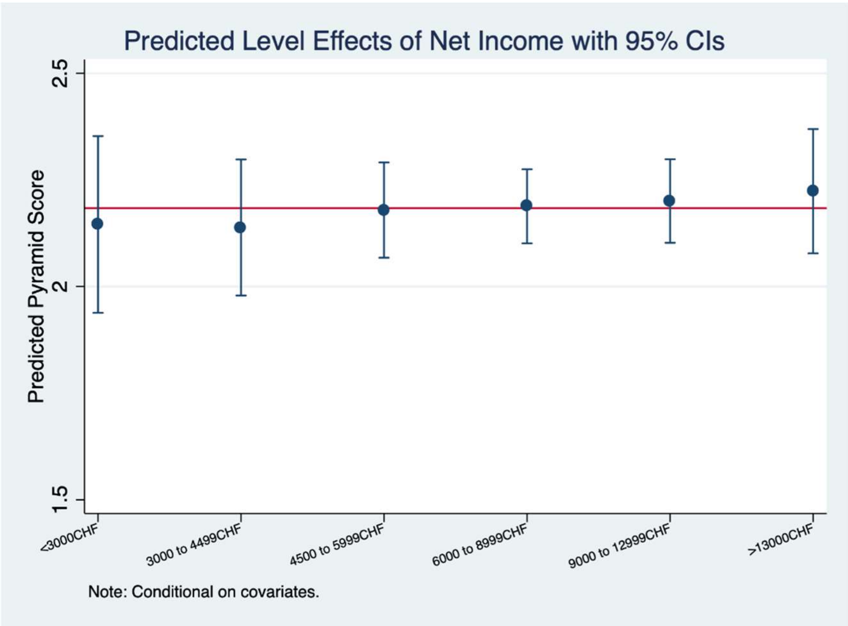


Figure 2.21 : Predicted level effects of net income on predicted HEI-2015

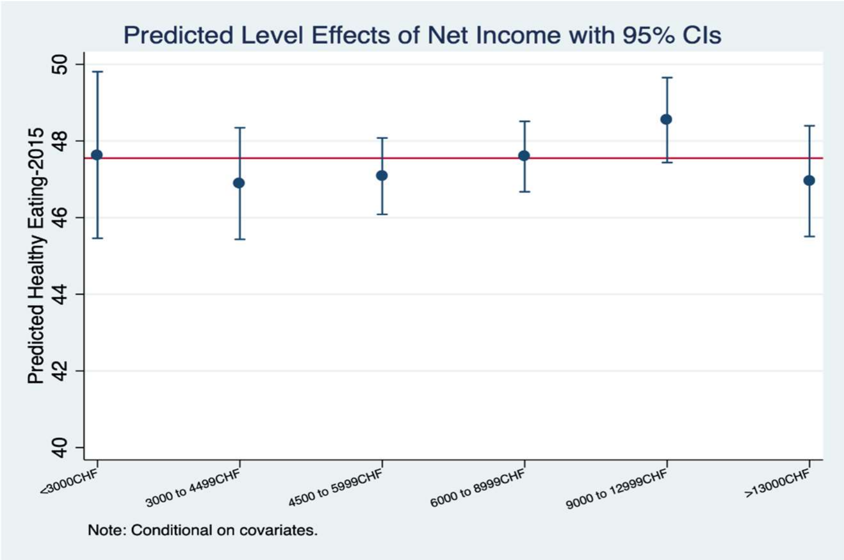


Figure 2.22 : Pyramid Score coefficients plot by work status

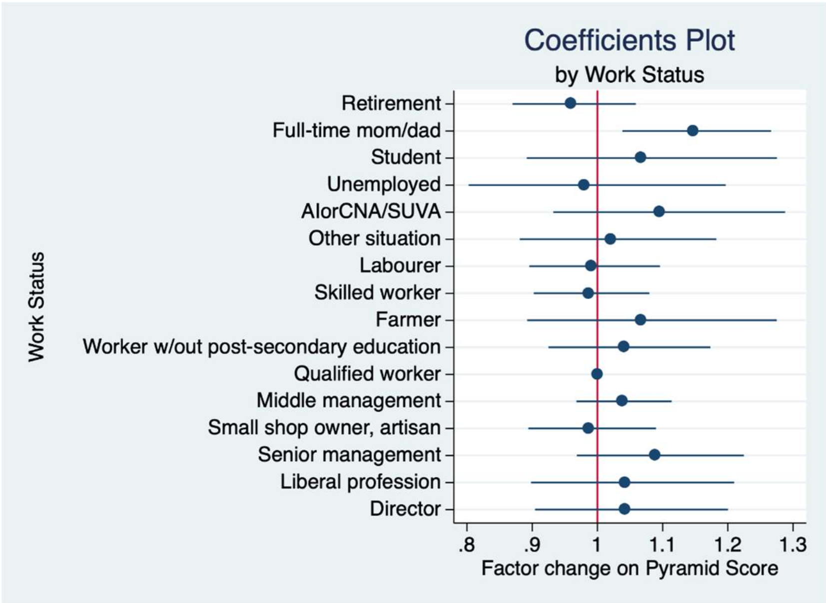
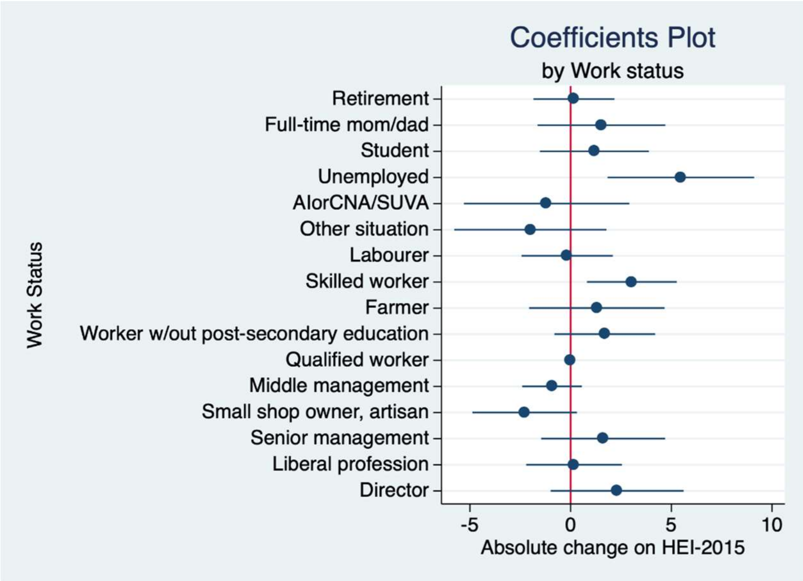


Figure 2.23 : HEI-2015 coefficients plot by work status



2.7.4 Association of diet knowledge, food and health preferences and other cultural factor with diet quality

In addition to the variables that relate diet cost with diet quality, and the socio-economic characteristics of households that affect diet quality as well as influencing food expenditures and time costs, it is also of interest to consider the influence of the other variables that may drive changes in diet quality, in particular diet knowledge, food preferences as well as health-related behaviors and cultural differences

For the Pyramid score lower nutrition knowledge (i.e. knowing none or only one of the nutrition concept) had a negative and significant impact on diet quality relative to knowing both nutrition concepts (5-a-day and Food Pyramid). The differences for lower knowledge were negative but not statistically significant when using HEI-2015 as the diet quality outcome (Figure 6.2 and Figure 6.3).

Individuals who reported being on a diet at the time of the survey were positively and significantly more likely to have higher diet quality than those who did not when the HEI-2015 was the outcome. There was no association with the Pyramid Score as the diet quality measure. Reported vegetarianism was significantly positively associated with diet quality for the Pyramid Score but not for the HEI-2015.

Figure 6.4 and Figure 6.5 show coefficients plots of the magnitude of the associations of the other explanatory variables on diet quality. Smokers had significantly lower diet quality scores for both outcomes. Physical activity was not significant when considering both measures of diet quality. Very bad perceived health status was associated negatively with the Pyramid Score and not significantly associated with the HEI.

Language regions represent proxies for cultural differences across Switzerland. The Pyramid Score is significantly worse in the French-speaking part of Switzerland compared to the German-speaking region, but the opposite result is found for the HEI-2015 as diet quality is better in the French than German speaking parts of the country. Diet quality is better in the Italian-speaking region. Household size was not associated with the Pyramide Score (Figure 6.6) , but tended to be associated negatively with the HEI-2015Being single was associated with better diet quality relative to being married or in a civil partnership (see Figure 6.6 and Figure 6.7).

2.8 Dietary patterns characteristics

To understand more about the nature of the differences in dietary patterns of individuals according to their dietary expenditures and quality, we classified individuals into four groups based on two estimated parameters from our regression models specified above. These groups reflect whether individuals were observed to have higher or lower than expected dietary quality based on their observable characteristics that are associated with nutritional quality, and whether they were indviduals with higher or lower than expected daily expenditures. To identify the groups we estimated and then plotted the residuals from the OLS model in Table 6.4 for HEI-2015 and residuals from OLS model in Table 6.5 for the logarithm of daily expenditures. Hence, we capture departures from the expected nutrition quality and daily expenditures that reflect individuals who achieve for instance better than expected levels of dietary quality with lower than expected expenditures, and alternatively individuals with lower than expected diet quality but higher than expected expenditures (inefficient). Figure 2.24 plots the estimated residuals from the two models. In the top left hand side of the plot in red are individuals that show lower daily expenditure on food but relatively higher diet quality that we defined as positive deviants. The positive deviance theory is based on the observation that even in "at risk" situations, there are some individuals or households, called "positive deviants," with uncommon but beneficial behavior.[189] In our analysis, this definition is simplified i.e. we defined them as more efficient in making food choices relative to other groups.

By analyzing differences in dietary patterns of positive deviants in terms of actual food groups consumed we can provide insights into which types of food choices may be more appropriate or effective in improving diets. Table 2.2 shows the mean quantity in grams (g) of food items consumed that are significantly different in positive deviants compared to individuals in the bottom left quadrant, i.e. individuals with relatively lower than expected expenditures but also lower than expected diet quality (green points). The positive deviants group consumed significantly more unsweetened drinks (water, coffee, tea and infusions), more alcoholic drinks, dairy products (excluding butter), vegetables, fruits and red meat, but less starchy and staple carbohydrate foods (pasta, bread and crackers), less sugar, sweet spreads, honey, jams, sweet sauces and chocolate bars, spreads, confectionery and powdered chocolate; as well as less processed fish products, butter and olives.

The top right hand-side of the residuals plot (Figure 2.24) depicts groups with higher daily expenditure residuals, but also higher than expected diet quality. We compare their food consumption patterns to individuals also spending more than expected but with worse dietary outcomes. Table 2.3 shows that the higher expenditure, but also higher diet quality group of individuals consumed significantly more unsweetened drinks (water, coffee, tea and infusions), dietary and sports nutrition products, vegetables and fruits, soft cheese, fish, seafood, poultry, ice cream, yogurts, vegetable oils (such as olive oil), condiments and Flour, starch, oatmeal, germs, flakes (incl. powdered dessert). Conversely, they consumed less sugar, sweet spreads, honey, jams, sweet sauces and chocolate bars, spreads, confectionery and powdered chocolate, breads and crackers.

Figure 2.24 : Residuals Plot

Table 2.2 : Food patterns between low expenditure groups

Food Items (g)	Lower Quality/lower expenditure	Positive Deviants	Difference
Water	1232.52	1316.94	84.42** (0.03)
Drinks with unspecified or mixed alcohol (e.g. punch. cocktails)	302.07	382.73	80.66* (0.09)
Milks. milk drinks and fermented milk	159.37	237.50	78.13*** (0.00)
Coffee. tea. fruit tea and infusions	590.61	653.45	62.84** (0.01)
Dried vegetables	42.35	100.93	58.58** (0.03)
Fruits	227.05	270.87	43.82*** (0.00)
Unspecified or mixed vegetables and salads	135.21	172.18	36.98** (0.01)
Cabbage	93.08	112.49	19.41** (0.01)
Yogurts	151.60	170.33	18.73** (0.01)
Potatoes	147.54	166.11	18.57** (0.03)
Fruiting Vegetables	98.34	115.72	17.38*** (0.00)
Leafy Vegetables (excl. Cabbage). and algae mesclun	50.33	62.73	12.40*** (0.00)
Red Meat	91.85	103.49	11.64* (0.09)

Cheese	55.50	63.33	7.83** (0.01)
Flour, starch, oatmeal, germs, flakes (incl. powdered dessert)	15.95	23.55	7.60** (0.01)
Bulb vegetables (e.g. garlic. leek. onion)	16.89	21.81	4.92* (0.06)
Vegetal oils	12.37	16.60	4.23*** (0.00)
Fats and oils unspecified or mixed	7.98	12.17	4.19*** (0.00)
Condiments (incl. Tapenade and pickles)	7.81	9.76	1.95** (0.03)
Spices and herbs	0.90	1.50	0.59*** (0.00)
Butter	16.99	14.23	-2.77*** (0.00)
Sugar, sweet spreads, honey, jams, sweet sauces and syrup	34.46	29.08	-5.38*** (0.00)
Chocolate bar, spreads, confectionery and powdered chocolate	35.52	28.23	-7.29*** (0.00)
Olives (incl. paste)	24.79	16.32	-8.47** (0.02)
Pasta, rice, other grains and seeds	195.32	181.69	-13.63* (0.07)
Breads and crackers	130.52	113.61	-16.91*** (0.00)
Products based on fish and breaded fish	134.70	76.22	-58.49* (0.09)

Notes: * $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$. T-statistics in parenthesis.

The right hand-side of the residuals plot (Figure 2.24) depicts groups with higher daily expenditure residuals. Table 2.3 shows that the higher expenditure and higher diet quality group consumed significantly more unsweetened drinks (water, coffee, tea and infusions), dietary and sports nutrition products, vegetables and fruits, soft cheese, fish, seafood, poultry, ice cream, yogurts, vegetal oils, condiments and Flour, starch, oatmeal, germs, flakes (incl. powdered dessert). Conversely, they consume less sugar, sweet spreads, honey, jams, sweet sauces and chocolate bars, spreads, confectionery and powdered chocolate, breads and crackers.

Table 2.3 : Food patterns between high expenditure groups

Food Items (g)	Lower Quality/higher expenditure	Higher Quality/higher expenditure	Difference
Water	1235.92	1400.95	165.03*** (0.00)
Dietary and sports nutrition products	5.34	98.34	92.99*** (0.00)
Unspecified or mixed vegetables and salads	124.62	213.83	89.20*** (0.00)
Milks, milk drinks and fermented milk	138.05	221.27	83.23*** (0.00)
Cottage cheese and curd	77.36	158.83	81.46*** (0.00)

Fruits	227.55	297.21	69.66*** (0.00)
Dried vegetables	59.88	108.59	48.71*** (0.00)
Coffee, tea, fruit tea and infusions	583.12	628.72	45.60* (0.09)
Fruiting Vegetables	94.85	131.15	36.30*** (0.00)
Cabbage	77.72	110.90	33.17*** (0.00)
Fish	93.40	125.45	32.05*** (0.00)
Seafood	47.56	78.76	31.20** (0.01)
Poultry	120.72	150.05	29.33** (0.01)
Ice cream, ice cream substitutes, sorbet and water ice creams	57.80	85.83	28.03*** (0.00)
Leafy Vegetables (excl. Cabbage),algae and mesclun	48.06	70.01	21.96*** (0.00)
Yogurts	157.46	175.82	18.36** (0.02)
Root vegetables	61.77	74.97	13.20** (0.01)
Flour, starch, oatmeal, germs, flakes (incl. powdered dessert)	14.99	25.73	10.74*** (0.00)
Bulb vegetables (e.g. garlic, leek, onion)	18.68	24.39	5.71* (0.08)
Vegetal oils	14.04	19.27	5.23*** (0.00)
Condiments (incl. Tapenade and pickles)	9.14	12.21	3.08*** (0.00)
Chocolate bar, spreads, confectionery and powder with chocolate	36.96	30.90	-6.06** (0.02)
Sugar, sweet spreads, honey, jams, sweet sauces and syrup	37.22	27.49	-9.73*** (0.00)
Breads and crackers	152.30	136.51	-15.79** (0.01)

Notes: * $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$. T-statistics in parenthesis.

2.9 Discussion

In this study, we have analyzed the relationship of diet quality with diet cost. Our findings show a non-linear relationship between food expenditure and diet quality. At lower levels of daily expenditure there is significant scope to increase daily expenditure on food with diet quality benefits. We find that close to 40% of the population would increase diet quality by increasing their daily expenditure over to 17 CHF per day, using the HEI as diet quality measure. The proportion of the population for whom this increase would be beneficial is significantly smaller when using the Pyramid Score. Furthermore, this non-linear relationship shows that after the turning point increasing daily expenditure on food has a detrimental impact on diet quality. Results seem to suggest that in the Swiss population there is both under- and over- consumption of food from a diet quality perspective. In fact, average diet quality is low scoring 2.17 for the Food Pyramid and 47.5 for the HEI.

Studies have specifically examined the cost of diets by only taking into account the monetary cost of food. We find higher time cost has a positive and significant impact on diet quality. We extend our analysis by including a measure of time cost of cooking. Although, the magnitude of the impact on diet quality of incurring higher time cost is small, individuals might have to substitute cooking time for meal eaten away from home that would greatly inflate their daily food expenditure. Therefore, investment on time cooking has the potential to be cost-effective in terms of improving diet quality.

We investigate the impact of socioeconomic status on diet quality. Results show that there is no direct impact of household net income on diet quality on the basis of menuCH data. Although, there is an indirect effect of net income through daily expenditure. Net income has a positive and significant effect on daily food expenditure in favor of wealthier individuals (Table 6.5), which confirms Engel's law that as income rises the absolute spending on food increases but the percentage of income allocated for food purchases decreases. Lower income households spend a greater proportion of their available income on food than middle or higher income households do.[190]

This analysis leverages on rich data from various sources that allowed controlling for multiple factors that might influence dietary choices. We find positive and significant impacts of nutrition knowledge on diet quality. In fact, less nutritional knowledge was significantly related with approximate 10% lower Pyramid Score. Smoking status was also negatively and significantly correlated with lower diet quality using both measures. As it can be interpreted as a proxy for healthy behavior which means that individuals that smoke heavily discount the costs of future costs and outcomes of poor diets.

Results also show that household size is negatively correlated with diet quality. Moreover, larger households tend to have lower daily food expenditure (Table 6.5). The latter might be seen as a measure of deprivation and increases the scope of policy interventions in this specific group.

Much variability in food consumption was observed, so it was possible to identify positive deviants who purchased higher-quality diets at a lower expenditure and to characterize their dietary patterns. We investigated deeply which type of products were consumed. Comparisons between individuals that have similar levels of daily food expenditure but different dietary patterns shows that individuals with lower diet quality overconsume products with low nutritional value relatively to their comparable groups. In particular, people who report low diet quality tend to report higher consumption of highly sugar dense products and starchy foods like breads, pasta and rice.

The results from this study suggest that higher daily expenditure and incurring higher time cost has a positive impact on diet quality for lower levels of diet cost, but they are smaller then results found elsewhere.[174] These findings are consistent with the hypothesis that adopting dietary recommendations may lead to higher food costs for consumers and informs policymakers on the scope of public health interventions to improve diet quality.

Whereas potentially all groups on Figure 2.24, apart from "positive deviants", might benefit from policy intervention its success is very much dependent on the characteristics of each group. People with low quality diet and low daily expenditure are the ones that might need interventions that are more pressing. The dietary patterns exhibited by the latter call for policy interventions aiming to change preferences. Dietary patterns of "positive deviants" might greatly inform policymakers. Results show that people with low quality diet and low daily expenditure consume less fruits and vegetables compared to "positive deviants". Targeted benefits are effective in increasing fruit and vegetable consumption. They work through economic incentives that were shown to be effective on improving diet quality in other settings.[191, 192] Transfers to individuals through vouchers for low-income families or incentivized health promotion program through health insurance bonus cards are some of the proven effective policies for these groups. Changing preferences is however extremely difficult and there is a need to control for unintended effects. These policies tend to increase available income and therefore individuals might spend the surplus on other food products that might have pervasive effects on diet quality.

The food environment makes it very difficult not to succumb to the temptations of highly caloric and palatable foods.[193] Redesigning the food environment encouraging people to automatically make healthy food choices could have long and lasting benefits because it does not require self-control or cognitive capacity. Public worksite bans on foods with low nutritional density have been proven effective to improve diet quality and health outcomes.[194-197]

Measures to target the market environment are more intrusive but may be more effective.[198, 199] Taxes have been implemented elsewhere and they were proven to improve diet quality and reduce consumption of low nutritional value food items.[172] Moreover, these type of interventions could raise valuable revenue for health-promoting interventions. In the Swiss setting, our research suggests that the distributional effects of a tax on sugary products might not be regressive since there is evidence that both on the low, as well as on the high, spectrum of daily food expenditures sugary products came as the type of products that are overly consumed by people with low quality diets.

3 Example of policy intervention: tax on sugar-sweetened beverages in Switzerland

3.1 Introduction

As reported by the Global Burden of Disease Study, unhealthy diets have a major impact on health and the risk of obesity and chronic diseases. [2] Both the World Health Organization (WHO) and the United Nations (UN) have called for public health interventions aiming at improving diets to reduce the burden of non-communicable diseases (NCDs). [200] Given the complex determinants of dietary choices, multisectoral and intersectoral strategies are needed to overcome barriers and enhance effectiveness. [201]

Policy makers have a long history of taxing or subsidizing different foods, but this was done primarily to secure food supplies and/or farmers' income. Fiscal policy tools are currently underused in reducing the consumption of unhealthy commodities to improve human health. Among the interventions available to influence people's diets are subsidies on healthy foods and taxes on unhealthy foods and beverages. During the past 10 years, there has been growing interest in exploring the impact of taxes and subsidies to encourage the consumption of healthy foods and diets. [11] There is consistent evidence that taxes and subsidies are able to modify dietary behaviors, in particular when they reach at least 10% or 15% and are used jointly. [200]

Obesity is becoming a growing public health problem worldwide and results from excessive energy intake combined with insufficient energy expenses, in particular via regular physical activity. Taxing all food products high in energy is, of course, politically unrealistic. Policy makers must, therefore, determine which food category (or categories), if taxed, will have the highest impact on the amount of consumed calories. Even though nutrition policy interventions could be based on nutrient content that has been shown to be more effective, it would be easier legislatively to tax specific categories of food, particularly those with limited nutritional value.[202-204]

Excessive consumption of sugar-sweetened beverages (SSBs) with high content of added sugar (i.e. sugar added during the industrial processing of sugar-sweetened beverages) contribute calories without providing essential nutrients. During the past 30 years, there has been a marked increase in the consumption of SSBs worldwide. [205] SSBs have been found to be a key contributor to sugar intake and the relationship between the consumption of SSBs and body weight has been examined in many cross-sectional and longitudinal studies, as summarized in systematic reviews.[206-209] The consumption of SSBs increases the risk of overweight, obesity, type 2 diabetes and cardiovascular disease.[205, 210-212] Some reports suggest that SSB consumption could even be associated with the risk of cancer [213, 214], nonalcoholic fatty liver disease [215] and neurodegenerative diseases [216-218].

SSB taxes were shown to significantly reduce the purchase of the taxed SSBs and increase the purchase of healthy beverages.[219] The World Health Organization (WHO) recommends to reduce the intake of free sugars in the diet to less than 10% of total energy intake (TEI) and preferably below 5% of TEI for both adults and children.[220] SSB taxation is the most commonly used policy intervention across countries and jurisdictions. The low purchase price of SSBs does not reflect their full costs from a societal point of view and makes SSB an important target food group for taxation. This is particularly relevant in youth and young adults who consume relatively higher amounts of SSBs. If these two groups present higher price elasticities than the general population, then we should expect more benefits of SBB taxes in these younger groups.[221-223]

3.2 Data sources

3.2.1 menuCH

The first national nutrition survey in Switzerland, menuCH, was conducted in 2014/2015 among non-institutionalized residents aged 18-75 years old.[178] Participants were recruited on the basis of a stratified random sample from the national sampling frame for person and household surveys by the Federal Statistical Office. The survey population was intended to be representative of the Swiss population in terms of age and place of residency across all seven major areas of Switzerland, but did not survey individuals from every canton. A total of 5496 eligible people reachable by phone were invited to participate, of whom 2086 (38%) responded [179]. The study was registered in the trial registry (identification number: ISRCTN16778734) and conducted according to the guidelines laid down in the Declaration of Helsinki. Each participant signed a written informed consent. Participants and non-participants had similar age and marital status but participants were more frequently women and Swiss nationals. Survey sampling weights were derived to adjust statistical analysis to be more representative of the corresponding Swiss population.

Trained dietitians conducted two non-consecutive 24-h recalls (24HDR, first: face-to-face and second: by phone, two to six weeks later). They used the computer-directed interview program GloboDiet®, which was previously known as EPIC-Soft® (International Agency for Research on Cancer (IARC), Lyon, France) [224, 225] following standardized steps for 24HDR: (1) general participant information (e.g., special diet, special day); (2) quick list of food consumption occasions and items; and (3) detailed description and quantification of all consumed foods and beverages, including conservation and preparation methods, sugar content/addition, and portion size. To support survey participants in quantifying consumed amounts, dietitians used a book with 119 series of six graduated portion-size pictures.[226] 24HDR were spread over all weekdays and seasons. All foods and beverages were classified into 30 food groups, based on their original classification from GloboDiet® (18 groups and 85 subgroups) and on their nutritional similarity regarding sugar content. menuCH provides detailed data on food consumption (items and quantities consumed), but it does not provide data on food prices.

