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The Welfare Effects of Health-based Food Tax Policy*

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Abstract: This paper examines the effects of health-oriented food tax reforms on the distribution of tax payments, food demand and health outcomes. Unlike earlier work, we also take into account the uncertainty related to both demand estimation and health estimates and report the confidence intervals for the overall health effects instead of only point estimates. A sugar tax of 1 ú / kg reduces the incidence of type 2 diabetes on average by 13% and it also leads to a reduction in coronary heart disease. The health effects appear to be most pronounced for low-income individuals, and the reforms may therefore reduce health inequality. This effect undermines the traditional regressivity argument against the heavy taxation of unhealthy food.

Key words: Sin taxes, food taxation, tax incidence, commodity demand, obesity, diabetes, coronary heart disease, bootstrapping.

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1. Introduction

Obesity is one of the most severe threats to public health in developed countries.[1] Since obesity is a major determinant of a number of illnesses, including coronary heart disease and, especially, type 2 diabetes, governments have become increasingly interested in the possibility of using tax policy to guide consumersô dietary choices.[2]

The traditional view in economics has been that taxation can have a corrective role only if consumption causes negative externalities. However, recent literature on behavioural economics has shown that consumers sometimes make sub-optimal decisions even from the point of view of their own welfare. In particular, consumers often behave myopically, and therefore consume too much of goods with delayed negative effects - excess consumption of unhealthy food and the resulting rise in obesity rates is an important example of this type of behaviour (see e.g. OôDonoghue and Rabin 2006). Taxation can potentially be used to counteract this tendency to over-consumption, and can, therefore, have corrective effects even in the absence of externalities.[3]

The use of tax policy tools in influencing diet choices has attracted a large amount of recent research. One part of the earlier empirical literature on health-based differentiation in food taxation has concentrated on estimating the impact of price changes on the demand for certain food categories such as soft drinks (Fletcher et al 2010), different types of butter and margarine (Griffith et al. 2010) or grain products (Nordström and Thunström 2009, 2011), often without a full-scale assessment of the potential health impacts. Another strand of earlier work has examined broader models of commodity demand (see e.g. Irz 2010, Allais et al. 2010), again without a full analysis of the health issue. Finally, some papers concentrate on detailed analysis of the health effects, but this literature typically uses existing estimates on commodity demand or just assumed cross-price elasticities (Mytton et al 2007; Nnoaham et al 2009). One exception is the paper by Tiffin and Arnoult (2011) that offers both a full commodity demand analysis and also examines the health effects of a fat tax. To the best of our knowledge, all earlier work has concentrated on

[1] See Brunello et al (2009) for a recent survey on this issue.
[2] Various types of health-motivated food taxes have been discussed, to name a few countries, in the US, the UK, Denmark and Finland.
[3] Even if one dislikes this type of paternalism, heavier taxation of unhealthy food may be justified by externalities arising through higher public health care expenditures, as well as by protecting children from the long-term consequences of their parentsô unhealthy lifestyles (Brunello et al. 2009).

estimating the mean health impacts of potential food policy reforms without examining the statistical significance of the response. Given that both the commodity demand estimates and the association between diet changes and health outcomes involve some uncertainty, taking into account both sources of uncertainty is potentially important.

The main message in the earlier work is that these types of tax reforms can help to achieve more healthy eating patterns, but there is a general worry that food tax reforms that involve price increases on unhealthy types of food and subsidies for healthier food items would be heavily regressive (Allais et al 2010). However, if low-income individuals have more elastic demand and/or higher levels of consumption of unhealthy food to start with, the beneficial health effects of the high taxation of unhealthy food would also be greatest for them. The regressivity argument against the heavy taxation of (unhealthy) food may therefore be overturned when not only the monetary cost but also the beneficial health effects of taxation are taken into account (Kotakorpi 2008). While Tiffin and Arnoult (2011) do not examine the issue in detail, they also point out that a possible widening of inequality in the income dimension may thus be counteracted by narrower inequality in the health dimension.[4]