3.2.2 Swiss Federal Office of Statistics Consumer Price Index Retail Scanner dataset

The Swiss Federal Office of Statistics Consumer Price Index Retail Scanner dataset (CPI) is a national survey of food retail prices for a large basket of food items most frequently consumed by the Swiss population. The retail price data is collected monthly from electronic retail scanner data from the major supermarket retailers across Switzerland (Coop, Migros, Denner) as well as from smaller retailers across Switzerland.[180] Information on the prices of different prepared foods and meals purchased outside the home from canteens, self-service restaurants, take-away food, cafes or restaurants is also available. Data is collected on a regional basis with the country split into 12 regions. The scanner data does not identify specific brands but provides significant detailed information on a generic product level. The data was structured hierarchically with food items grouped in up to four product category levels. In total around 554 generic food items and their prices were provided at the lowest level. This data provides detailed price variation within food item categories by region and month. Data on all the collected prices from the different retailers per quantity (kg, liter) grouped within the generic food item classifications defined by the OFS were obtained for each region and month for the years 2013 to 2015 and utilized to attribute prices to the menuCH data. Some 840 000 prices are collected every year. Decisive for calculating the CPI are transaction prices, i.e. the price paid by consumers for a specific good or service, including indirect taxes (chiefly VAT and incentive fees), customs duties, environmental taxes and subsidies. Credit or interest costs are not taken into account. Price reductions (special offers, promotions, discounts, sales) are taken into account. In all, approximately 2,700 sales outlets participate in the successive surveys. The data collection procedure and further information were already discussed elsewhere.[180]

3.2.3 Swiss Household Budget Expenditure Survey (SHBES)

We obtained individual household level data for the Swiss Household Budget Expenditure Survey (SHBES) for the years 2006 to 2015 collected by the Swiss Federal Statistical Office (FSO).[181] It is an annual nation-wide household survey on household expenditure patterns of 3,300 individuals aged 15 and over (from 2012 data on children over 6 years was also collected). The data was stratified by the seven large Swiss regions consisting of private households permanently residing in Switzerland. Additional information was collected on the labor market situation and on the social and educational background of the household members. The survey contains itemized food expenditures during the survey period (quantity and cost) as well as major expenditures in the past 5 months, and household mobility with a travel diary with information on all trips within and outside of Switzerland during the survey period including reasons for travel, geographic coordinates of destination and expenditures. The survey contains 14 broad food categories and a further 7 categories for external catering or food gifts. These groups nest a further 120 food item classifications. For each household the total monthly quantity purchased in kilograms or liters and the amount spent for each item is recorded. The limitation of the data is that the 120 food items, while covering the majority of most frequently consumed foods, contains a number of aggregate and general categories – it is a fraction of the generic food items in menuCH (964 or approx. 10%).

3.3 Compliance with Nutritional Guidelines

The over and under consumption of certain nutrients has harmful consequences to health. In this section, we present results of the analysis of the menu-CH1 database focusing on consumption of added sugars in general and the contribution of SSBs to added sugar calories.

In order to assess compliance with national dietary recommendations we calculate the proportion of the population meeting those recommendations based on the guidelines from the Federal Food Safety and Veterinary Office (FSVO). Table 3.1 shows the mean intake of nutrients and compliance with FSVO nutritional guidelines. Across the majority of the reference values from national guidelines, less than 40% of all individuals meet the dietary recommendations. Less than one-third met the guidelines for protein, monounsaturated fat, fibres and total energy intake. However, mean daily energy intake seems to be close to the recommended daily intake calculated based on physical activity, gender and age. In contrast, more than two thirds met the recommendation for added sugar.

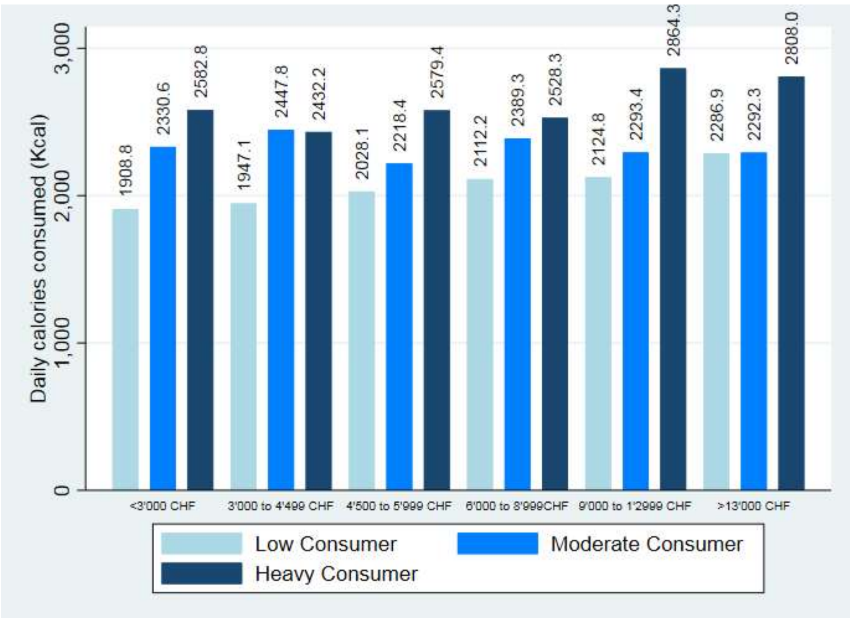
Population average compliance with added sugar intake guidelines does not immediately render SSBs as an obvious candidate for policy intervention. Changing the relative price of protein and fibre would potentially improve compliance with nutritional guidelines. SSBs offer an ideal target for public health tax policies because of their negative effects on nutrition and higher own-price elasticity than food items with high content of protein and fibres.[150]

Table 3.1 : Mean intake of nutrients and compliance with FSVO nutritional guidelines (SD)

Compliance with FSVO guidelines				
Daily Intake	**Mean Intake**	**Percentage of daily energy (%)**	**Recommended Daily Intake***	**Meeting Guidelines (%)**
Total Energy (Kcal)	2227.04	-	2300 Kcals	10% (0.5)
Total Fat (Kcal)	(20.73)	35.86% (0.42)	20-35% (max.	38.21% (0.97)
Saturated Fat (Kcal)	817.19 (9.77)	13.54% (0.18)	40%)	37.67% (1.05)
Monounsaturated Fat (Kcal)	308.25 (4.21)	9.42% (0.14)	<10%	21.07% (0.81)
Total Carbohydrates (Kcal)	214.99 (3.40)	40.67% (0.42)	10-15%	16.65% (0.84)
Added Sugar (Kcal)	931.90 (9.61)	7.64% (0.21)	(max.20%)	72.69% (1.03)
Fibres (g)	176.42 (4.88)	-	45–55%	13.77% (0.77)
Protein (Kcal)	20.28 (0.24)	14.76% (0.15)	max. 10 %	6.72% (0.459)
	339.04 (3.73)		30g	
			0.8g/kg body weight	

Source: Menu-CH1 data.* Based on guidelines from FSVO. Recommended daily energy intake was calculated conditional on physical activity, gender and age of menuCH participants.

Figure 3.1 : Daily caloric intake by sugar-sweetened beverages consumer type across socioeconomic groups (income)

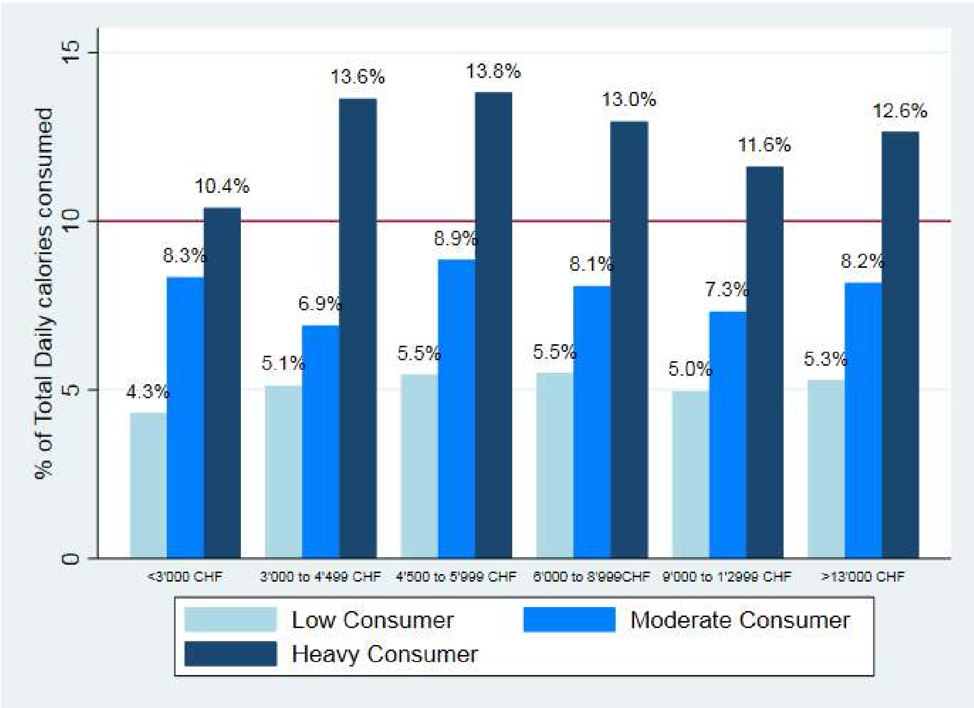


Source: menuCH data.

When we analyse daily caloric intake (Figure 3.1) we can see that moderate and high SSBs consumption is correlated with higher levels of daily calories consumed, within each income category. It is interesting to see that in the Swiss population calorie intake increases monotonically with incomes, on average. This positive income association is consistent with an Engel curve relationship with food expenditures and consumption rising with incomes and wealth. The poorest fifth of households in the SHBS spent 960 CHF per head/month on food compared to 1258 CHF per head/month amongst the richest fifth of households (31% more), suggesting greater quantities of food purchased, but also higher prices paid and a better quality of food.

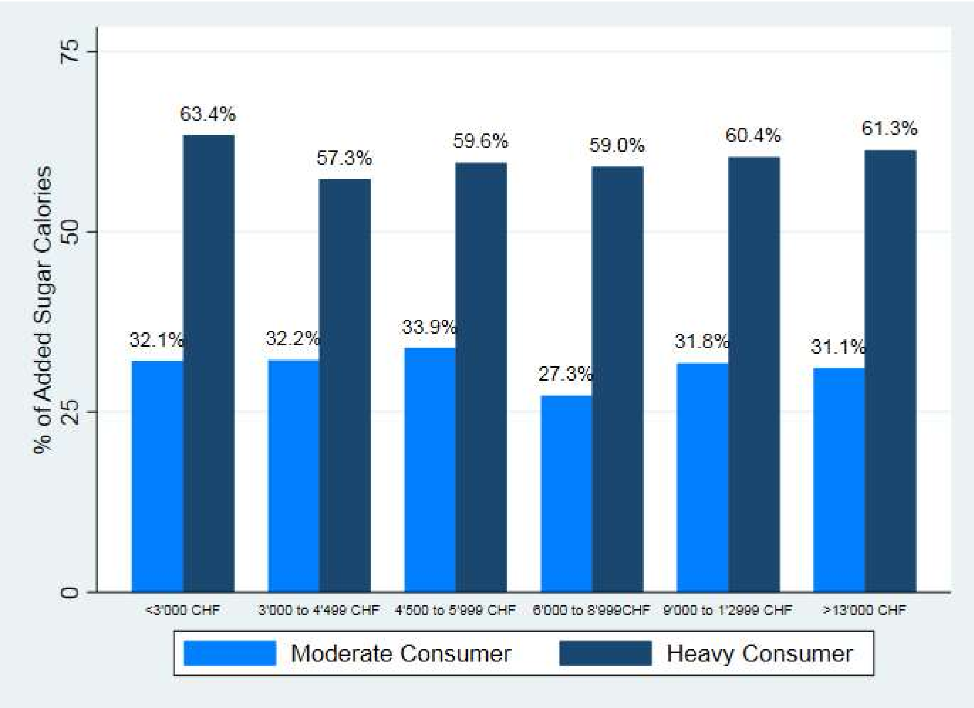
Within each income category, heavy consumers of SSBs have more than 10% of their consumed daily calories attributable to added sugar (Figure 3.2). As this analysis focuses on SSBs, it is of interest to analyse the contribution of SSBs to added sugar intake. We observed that the poorest households consume relatively lower quantities of added sugar in their diets, however, as Figure 3.3 shows, for heavy consumers from low-income groups SSBs contribute the most for added sugar intake, approximately 63%. Hence, with nearly a third of added sugar calories coming from SSBs for heavy consumers, policies that target SSB reduction would have more significant health effects in terms of sugar intake reduction in the poorer households.

Figure 3.2 : Percentage of daily caloric intake from added sugar



Source: menuCH data.

Figure 3.3 : Percentage of added sugar calories from sugar-sweetened beverages



Source: Menu-CH1 data.

To explore the variation in total calories and calories from added sugar associated with SSB consumption we stratified the sample of person day observations by consumer type of SSB. Table 3.2 reports average differences for the population. Moderate and heavy consumers of SSBs, have significantly higher average added sugar intake 188.24 Kcal per day (95% CI: 174.20 to 202.27) and 315.38 Kcal per day (95% CI: 296.59 to 334.19) compared to those who did not consume SSBs on a given day (115.07 kcal; 95% CI: 107.24 to 122.90). It is rather explicit from the analysis that SSBs are the main contributor and that SSB preferences and consumption appears a strong indicator of excess added sugar and calorie intake in the population. Given the problem is more acute amongst middle to lower income individuals who may be more sensitive to price, targeting SSB consumers through fiscal or other policies may be an effective means of targeting higher health risk groups. From an equity perspective, the greater problem concentrated on the middle-income group reduces equity concerns somewhat.

Table 3.2 : Average calories (Kcal) consumed by person days with low, moderate and heavy consumption of SSBs

Total daily calories coming from added sugars by consumer type				
Average daily calories (kcal) from added sugars	N	Mean	Std. Err.	[95% Conf. Interval]
Low-consumers (0 servings in 2 dietary recalls	1,255	115.07	3.99	107.24, 122.90
Moderate-consumers (1 serving in 2 dietary recalls)	520	188.24	7.14	174.20, 202.27
Heavy-consumer (2 or more servings in 2 dietary recalls)	610	315.38	9.57	296.59, 334.19

Source: menuCH data.

The above analysis looked at averages across income groups in absolute and relative added sugar consumption, but masks the variation in the distribution of sugar consumption within groups. Table 3.3 reports the proportion of individual daily food consumption consistent with the recommended Swiss guideline of less than 10% of calories coming from added sugars. We note 74.6% (95% CI: 72.6% to 76.5%) of individuals' daily consumption was within this recommendation, implying 1 in 4 individuals consumed excess added sugar on a daily basis. Interestingly, the wealthiest households had the lowest proportion 72.4% meeting this recommendation whilst the poorest households had the highest at 79%, possibly reflecting the non-essential nature of foods with high-added sugar content. Middle and lower middle-income households had over 25% of individuals' daily consumption of sugars in excess of recommendations. The variation is less noticeable across education levels, although individuals who have not qualified with any profession/vocation had the lowest proportion with only 71% meeting guidelines (see Table 3.3 and Table 3.4).

Table 3.3 : Proportion of the population meeting Swiss dietary recommendation of not more than 10% of calories from added sugars by household incomes

Compliance with Swiss dietary recommendation for added sugar by household income			
Household income	Mean	Std. Err.	[95% Conf. Interval]
<3000	0.790	0.031	0.728, 0.851
3000 to 4499	0.748	0.026	0.697, 0.799
4500 to 5999	0.740	0.022	0.697, 0.783
6000 to 8999	0.726	0.020	0.687, 0.764
9000 to 12999	0.771	0.019	0.733, 0.809
> 13000	0.724	0.039	0.646, 0.801
Overall mean	0.746	0.010	0.726, 0.765
N (person days)	4133		

Source: Menu-CH1 data.

Table 3.4 : Proportion of the population meeting Swiss dietary recommendation of not more than 10% of calories from added sugars by education level

Compliance with Swiss dietary recommendation for added sugar by education level			
Education level	Mean	Std. Err.	[95% Conf. Interval]
Mandatory or less	0.749	0.045	0.660, 0.837
Incomplete Professional	0.711	0.031	0.651, 0.772
Professional	0.735	0.018	0.700, 0.770
High school	0.757	0.027	0.703, 0.810
Superior professional	0.758	0.019	0.721, 0.795
University and HES	0.751	0.021	0.710, 0.793
N (person days)	4133		

Source: Menu-CH1 data.

3.4 Sugar-sweetened beverages tax in Switzerland: policy simulation

3.4.1 Trends in prices of SSBs over time

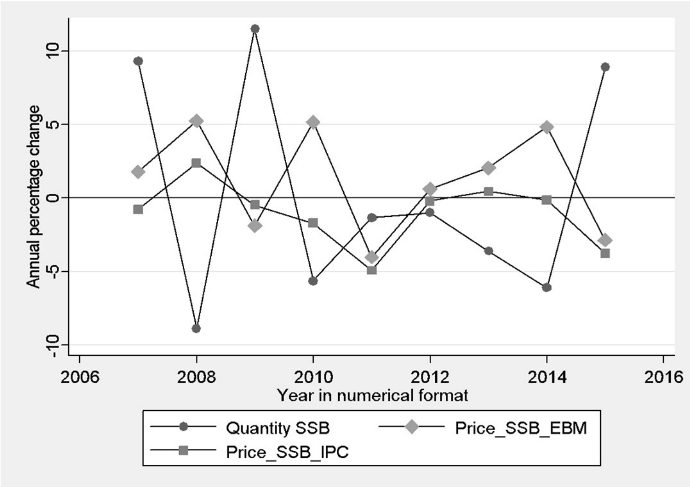
Figure 3.4 shows the relative changes over time in the monthly consumer price index (CPI) for SSBs across Switzerland between January 2000 and October 2016. Indexed at 100 in December in 2015 it is evident that prices have experienced a 15% reduction since their highs in January 2004 and January 2010. This general trend is likely a reflection of the significant fall in sugar prices over this period and strengthening of the Swiss Franc so that SSBs prices appear at their lowest for over 15 years in 2016. Before the recent drop in prices, there were more cyclical fluctuations up and down between January 2000 and January 2014.

We exploit annual fluctuations in prices and associated demand responses in consumption to estimate the price elasticity of demand of SSBs amongst Swiss households. Figure 3.5 and Figure 3.6 illustrate graphically our estimation strategy plotting trends in relative annual SSB price changes and corresponding annual changes in the quantity demanded expressed as a percentage change from the previous year's level. This is aggregate time series data from the Swiss Household Budget Survey (SHBS), which measured the monthly expenditure and quantity of SSBs consumed as well as the Swiss CPI price index average annual changes. We observe a noticeable negative correlation between annual percentage changes in prices and quantity demanded, with larger positive (negative) responses in quantities of SSBs consumed to increases (decreases) in prices. The CPI and SHBS price changes move reasonably in unison.

Figure 3.4 : Trends in relative price index of SSBs across Switzerland over time (Dec. 2015 = 100)

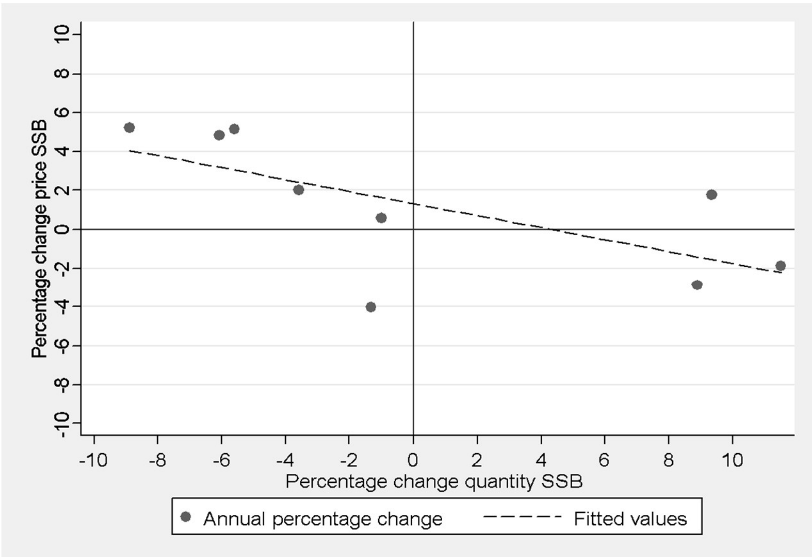
Source: OFS IPC (Consumer Price Index Time Series Bundesamt für Statistik, Espace de l'Europe 10, CH-2010 Neuchâtel)

Figure 3.5 : Relationship between changes in prices and changes in quantity demanded (proportionate)



Source of data: Swiss Household Budget Survey 2006-2015 (Bundesamt für Statistik, Haushaltsbudgeterhebung (HABE)) and the Consumer price index.

Figure 3.6 : Correlation between proportionate changes in prices and changes in quantity demanded (proportionate) for SSBs



Source of data: Swiss Household Budget Survey 2006-2015 (Bundesamt für Statistik, Haushaltsbudgeterhebung (HABE))

3.4.2 Estimated own and cross-price elasticities of demand for SSBs

To more formally estimate the own price elasticity of demand for SSBs with respect to price we estimate the log differenced specification in Equation 1 using a simple log-linear OLS model with annual change in the logarithm of quantity consumed from the SHBS regressed against annual changes in the logarithm of average prices paid by households and income per head. This model estimates the own price elasticity of demand to be -1.32 and statistically significant although not that precisely estimated (95% CI -2.5, -0.14). This estimate is very close to those reported in a recent meta-analysis estimate of -1.3 (another reported estimates ranging from -1.2 to -0.8). This suggests that on average Swiss households are price sensitive and respond to a 1% price increase by reducing consumption by more than 1% (Table 3.5).

To verify whether the estimate is robust we use an instrumental variable (IV) approach that predicts price variation based on the observed CPI price and not the average price changes reported in the SHBS, which could be capturing changing preferences over time for those surveyed, and not simply the price levels on offer in retailers. The IV estimates showed that trends in the CPI and SHBS prices were strongly correlated and that the estimated elasticity of demand of -1.41 was also statistically significant (95% CI: -2.427, -0.402) and more precisely estimated (see Table 3.5).

It is also worth noting that a significant and positive income effect of 1.67 was estimated implying that increases in average incomes was associated with higher consumption levels, suggesting that SSBs are a ‘normal’ good for most households and not seen as an ‘essential’ good, which would be less sensitive to household incomes and prices.

These estimates reflect average consumption behaviour for households with incomes of around 9,500 CHF who faced average prices for SSBs of 1.42 CHF/L and who were consuming around 4.25 L per person per month of SSBs. Price elasticity estimates are known to depend on the quantity consumed, with high consumption households having lower price elasticities (wealthier households and households facing lower price levels would also be expected to be less price sensitive).

Finally, we also pooled price and consumption data for syrups with SSBs (see Table 3.6) as these would be very close products and considered SSBs although the quantity of sugar can be adjusted according to taste. The pooled estimates of -1.396 (95% CI: -1.95, -0.84) are very close to previous estimates, but more precisely estimated. This analysis indicates that on average, Swiss consumers appear to have quite strong price sensitivity when consuming SSBs, and reduce (increase) consumption in a more than proportionate response to prices.

Table 3.5 : Estimated own price elasticities of demand for SSBs. Comparison of estimates with and without using the CPI index as an instrumental variable without Syrups

OLS					
D.log(quantity)	**Coef.**	**Std. Err.**	**T**	**P>t**	**[95% Conf. Interval]**
D1. Log(price)	-1.324	0.483	-2.740	0.034	-2.506, -0.142
D1. Log(income)	1.665	0.656	2.540	0.044	0.059, 3.271
Constant	-0.017	0.024	-0.700	0.513	-0.076, 0.042
N	9				
R-squared	0.7173				
Average consumption (L/head/mth)	4.25				
Average price CHF/L	1.42				
Average expenditure CHF/head/month	6.035				
IV - Estimation estimates of own price elasticity of demand for SSBs (CPI Price)					
D.log(quantity)	**Coef.**	**Std. Err.**	**T**	**P>t**	**[95% Conf. Interval]**
D1. Log(price)	-1.414	0.516	-2.740	0.006	-2.427, -0.402
D1. Log(income)	1.653	0.573	2.890	0.004	0.530, 2.776
Constant	-0.015	0.021	-0.720	0.470	-0.057, 0.026
N	9				
R-squared	0.7156				
First-stage regression					
D1:CPI_SSB_price	0.012	0.002	5.550	0.001	0.007, 0.018

Notes: OLS linear regression of the annual difference in the logarithm of average monthly SSB consumption per head over time between 2006 and 2015. Instrumental variables regression uses the CPI for SSB prices to predict (instrument for) the observed SHBS price that may reflect changes in product tastes and preferences. IV estimates are nearly identical and statistically significant, indicating estimated price elasticity appears to be unbiased and reasonably precisely estimated.

Table 3.6 : Estimated own price elasticities of demand for SSBs. Estimates combining time series data for both SSBs and Syrups

OLS					
D.log(quantity)	**Coef.**	**Robust Std. Err.**	**T**	**P>t**	**[95% Conf.Interval]**
D1.log(price)	-1.396	0.256	-5.460	0.000	-1.948, -0.844
Syrups	-0.001	0.042	-0.030	0.975	-0.093, 0.090
D.log(income) interactions					
D1.log(income)#SSBs	1.655	0.639	2.590	0.022	0.275, 3.036
D1.log(income)#Syrups	-0.060	0.807	-0.070	0.942	-1.804, 1.684
Constant	-0.016	0.021	-0.760	0.461	-0.060, 0.029
N	18				
R-squared	0.732				
	SSBs	Syrups			
Average consumption (L/head/mth)	4.25	0.15			
Average price CHF/L	1.42	4.3			
Average expenditure CHF/ head/mth (CHF)	6.035	0.645			

Notes: Pooled sugar sweetened drinks and syrups regression using price variation in both types of products to estimate price elasticity for SSBs. Data from Swiss Household Budget Survey 2006-2015.

As a means of comparison, and to understand substitution possibilities by consumers between SSBs and other non-alcoholic drinks, we estimate own and cross price elasticities for the quantity consumed of a range of other drinks listed in Table 3.7 below. We observe similar price elasticities of -1.43 and -1.45 for coffee and cocoa based drinks although these estimates are less statistically significant (precisely estimated) as SSBs. Cross price elasticities for these drinks were also positive and quite large (0.76 and 0.22 respectively) indicating some moderate substitution between these drinks and SSBs in response to a change in SSB price. Interestingly, other strong substitutes were fruit juices and whole milk (0.63 and 0.57) although these drinks were not in themselves price sensitive, implying they would be considered more ‘essential’ and households would shift expenditures to coffee, cocoa, fruit juices and whole milk if SSB prices rose. Tea and milk based drinks were also significantly price sensitive but not strong substitutes for SSBs

Table 3.7 : Estimated own and cross price elasticities of demand for other drinks/beverages with respect to SSBs (cross-price elasticity)

Own price elasticity estimates of other drink products					
Product	**Own price elasticity**	**Std. Err.**	**t**	**P>t**	**[95% Conf. Interval]**
Milk drinks and skim milk	-1.767	0.761	-2.320	0.059	-3.629, 0.094
Whole milk	0.404	0.719	0.560	0.595	-1.355, 2.163
Fruit juice	0.106	0.626	0.170	0.871	-1.426, 1.638
Vegetable juice	-0.327	0.688	-0.480	0.651	-2.010, 1.355
Mineral water	-0.528	0.551	-0.960	0.375	-1.878, 0.821
Tea, tisanes or substitutes	-0.688	0.199	-3.450	0.014	-1.174, -0.201
Cocoa and soluble chocolate	-1.434	1.433	-1.000	0.356	-4.940, 2.073
Coffee, beans, ground or soluble	-1.449	0.698	-2.080	0.057	-2.946, 0.048

Cross price elasticity with SSBs and Syrups combined					
Product	**Cross price elasticity**	**Std. Err.**	**t-stat**	**P>t**	**[95% Conf. Interval]**
Milk drinks and skim milk	-0.196	0.981	-0.200	0.851	-2.920, 2.529
Whole milk	0.572	0.664	0.860	0.438	-1.272, 2.415
Fruit juice	0.634	0.269	2.360	0.078	-0.112, 1.381
Vegetable juice	0.058	1.678	0.030	0.974	-4.601, 4.717
Mineral water	-0.239	0.546	-0.440	0.684	-1.756, 1.277
Tea, tisanes or substitutes	-0.183	0.594	-0.310	0.774	-1.833, 1.467
Cocoa and soluble chocolate	0.219	0.534	0.410	0.703	-1.263, 1.700
Coffee, beans, ground or soluble	0.756	0.522	1.450	0.174	-0.382, 1.894

Data: Swiss Household Budget Survey 2006-2015

3.4.3 Policy simulation of the effects of an introduction of a 25% VAT on SSBs on daily calorie intake across SSBs consumption propensities in the Swiss population

This section explores in more depth the possible contribution of a tax targeting SSB can have on added sugar consumption and ultimately daily calorie intake. Given the marked differences in calories from added sugars between individuals that consumed SSBs on a given day, we stratify the analysis by SSB consumption. Three groups of individuals were defined 1) low consumption individuals had no observed consumption of either of their two recorded food intake days, 2) moderate consumption had only one day of observed SSB consumption out of the two observations, and 3) heavy consumption consists of individuals having consumed SSB on both days. Overall 15.7% of the were heavy consumers of SSBs. The highest proportions of low-consumption individuals were in the upper middle income groups at around 60% of the population, whereas the lowest proportion were amongst the poorest and richest groups (53%), these groups however, also had the lowest proportion of heavy consumers at 14.8 and 13.7% respectively. The highest concentrations of heavy SSBs drinkers were found in the lower and middle income groups (between 3,000 to 5999) CHF a month with 17.6 to 16.8 % reporting SSB consumption of both survey days (see Table 3.8).

Table 3.8 : A Distribution of average total daily calories and calories coming from added sugars by income group for individuals who consumed SSBs as part of their daily diet

	SSB consumer type		
Household income	**Low-consumption**	**Moderate-consumption**	**Heavy-consumption**
<3000	0.5278	0.3242	0.1479
3000 to 4499	0.5863	0.2376	0.1762
4500 to 5999	0.609	0.2234	0.1676
6000 to 8999	0.6192	0.2159	0.1649
9000 to 12999	0.5984	0.2601	0.1415
> 13000	0.5385	0.3247	0.1367
Overall	0.5937	0.2486	0.1577
N	2,080		

Source: Menu-CH1 data.

We explored how an added-value tax (VAT) imposed at a 25% rate on the Swiss population would affect daily sugar and calorie intake. We assumed a range of own price elasticities of demand for SSBs from -0.8 to -1.2 as well as incorporated substitution effects to other non-alcoholic drinks, imposing cross price elasticities of demand fixed at between 0.3 and 0.19 for fruit juices, coffees, teas, milk drinks, and artificially sweetened drinks. The set of substitution products was limited and it should be noted that other studies have found cross-substitution to alcoholic drinks (mainly beer) and other non-beverage confectionary as an alternative energy source. These other foods were not included in the simulation. However, as alcoholic beverages are relatively cheap in Switzerland, these potential subsitution effects should be carfully considered when designing the policy, especially in adolescents and young adults. For the SSB own price elasticity of -1.4 (closer to the observed elasticity in the SHBS data and trends) were also increased the cross price elasticity magnitudes.

Results of the simulation stratified by our three SSB consumer types are presented in Table 3.9. We report effects on total Kcal. Firstly, at baseline there is significantly higher average daily calorie intakes across all three groups with regular SSB consumers having nearly 26% more Kcals each day. We report the difference in average Kcals and a crude estimate of weight loss based on a constant conversion factor across all individuals of a 22 Kcal reduction resulting in a 1Kg weight reduction.[227]

Looking at an SSB own price elasticity of -1.2, and concentrating on occasional and regular SSB consumers (infrequent consumers in our data with no reported SSB consumption would only show the effects of substituting to other products - presumably because of relative prices comparisons). The heavy SSB consumers experience an absolute calorie reduction of 67.6 Kcal (2.6% reduction) per day roughly equating to a 3kg weight reduction on average. Heavy SSB consumers reduce day calorie intake by about 20 Kcal or 0.86% on average. The substitution effects (indicated by low SSB consumers) would increase daily calories by at least 5.71 Kcal to offset some of the reductions from lower SSB consumption. The simulation with larger own and cross price elasticities showed a slightly larger daily Kcal reduction of -74 Kcal (2.8% reduction) daily with an average expected weight loss of -3.35. However, the larger own price effect was offset by the larger cross price effect for occasional consumers, hence the importance of the magnitude of absolute SSB consumption and distribution of substitution to other products in determining the health benefits of an SSB VAT tax (see Table 3.9).

Table 3.9 : Impact on daily calorie intake and body weight following the introduction of a 25% SSB tax

Simulation scenarios based on different own-price elasticities						
Frequency of SSB consumption	Mean daily energy intake	Std.Err.	[95% Conf. Interval]		Difference from baseline	Estimated weight loss (Kg)*
Baseline case no SSB VAT tax						
Low-Consumption	2079.80	24.12	2032.49	2127.11		
Moderate-Consumption	2327.09	39.93	2248.78	2405.41		
Heavy-Consumption	2617.21	63.91	2491.88	2742.55		
Tax simulation 1 (-0.8 elasticity)						
Low-Consumption	2085.50	24.17	2038.11	2132.90	5.71	0.26
Moderate-Consumption	2316.39	39.75	2238.44	2394.34	-10.71	-0.48
Heavy-Consumption	2574.39	63.08	2450.68	2698.09	-42.83	-1.94
Tax simulation 2 (-1 elasticity)						
Low-Consumption	2085.50	24.17	2038.11	2132.90	5.71	0.26
Moderate-Consumption	2311.97	39.68	2234.16	2389.78	-15.12	-0.68

Heavy-Consumption	2561.98	62.85	2438.73	2685.24	-55.23	-2.50
Tax simulation 3 (-1.2 elasticity)						
Low-Consumption	2085.50	24.17	2038.11	2132.90	5.71	0.26
Moderate-Consumption	2307.55	39.60	2229.89	2385.22	-19.54	-0.88
Heavy-Consumption	2549.58	62.63	2426.75	2672.40	-67.64	-3.06

Notes: *Simple conversion factor of 22.1 reduction in daily calorie intake results in a 1 kg reduction in weight in the first year.

3.4.4 Forecasted average price and consumption changes as well as tax revenue potential from an introduction of an introduction of a 25% VAT on SSBs

To illustrate how elasticity estimates can be applied to provide some insights into the effects of an introduction of an ad valorem tax to supply of SSBs, we assume a 25% VAT on manufacturers is fully passed on to consumers (Table 3.10). Looking only at SSBs initially, this would increase average prices by 31 cents, and subsequently reduce average household consumption by 33%. Consumption would fall by 1.41 L/mth per person on average (if we assumed 80g of sugar per litre that would reduce monthly sugar intake by about 113 grams equivalent to 15 fewer kilo calories per day). Households would also spend less money on SSBs, around 4.91 CHF per person a month, but 25% of this expenditure would contribute a tax of around 33 CHF per household per year on average. Scaling this up to the Swiss population would equate to over 126 million CHF a year in tax revenues, a gain of 111 million CHF compared to the situation with the existing 2.5% VAT tax.

Table 3.10 : Estimated average impacts of 25% SSB tax on price, quantity demanded, and expenditures on SSBs.

Estimated impact on price, consumption and tax revenue			
Average price (CHF/L)	1.42	**Price 25% VAT**	1.73
Average consumption (L/mth)	4.25	**Consumption 25% VAT**	2.84
Average expenditure (CHF/head/month)	6.04	**Average expenditure 25% VAT (CHF)**	4.91
		Average annual household tax burden (CHF)	32.61
Standard VAT revenue (2.5%) national (CHF)	15,527,673.07	**Annual Tax revenue (CHF) 25% VAT nationally**	126,226,613.88
		Net of standard VAT (CHF)	110,698,940.81

Notes: Authors calculations. Estimates apply the own price elasticity for SSBs of -1.32.

These estimates can be compared to figures from France where it was reported annual revenues of 280 million Euros following roughly a 10% VAT rate.[228] Our estimate is roughly 2.5 times smaller for a VAT rate twice as high, hence effectively a 5 times smaller estimate more or less which could reflect the population (market size) differences between France and Switzerland.

Table 3.11 extends the analysis to include syrups as well as SSBs and slightly increases expected tax revenues to around 140 million and would reduce monthly sugar intake by roughly 116 grams as syrups are consumed in less quantity.

Table 3.11 : Estimated average impacts of 25% SSB tax on price, quantity demanded and expenditures on all SSBs and Syrups combined.

Estimated impact on price, consumption and tax revenue including syrups							
	SSBs	**Syrups**	**Combined total**		**SSBs**	**Syrups**	**Combined total**
Average price CHF/L	1.42	4.30		**Price 25% VAT**	1.73	5.24	
Average consumption (L/mth)	4.25	0.15		**Consumption 25% VAT**	2.84	0.10	
Average expenditure CHF/head/ mth	6.04	0.65		**Average expenditures 25% VAT**	4.91	0.52	
				Average annual household tax burden	32.61	3.45	
Standard VAT revenue (2.5%) national CHF	15,527,673.07	1,671,024.42	**17,198,697.49**	**Annual Tax revenue (25% SSB VAT) CHF**	126,226,613.9	13,368,195.4	139,594,809.2
				Net of previous VAT CHF	110,698,940.8	11,697,170.9	122,396,111.7

Notes: Authors calculations considering most recent population figures from OFS. Estimates apply the own price elasticity for SSBs of -1.32.

It should be noted this illustration assumes consumers are not able to further reduce retail price (i.e. by searching for discounts etc.). In addition, the tax burden for an average household will vary considerably with ‘no SSB consumption’ households not bearing any burden, while the tax incidence will be borne by heavy consuming households if they are not able to reduce consumption significantly.

The estimates are based only on average observed consumption levels and estimated elasticities and the demand/consumption response (i.e. the health benefits) of the tax could be lower if the tax is not fully passed through to consumers. If consumers shop around for cheaper priced SSBs or increase their intensity of cross-border shopping this would reduce tax revenues. There is evidence that these revenue forecasts over-estimate the amount due to stronger demand side responses by consumers, but also importantly supply side responses to reduce sugar content in drinks and reduce the size of drinks sold to reduce the impact of the tax if linked directly to sugar concentrations or amounts. The recent UK sugar tax lead Her Majesties Customs and Excise Duty Department to reduce their expected tax revenues to £400 million following significant product reformulation to be exempt or eligible for low tier tax bracket based on reduced added sugar levels.

3.5 Equity considerations following a SSB tax introduction in Switzerland

Equity concerns are a major consideration with respect to VAT based policies. Contributions are directly linked to expenditure, which for poorer households constitutes a higher proportion of their income, hence the tax is likely to be regressive. An SSB tax will also affect high volume consumers more than low consumers, and consumers who are less price sensitive. While poorer households may be more price sensitive, and with lower incomes may choose to purchase less SSBs.

It may still be the case that they spend relatively more on SSBs as they are a cheaper source of indulgence in the diet and health knowledge and priorities may be different. Poorer households may have place less importance on future health risks due to lower expectations of future health as well as higher preferences for current consumption than future health consequences.

However, the fact that a SSBs tax affects high consumers more implies they are also the group who are likely to get the most health benefits from a tax that succeeds in inducing significant reductions in consumption. So that even if they may be less price sensitive, even a low price elasticity could result in a relatively large reduction in sugar consumption with measurable health improvements.

In summary the tax incidence/burden will depend on SSBs consumption, so will fall more heavily on high consumption households that are less sensitive to price, and the relative tax burden will be greater for lower income households with otherwise similar consumption patterns. The tax burden would be lowest for high-income households that do not consume much or any SSB and who are sensitive to price, thus switching away from taxed SSBs.

To illustrate the equity implications of a SSBs VAT tax of 25% we stratified the analysis of consumption changes and tax burden by quintiles of household income. Table 3.12 presents the levels of average SSB consumption, average prices paid and expenditures before and after a 25% VAT. Assuming the same elasticity of demand by income groups (ranging from below 2,500 CHF per head/month to at least 7,000 CHF per head/month). Interestingly we observe that the largest consumer of SSBs are lower to upper middle-income households consuming around 4.34 L/month per person. The poorest and richest household groups consume the least 3.55 and 3.8 L/mth respectively.

In absolute terms, the tax burden falls heaviest on the lower middle income households having to contribute 15.34 CHF per person per year on average, whilst the poorest households would contribute the least on average 12.49 CHF per person per year on average. The tax is still regressive as in relative terms this contribution is a higher proportion of the poorest households' monthly income than the richest 0.041% compared to 0.017%.

On average the tax burden does not appear too onerous, however, it is important to note that the distribution of SSB consumption across individuals is highly skewed with a very high proportion of very infrequent consumers while a significant share of consumption is concentrated amongst frequent or high volume consumers. These individuals/households will have a large tax burden if they are unable to reduce consumption. For equity concerns to be addressed, it is therefore important that tax revenues are invested into health promotion, health information and interventions that target these high consumption groups and so that they receive proportionately greater benefits as well.[229]

The analysis below assumes the same price elasticity of demand across income groups. This may not be the case as elasticity is sensitive to income as well, being greater when incomes are lower. Hence, it is possible to observe larger reduction and lower tax burden in the lower income groups, although the tax is still likely to be regressive. The largest absolute health benefits would likely occur in the lower and middle-income groups, not the richest, as they consume more SSBs.

Table 3.12 : Distributional consequences of tax burden of imposing a 25% VAT on SSBs

Impact of 25% tax introduction across socioeconomic groups					
Average household (Income/head)	2527.54	3444.78	3690.10	4400.48	6959.02
Pre-tax consumption per head (L/mth)	3.55	4.34	4.21	4.18	3.81
Post-tax Consumption per head 25% VAT (L/mth)	2.38	2.91	2.82	2.80	2.55
Pre-tax price (CHF/L)	1.44	1.44	1.42	1.41	1.54
Post-tax Price 25% VAT (CHF/L)	1.75	1.76	1.72	1.71	1.88
Pre-tax average expenditure (CHF/head/mth)	5.10	6.26	5.96	5.89	5.88
Post-tax average expenditure (CHF/head/mth)	4.16	5.11	4.87	4.81	4.80
Average annual tax burden (CHF/head/mth)	12.49	15.34	14.61	14.42	14.39
Annual Tax burden as share of household income/head (%)	0.041	0.037	0.033	0.027	0.017
Household size	1.40	1.79	2.34	2.75	2.92

3.6 Discussion

We reviewed the literature on diet cost and nutritional quality and found that the economic costs of achieving a healthier diet are significant and that these are likely to be relatively higher for certain population groups. Findings from the meta-analysis indicate that lowering the price of healthier dietary patterns, on average 37% more expensive, support direct price interventions that tax unhealthy foods and subsidize healthier food groups. We conducted a short review on policy interventions aiming to improve dietary patterns across countries and jurisdictions. We found that targeting sugar-sweetened beverages has been proven effective in reducing added sugar intake and relatively easy to implement. SSBs can be described as "liquid candy", providing high energy levels with no nutritional benefit.

We investigated compliance with Swiss nutritional guidelines in the population leveraging on data from Menu-CH1. We confirmed previous reports that a considerable portion of the population are regular consumers of SSBs and that those who frequently consume them have higher levels of total energy intake as well as higher intake of added sugars.

Furthermore, we estimated own- and cross-price elasticities of demand for SSBs and close substitutes using publicly available data from the Swiss Household Budget Survey (SHBS). Our estimates seem to be in line with estimates conducted in other settings. Of note, one limitation of our study is that we did not take potential cross-subsitution effects with alcoholic beverages, which might be of public health concern, expecially in adolescents and young adults.

This chapter suggests that a tax on SSBs in Switzerland would have an important effect on the reduction of SSBs consumption. Our results suggest that a relatively large increase of 25 percentage points may have a substantial effect on population weight. While such tax would be perceived as affecting the whole population, from a public health perspective heavy consumers of SSBs are the ones that would benefit the most from the reduction of SSBs intake.

The demonstrated effect across countries on SSBs consumption is only an indirect measure of the long-term health effects of the considered taxation scenarios. The direct health effects depend on the relationships between diet and lifestyle-related illnesses – relationships that may often be highly complex.

A common objection to food taxation on equity grounds is linked to its regressive nature. Low-income households spend a higher proportion of their income on food. However, if low-income households are more price elastic and/or consumed proportionately more of the taxed product, they would benefit the most from the reduction of consumption that product.

Despite the merits of such policy interventions, policy makers need to consider both effectiveness and acceptability by the general population. In Switzerland, the latter plays an even more important role due to the direct democratic rules that imposes restraints on government own power to introduce relative price changing. Recent research shows that public acceptance varies considerably between interventions designed to reduce consumption of unhealthier food items, with higher acceptance for least intrusive interventions, public health campaigns and nutritional labelling, and higher resistance more restrictive interventions as taxation.[230]

As showed estimated tax revenues from the introduction of relatively large SSB tax are considerably higher of the actual revenues from the 2.5% tax imposed on these products. How the tax revenues are invested, might be a major driver for public acceptance of the tax. Investing tax revenue on nutritional quality enhancing programs for more deprived individuals by subsidizing fruits and vegetables consumption might lead to a higher proportion of the population meeting national dietary guidelines.

Some may argue that the compliance with nutritional guidelines in the Swiss setup is better that in other countries and that there is no obesity pandemic. Policy maker should have in mind that these interventions are aimed to reduce the prevalence of non-communicable diseases in the population but also as prevention measures for the future.

Future research might improve on results from this report by estimate the direct effects of these taxes on weight outcomes. Because youths and young adults consume the greatest number of soft drinks, further attention should be given to the estimation of elasticities across sociodemographic groups.[222] If such elasticities are higher for younger group, then we can expect to see changes that are more beneficial in the latter. This is particularly important because our dietary patterns are less suitable to changes as we age leading to potential health harm in the future. Furthermore, researchers should focus on predicting the impact of specific public health policies aimed at improving diets and reducing the burden of chronic disease.

4 Diet quality and food prices: Evidence from an exchange rate shock

4.1 Introduction

While there is good evidence on the association between food cost and diet quality (see chapter 1), it is often based on observational studies which limits the ability of researchers to make causal claims. Of particular concern is the endogeneity of price in food demand. In this chapter, we overcome some of these issues by exploiting a large exchange rate shock as a natural experiment to investigate the causal relationship of an increase in purchasing power on changes in individual food consumption and on the nutritional quality of diets.

Specifically, on the 15th January of 2015, the Swiss national bank (SNB) unexpectedly gave up the exchange rate (ER) lower bound due to high pressure of investors to buy Swiss francs. The exchange rate dropped by more than 14% instantaneously. Switzerland is surrounded by four European countries using the Euro. A large proportion of the swiss population lives near the border hence cross border shopping is relatively easy. Despite quantity restrictions and border regulations, this exchange rate shock likely significantly increased the purchasing power of Swiss residents or workers earning in Swiss Francs.

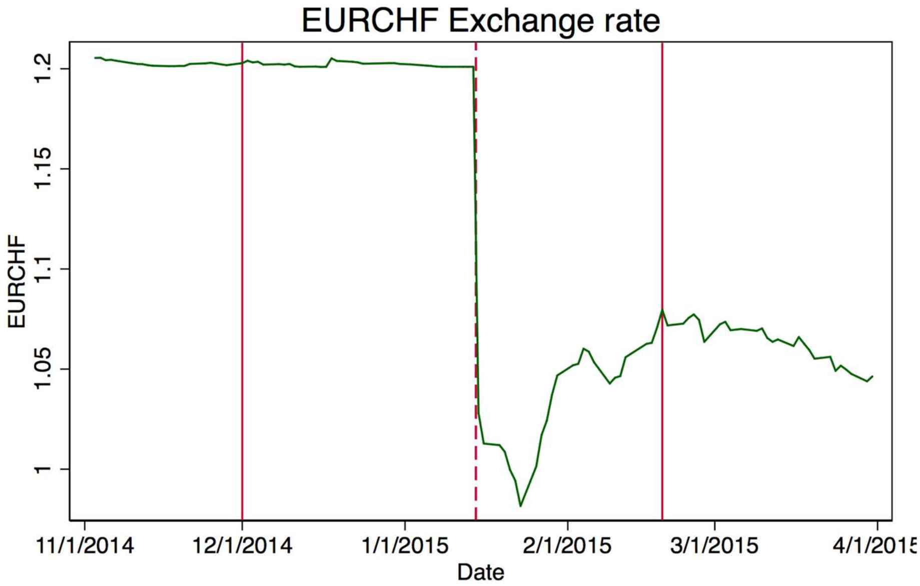
We exploit detailed individual-level dietary data collected before and after the shock in a regression discontinuity design (RDD) framework with time to the exchange rate shock as the running variable. Results indicate a heterogeneous effect on the diet quality. Sodium significantly decreased, which would be associated with expected reductions in associated health risks, but fiber and vegetable consumption also decreased, which would be linked to increased risks from worse diet quality. There was weaker evidence that consumption of sugar sweetened beverages increased with negative health consequences whereas milk consumption increased with associated health benefits. Interestingly, total calories consumed decreased, and there was a switch from carbohydrates to protein primarily from red meat. There was a small and insignificant increase in the overall healthy eating index.

4.2 Background

To understand the discontinuity exploited in this chapter, it is useful to understand the decision of the Swiss National Bank (SNB) on January 15th, 2015.[231] The Swiss franc is often seen as a safe asset when uncertainty rises in the financial markets in the world.[232] During the recent Financial and Euro crisis between August 2008 to August 2011, the EUR-CHF exchange rate pressure rose from 1.6 to 1.1. The Swiss franc acted as a safer asset. The SNB decided to implement an unconventional policy: an exchange rate floor of 1.2 CHF for 1 Euro the September 6 2011.[233] According to the SNB, the Swiss franc was overvalued by investors and they wanted to protect the exports industry of Switzerland. On December 18, 2014, the SNB insisted again on the importance of the exchange rate floor introducing at the same time negative interest on sight deposit account balances at the SNB.[234] Therefore investors (and even more consumers) could hardly anticipate the exchange rate removal on January 15h, 2015 on the basis of the communication of the SNB.

Figure 4.1 plots the daily EUR-CHF exchange rate between November 2014 and March 2015. The exchange rate is stable around 1.2 before the announcement and abruptly decreased by about 14% in a single day. It fell sharply and largely on January 15, 2015 indicating that the financial markets had not taken the removal into account before the SNB's announcement. The exchange rate's drop was large, unanticipated, and sharp.

Figure 4.1 : EUR-CHF Exchange rate shock in January 2015.



Note: Daily drop of 14.4%. Drop on average of 13.7% between the two periods of the sample.
The red solid bars delimits the studied period.

Switzerland being surrounded by four countries from the Euro zone (Austria, France, Germany, and Italy), the exchange rate shock might impact the diet quality of people through two main paths. First, assuming Swiss residents wage is labelled in Swiss francs, food items bought in the Euro countries become much cheaper. Cross-border shopping therefore becomes more appealing in particular for people living close to the border. We can expect the shopping effort to increase to access cheaper food prices (note that some food items such as meat have quantity restrictions so that individuals can only buy a limited amount on any given day, which can mitigate the phenomena).

The second path is through imports for Swiss retailers. Goods imported from the Euro area are cheaper. If the invoice is labelled in Euro, the importer has a large increase in his margin. The price paid by the Swiss consumer will probably partly capture this surplus in the margin. In addition, the pressure on Swiss goods will probably increase with the competition of goods coming from the Euro area. The price of goods in Swiss retails will also decrease after the exchange rate shock.

4.3 Literature review

4.3.1 Impact of exchange rate on prices

The exchange rate shock pass through (ER pass through) (i.e. the extent to which the change in exchange rate is reflected in prices) might take time and vary across products. The relationships between exchange rates and prices have been extensively studied in the United States. In terms of timing Gopinath and Rigobon (2008) found that the food items' prices take between 1 and 5 months to pass-through after an exchange rate shock in the US. And the ER pass through is low at 22% for US imports.[235] The ER pass through might also differ depending on the market structure. Auer and Schoenle (2015) and Devereux and al. (2017) studied this price stickiness at the border. The price response to the exchange rate has an inversed U-shaped relationship in the importer market share. Small or large importing firms have a lower ER pass through. Foods and beverages seem to have a partial ER pass through.[236, 237] Assuming a similar situation in Switzerland, the ER pass through is expected to be slow and partial since the market is dominated by two actors with more than 60% of the Swiss market share.

4.3.2 Impact of the 2015 EUR-CHF Exchange rate shock on economic outcomes

In Switzerland, several studies explored the effects of the discontinuation of the minimum exchange rate. Bonadio and al. (2019) showed that the price of goods invoiced in Euro adapted instantaneously. Goods labelled in Swiss francs adapted rarely instantaneously and more than ten days were needed to pass through.[238] Using transaction-level data, Lein and al (2018) found similar results. EUR-invoiced goods' prices of retailers and importing firms fell more at the shock than CHF-invoiced goods' prices. Domestic goods' prices fell more if similar EUR-invoiced goods fell more due to increase in competition. Swiss retailers also increased their part of imports after the ER shock. Finally, price adjustments increased in size and frequency after the shock, especially for imported goods.[239] Biello Pierra (2017) documents an increase of cross-border travel after the ER shock in the border region of South Switzerland. Italian supermarkets bordering Switzerland increased their sales.[240] The ER pass through heterogeneity in goods and speed might change the exposition to the shock for Swiss citizens.

4.3.3 Impacts of price changes on dietary intakes

Several manuscripts look at the change in diet during the last financial crisis. Griffith and al. (2015) studied the large inflation for foods prices in UK between 2007 and 2009. Households were able to maintain the energy intake and the diet quality by increasing shopping effort and slightly changing their preferences.[149, 152] Alves and al. (2018) explored the change of diet before and after the Great Recession in Portugal. The observed changes didn't seem to be linked to the economic crisis.[241] Bartoll and al. (2015) showed that Spanish households reduced fruits, meat and cold meat consumption during the Financial crisis.[242]

The response of households is also studied in other settings. In developing countries, Alem and Söderbom (2012) looked at the response to a food price inflation between 2004 and 2008 in Ethiopia. Low asset and income households were particularly hit in this African country. Higher income households could better absorb the shock.[243] Ruhm (2000) showed that fruits and vegetable consumption increased, and fat consumption reduced when economic conditions worsened.[244] Studying gasoline price changes, Gicheva and al. (2010) showed that US households buy proportionally more sales food items when gasoline price rises.[245] Other types of shocks are also studied such as the anticipated shock at retirement. Aguiar and Hurst (2005) showed that people are able to smooth quality and quantity intake for retirement.[133]

4.3.4 Impact of policies on diets and prices

Some policies modify the prices of food items for selected groups of the population which provides opportunities to explore households' responses. The US Supplemental Nutrition Assistance Program (SNAP) provides such a framework. The goal of this program is to reduce poverty and food insecurity by providing support to low-income households. The program seems effective against food insecurity.[246, 247] In a systematic review, Andreyeva and al. (2015) showed that the impact on diet quality appears to be limited.[248] Griffith and al. (2018) showed that a UK policy introducing vouchers for fruit, vegetables and milk have a positive effect on diet quality. The use of vouchers is also more effective than a transfer in cash.[192] Using an experimental design, Muller and al. (2017) showed that taxing unhealthy foods and subsidizing healthy foods tends to be regressive.[249] The diet quality of high-income women before the experiment is higher than for low-income women. Hence the tax will impact more low income than high income women. In addition, the response of the high-income women tends to be larger. Sugar taxation is one of the most advanced policy trying to influence the food choices of individuals. The tax should increase the price of unhealthy foods and reduce their consumption. Cawley and Frisvold (2017) studied the impact of a sugar tax on sugar-sweetened beverages in Berkeley.[250] The ability to cross-border shop was found to limit the transmission of the tax to the prices, with only 43% of the tax passing through the prices. Using the same methodology, Cawley and al. (2018) found a higher pass-through of 93% in Philadelphia.[251]

4.3.5 Heterogeneity in dietary intakes in the population

Darmon and Drewnowski (2008) uses 4 main reasons to explain the variation of nutrition in the population.[252] Education and culture are one potential factor influencing the diet. Cooking skills, motivation or nutrition knowledge are the underlying mechanism impacting the diet. These explanations probably did not vary in the case studied hereafter. The second explanation is access to food. Restrictive choice of food could push individuals to unhealthy processed food (longer life cycle). Alcott and al. (2018) find that more than 90% of the diet difference between high and low income is driven by the demand in the United States.[253] This result limits the restrictive offer explanation in the results obtained. In addition, Switzerland is a smaller country hence all consumers can access easily to supermarkets. Thirdly the budget constraint of households and relative food prices might drive the consumption to unhealthy food items. Darmon and al (2004) finds a lower diet cost for energy-dense food.[116] Nonetheless Gao and al. (2013) find that own-price elasticities of demand for diet quality are inelastic.[120] This result indicate that the budget constraint might trigger the poor food diet behavior of some Swiss residents. A higher change in the diet for low income households after the shock might indicate this budget constraint. Lastly the stickiness of the preferences might play a great role and potentially offsetting the effect through the price change.

4.4 Data and methods

4.4.1 Data: MenuCH

The dataset includes two non-consecutive 24-hour dietary recalls (first by face-to-face interview and the second by telephone interview, both with a certified dietician) from more than 2000 participants aged 18 to 75 years from the three main linguistic regions of Switzerland.[178]

Participants were recruited from the national sampling frame for person and household surveys. The survey population was intended to be representative of the Swiss population in terms of age and place of residency across all seven major areas of Switzerland, but did not survey people from every canton. A total of 5496 eligible people reachable by phone were invited to participate, of whom 2086 (38%) responded [179]. Participants and non-participants had similar age and marital status but participants were more frequently women and Swiss nationals than non-participants. Survey sampling weights were derived to adjust statistical analysis to be more representative of the Swiss adult population aged 18 to 75 years and to account for non-response.

4.4.2 Empirical approach

Using the unexpected removal of the EURCHF lower bound as a natural experiment we implement a regression discontinuity design (RDD) approach. The general idea is to compare dietary choices of individuals in a restricted window before and after the exchange rate shock. Under several assumption (see below), any observed change in dietary patterns can be attributable to the shock as individuals should be comparable in any other characteristics just before and just after the shock. One key assumption is that individuals cannot manipulate or anticipate the shock. In our case, individuals could not manipulate their exposition to the shock or the timing of the shock since only the members of the Swiss National Bank board took this decision. In addition, as Figure 4.1 shows the shock was largely unexpected by financial markets therefore Swiss households could probably not anticipate this decision and change their behaviour ex ante. Equation 1 shows how this is implemented in practice.

$$y_i = \beta_o + \beta_1 Post_i + \beta_2 Distance\ to\ shock_i + \beta_3 Distance\ to\ shock_i \times Post_i + \varepsilon_i \ (1)$$

The dependent variables of interest (yi) are the different diet quality indicators, an overall healthy heating index (HEI), total calories, and food expenditures. Post is a variable indicating whether the observation is before or after the shock. Distance to shock reflects the time difference between a specific observation and the shock, in days (here, a linear relationship is assumed). β_1 measures the impact of the shock on the dependent variable.

4.4.3 Sample selection

To implement the regression discontinuity design (RDD) strategy, we focused on the period ranging from the December 1st, 2014 to February 19th, 2015. The sample is composed of 756 dietary recalls (see Table 4.1 for descriptive statistics). The average age of the subset of selected participants was 46 years old and ranged from 19 to 76 years old. Individuals had a mean BMI of 24.6 kg/m^2. Male composed 43% of the sample. The subsample contained mainly workers, retirees, student and full-time fathers or mothers. More than 81% had Swiss nationality. The subsample had high proportion of highly educated individuals, i.e. 32% achieved a university degree or equivalent. The proportion of student (8%) was also high. More than 80 % of the subsample reported having a good or very good health.

Table 4.1 : Sample description

Variables	Mean	SD	Min	Max	Median
Age at time of interview (years)	46.11	0.66	19	76	46.80
BMI (kg/m^2)	24.58	0.21	16	47	23.85
Dummy or categorical variables					
Gender (1 = Male)	0.43	0.02			
Smoker (1 = Smoker)	0.23	0.02			
Language Region					
German speaking	0.55	0.02			
French speaking	0.33	0.02			
Italian speaking	0.13	0.01			
Recall day type					
Monday	0.14	0.01			
Tuesday	0.20	0.01			
Wednesday	0.22	0.01			
Thursday	0.19	0.01			
Friday	0.10	0.01			
Saturday	0.06	0.01			
Sunday	0.09	0.01			
Main activity					
Worker	0.65	0.02			
Retirement	0.17	0.02			
Full-time mom/dad	0.05	0.01			
Student	0.08	0.01			
Unemployed, AI or CNA/SUVA	0.03	0.01			

Variables	Mean	SD	Min	Max	Median
Other situation	0.03	0.01			
Civil status					
Single	0.33	0.02			
Married, in a registered partnership	0.52	0.02			
Divorced, separated, partnership dissolved	0.12	0.02			
Others	0.03	0.01			
Household status					
Living alone	0.16	0.02			
Couple without children	0.33	0.02			
Couple with children	0.31	0.02			
One-adult parent family with children	0.07	0.01			
Adult living with parents	0.08	0.01			
Others	0.06	0.01			
Nationality					
African / Eastern Mediterranean Region	0.01	0.00			
European Region	0.15	0.02			
Region of the Americas	0.01	0.00			
Switzerland and Liechtenstein	0.81	0.02			
Western Pacific / South-East Asia Region	0.02	0.01			
Education					
Mandatory or less	0.04	0.01			
Incomplete Professional education	0.10	0.01			
Professional education	0.25	0.02			
High-school	0.11	0.01			
Superior Professional education	0.18	0.02			
University & High Secondary school	0.32	0.02			
Net Income					
<3'000 CHF	0.05	0.01			
3'000 to 4'499 CHF	0.13	0.02			
4'500 to 5'999 CHF	0.22	0.02			
6'000 to 8'999 CHF	0.33	0.02			
9'000 to 12'999 CHF	0.19	0.02			
>13'000 CHF	0.08	0.01			
Health status					
Very bad	0.00	0.00			
Bad	0.01	0.01			
Medium	0.15	0.02			
Good	0.52	0.02			
Very good	0.31	0.02			

Note : 480 observations before the shock and 276 observations after the shock. For categorical variables, the mean reflects the proportion of participants in this category.

4.4.4 Outcome variables

Table 4.2 shows the dependent variables of interest and the mean in the analytic sample. Expenditures describe the daily cost of food items bought for the day. As menuCH participants did not report the cost of their diet, we used the Consumer Price Index (CPI) database to calculate the daily cost measured at the median price. We merged each product reported in menuCH with its median price in the CPI database[1]. Hence, this variable does not reflect the effective or reported price paid by menuCH participants but it represents a suitable proxy. A change of this variable reflects more a change in the food items consumed. The mean daily expected expenditure was calculated at 18.65 CHF.

For each of the diet-related outcomes, we compare means observed in our sample with optimal levels for each diet using the Global Burden Disease study criteria. Consumption of legumes, nuts and seeds are particularly low. Less than 25% of the optimal needs are fulfilled. Similar issues exist with vegetables and milk consumption. On average, menuCH participants consumed more than 65 times the optimal level of sugary beverages and more than 17 times the optimal level of processed meat. Such dysbalances existed already in the diets before the shock which is coherent with the findings of Chatelan and al. (2017).

Table 4.2 : Dependent variables of interest

Dependent variables	Definition	Optimal level GBD 2017 (add ref)	Mean
Expenditures	Daily cost of food intake (CHF)	-	18.65
Health eating index	Daily index of food healthiness (0 to 100)	100	47.47
Quantity	Daily quantity of food consumed (g)	-	3262.85
Energy	Daily energy intakes (Kcal)	2000	2097.12
Diet high in sodium	Daily intake of sodium (g)	3	3.06
Diet low in polyunsaturated fatty acids	Daily intake of polyunsaturated fatty acids (Proportion of total daily energy)	0.11	0.04
Diet low in calcium	Daily intake of calcium (g)	1.25	0.68
Diet low in fibre	Daily intake of fibre (g)	24	19.48
Diet low in fruits	Daily consumption of fruits (g)	250	155.76
Diet high in sugar-sweetened beverages	Daily consumption of beverages with >50 kcal per 226.8 servings (g)	3	193.5
Diet low in legumes	Daily consumption of legumes (g)	60	6.17
Diet low in nuts and seeds	Daily consumption of nuts and seeds (g)	21	5.29
Diet low in vegetables	Daily consumption of vegetables (g)	360	146.03
Diet high in processed meat	Daily consumption of processed meat (g)	2	35.75
Diet low in milk	Daily consumption of milk (g)	435	93.05
Diet high in red meat	Daily consumption of red meat (g)	23	25.33

GBD 2017, Global Burden of Disease 2017. Optimal level as defined in the Global Burden of Disease Study 2017. GBD 2017 Diet Collaborators. Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis of the Global Burden of Disease Study 2017. Lancet 2019. 393, 10184, 1958-1972. https://doi.org/10.1016/S0140-6736(19)30041-8.

[1] Each month the Federal Statistical Office (FSO) collects prices on a basket of goods in 11 regions of Switzerland to construct the CPI. The CPI database therefore represents the retail prices of Swiss food items faced by the consumer. In our analysis, we only used the food items bought by menuCH participants and observations between November 2014 and March 2015 to see the change in Swiss prices.

4.4.5 Quality of the identification strategy

Our empirical strategy relies on comparability of individuals just before and just after the shock. MenuCH Survey is a random stratified sample therefore no differences on average should appear between the samples before and after the shock unless the data collection procedure differs in time depending on different covariates, such as household location. Table 4.3 shows tests on socioeconomic covariates before and after the shock. The shock should not impact these covariates a priori. The difference is significant only for 2 covariates at a 10% level. The type of interview is expected since the first interview is always the face-to-face meeting, and as the shock occurred right at the end of the sampling period we would have more phone call interviews after the shock. The linguistic region is significant since proportionally more French and Italian speaking individuals responded or were interviewed after the shock. Since the diets differ between the linguistic region controlling for this variable will be important. Similarly, a Hawthorne effect due to behavioral change from being included in the survey and thinking about dietary behavior as well as prior contact with the nutritionist in the first survey could lead to a systematic difference between the first and second surveys.[254] We will then include the significant covariates and the ones close to being significant as controls. Namely, the age, number of people living in the households, nationality, gender, type of interview, linguistic region and the day recall of the week will be included in the models of the robustness section. As some observable variables seems different on both sides of the shock, we cannot exclude that some unobservable variables differ between the treatment and the control group. An additional threat is the existence of a shock happening at the same time of the currency shock. we find no such shock in the literature.

Seasonality might be problematic. The diets might change not because of the shock but due to seasonality in habits or availability of food items. To limits this issue, we restrict the bandwidth around the cutoff to 45 days. Hence the studied period is from the 1st December 2014 to the 19th February 2015. The habits might still be problematic since Christmas and New Year's Eve is in the period but there are no dietary recalls between the 22nd of December 2104 and the 3rd January 2015. Still an effect such as a New Year's Eve resolution might influence the estimates although we have some observations between the 3rd and the 15th January 2015. The trend measured by the model before and after the shock might partly show this seasonality in diets.

Table 4.3: Covariates balance

Covariates	P-value
Age at time of interview (years)	0.293
Education categories	0.605
Number of people living in HH	0.267
Number of cars	0.889
Net Income	0.467
Health status	0.345
Nationality	0.235
Gender	0.110
Type of interview	0.000
Linguistic region	0.009
Household status	0.839
Civil status	0.851
Activity (Worker, retiree...)	0.431

Smoking status	0.956
Recall day number	0.179

4.4.6 Robustness checks

As said in the previous section, there are two main threats to validity of the discontinuity due to the survey sampling. Namely, the sampling of individuals while random, the collection of the data over time was not, hence individuals sampled prior to the shock may differ to individuals sampled after the shock. Secondly, two surveys of diets were undertaken, the first a face to face interview and the second a phone call interview. Given the sample exposed to the shock was composed of individuals right at the end of the study it is more likely that we have a higher proportion of second interviews in this sample. If the sampling method influences reporting of outcomes this could affect results. There may also be behavioural change linked to the first interview when a nutritionist was present either during the first interview or subsequently afterwards. Below we indicate how we allowed for these potential biases.

The two first robustness checks are usual in the RDD literature. First, we add controls, including the type of interview (first face to face or second/nutritionist) and a rich set of individual and household controls reported previously to see if it changes the results. Second, we change the functional form before and after the shock with a second and third order polynomial for potential non linearities linking the diet and time such as seasonality in the diets.

Thirdly we implement the inverse probability propensity score matching procedure. In the first step we calculate the probability of being observed after the shock based on the unbalanced controls using a logit model. We then weight the observations before and after the shock by the inverse of the probability to be in the group before the shock (1 – probability exposed to shock). It allows to increase the weight of observations close to the group after the shock. The weight for the group observed after the shock is the inverse of the probability of being in the second group to give more weight on observations close to the group before the shock. These weights should increase the comparability of the sample before and after the shock based on the controls used in the first logistic regression.

Fourthly, as the MenuCH survey had two interviews, we keep only individuals observed on both sides of the shock hence the population is similar on both sides. This implies identical samples before and after the shock, however, it reduces unfortunately the sample size by more than half limiting the power of the coefficients but increasing probably the accuracy. The only differences between the groups are potential time trends and the type of interviews, a face-to-face interview before the shock and phone interview after the shock, hence the estimates are unbiased only if we assume no effects of the survey methods and timing.

Finally, we implement some placebo tests at different dates where no such shock happened a priori and the seasonality of diets should not impact the estimates. Hence, we select dates during the summer 2014. The sample is not restricted to individuals observed on both side of the “placebo” shock. The time span before and after the shock is also 45 days and the “placebo” shock is placed the 15th of the month as in the basic setup.

In addition, the distribution of the dependent variables is also explored. The diets measured at the food item level such as legumes show a large mass point at zero. Modelling this mass point with a two-part model with a logistic regression and a usual regression in the second part does not change much the point estimates or the standard errors. Table 6.6 in the appendix shows the results of both methods.

4.4.7 Heterogeneity of effects

We use the time cost to reach the border as a proxy of the degree of exposition to the shock. Individuals living near the border could easily go abroad and experience the full impact of the exchange rate shock assuming prices stayed unchanged in Switzerland. The effect of the border population is expected to be stronger where the probability and the frequency is higher. We calculate the travel time to reach the border using the geo-localisation of individuals' houses and the Swiss border points. The border points are the main roads crossing the border. Due to data availability, we could not find small roads crossing the border. This travel time is then valued using the opportunity cost of time. We then create two groups. The border group consists of households having an estimated travel time cost below the mean and a non-border group having an estimated travel time cost above the mean. The resulting model is:

$$y_i = \beta_o + \beta_1 Post_i + \beta_2 Distance\ to\ shock_i + \beta_3 Distance\ to\ shock_i \times Post_i + \beta_4 Border_i + \beta_5 Border_i \times Post_i + \varepsilon_i \quad (4)$$

β_5 is the coefficient of interest which measure the difference between the two groups living near or far from the border. 4 observations on 756 are lost due to the unavailability of the household location. This loss should not drive the result.

We finally also look at the response of lower income compared to higher income households. Food expenditures represent a higher proportion of household income/budgets for low-income households, hence they face tighter budget constraints and hence the effects of any price shock would on diet choices and food consumption is likely to be more significant.

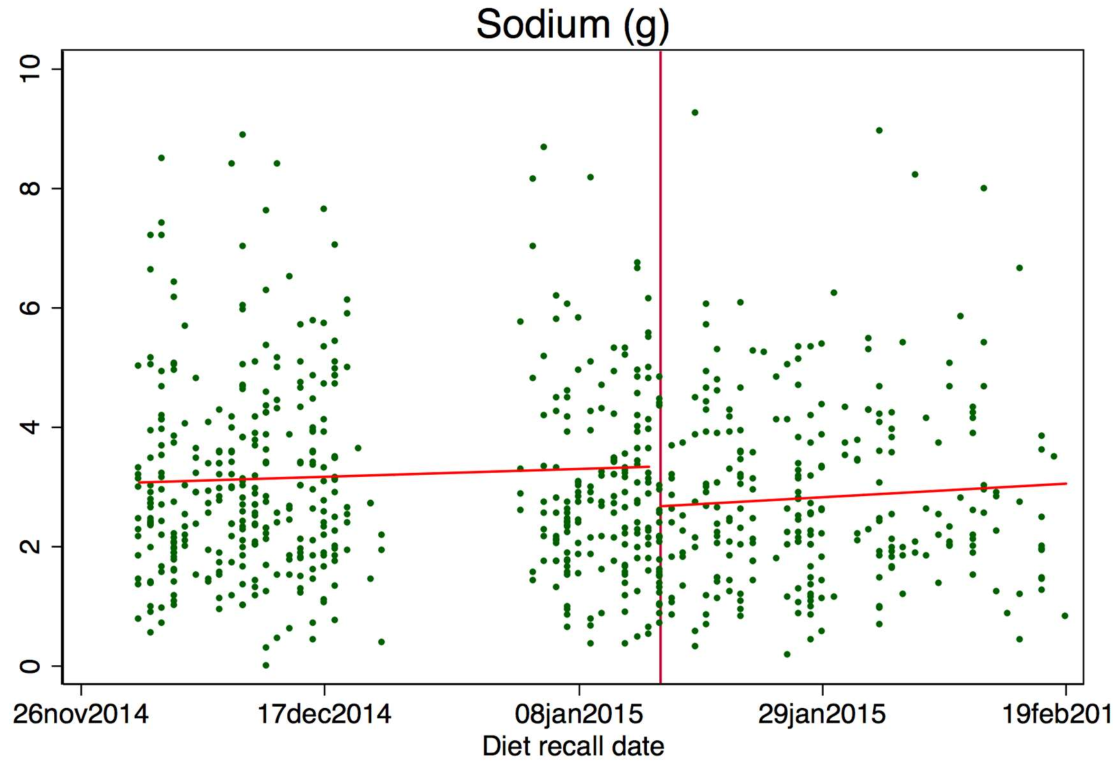
4.5 Results

4.5.1 Descriptive analyses

4.5.1.1 Graphical analysis

Figure 4.2 shows sodium intake before and after the shock and fitted lines. A small upward trend is present on both sides of the cutoff. At the discontinuity a drop occurs.

Figure 4.2 : Sodium intake across time



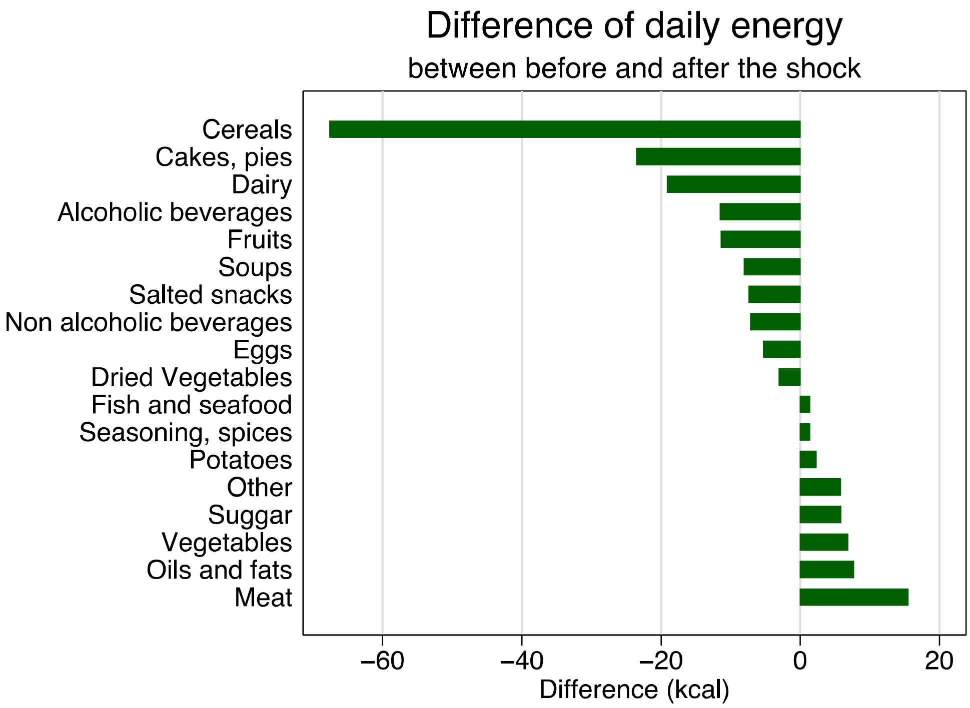
The appendix presents the graphs for the rest of the dependent variables (Figure 6.10 to Figure 6.12). Fibre consumption seems to react in the same direction as sodium intake, knowing that the sample already under consume fibre. Energy drops which is positive as an overconsumption of energy leads to obesity. Daily expenditures decrease but the healthy eating index increases at the same time. Individuals might be able to attain a better diet without paying more. At the food item level, many observations show no consumption of nuts and seeds, and legumes. More than 94% of the days observed do not contain legumes and 77% do not contain nuts and seeds. The extensive margin seems to explain the low average seen in the Table 4.2. On most figures no large trend seems to be present reinforcing the assumption of the absence of trends in diets in this period. Hence the estimated drop is not due to seasonality. The only food item where a time trend exists is vegetables consumption. On both sides of the cutoff a large positive trend appears.

Table 6.7 in the appendix shows the slope coefficient before and after the shock of the main RDD specification. All the slope's coefficients except for one variable are not significant. The coefficients of vegetables consumption are indeed significant at a 5% level. Nonetheless the difference between the two periods in the slopes is never significant for all dependent variables. The robustness section will show that the functional form does not drive the results a priori.

4.5.1.2 Mean differences

Figure 4.3 shows the difference of daily energy source in the different categories of MenuCH between before and after the ER shock. The mean comparison shows that the total of energy consumption decreases. The largest decrease is among the cereal based food, such as rice. Within this category, the decrease of bread explains this large reduction. The largest increase comes from meat consumption. Comparing only the mean, vegetables consumption increases whereas shown in Figure 6.12, considering a linear trend the shock shows a decrease of vegetables consumption.
Figure 6.13 and Figure 6.14 show a similar graph for the source of sodium and fibre intake. Overall, the mean difference shows a decrease of sodium and fibre intake. The main decrease comes again from cereal based food and bread more specifically. In almost all categories of food, there is no increase of sodium intake.

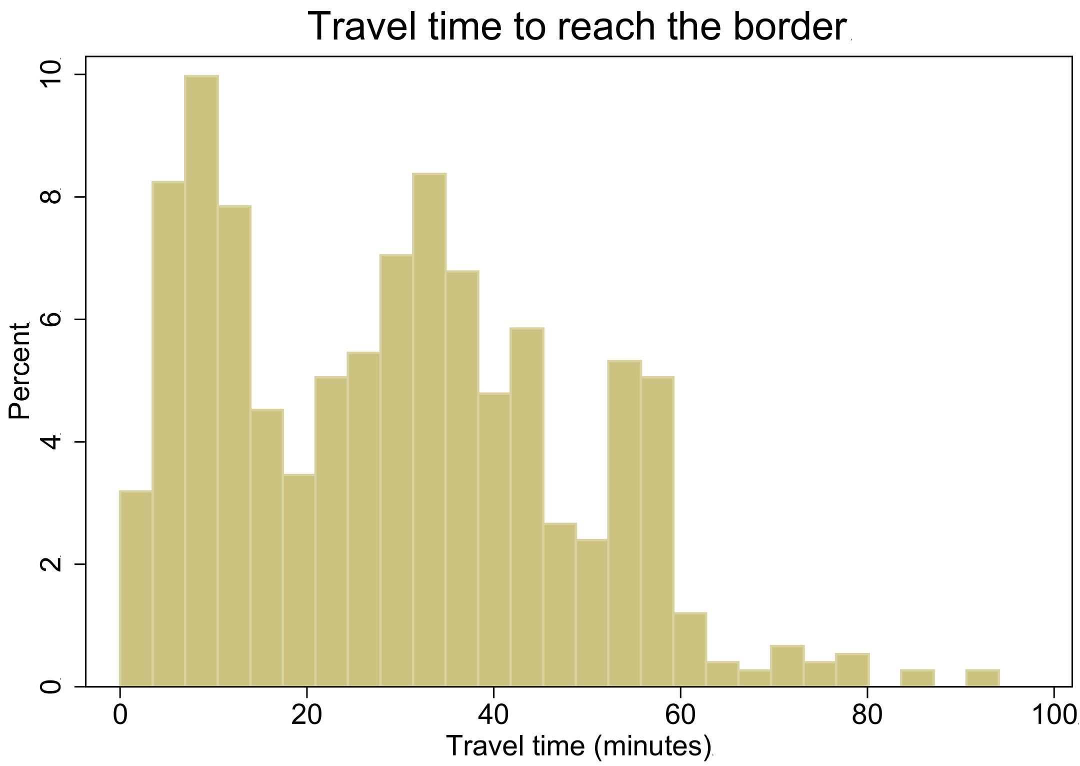
Figure 4.3: Difference of energy consumption



4.5.1.3 Spatial distribution

The price mechanism is explored using the spatial location of households. Figure 6.15 in the appendix shows the map of the individuals' location. As expected, many individuals live concentrated near the main cities of Switzerland. The number of individuals living in the mountain area is relatively small. As Figure 4.4 shows, individuals can quickly reach the Swiss border. More than 30% of the individuals live at less than 20 minutes of the border thanks to large cities, such as Geneva or Basel. Switzerland is a small country; hence the maximum time is around 90 minutes to reach a country in the Euro area. Cross border shopping is reachable for most individuals having a car.

Figure 4.4: Travel time to reach the border



4.5.2 RDD Regression Estimates

Table 4.4 shows the impact of the removal of the CHF/EUR exchange rate lower bound from estimating the model specified in equation 1 on the set of diet indicators defined above. The first three columns present three different bandwidths around the cutoff to see if the coefficients are stable. The 15 day bandwidth ensures everyone has entered to the new year to verify any ‘new year resolution' effect. The fourth column calculates the relative impact of the shock compared to the mean before the shock using the 45 days before and after the shock bandwidth, which is the preferred model.

The daily expenditures on food consumed decrease by 4.75 % and the HEI increases by 2 %. Energy consumption decreases by 6%, but the quantity consumed by only 3% hence individuals seem to switch to less energy dense food after the shock. None of these effects are statistically significant at the 5% level. As observed in Figure 4.3, which shows the difference between the two period of daily energy source, individuals seem to substitute from cereal and pastry based food items to meats, switching from carbohydrates to protein.

Sodium intake significantly decreased by 0.6 g (>20% decrease). Figure 6.13 in the appendix shows the difference of sodium intake in each product category. It is mainly among cereal based food items, and to a lesser extent soups, where the reduction in consumption after the exchange rate shock is associated with the decrease sodium intake. Bread consumption decreases a lot which probably explains the effect of sodium as a lot of salt is added in bread during the production process. Fibre consumption significantly decreases by 2.8g (14.3%).Again, it is likely the reduction in consumption of cereal products is associated with the reduction of fibre intake. Vegetable consumption significantly decreases by 30 g (22%) which might also explain some of the decrease in fiber consumption. Hence in terms of impact on diet quality, the exchange rate shock has had mixed effects,.. Substitution between processed meats and red meat seems to happen with similar absolute increases and decreases respectively, suggesting individuals switch to better quality sources of protein. Milk consumption which is on average below optimal levels was positively impacted by the ER shock with a 27 percent increase

Table 4.4: RDD estimates and percentage marginal effects for the effects of the exchange rate lower bound removal's impact on diet indicators

Dependent variables	Number of days before and after the shock			Percent change
	15 days	45 days	75 days	
Daily Expenditures (CHF)	-2.855	-0.894	-0.428	-4.75
	(2.654)	(1.587)	(1.464)	
Healthy Eating Index (0-100)	-1.848	1.131	1.279	2.41
	(2.254)	(1.405)	(1.290)	
Quantity (g)	-13.362	-112.960	-87.451	-3.42
	(183.873)	(120.807)	(109.427)	
Energy (kcal)	15.395	-145.316	-130.105	-6.79
	(175.027)	(112.434)	(104.316)	
Sodium (g)	-0.722*	-0.667***	-0.615***	-20.90
	(0.395)	(0.258)	(0.216)	
Polyunsaturated fat (Prop of total daily energy)	0.000	0.004	0.004	10.67
	(0.004)	(0.003)	(0.003)	
Calcium (g)	0.114	-0.048	-0.021	-6.90
	(0.082)	(0.057)	(0.052)	
Fibre (g)	-2.937	-2.855**	-2.308**	-14.34
	(1.840)	(1.121)	(1.032)	
Fruits (g)	4.596	2.657	7.275	1.69
	(40.214)	(26.364)	(24.762)	
Sugary beverages (g)	145.685**	46.502	26.177	23.55
	(63.887)	(42.932)	(40.997)	
Legumes (g)	-6.830	-4.813	-4.830	-77.68
	(6.266)	(3.780)	(3.340)	
Nuts and seeds (g)	-1.490	-0.777	-0.694	-13.26
	(2.305)	(1.533)	(1.449)	
Vegetables (g)	-39.442*	-30.508*	-9.747	-21.76
	(23.353)	(16.874)	(15.384)	
Processed meat (g)	-2.949	-7.742	-6.770	-20.79
	(10.835)	(7.150)	(6.474)	
Milk (g)	63.619**	25.749	22.177	27.82
	(28.556)	(19.934)	(19.037)	
Red meat (g)	12.166	10.923	12.301*	43.31
	(11.635)	(7.433)	(7.179)	
Observations	349	756	1185	

Note: Clustered standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1). Rates are per 100’000 individuals. The percent change is compared to the mean before the shock.

4.5.2.1 Robustness checks

Table 4.4 already shows the influence of changing the bandwidth around the shock date. It does not strongly alter the sign and magnitude of our main significant results, but does sometimes change their significance. The direction of the other indicator impacts does not change except for energy and calcium when selecting the smallest sample of 15 days around the cutoff. The sample size might partly drive this result. The standard errors do not reduce a lot probably since the last observation of MenuCH is the 19th February 2015.

Table 4.5 shows the robustness checks; allowing for observed covariates, selecting only balanced sample before and after the shock and using flexible pre and post shock trend polynomial functional forms on the impact of the shock. The last column describes the basic estimates of the sample containing observations at a maximum of 45 days. Adding covariates to the model does not change the direction and the magnitude of the estimates greatly. The only coefficient changing sign is the estimate of fruit consumption, but it stays none significant. Some effects such as the reduction in total calories are not as large, but the significance remains unchanged. The model including weights to increase the comparability between the sample before and after the shock yields similar results as the model with covariates. Spotting difference in the procedure of data collection of MenuCH, the sample containing the same individuals on both sides of the cutoff seems to be the most reliable in terms of accuracy. The estimates are close in terms of sign and magnitude to the basic estimates that do not restrict the sample except legumes where the sign differs, and energy were the magnitude is twice as large. Mechanically the standard errors are higher due to the much restricted sample. Changing the functional form before and after the shock with a 2nd or a 3rd order polynomial is more sensitive for the magnitude of the estimates and less for the sign.

Table 6.8 in the appendix shows the results of the placebo tests on other cutoff dates. We select dates in the summer where the diet is not likely to vary due to seasonal transitions and food price shocks and we keep the 15th of each month to avoid effects such as individuals buying food at the end of the month when they get their salaries. Only four coefficients are significant on the 80 regressions which is statistically reasonable if the rejection threshold is 5% hence the null is falsely rejected 5% of the time. Daily expenditures, nuts and seeds, and legumes significantly decrease the month of May. Vegetables consumption significantly decrease in September. These coefficients were all in May and September so may reflect some seasonal changes in price and choices.

Table 4.5: Robustness checks for RDD specification of the exchange rate lower bound removal

Dependent variables	Covariates	IPWM	Cross shock	Polynomial order 2	Polynomial order 3	Basic Estimates
Daily Expenditures (CHF)	-0.839	-1.037	-2.411	-1.225	-4.459	-0.894
	(1.564)	(1.713)	(2.329)	(2.225)	(3.042)	(1.587)
Healthy Eating Index (0-100)	0.603	0.486	-0.180	-0.475	-1.296	1.131
	(1.405)	(1.588)	(2.032)	(1.910)	(2.628)	(1.405)
Quantity (g)	-44.156	-41.399	-160.183	-30.465	-114.236	-112.960
	(120.241)	(132.099)	(190.408)	(160.074)	(211.318)	(120.807)
Energy (Kcal)	-102.072	-60.965	-252.640	-61.713	-58.920	-145.316
	(108.278)	(129.769)	(166.415)	(152.757)	(192.339)	(112.434)
Sodium (g)	-0.546**	-0.589**	-0.622	-0.799**	-0.887**	-0.667***
	(0.226)	(0.247)	(0.453)	(0.335)	(0.419)	(0.258)

Polyunsaturated fat (Prop of total daily energy)	0.003	0.001	0.006	0.004	-0.004	0.004
	(0.003)	(0.003)	(0.005)	(0.004)	(0.005)	(0.003)
Calcium (g)	-0.014	0.001	-0.068	-0.001	0.130	-0.048
	(0.059)	(0.066)	(0.087)	(0.075)	(0.097)	(0.057)
Fibre (g)	-3.149***	-3.078**	-3.206**	-2.841*	-3.894*	-2.855**
	(1.174)	(1.265)	(1.610)	(1.617)	(2.085)	(1.121)
Fruits (g)	-15.423	-7.696	10.230	7.739	12.023	2.657
	(25.632)	(31.790)	(37.007)	(36.223)	(50.661)	(26.364)
Sugary beverages (g)	41.366	90.389*	45.579	155.949***	126.468*	46.502
	(42.583)	(50.891)	(57.423)	(59.695)	(75.977)	(42.932)
Legumes (g)	-5.987	-5.963	-5.227	-8.420*	-9.372	-4.813
	(3.708)	(3.824)	(4.517)	(4.456)	(7.615)	(3.780)
Nuts and seeds (g)	-1.451	-2.046*	1.649	-0.335	-3.409	-0.777
	(1.505)	(1.220)	(2.574)	(2.156)	(2.959)	(1.533)
Vegetables (g)	-37.560**	-38.502**	-47.981*	-17.966	-55.177**	-30.508*
	(18.038)	(16.894)	(26.546)	(21.572)	(27.151)	(16.874)
Processed meat (g)	-6.395	-4.788	-15.721	-5.383	-2.608	-7.742
	(7.511)	(7.593)	(11.289)	(9.663)	(12.160)	(7.150)
Milk (g)	32.123	32.785	43.893	56.099**	83.993**	25.749
	(20.417)	(25.757)	(29.473)	(27.067)	(34.527)	(19.934)
Red meat (g)	11.041	7.340	7.164	16.390*	3.845	10.923
	(8.006)	(7.833)	(10.429)	(9.588)	(12.946)	(7.433)
Observations	756	756	318	756	756	756

Note: Clustered standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1). Covariates stands for the basic RDD specification adding controls. IPWM = Inverse Probability Weighting Matching. Cross shock restricts the sample to the same individuals on both sides of the shock.

4.5.3 Heterogeneity of effects

Table 4.6 shows the estimates for the sample closest and furthest to the border in terms of time cost. The difference between the two groups is significant only for the polyunsaturated fat intake at a 10% level. The border group increase more their consumption of polyunsaturated fat. The other coefficients are mostly coherent with the assumption that the border group tend to experience more the shock. Hence the effect found in the basic estimates is probably coming more from this group. The decrease in vegetables intake is significant only for the border group. Milk consumption for the border group increases significantly.

Table 4.6: Heterogeneity in effects of exchange rate lower bound removal by time cost to reach the border

Dependent variables	Non-Border	Border	Difference	Basic Estimates
Daily Expenditures (CHF)	-0.569	-1.144	-0.575	-0.894
	(1.859)	(1.863)	(1.908)	(1.587)
Healthy Eating Index (0-100)	0.827	1.420	0.593	1.131
	(1.598)	(1.647)	(1.627)	(1.405)
Quantity (g)	-115.961	-75.540	40.422	-112.960

	(141.750)	(134.641)	(135.921)	(120.807)
Energy (kcal)	-122.994	-165.344	-42.351	-145.316
	(119.795)	(134.428)	(122.616)	(112.434)
Sodium (g)	-0.685**	-0.675**	0.010	-0.667**
	(0.315)	(0.269)	(0.264)	(0.258)
Polyunsaturated fat (Prop of total daily energy)	-0.000	0.006*	0.007	0.004
	(0.003)	(0.004)	(0.003)	(0.003)
Calcium (g)	-0.028	-0.052	-0.024	-0.048
	(0.074)	(0.062)	(0.071)	(0.057)
Fibre (g)	-3.451***	-2.336*	1.114	-2.855**
	(1.305)	(1.304)	(1.340)	(1.121)
Fruits (g)	-5.325	10.207	15.533	2.657
	(29.545)	(29.209)	(25.652)	(26.364)
Sugary beverages (g)	77.646*	18.557	-59.089	46.502
	(45.333)	(52.910)	(50.023)	(42.932)
Legumes (g)	-4.437	-5.250	-0.813	-4.813
	(4.179)	(4.617)	(4.571)	(3.780)
Nuts and seeds (g)	-1.011	-0.531	0.481	-0.777
	(2.252)	(1.693)	(2.432)	(1.533)
Vegetables (g)	-16.378	-41.573**	-25.196	-30.508*
	(19.840)	(18.827)	(18.105)	(16.874)
Processed meat (g)	-5.242	-9.191	-3.949	-7.742
	(8.906)	(8.018)	(8.753)	(7.150)
Milk (g)	17.114	35.858*	18.744	25.749
	(25.694)	(20.876)	(22.853)	(19.934)
Red meat (g)	14.136	11.373	-2.763	10.923
	(9.797)	(7.880)	(9.512)	(7.433)
Observations	752	752	752	756

Note: Clustered standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table 4.7 shows the difference of the shock impact comparing high and low income individuals. There are stronger effects coming for most of the dependent variables from the low income group indicating probably potential budget constraints released by the shock. Yet, the difference between the two groups is never significant. Both groups reduce significantly sodium and fibre intakes. Reduction in vegetables consumption is significant only for the low income group. The evidence of a distinct budget constraint between income groups is limited.

Table 4.7: Heterogeneity by socioeconomic group of exchange rate lower bound removal

Dependent variables	Low Income	High Income	Difference
Daily Expenditures (CHF)	-1.115	-0.324	0.790
	(1.673)	(1.908)	(1.777)
Healthy Eating Index (0-100)	1.436	0.801	-0.636
	(1.767)	(1.544)	(1.717)
Quantity (g)	-159.157	-48.734	110.422
	(140.806)	(136.699)	(135.695)
Energy (kcal)	-190.985	-96.903	94.082
	(116.202)	(135.079)	(121.502)
Sodium (g)	-0.684**	-0.626**	0.058
	(0.276)	(0.293)	(0.252)
Polyunsaturated fat (Prop of total daily energy)	0.003	0.004	0.001
	(0.004)	(0.003)	(0.004)
Calcium (g)	-0.048	-0.046	0.001
	(0.065)	(0.068)	(0.068)
Fibre (g)	-2.705**	-2.750**	-0.045
	(1.296)	(1.283)	(1.276)
Fruits (g)	-2.009	7.697	9.706
	(28.531)	(30.013)	(25.633)
Sugary beverages (g)	70.472	21.888	-48.584
	(50.465)	(48.892)	(52.061)
Legumes (g)	-8.651	-1.772	6.878
	(5.515)	(3.728)	(5.178)
Nuts and seeds (g)	-0.105	-0.788	-0.684
	(1.720)	(1.986)	(2.138)
Vegetables (g)	-43.305**	-23.243	20.061
	(19.972)	(18.864)	(18.541)
Processed meat (g)	-9.361	-5.855	3.506
	(8.598)	(8.190)	(8.408)
Milk (g)	22.314	27.887	5.574
	(22.170)	(23.064)	(21.839)
Red meat (g)	8.717	13.712	4.995
	(8.126)	(8.954)	(8.696)

Note: Clustered standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

4.6 Discussion

The exchange rate shock had mixed effects on diet quality. Sodium intake was significantly lower, total calories and processed meat intakes fell and the overall healthy eating index slightly rose . However, fiber intake also fell significantly, vegetable consumption dropped, while sugar sweetened beverage consumption and red meat increased. One possible explanation for these results is the release of an income constraint. Individuals have preferences over the food eaten but they cannot meet them due to insufficient resources. It appears that preferences are not always for healthier foods. While red meat for instance may increase protein and iron intakes, it increases risks of cancer and cardiometabolic diseases.

Most of the coefficients are not statistically significant. Several reasons can explain it. Firstly, the shock may not have changed individual's food choices. Secondly, there was a lack of power. Also, the last observation was only one month after the shock and we expect delayed responses to the shock because people need to first consume what they have bought before the shock and they likely only go to the supermarket on a weekly or monthly basis. A longer observation period after the shock might help increase the power but also the accuracy of the estimates.

The impact of the shock is heterogeneous among Swiss households. The population living near the border can more easily benefit from the shock as they can make more frequent and less costly trips, and purchase more perishable items . However, only one significant heterogeneous impact can be shown as a function of the time cost to reach the border. Switzerland is rather a small country and individuals can easily go abroad. We found significant differences between the two groups for vegetables and milk consumptions, which makes sense given that these items are more perishable. The border community were likely already benefiting from relatively lower prices before the shock, and the exchange rate shock may have increased the propensity of individuals further from the border to travel, particularly for highly preferred and relatively expensive foods in Switzerland.

In terms of policy, several implications may arise. Policy makers should design a program such as the Supplemental Nutrition Assistance Program (SNAP) with caution. The subsidies should not be on all food items since people will probably increase the consumption of some unhealthy foods. Targeted and conditional subsidies in cash to certain food groups might mitigate this effect increasing the efficiency of a policy such as the SNAP program. Unfortunately, households might save this subsidy to buy unhealthy food instead.[192] To circumvent this issue vouchers or an increasing subsidy with quantity could improve the program. In addition, as shown in this paper some food items do not appear to react strongly. A tax or subsidy might not be appropriate in these cases as households' response may be weak. For the Swiss population specifically, the exchange rate shock is revealing in terms of dietary consequences of the food environment. Exposure to sodium through cereals and other carbohydrates appears important, so pursuing other policies on the supply side to reduce added sodium in the food process would have population health benefits. Sugar sweetened beverages appear quite price sensitive, as has been observed from evaluations of the imposition of sugar taxes, and as households are willing to cross borders to obtain cheaper prices, the effectiveness of any sugar tax in Switzerland at the canton or national level could be reduced if neighboring cantons or countries do not follow. The reduction in fiber from substituting away from cereals would also be a public health concern, given the strong evidence of the health benefits of fiber. Education or information campaigns or possible supply side policies such as fortification of foods (for example, reduced refinement of foods or reduction of highly processed foods) could be options.

4.6.1 Limitations

Under reporting seems to happen in large scale nutritional studies relying on self-reporting.[255] Individuals might misreport some specific food items if they consider that they do not meet current expectations for a healthy diet.

Differences in the characteristics of the participants involved in the two periods could partly be solved by observing the same individuals on both sides of the cutoff. The sample is randomly selected but observations exists from January 2014 to February 2015 and the order of asking individuals might not be random.[179]

Responders could partly choose the date when answering the 24h dietary recall's questions. If the order is linked to unobservable variables that impact the dependent variables, then it would impact the estimates. The observed effect is specific to a narrow time period in a single country, Switzerland. The shock may also reflect the response of a specific subgroup of the population more sensitive to the price shock and its relative price effects, for instance on lower income households with a high preference for meat. The nature of the response and effects are also very specific to the season, mid-winter, when dietary preferences and choices are influenced by the cold temperatures and constrained by the quality of available foods.

4.7 Conclusion

The goal of this analysis was to measure the impact of a large exchange rate shock on dietary habits of Swiss individuals. Given the importance of dietary behaviors on the health of the population, understanding the response of individuals to a decrease in food prices is relevant from a public health point of view. We find a heterogeneous effect on diet quality. Sodium intake decreases but vegetables and fiber intake also decrease. The effect differences seem to come mainly from the border population, although the largest effects are consistent across all individuals. A significant price reduction across all foods did not appear to significantly increase the consumption of healthier foods. These results therefore suggest that targeted policies may be required to improve nutritional quality in Switzerland. Further research is however needed to better understand the impact of sudden food prices changes on food intakes and choices within the Swiss context.

5 General discussion

In this report, we first show consistent evidence from an extensive review of the literature of a positive association between diet cost and nutritional quality. For instance, our results show that most expensive diets are 45% healthier than least expensive ones, when extreme comparisons are made. However, our review of findings also show considerable heterogeneity in effects size, study design and data quality. In addition, we provide evidence of publication bias in the area. More importantly, as most studies use observational data, making causal claims is often challenging. The literature review also highlights the importance of considering measures that take a broader view of diet costs such as search and time costs of accessing healthier foods.

Then, using data from the first national nutritional survey, menuCH, we show a non-linear relationship between food expenditure and diet quality. At lower levels of daily expenditure, there is significant scope to increase daily expenditure on food with diet quality benefits. We find that close to 40% of the population would increase diet quality by increasing their daily expenditure to 17 CHF per day, using the HEI as diet quality measure.

Results also suggest that in the Swiss population there is both under- and over- consumption of food from a diet quality perspective and find that higher time cost has a positive and significant impact on diet quality. However, we do not find any direct impact of household net income on diet quality on the basis of menuCH data, but only an indirect effect of net income through daily expenditure. Net income has a positive and significant effect on daily food expenditure in favor of wealthier individuals, which confirms Engel's law that, as income rises, the absolute spending on food increases while the percentage of income allocated for food purchases decreases. Lower income households spend a greater proportion of their available income on food than middle or higher income households do. Finally, comparisons between individuals that have similar levels of daily food expenditure but different dietary patterns shows that individuals with lower diet quality overconsume products with low nutritional value relatively to their comparable groups. In particular, people who report low diet quality tend to report higher consumption of sugar dense products and starchy foods like breads, pasta and rice. Overall, individuals with low quality diet and low daily expenditure are the ones with the most pressing need of policy intervention.

Among policy options, measures to target the market environment are intrusive but are highly effective. Taxes have been implemented elsewhere and they were proven to improve diet quality and reduce consumption of low nutritional value food items. Moreover, these types of interventions could raise valuable revenue for health-promoting interventions. In the Swiss setting, our research suggests that the distributional effects of a tax on sugary products might not be regressive since there is evidence that both on the low, as well as on the high, spectrum of daily food expenditures sugary products came as the type of products that are overly consumed by people with low quality diets. Howerer, recent research shows that public acceptance varies considerably between interventions designed to reduce consumption of unhealthier food items, with higher acceptance for least intrusive interventions, such as public health campaigns and nutritional labelling, and higher resistance for more restrictive interventions such as taxation.

Finally , we exploit a sharp and unexpected change in macroeconomic policy in Switzerland to study the impact of price changes on dietary habits in the country. We find a heterogeneous effect on diet quality. Sodium intake decreases but vegetables and fiber intake also decrease. The effect differences seem to come mainly from the border population, although the largest effects are consistent across all individuals. A significant price reduction across all foods did not appear to significantly increase the consumption of healthier foods. These results therefore suggest that multi-sectoral policies may be required to improve nutritional quality in Switzerland. Further research is however needed to better understand the impact of sudden food prices changes on food intakes and choices within the Swiss context.

Overall, our results suggest that the relationship between food cost and diet quality is complex and that there might not be a one-size fits all policy option to address the public health and equity consequences of unhealthy diets.

6 Appendix

6.1 Relationship between diet cost and nutritional quality: evidence from the public health, nutrition science, and economics literature

Table 6.1 : Search strings for literature review strategy (OVID)

Sr. No.	Search terms	Number of hits
1	(cost$ and (diet* or energy or nutri*))	53464
2	(food and (price$ or expenditure$ or elasticitie$))	14696
3	1 OR 2	66476
4	(density and (nutri* or energy or calori*))	77905
5	(diet* and (quality or recommendation$ or guideline$))	110184
6	((consumption and (fruit$ or vegetable$)) or (intake and (nutrient or energy)) or (index and (healthy or hei or nutri* or mediterranean)) or (mean adequacy ratio or MAR or mean excess ratio or mer))	340878
7	4 OR 5 OR 6	482326
8	3 AND 7	23844
9	(Diet* and (record$ or histry or intake or recall$ or survey or food frequency questionnaire or FFQ))	313217
10	(food and (diary or receipt$ or record$))	20071
11	9 OR 10	331743
12	($health$ and (food basket$ or menu$ or diet$))	191581
13	((model and (econom* or optima?ation or utility)) or linear programming)	101524
14	12 OR 13	291696
15	(shock$ and (economic or income or price))	1438
16	11 AND 14	97177
17	15 OR 16	98602
18	8 AND 17	4474
19	After duplicates	3381

Figure 6.1 : Prisma Flow chart

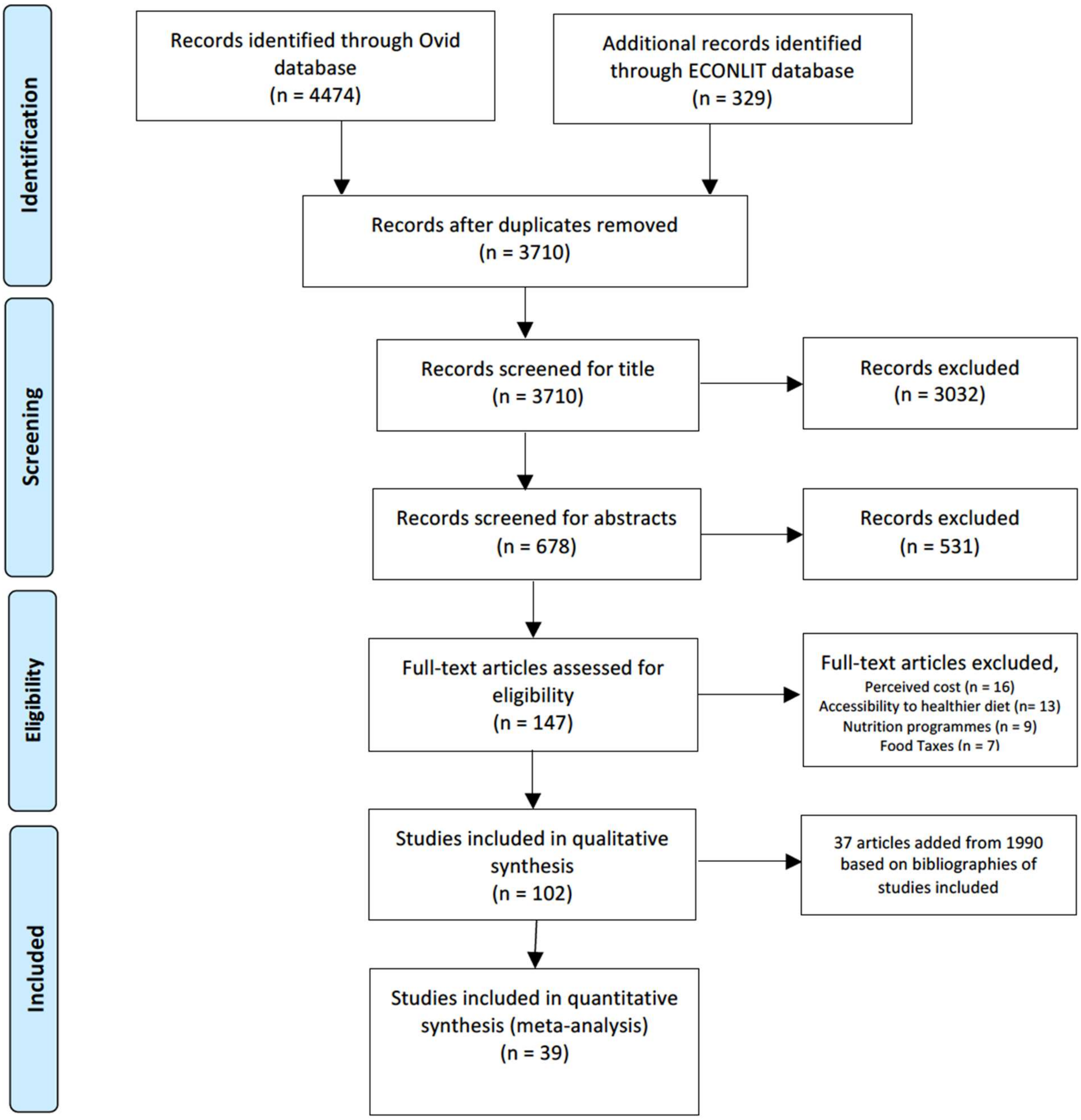


Table 6.2 : Data extraction table

S. No.	Full Reference	Year	Country	Title	Study Objective	Study Type	Cost Data	Main Findings
1	Aggarwal, A.; Monsivais, P.; Cook, A.J.; Drewnowski, A.	2011	USA	Does diet cost mediate the relation between socioeconomic position and quality?	To test the hypothesis that socioeconomic disparities are mediated, in part, by diet cost.	Dietary assessment	Storecheck	Higher income and education were associated with lower energy density and higher MAR scores, adjusting for covariates. Higher income and education were also associated with higher energy adjusted diet cost. Higher quality diets were in turn associated with higher diet costs.
2	Andrieu, E; Darmon, N.; Drewnowski, A.	2006	France	Low-cost diets: more energy, fewer nutrients	To evaluate if more nutrient dense diets associated with a lower energy density are likely to cost more.	Dietary assessment	National price data	Participants in the lowest quartile of energy cost had the highest energy intakes, the most energy dense diets and the lowest daily intakes of key vitamins and micronutrients. Participants in the highest quartile of energy cost had lower energy intakes, and diets that were higher in nutrients and lower in energy density. However, their daily diet costs were 165% higher. The more nutrient dense diets were associated with higher diet costs.
3	Bernstein, A.; Bloom, D.; Rosner, B.; Franz, M.; Willett, W.	2010	USA	Relation of food cost to healthfulness of diet among US women.	Evaluate the cost of a dietary pattern that may prevent cardio-vascular disease among women residing in the US.	Dietary assessment	National price data	Highest AHEI quintile spent 24% more money each day on food prepared at home than those in the lowest quintile. Had higher intakes of fruits and vegetables, intakes of processed meat, high fat dairy, grains, and snacks and vegetables, fish, nuts, soy and beans. Lower sweets. Had lower rates of angina, diabetes, and hypertension.
4	Cade, J.; Upmeier, H.; Calvert, C.; Greenwood, D.	1999	UK	Costs of a healthy diet: analysis from the UK Women's Cohort Study.	To investigate the direct and indirect cost differences associated with eating a 'healthy' or 'unhealthy' diet.	Dietary assessment	National price data	The difference between the most extreme hdi groups was £1.48/day (equivalent to £540/year), with fruit and vegetable expenditure being the main items making a healthy diet more expensive.
5	Conklin, A.; Monsivais, P.; Khaw, K.; Wareham, N.; Forouhi, N.	2016	UK	Dietary Diversity, Diet Cost, and Incidence of Type 2 Diabetes in the United Kingdom: A Prospective Cohort Study.	Examine the association of reported diversity of intake of food groups with risk of developing type 2 diabetes and to estimate the monetary cost associated with dietary diversity.	Dietary assessment	Storecheck	People who reported consuming all five food groups had a 30% reduced incidence of type 2 diabetes, but the cost of such a diet was 18% higher than a diet comprising three or fewer food groups.

S. No.	Full Reference	Year	Country	Title	Study Objective	Study Type	Cost Data	Main Findings
6	Drewnowski, A.; Darmon, N.; Briend, A.	2004	France	Replacing Fats and Sweets With Vegetables and Fruits? A Question of Cost	Examined the association between diet quality and estimated diet costs.	Dietary assessment	National price data	Higher consumption of fats and sweets was associated not only with reduced energy cost but also with lower absolute diet costs. In contrast, each additional 100g of vegetables and fruit was associated with higher diet costs.
7	Drewnowski, A.; Monsivais, P.; Maillot, M.; Darmon, N.	2007	France	Low-Energy-Density Diets Are Associated with Higher Diet Quality and Higher Diet Costs in French	This study tested the hypothesis that energy-dense diets have a relatively low monetary cost, whereas less energy-dense diets are more expensive.	Dietary assessment	Scanner data	Negative relationship between dietary energy density and diet quality. At each level of energy intake, higher dietary energy density was associated with lower diet costs. Vitamin C is one index of diet quality. At each level of energy intake, higher consumption of vitamin C was associated with higher diet costs.
8	Hyder, J.; Thomson, C.; Natarajan, L.; Madlensky, L.; Pu, M.; Emond, J.; Kealey, S.; Rock, C.; Flatt, S.; Pierce, J.	2009	USA	Adopting a plant-based diet minimally increased food costs in WHEL Study.	To examine whether adopting a plant-based dietary pattern would improve prognosis among women previously diagnosed with early stage breast cancer.	Dietary assessment	Receipts	The weekly grocery cost was 3.6% per person greater in the intervention group. A major change to a plant-based diet was associated with minimal increase in grocery costs
9	Jetter, J.; Cassady, D.	2006	USA	The availability and cost of healthier food alternatives.	Investigate the cost and availability of a standard market basket of foods, and a healthier basket that included low-fat meat and dairy and whole grain products.	Market basket	Storecheck	TFP market-basket cost was $194, and the healthier market-basket cost was $230. The average cost of the healthier market basket was more expensive by $36 due to higher costs of whole grains, lean ground beef, and skinless poultry. The higher cost of the healthier basket is equal to about 35% to 40% of low-income consumers' food budgets of $2410 a year.
10	Jones, N.; Conklin, A.; Suhrcke, M.; Monsivais, P.	2014	UK	The Growing Price Gap between More and Less Healthy Foods: Analysis of a Novel Longitudinal UK Dataset.	Investigate the prices of more and less healthy foods over time using existing government data on national food prices and nutrition content.	Market basket	National pricedata	Less healthy food was significantly cheaper than healthy food. All prices rose in the period considered, but more healthy items rose faster than less healthy ones in absolute terms.

S. No.	Full Reference	Year	Country	Title	Study Objective	Study Type	Cost Data	Main Findings
11	Jones, N.; Conklin, A.; Suhrcke, M.; Monsivais, P.	2014	UK	The Growing Price Gap between More and Less Healthy Foods: Analysis of a Novel Longitudinal UK Dataset	Investigate the prices of more and less healthy foods over time using existing government data on national food prices and nutrition content	Market basket	National price data	Less healthy food was significantly cheaper than healthy food. All prices rose in the period, but healthier items rose faster than less healthy ones in absolute terms.
12	Katz, D., Doughty, K., Njike, V., Treu, J., Reynolds, J., Walker, J., Katz, C.	2011	USA	A cost comparison of more and less nutritious food choices in US supermarkets.	The study directly compared prices of more and less nutritious foods within given categories in US supermarkets.	Market basket	Storecheck	Average price of the more nutritious food did not differ significantly from that of less nutritious foods overall.
13	Krukowski, R. A., West, D. S., Harvey-Berino, J., Prewitt, T. E.	2010	USA	Neighborhood Impact on Healthy Food Availability and Pricing in Food Stores.	Do demographic and structure factors have an impact on the availability and price of healthy foods?	Market basket	Storecheck	Buying the 10 non-produce healthier items on the measure was significantly more expensive than the standard items, reflecting a significantly higher cost for five of the healthier items compared with the regular option.
14	Liese, A.; Weis, K.; Pluto, D.; Smith, E.; Lawson, A	2007	USA	Food Store Types, Availability, and Cost of Foods in a Rural Environment.	To characterize the built nutritional environment in terms of types and number of food stores, availability, and cost of selected food items in a rural area.	Market basket	Storecheck	Availability of more healthful foods was substantially higher at supermarkets and grocery stores. Foods that were available at both supermarkets and convenience stores tended to be substantially more expensive at convenience stores. The healthful version of a food was typically more expensive than the less healthful version.
15	Lipsky, L.	2009	USA	Are energy-dense foods really cheaper? Reexamining the relation between food price and energy density UK	Methodologic assessment of weaknesses of comparing energy density and energy cost.	Market basket	Storecheck	Energy cost was higher for produce than for snacks. However, total price and unit price were lower for produce. Serving price and serving size were greater for produce than for snacks. Within food categories, energy density was uncorrelated with most measures of food price, except for a weak positive correlation with serving price within the produce category.

S. No.	Full Reference	Year	Country	Title	Study Objective	Study Type	Cost Data	Main Findings
16	Lopez, C.; Martinez-Gonzalez, M.; Sanchez-Villegas, A.; Alonso, A.; Pimenta, A.; Bes-Rastrollo, M.	2009	Spain	Costs of Mediterranean and western dietary patterns in a Spanish cohort and their relationship with prospective weight change	Examine the costs of observed dietary patterns in a mediterranean cohort. Interested in increasing trend towards a more modern western diet.	Dietary assessment	National price data	Participants with lowest nutritional quality dietary pattern (fifth quintile vs first quintile) spent less money (-\$0.80) per 1000/kcal on their daily food costs, whereas the opposite was true for the highest nutritional dietary pattern (+\$0.90). Higher daily food costs were significantly associated with greater weight gain.
17	Mackenbach, J. D.; Brage, S.; Forouhi, N.; Griffin, S.; Wareham, N.; Monsivais, P.	2011	UK	Does the importance of dietary costs for fruit and vegetable intake vary by socioeconomic position?	Examine whether dietary costs are more strongly associated with fruit and vegetable intake in lower SES groups than in higher SES groups.	Dietary assessment	National price data	Higher fruit and vegetable intakes are associated with higher dietary costs; educational differences were not evident in the stratum of adults with highest dietary costs but amplified among those with lower-cost diets. Dietary costs are not equally important for fruit and vegetable intake across all socioeconomic groups. Educational differences in intake were only observed in individuals with the lowest diet cost.
18	Maillot M.; Vieux F.; Delaere F.; Lluch A.; Darmon	2007	France	Dietary changes needed to reach nutritional adequacy without increasing diet cost according to income: An analysis among French adults	To explore the dietary changes needed to achieve nutritional adequacy across income levels at constant energy and diet cost.	Market basket	Scanner data	The cost of observed diets increased with increasing income quintiles. In free-cost models, the optimization increased diet cost on average (0.22 ±1.03 €/day) and within each income quintile, with no significant difference between quintiles, but with systematic increases for observed costs lower than €3.85/day.
19	Marty, L.; Dubois, C.; Gaubard, M. S.; Maidon, A.; Lesturgeon, A.; Gaigi, H.; Darmon, N.	2015	France	Higher nutritional quality at no additional cost among low-income households: insights from food purchases of "positive deviants"	Investigate the relation between actual expenditure on food and nutritional quality and to identify "positive deviants" among low income households	Dietary assessment	Receipts	Low socioeconomic individuals selected less expensive food options relatively to the average population. Higher diet costs were associated with higher nutritional quality (higher MAR, lower ED). Positive deviants made significantly healthier purchases than did other participants at higher estimated costs. Yet they did not spend more on food, which showed they purchased food with higher nutritional quality for their price.
20	Masset, G.; Vieux, F.; Verger, E.; Soler, L.; Touazi, D.; Darmon, N.	2014	France	Reducing energy intake and energy density for a sustainable diet: a study based on self-selected diets in French adults	The objective was to identify the most sustainable diets consumed by people in everyday life.	Dietary assessment	Scanner data	Higher quality diets had a relatively higher diet cost than lower quality diets

S. No.	Full Reference	Year	Country	Title	Study Objective	Study Type	Cost Data	Main Findings
21	McManus, R.; Bouwmeester, A.; Hinz, L.; Caraiscos, V.; Nairn, J.; Giroux, I.	2003	USA	Costs of recalled and recommended diets for pregnant women with type 1, type 2 and gestational diabetes.	Compare the associated costs of actual food choices versus the cost of a constructed recommended diet for diabetic pregnant women.	Dietary assessment	Storecheck	There were no significant cost differences between recommended and Actual. Percentage of fiber intake was lower for Actual Diets than Recommended Diet for all groups, while percentage of protein intake was lower in Actual than Recommended Diet for women with type 1 diabetes.
22	Mitchell, D.; Shannon, B.; McKenzie, J.; Smiciklas-Wright, H.; Miller, B.; Tershakovec, A.	2000	USA	Lower fat diets for children did not increase food costs.	Examine the food costs in diets of hypercholestorolic children who were adhering to a low-fat diet.	Dietary assessment	Storecheck	The children in the treatment group appeared to have lower food costs; however, the differences were not significant and likely can be accounted for by slightly lower energy intakes of the children in this group.
23	Monsivais, P.; Drewnowski, A.	2009	USA	Lower-Energy-Density Diets Are Associated with Higher Monetary Costs per Kilocalorie and Are Consumed by Women of Higher Socioeconomic Status.	This study examined associations among dietary energy density, energy-adjusted diet costs, and socioeconomic indicators of study participants.	Dietary assessment	Storecheck	Diets of lower energy density were associated with higher absolute nutrient intakes. Diets of lower energy density were also associated with higher energy-adjusted diet costs. Conversely, highest energy density diets were associated with lower intakes of micronutrients and fiber and lower costs. Education and household incomes showed a positive association with the energy-adjusted cost of the diet. Education was a stronger predictor of both energy density and energy cost than was household income.
24	Monsivais, P.; Aggarwal, A.; Drewnowski, A.	2012	USA	Are socio-economic disparities in diet quality explained by diet cost?	This study tested the hypothesis that socioeconomic differences in nutrient intakes can be accounted for, in part, by diet cost.	Dietary assessment	Storecheck	Controlling for energy and other covariates, higher-cost diets were significantly higher in all seven nutrients and in overall nutrient density.
25	Morris, M.; Hulme, C.; Clarke, G.; Edwards, K.; Cade, J.	2014	UK	What is the cost of a healthy diet? Using diet data from the UK Women's Cohort Study.	This study will investigate the cost of consuming a range of dietary patterns.	Dietary assessment	National price data	A significant positive association was observed between diet cost and healthiness of the diet. The healthiest dietary pattern was double the price of the least healthy, £6.63/day and £3.29/day, respectively. Dietary diversity, described by the patterns, was also shown to be associated with increased cost.

S. No.	Full Reference	Year	Country	Title	Study Objective	Study Type	Cost Data	Main Findings
26	Monsivais, P.; Scarborough, P.; Lloyd, R.; Mizdrak, A.; Luben, R.; Mulligan, A.; Wareham, N.; Woodcock, J.	2015	UK	Greater accordance with the dietary approaches to stop hypertension dietary pattern is associated with lower diet-related greenhouse gas production but higher dietary costs in the United Kingdom.	Examine the relation between dietary accordance with the DASH diet and associated GHGs. A secondary aim was to examine the retail cost of diets by level of DASH accordance.	Dietary assessment	Storecheck	Higher accordance with the DASH diet was associated with higher dietary costs, with the mean cost of diets in the top quintile of DASH scores 18% higher than that of diets in the lowest quintile.
27	Nansel, T.; Haynie, D.; Lipsky, L.; Mehta, S.; Laffel, L.	2015	USA	Overall diet quality is not associated with diet cost among youth with type 1 diabetes.	Examine the association of diet quality with diet cost in a sample of youth with type 1 diabetes.	Dietary assessment	Storecheck	Mean estimated daily diet cost was $6.93, which is similar to national estimates and within the range of average costs of USDA food plans for children. Findings suggest that a more healthful diet may be achieved at a cost comparable to a less healthful diet.
28	Pondor, I.; Gan, W.; Appannah, G.	2017	Malaysia	Higher Dietary Cost Is Associated with Higher Diet Quality: A Cross-Sectional Study among Selected Malaysian Adults	This study aimed to examine socio-economic characteristics and daily dietary cost (DDC) in relation to diet quality	Dietary assessment	National price data	Positive association between daily dietary costs and higher mean healthy eating index. The highest quintile of daily diet cost had higher HEI scores for all respondents (Q1: 57.14±10.07 vs. Q5: 63.26±11.54).
29	Rauber, F.; Vitolo, M.	2009	Brazil	Nutritional quality and food expenditure in preschool children	Assess association between cost and nutritional quality of the diets of young children.	Dietary assessment	Storecheck	There was a positive correlation between micronutrients intake and expenditure on food. Nutritional quality, assessed in the form of essential micronutrient intakes, demonstrated a positive correlation with food cost.
30	Raynor, H.; Kilanowski, C.; Esterlis, I.; Epstein, L.	2002	USA	A cost-analysis of adopting a healthful diet in a family-based obesity treatment program.	Assess dietary costs during a family-based pediatric obesity intervention.	Dietary assessment	Storecheck	Energy intake for parents and children significantly decreased from baseline. Servings from low nutrient density foods significantly decreased, causing a significant increase in diet nutrient density. Dietary cost did not significantly change from baseline at 6-month but significantly decrease after 1-year. Cost per 1000/kcal did not significantly change.

S. No.	Full Reference	Year	Country	Title	Study Objective	Study Type	Cost Data	Main Findings
31	Rehm, C.; Monsivais, P.; Drewnowski, A.	2011	USA	The quality and monetary value of diets consumed by adults in the United States	Explore the association of diet cost and diet quality among strata of the US population.	Dietary assessment	Scanner data	Higher diet costs were associated with higher HEI-2005. Higher diet cost was strongly associated with consuming more servings of fruit and vegetables and fewer calories from solid fat, alcoholic beverages, and added sugars.
32	Rehm, C.; Monsivais, P.; Drewnowski, A.	2015	USA	Relation between diet cost and Healthy Eating Index 2010 scores among adults in the United States 2007-2010	To evaluate the association between diet costs and the Healthy Eating Index-2010 & Dietary Assessment.	Dietary assessment	National price data	Among the population, there was significant and positive association between higher diet cost and higher HEI-2010 scores. Persons in the highest diet cost quintile had HEI-2010 scores that were 22.4 points higher than those consuming lower cost diets.
33	Rydèn, P. J.; Hagfors, L.	2011	Sweden	Diet cost, diet quality and socio-economic position: how are they related and what contributes to differences in diet costs?	Examine diet costs in relation to dietary quality and socio-economic position, and to investigate underlying reasons for differences in diet costs.	Dietary assessment	Storecheck	Higher HEI scores resulted in higher diets costs and, conversely, higher diet costs were linked to increased total HEI scores. Children who consumed the most healthy and/or expensive diets ate a more energy-dilute and varied diet compared with those who ate the least healthy and/or least expensive diets.
34	Scarborough, P.; Kaur, A.; Cobiac, L.; Owens, P.; Parlesak, A.; Sweeney, K.; Rayner, M.	2016	UK	Eatwell Guide: Modelling the dietary and cost implications of incorporating new sugar and fibre guidelines. &	To model food group consumption and price of diet associated with achieving UK dietary recommendations while deviating as little as possible from the current UK diet.	Market basket	Storecheck	The modelled diet to achieve dietary recommendations would cost £5.99 (£5.93 to £6.05) per adult per day, very similar to the cost of the current diet: £6.02 (£5.96 to £6.08).
35	Schroder, H.; Gomez, S.; Ribas-Barba, L.; Perez-Rodrigo, C.; Bawaked, R.; Fito, M.; Serra-Majem, L.	2016	Spain	Monetary diet cost, diet quality, and parental socioeconomic status in Spanish Youth	Determine relationships between monetary daily diet cost, diet quality, and parental socioeconomic status.	Dietary Assessment	National price data	High Mediterranean diet adherence (KIDMED score 8-12) was €0.71/day (€0.28/1000kcal/day) more expensive than low compliance (KIDMED score 0-3).

S. No.	Full Reference	Year	Country	Title	Study Objective	Study Type	Cost Data	Main Findings
36	Townsend, M. S.; Aaron, G. J.; Monsivais, P.; Keim, N. L.; Drewnowski, A.	2009	USA	Less-energy-dense diets of low-income women in California are associated with higher energy-adjusted diet costs.	To analyse the nutritional content and cost of diets among low socioeconomic women.	Dietary assessment	Storecheck	Higher diet cost was associated with significantly lower dietary energy density, total fat and saturated fat, and with significantly higher intakes of vitamins A and C. Each additional dollar in estimated diet costs was associated with a drop in energy density of 0.94 MJ/kg (0.225 kcal/g).
37	Wang, J.; Williams, M.; Rush, E.; Crook, N.; Forouhi, N.; Simmons, D.	2010	New Zealand	Mapping the availability and accessibility of healthy food in rural and urban New Zealand? Te Wai o Rona: Diabetes Prevention Strategy.	To examine the availability and accessibility of "healthy" foods in rural and urban New Zealand.	Market basket	Storecheck	Healthy foods were more expensive than 'regular' foods after adjusting for area population and income level. The weekly family cost of a 'healthy' food basket (without sugar) was 29.1% more expensive than the 'regular' basket ($NZ 176.72 v. $NZ 136.84).
38	Waterlander, Wilma E.; de Haas, Wendy E.; van Amstel, Inge; Schuit, Albertine J.; Twisk, Jos W. R.; Visser, Marjolein; Seidell, Jacob C.; Steenhuis, Ingrid H. M.	2016	Netherlands	Energy density, energy costs and income - how are they related?	To examine the association between energy density and energy costs in single food items and composed diets, and to explore differences in energy density and energy cost between income levels.	Dietary Assessment	Storecheck	Significant inverse associations between energy density and energy costs in single food items and composed diets. Individuals stratified into higher energy density quartiles consumed significantly more energy per day and had significantly lower diet costs.
39	Ricciuto, L., Lin, K., Tarasuk, V.	2009	Canada	A comparison of the fat composition and prices of margarines between 2002 and 2006, when new Canadian labelling regulations came into effect.	To examine the effect of the new Canadian labelling regulations on the fat composition and prices of margarines.	Market basket	National price data	Margarines lower in trans-fat acids on average cost significantly more than margarines with greater amounts of these fats, and this relationship appeared stronger in 2006 relative to 2002

6.2 The cost of food consumption across socioeconomic groups in Switzerland

Table 6.3 : Summary statistics

Variables	Mean	Std. Dev.	Min.	Max.
HEI2015	47.55	10.88	12.85	91.47
Pyramid Score	2.18	1.19	0	7
Log (Exp)	2.81	0.61	-0.03	5.03
Time cost	20.84	18.00	0	152.32
Education				
Mandatory or less	0.05	0.21	0	1
Incomplete Professional education	0.08	0.28	0	1
Professional education	0.23	0.42	0	1
High-school	0.10	0.30	0	1
Superior Professional education	0.18	0.39	0	1
University & HES	0.35	0.48	0	1
Net Income				
<3000CHF	0.08	0.27	0	1
3000 to 4499CHF	0.12	0.32	0	1
4500 to 5999CHF	0.19	0.39	0	1
6000 to 8999CHF	0.30	0.46	0	1
9000 to 12999CHF	0.21	0.41	0	1
>13000CHF	0.10	0.31	0	1
Work Status				
Retirement	0.14	0.35	0	1
Full-time mom/dad	0.04	0.19	0	1
Student	0.04	0.18	0	1
Unemployed	0.02	0.14	0	1
AI or CNA/SUVA	0.01	0.09	0	1
Other situation	0.02	0.13	0	1
Labourer	0.08	0.27	0	1
Skilled worker	0.07	0.26	0	1
Farmer	0.01	0.07	0	1
Worker w/..	0.03	0.18	0	1
Qualified Worker	0.20	0.40	0	1
Middle management	0.18	0.39	0	1
Small shop owner	0.04	0.20	0	1
Senior management	0.06	0.24	0	1
Liberal professional	0.03	0.17	0	1
Director	0.04	0.20	0	1

Smoker Status				
Never-Smoked	0.42	0.49	0	1
Former Smoker	0.35	0.48	0	1
Current Smoker	0.22	0.42	0	1
Physical Activity				
Low physical activity <2.5hp/week	0.27	0.44	0	1
Moderate physical activity >2.5h p/week	0.00	0.05	0	1
High physical activity >1.25h p/week	0.01	0.10	0	1
Perceived Health Status				
Very bad	0.00	0.05	0	1
Bad	0.01	0.10	0	1
Medium	0.11	0.31	0	1
Good	0.55	0.10	0	1
Very good	0.33	0.47	0	1
Language Region				
D-CH (AG, BE, BS-BL, LU, SG, ZH)	0.05	0.23	0	1
F-CH (GE, VD, NE-JU)	0.25	0.43	0	1
I-CH (TI)	0.05	0.23	0	1
Age	46.35	15.34	18.05	77
Male	0.50	0.50	0	1
Household size				
size=1	0.18	0.38	0	1
size=2	0.33	0.47	0	1
size=3	0.32	0.47	0	1
size=4	0.04	0.20	0	1
size=5	0.07	0.25	0	1
size>=6	0.06	0.24	0	1
Civil status				
Single	0.31	0.46	0	1
Married/Partnership	0.53	0.50	0	1
Divorced/Separated	0.11	0.32	0	1
Others	0.05	0.21	0	1
Nutrition Knowledge				
None	0.17	0.37	0	1
5-a-day or Food Pyramid	0.32	0.47	0	1
5-a-day and Food Pyramid	0.51	0.50	0	1
Being on a diet (Yes)	0.06	0.24	0	1
Vegetarian (Yes)	0.05	0.22	0	1
Type of Interview				
Telephone	0.50	0.50	0	1
Face-to-face	0.50	0.50	0	1

Notes:* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$. Standard Errors in parenthesis. Reference categories are chosen for highest frequency and include University and HES (Education); 6000 to 7999CHF (Net Income); and Qualified Worker (Work Status); 5-a-day and Food Pyramid (Nutrition Knowledge); non-smoker (Smoking Status); Good (Perceived Health Status); D-CH (Language Region); Household size=2; Married/Partnership (Civil Status); Face-to-Face (Type of Interview).

Table 6.4 : Validation regressions for diet quality measures

Covariates	Pyramid Score (Poisson regression)	HEI- 2015 (OLS)
Education		
Mandatory or less	-0.069	0.954
	-0.065	-1.435
Incomplete Professional education	-0.114**	-0.905
	-0.039	-0.941
Professional education	-0.097***	-0.973
	-0.027	-0.671
High-school	-0.006	1.333
	-0.036	-0.893
Superior Professional education	-0.021	0.225
	-0.029	-0.657
Net Income		
<3000CHF	-0.024	-0.398
	-0.044	-1.253
3000 to 4499CHF	-0.015	-0.624
	-0.038	-0.934
4500 to 5999CHF	-0.009	-0.380
	-0.030	-0.704
9000 to 12999CHF	0.019	0.832
	-0.028	-0.719
>13000CHF	0.038	-0.564
	-0.034	-0.856
Nutrition Knowledge		
None	-0.105**	-0.720
	-0.034	-0.900
5-a-day or Food Pyramid	-0.106***	-0.773
	-0.024	-0.586
Being on a diet (Yes)	0.082	2.443*
	-0.052	-1.061
Vegetarian (Yes)	0.347***	0.064
	-0.036	-0.900
Smoking Status		
Former smoker	-0.031	-1.500**
	-0.023	-0.581
Current smoker	-0.080**	-1.730**
	-0.027	-0.629
Body Mass Index (Measured)	-0.010***	-0.096
	-0.003	-0.065
Physical Activity		
Low physical activity <2.5hp/week	-0.016	-0.788
	-0.024	-0.608
Moderate physical activity >2.5h p/week	0.032	-0.141
	-0.030	-0.847
Perceived Health Status		
Very bad	-0.643*	1.835
	-0.266	-1.653
Bad	0.081	0.119
	-0.082	-2.186

Medium	-0.011	-0.500
	-0.033	-0.746
Very good	0.004	0.595
	-0.022	-0.574
Age at time of interview (years)	0.003***	0.043
	-0.001	-0.023
Female	0.007	-1.386*
	-0.023	-0.572
Meals eaten away from home	0	-0.111
	-0.005	-0.130
Language Region		
F-CH (GE. VD. NE-JU)	-0.080**	1.853**
	-0.024	-0.608
I-CH (TI)	0.061	3.553***
	-0.036	-0.919
Household Size		
Household size=1	0.048	0.958
	-0.037	-1.078
Household size=3	0.014	0.135
	-0.028	-0.662
Household size=4	-0.042	-2.412*
	-0.058	-1.214
Household size=5	-0.005	-1.015
	-0.044	-1.072
Household size>=6	-0.040	-1.432
	-0.052	-1.145
Civil Status		
Single	0.030	1.677
	-0.034	-0.931
Divorced/Separated	-0.009	0.983
	-0.041	-1.070
Others	-0.056	-0.784
	-0.056	-1.301
Type of Interview		
Telephone (second)	-0.368***	0.480
	-0.021	-0.369
Constant	1.091***	48.069***
	-0.105	-2.517
Pseudo R^2/R^2	0.1505	0.057
Chi^2	668.192	
N	3618	3618

Notes:* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$. Standard Errors in parenthesis. Reference categories are chosen for highest frequency and include University and HES (Education); 6000 to 7999CHF (Net Income); and Qualified Worker (Work Status); 5-a-day and Food Pyramid (Nutrition Knowledge); non-smoker (Smoking Status); Good (Perceived Health Status); D-CH (Language Region); Household size=2; Married/Partnership (Civil Status); Face-to-Face (Type of Interview).

Table 6.5 : Validation regression for the logarithm of daily expenditure

Covariates	Log(Daily Expenditure) (OLS)
Education	
Mandatory or less	-0.195**
	(0.066)
Incomplete Professional educ.	-0.109**
	(0.041)
Professional education	-0.084*
	(0.036)
High-school	-0.068
	(0.045)
Superior Professiona educ.	-0.120**
	(0.038)
Net Income	
<3000CHF	-0.100
	(0.066)
3000 to 4499CHF	0.012
	(0.044)
4500 to 5999CHF	-0.042
	(0.037)
9000 to 12999CHF	0.059
	(0.038)
>13000CHF	0.119**
	(0.045)
Nutrition Knowledge	
None	0.034
	(0.038)
5-a-day or Food Pyramid	0.027
	(0.031)
Being on a diet (Yes)	0.033
	(0.052)
Vegetarian (Yes)	-0.112
	(0.062)
Smoking Status	
Former smoker	0.058
	(0.030)
Current smoker	0.079*
	(0.032)
Physical Activity	
Low physical activity <2.5hp/week	0.029
	(0.031)
Moderate physical activity >2.5h p/week	-0.008
	(0.043)
Perceived Health Status	
Very bad	-0.576***
	(0.148)
Bad	-0.240**
	(0.077)
Medium	-0.012
	(0.042)
Very good	0.037
	(0.028)

Age at time of interview (years)	-0.002
	(0.001)
Gender	0.209***
	(0.028)
Meals eaten away from home	0.037***
	(0.007)
Language Region	
F-CH (GE. VD. NE-JU)	-0.054
	(0.031)
I-CH (TI)	-0.045
Household Size	
	(0.039)
Household size=1	0.034
	(0.053)
Household size=3	-0.074*
	(0.033)
Household size=4	-0.103
	(0.065)
Household size=5	-0.148*
	(0.062)
Household size>=6	-0.135
	(0.072)
Civil Status	
Single	0.018
	(0.043)
Divorced/Separated	0.019
	(0.055)
Others	-0.101
	(0.076)
Type of Interview	
Telephone (second)	-0.060**
	(0.021)
Constant	2.816***
	(0.095)
R-Squared	0.121
N	3682

Notes: * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$. Standard Errors in parenthesis. Reference categories are chosen for highest frequency and include University and HES for Education; 6000 to 7999CHF for Net Income; and Qualified Worker for Work Status; 5-a-day and Food Pyramid for Nutrition Knowledge; non-smoker for Smoking Status; Good for Perceived Health Status; D-CH for Language Region; Household size=2 for Household size; Married/Partnership for Civil Status; Face-to-Face for Type of Interview.

Figure 6.2 : Pyramid Score coefficients plot by food preferences proxies

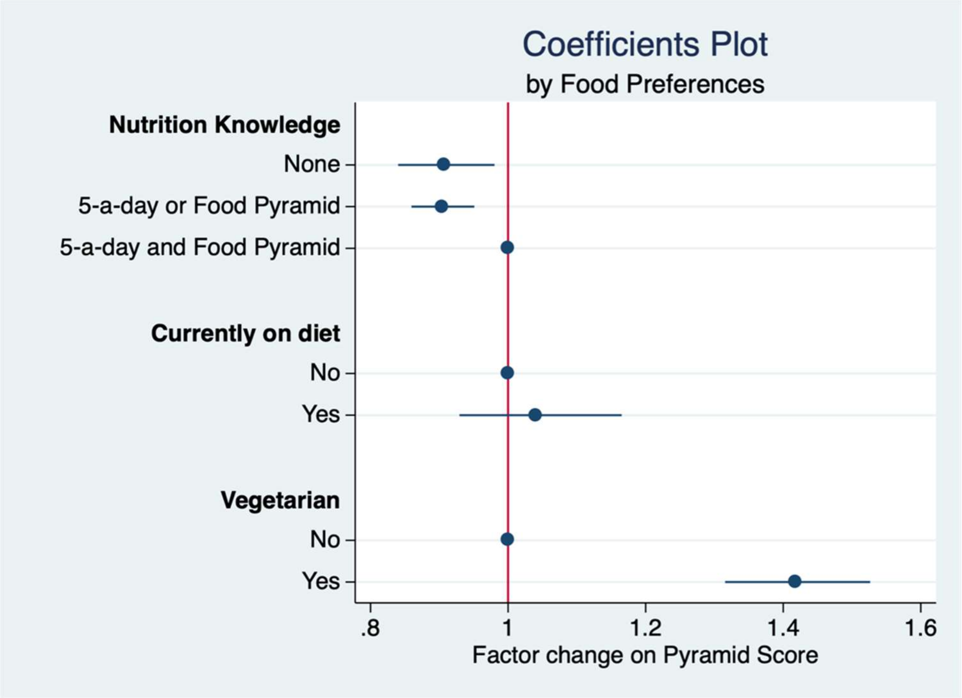


Figure 6.3 : Healthy Eating Index coefficients plot by food preferences proxies

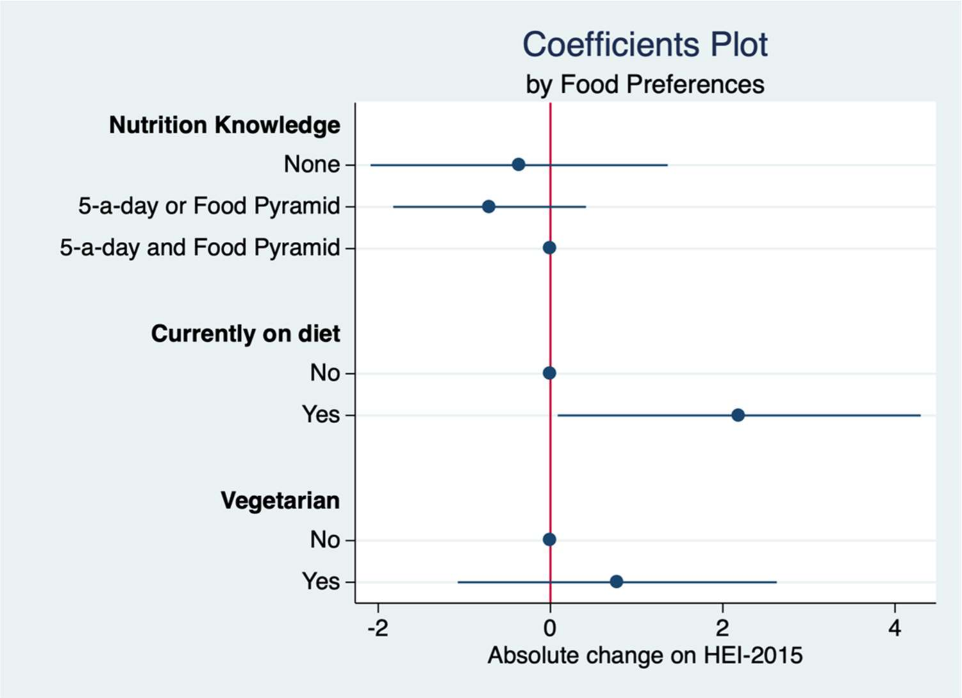


Figure 6.4 : Pyramid Score coefficients plot of healthy behaviors proxies

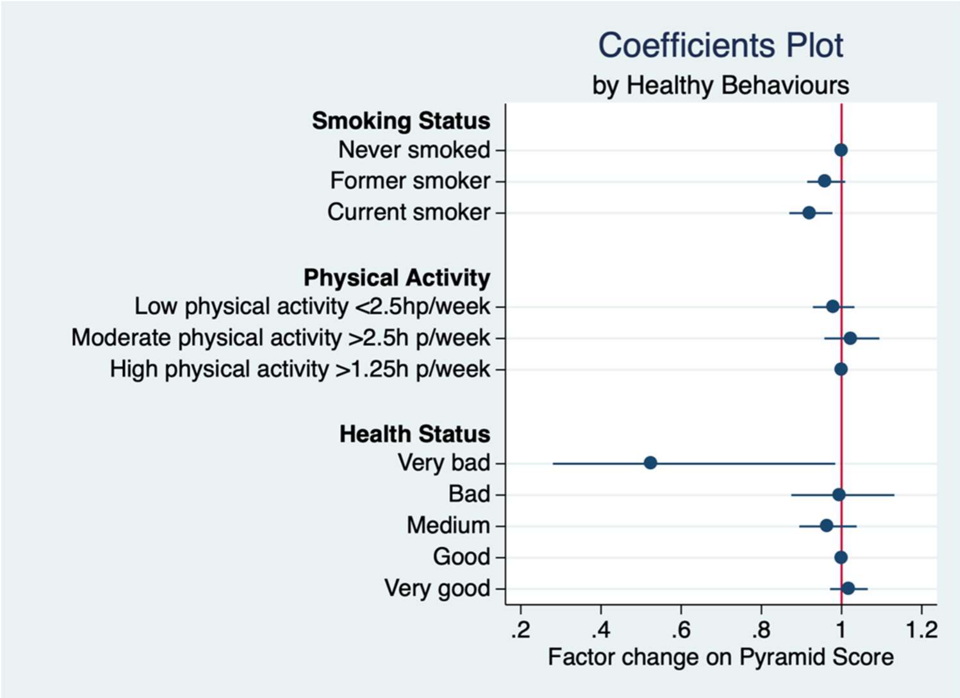


Figure 6.5 : Healthy Eating Index coefficients plot of healthy behaviors proxies

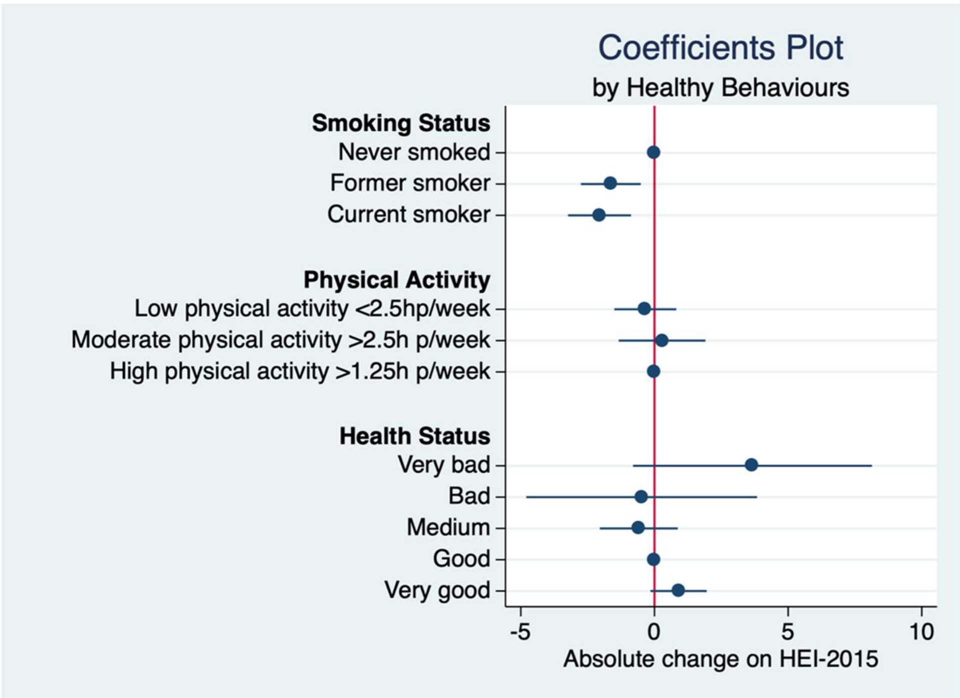


Figure 6.6 : Pyramid Score coefficients plot of demographics

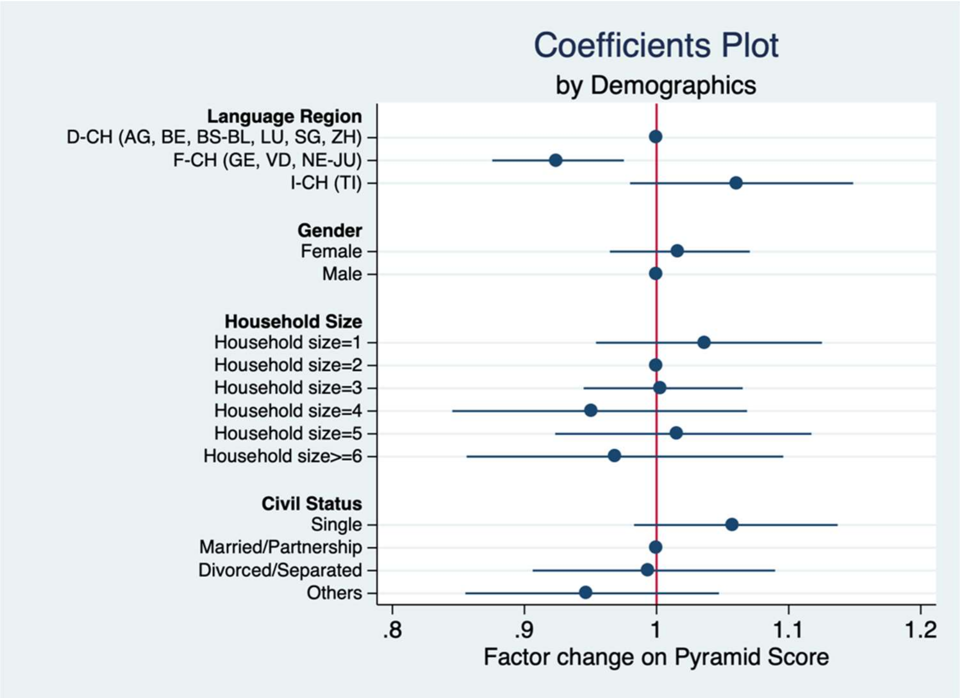


Figure 6.7 : Healthy Eating Index coefficients plot by demographics

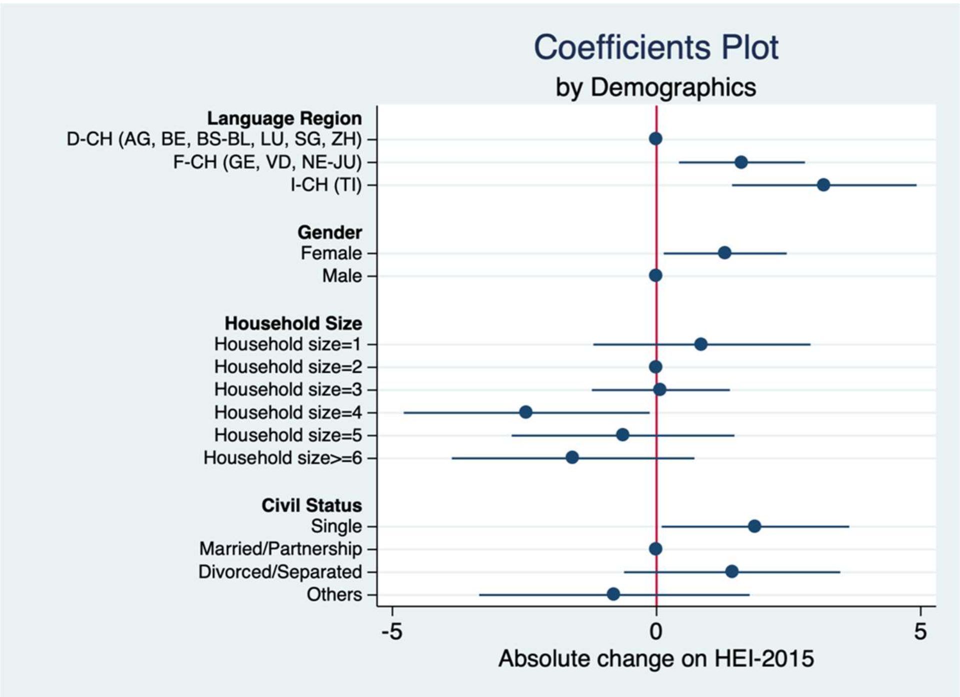


Figure 6.8 : Healthy Eating Index components and scoring standards

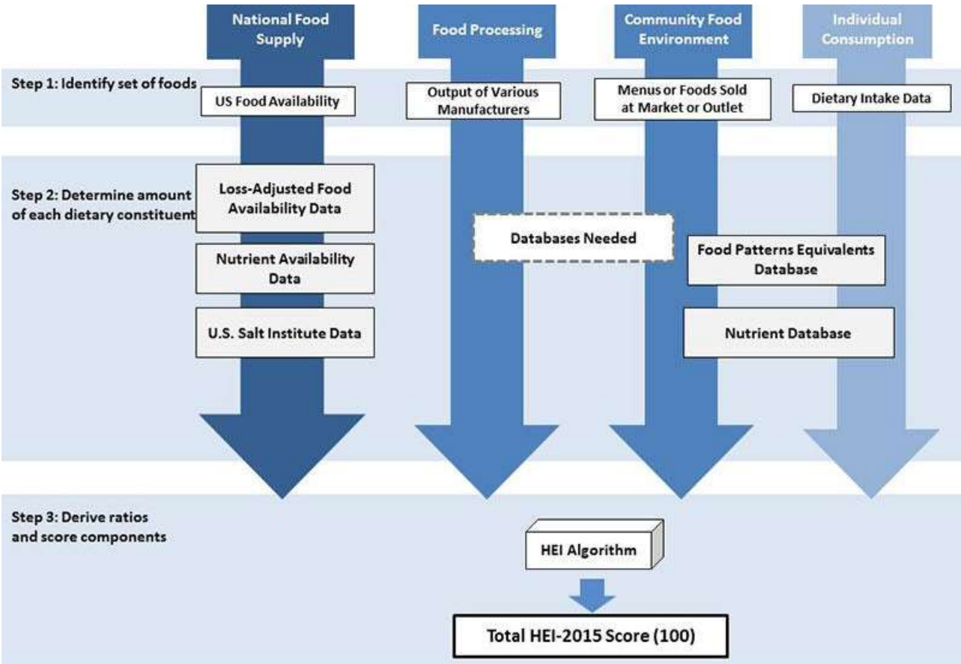
HEI-2015[1] Components and Scoring Standards

Component	Maximum points	Standard for maximum score	Standard for minimum score of zero
Adequacy:			
Total Fruits[2]	5	≥0.8 cup equivalent per 1,000 kcal	No Fruit
Whole Fruits[3]	5	≥0.4 cup equivalent per 1,000 kcal	No Whole Fruit
Total Vegetables[4]	5	≥1.1 cup equivalent per 1,000 kcal	No Vegetables
Greens and Beans[4]	5	≥0.2 cup equivalent per 1,000 kcal	No Dark-Green Vegetables or Legumes
Whole Grains	10	≥1.5 ounce equivalent per 1,000 kcal	No Whole Grains
Dairy[5]	10	≥1.3 cup equivalent per 1,000 kcal	No Dairy
Total Protein Foods[4]	5	≥2.5 ounce equivalent per 1,000 kcal	No Protein Foods
Seafood and Plant Proteins[4,6]	5	≥0.8 ounce equivalent per 1,000 kcal	No Seafood or Plant Proteins
Fatty Acids[7]	10	(PUFAs + MUFAs) / SFAs ≥2.5	(PUFAs + MUFAs)/SFAs ≤1.2
Moderation:			
Refined Grains	10	≤1.8 ounce equivalent per 1,000 kcal	≥4.3 ounce equivalent per 1,000 kcal
Sodium	10	≤1.1 grams per 1,000 kcal	≥2.0 grams per 1,000 kcal
Added Sugars	10	≤6.5% of energy	≥26% of energy
Saturated Fats	10	≤8% of energy	≥16% of energy

[1] Intakes between the minimum and maximum standards are scored proportionately.
[2] Includes 100% fruit juice.
[3] Includes all forms except juice.
[4] Includes legumes (beans and peas).
[5] Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages.
[6] Includes seafood; nuts, seeds, soy products (other than beverages), and legumes (beans and peas).
[7] Ratio of poly- and mono-unsaturated fatty acids (PUFAs and MUFAs) to saturated fatty acids (SFAs).

Source: Food and Nutrition Service, U.S. Department of Agriculture. Available on: https://fns-prod.azureedge.net/sites/default/files/healthy_eating_index/HEI-2015%20Components%20and%20Scoring%20Standards_2.pdf.

Figure 6.9 : Healthy Eating Index calculation diagram



Source: Food and Nutrition Service, U.S. Department of Agriculture. Available on: https://fns-prod.azureedge.net/sites/default/files/healthy_eating_index/HEI2015%20Components-%20and%20Scoring%20Standards_2.pdf.

6.3 Diet quality and food prices: Evidence from an exchange rate shock

6.3.1 Modelling with a two-part model

Table 6.6: Two-part model vs basic model

Dependent variables	Two-Part model	Basic Estimates
Fruits (g)	3.447	2.657
	(26.725)	(26.364)
Sugary beverages (g)	48.235	46.502
	(43.996)	(42.932)
Legumes (g)	-4.478	-4.813
	(3.037)	(3.780)
Nuts and seeds (g)	-0.798	-0.777
	(1.667)	(1.533)
Vegetables (g)	-30.688*	-30.508*
	(16.946)	(16.874)
Processed meat (g)	-7.528	-7.742
	(7.057)	(7.150)
Milk (g)	26.179	25.749
	(20.642)	(19.934)
Red meat (g)	11.311	10.923
	(7.887)	(7.433)

Note: Clustered standard errors in parentheses (*** $p<0.01$, ** $p<0.05$, * $p<0.1$). The two-part model is composed of a logistic regression in the first part and an OLS in the second part.

6.3.2 Consumption during the shock

Figure 6.10: Expenditures, quality, energy across time

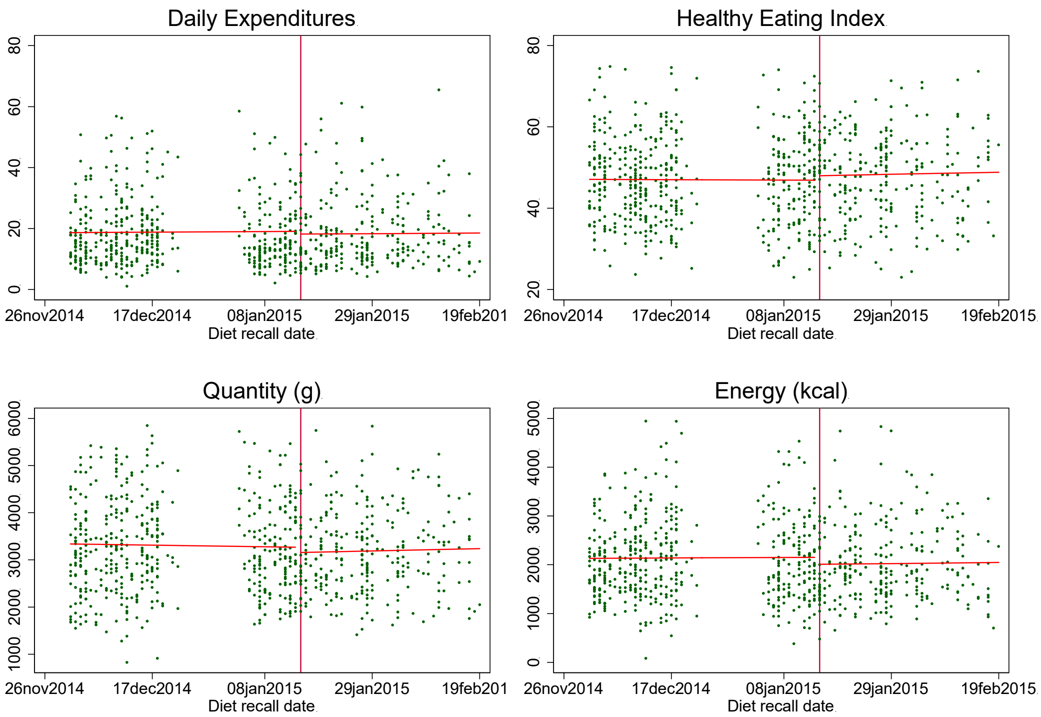


Figure 6.11 : Macronutrients across time

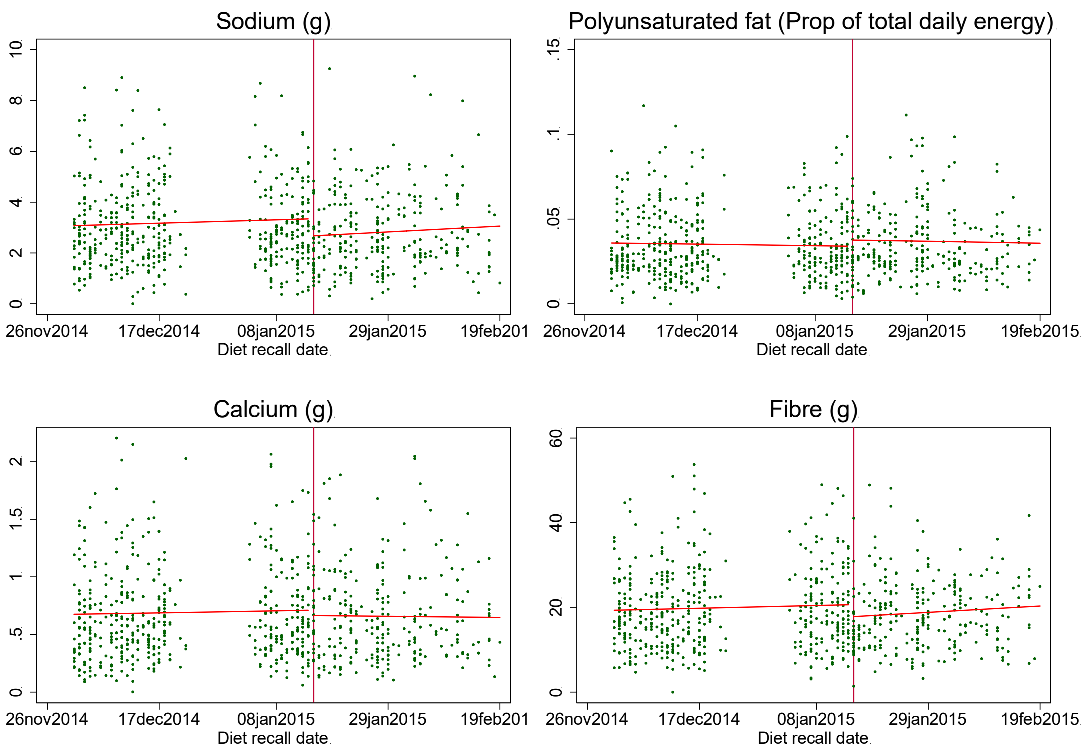
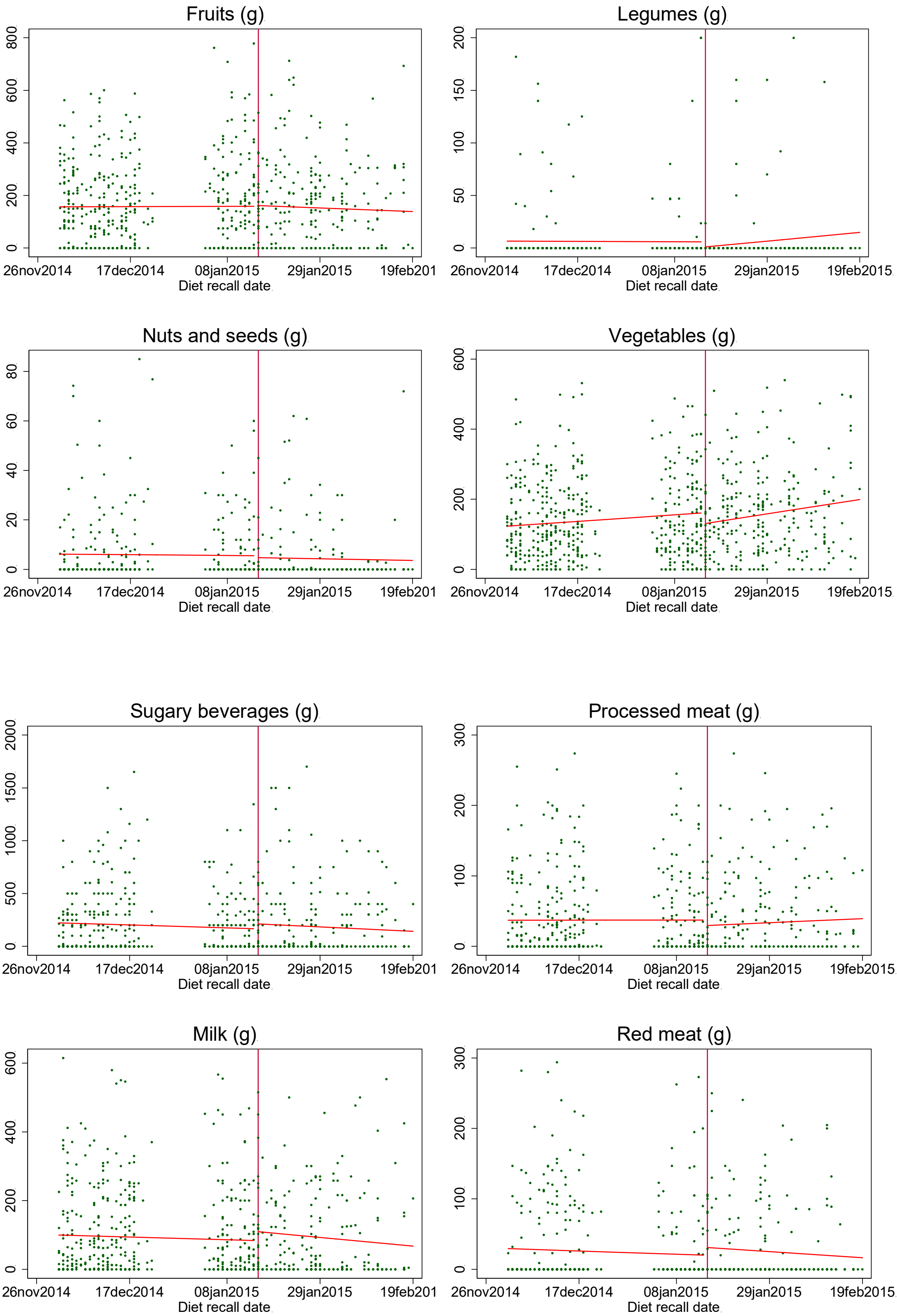


Figure 6.12: Food item level consumption across time



6.3.3 Source of sodium and fibre intake

Figure 6.13: Difference in sodium intake before and after the exchange rate shock by type of food items

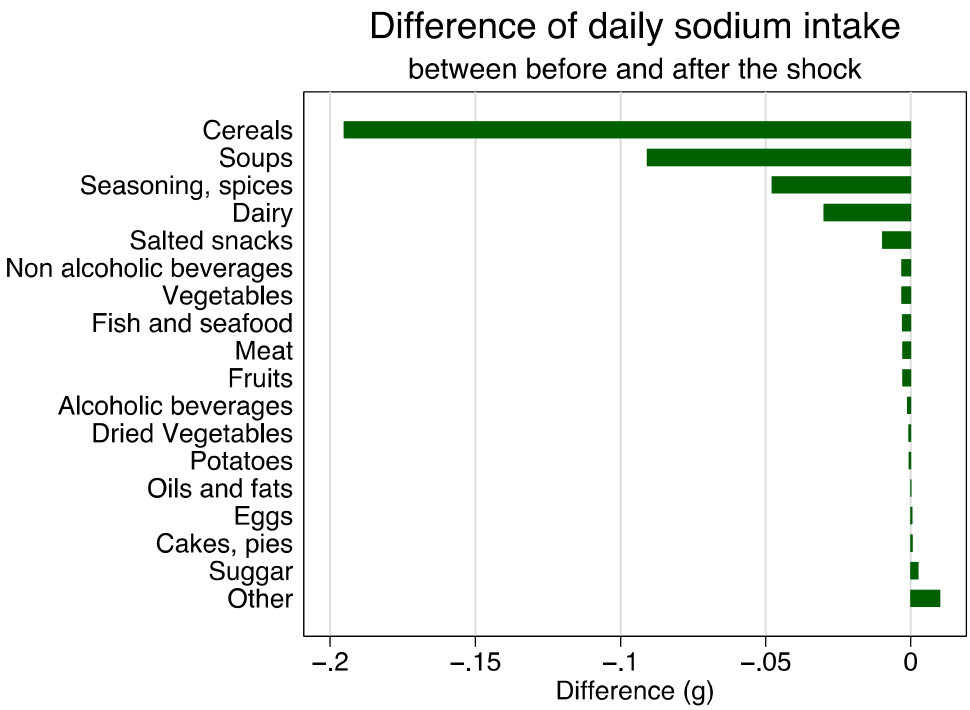
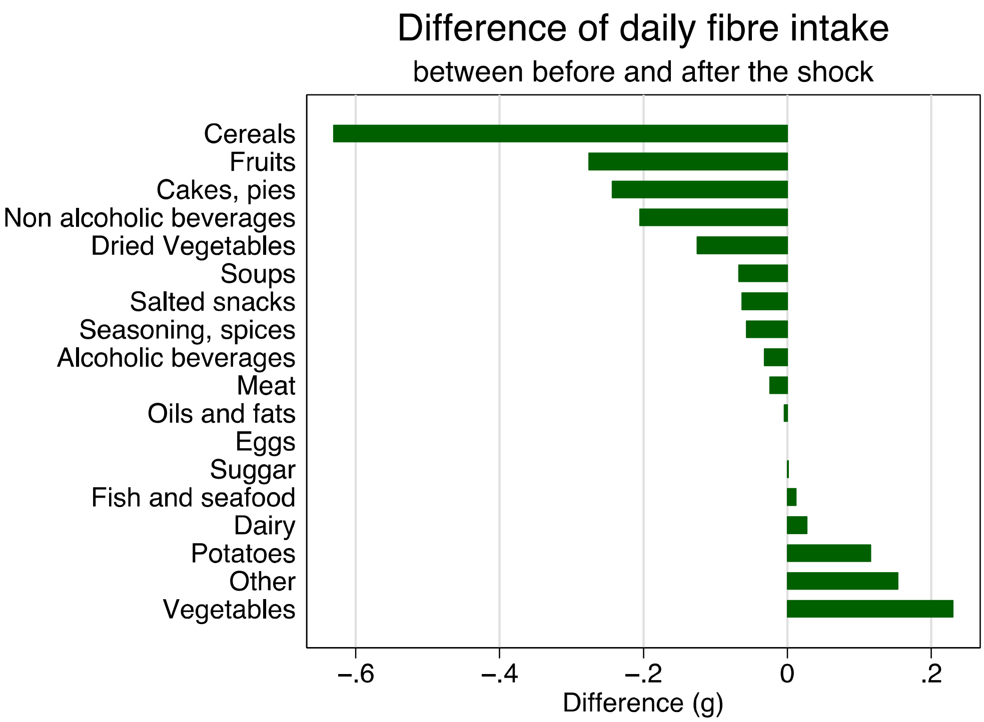
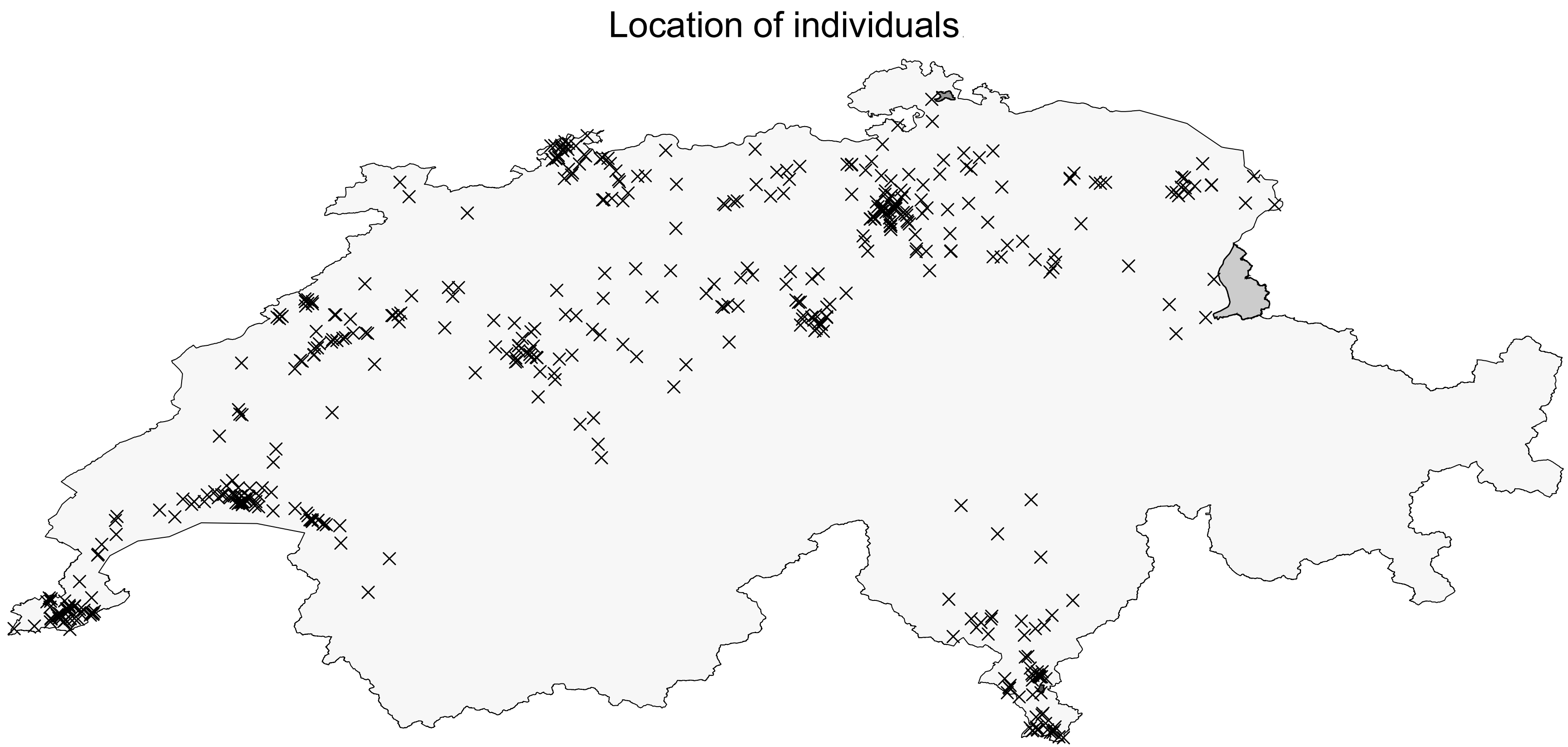


Figure 6.14: Difference in fibre intake before and after the exchange rate shock by type of food items



6.3.4 Location of the individuals

Figure 6.15: Location of each individual



6.3.5 Slopes of the dependent variables around the shock

Table 6.7: Slopes on both sides of the exchange rate lower bound removal

Dependent variables	Pre-shock	Post-shock	Difference
Daily Expenditures (CHF)	0.009	0.011	0.001
	(0.037)	(0.069)	(0.078)
Healthy Eating Index (0-100)	-0.005	0.023	0.028
	(0.031)	(0.065)	(0.071)
Quantity (g)	-1.501	2.386	3.887
	(2.716)	(5.373)	(5.554)
Energy (kcal)	0.519	1.142	0.624
	(2.303)	(4.582)	(4.801)
Sodium (g)	0.006	0.011	0.005
	(0.006)	(0.009)	(0.010)
Polyunsaturated fat (Prop of total daily energy)	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Calcium (g)	0.001	-0.000	-0.001
	(0.001)	(0.002)	(0.003)
Fibre (g)	0.030	0.071	0.041
	(0.027)	(0.050)	(0.054)
Fruits (g)	0.044	-0.646	-0.689
	(0.488)	(1.287)	(1.304)
Sugary beverages (g)	-1.260	-1.998	-0.739
	(0.779)	(1.774)	(1.845)
Legumes (g)	-0.014	0.394	0.408
	(0.103)	(0.256)	(0.277)
Nuts and seeds (g)	-0.014	-0.033	-0.019
	(0.042)	(0.072)	(0.078)
Vegetables (g)	0.842**	1.958**	1.115
	(0.367)	(0.925)	(0.987)
Processed meat (g)	0.004	0.277	0.274
	(0.175)	(0.317)	(0.346)
Milk (g)	-0.355	-1.196	-0.841
	(0.342)	(0.929)	(0.952)
Red meat (g)	-0.212	-0.410	-0.198
	(0.161)	(0.325)	(0.358)

Note: Clustered standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

6.3.6 Placebo tests

Table 6.8: Placebo tests on different dates

Dependent variables	Day of the placebo shock				
	15th may	15th June	15th July	15th August	15th September
Daily Expenditures (CHF)	-2.395*	1.423	2.562	0.619	1.356
	(1.406)	(1.428)	(1.691)	(1.400)	(1.650)
Healthy Eating Index (0-100)	-0.659	-2.248	-0.001	0.255	-0.162
	(1.222)	(1.392)	(1.432)	(1.355)	(1.299)
Quantity (g)	158.223	-220.462	184.521	-45.018	-48.145
	(116.005)	(144.562)	(150.507)	(117.583)	(132.457)
Energy (kcal)	-8.202	-10.544	80.830	82.600	-56.016
	(93.392)	(96.690)	(109.398)	(104.884)	(110.992)
Sodium (g)	-0.077	0.022	0.132	-0.106	-0.109
	(0.182)	(0.210)	(0.202)	(0.193)	(0.206)
Polyunsaturated fat (Prop of total daily energy)	0.002	-0.003	0.005	-0.001	-0.000
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Calcium (g)	-0.025	-0.018	0.073	0.040	0.005
	(0.050)	(0.056)	(0.057)	(0.062)	(0.054)
Fibre (g)	-0.174	-0.014	0.552	1.066	-1.424
	(1.058)	(1.228)	(1.344)	(1.112)	(1.246)
Fruits (g)	15.728	3.193	0.549	10.343	17.171
	(18.696)	(26.317)	(27.355)	(27.966)	(25.168)
Sugary beverages (g)	5.021	-20.209	-10.789	-10.212	43.274
	(42.225)	(49.356)	(73.596)	(51.748)	(50.115)
Legumes (g)	-10.603***	2.304	-1.070	-0.953	-0.383
	(3.862)	(2.729)	(2.487)	(2.489)	(4.530)
Nuts and seeds (g)	-2.728**	1.202	1.443	-1.536	-1.610
	(1.309)	(1.380)	(2.326)	(2.031)	(1.897)
Vegetables (g)	-6.080	-13.760	23.934	16.306	-53.318**
	(17.374)	(20.724)	(22.635)	(18.769)	(22.850)
Processed meat (g)	-1.862	7.114	-6.682	6.989	-12.965
	(7.143)	(7.627)	(7.014)	(7.225)	(8.077)
Milk (g)	9.711	-12.084	4.440	-8.385	-7.321
	(17.596)	(18.320)	(21.582)	(18.373)	(21.054)
Red meat (g)	-6.467	4.810	8.145	8.781	-0.956
	(8.186)	(10.398)	(8.477)	(7.134)	(8.097)

Note: Clustered standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

6.3.7 Drop in the Swiss retailers' price

Table 6.9: Swiss prices' drop

	Cereals	Meat	Fish and seafood	Milk, cheese, eggs	Oils and fats	Fruits and vegetables	Sugar sweet products	Other food	Coffee and tee	Non-alcoholic drinks	Spirits	Wine	Beer
January	0.0180	0.512*	-0.0947	0.0129	-1.500***	-0.118	-1.759*	3.399	-4.556	-0.197*	-1.530**	-0.998***	-0.146**
	(0.469)	(0.261)	(0.934)	(0.181)	(0.404)	(0.130)	(0.818)	(4.608)	(3.022)	(0.0923)	(0.553)	(0.168)	(0.0570)
February or March	0.287	0.915*	1.929	0.353	-1.717***	-0.114	-2.014*	3.868	-4.986*	-0.0350	-3.172**	-1.671**	-0.270***
	(0.710)	(0.533)	(2.569)	(0.278)	(0.464)	(0.376)	(1.107)	(4.285)	(2.499)	(0.126)	(1.196)	(0.758)	(0.0546)
Observations	11,392	12,616	2,377	9,564	1,318	16,258	2,865	4,495	1,866	2,537	2,485	5,279	1,282
R-squared	0.000	0.000	0.000	0.000	0.005	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.002
Mean price	18.66	42.19	46.82	15.33	16.38	9.524	23.49	58.57	54.36	3.335	43	24.28	4.952
Change in February (%)	1.538	2.170	4.120	2.305	-10.48	-1.194	-8.576	6.604	-9.172	-1.050	-7.377	-6.883	-5.458

Note : Clustered standard errors in parentheses (*** $p<0.01$, ** $p<0.05$, * $p<0.1$). February or March shows the drop between end of December and early February. Mean price calculates the mean in November and December. The change in February correspond to the point estimate divided by the mean price.

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