This paper provides a comprehensive analysis of health-based tax policy, including both an estimation of a complete food demand system and a simulation of the health consequences of changes in the consumption of different kinds of food. The paper is based on cross-disciplinary research by economists and nutrition specialists. We use household-level budget share data from the Finnish Household Budget surveys (1995, 1998, 2001 and 2006) to estimate demand elasticities for different categories of food, using a quadratic extension of the Almost Ideal Demand System (QAIDS) drawing on Banks et al. (1997).[5] Secondly, we use these elasticity estimates to assess the effects of health-oriented tax reforms (excise taxes on sugar and lower VAT rates for fresh fruit and vegetables) on the demand of different food categories. Thirdly, we combine detailed data on the nutrient content of different foods and the Health 2000 Survey (Aromaa and Koskinen, 2004, Männistö et al. 2008), which represents the food intake in the Finnish population, to calculate the corresponding changes in the intake of nutrients and energy. Fourthly, the implied changes in the incidence of obesity and overweight and the most important

[4] See Gruber and Köszegi (2004) for an analysis of the incidence of sin taxes in the context of cigarette taxation.
[5] Irz (2010) also examines food demand using Finnish data. His main point is methodological: he uses macro-level data and explicitly models the link between composite demand and physical quantities, which leads to a novel way to estimate nutrient elasticities. He also simulates the effects of tax changes, and we discuss below some of the differences in our results to his findings.

overweight-related diseases (coronary heart disease and type 2 diabetes) are then calculated using the results of meta-analyses reported in the literature.

This study contributes to the literature in four main ways. First, ours is one of the few studies that offer both commodity demand estimation results and a broad analysis of health impacts.[6] Second, our main interest is in the tax on sugar, the impacts of which have received less attention in the earlier work than fat taxes have. Third, a key element that distinguishes our paper from the earlier literature is that we fully account for the sources of uncertainty in the four steps of the analysis described in the previous paragraph, so that we are able to obtain standard errors and confidence intervals for the overall health effects of the tax reforms that we consider. And fourth, we pay particular attention to the way in which the effects of food taxation are distributed between population groups by examining both the monetary incidence of taxation and potentially heterogeneous responses to tax policy, leading to heterogeneity in health outcomes.

The main results are the following. The commodity demand system estimates indicate that sweets and other sugary products are price-elastic (with an uncompensated price elasticity of 2-2.5, depending on specification). Negative and statistically significant own-price elasticities are obtained irrespective of the estimation method (3SLS, SUR or one-equation IV) and it thus appears to be a robust finding. The price-elasticities for fish and fruit and vegetables are -1 and -0.5, respectively; while some of the food categories (such as meat) do not have a statistically significant own-price elasticity, and most of the cross-price elasticities remain insignificant. The estimation results are then used to simulate commodity demand changes associated with a sugar tax and reduced VAT rates on fresh fish, fruit and vegetables. For example, an excise tax on the sugar content of foods leading to a 10 per cent increase in the consumer price of sugary products and the resulting reduction in the consumption of these products could lead to a 3 kg reduction in the average body weight of the adult population. According to recent meta-analyses, weight has a marked impact on the relative risk of type 2 diabetes: the relative risk is seven times higher for an obese person in comparison to someone with normal weight. Therefore, even a small change in the average weight and the weight distribution can lead to a significant reduction in the incidence of diabetes. According to our results, the sugar tax could help prevent approximately 13 per cent of the new cases of type 2 diabetes. This is a large effect in comparison to the potential impacts of smaller-scale prevention programmes, such as individual health counselling. Since the relative

[6] The paper also discusses the possible cost savings for the public health system from tax policy changes.

risk of coronary heart disease increases less rapidly with BMI, the impacts of the sugar tax on coronary heart disease are smaller but still sizable (a reduction of 3 per cent in the number of new cases).

Lowering the VAT rate on fresh fish, fruit and vegetables would lead to an increase in the intake of these foods, which would have the direct beneficial effect of reducing the incidence of coronary heart disease due to the healthy nutrients that these foods contain. According to our results, a zero VAT rate on fish, fruit and vegetables would reduce the risk of cardiovascular mortality by approximately 4% and the risk of CHD by slightly below 1%. This type of reform might also have indirect effects through changes in energy intake, but we find these effects to be insignificant.

When we turn to the results concerning the question of how the effects of health-based food tax differentiation vary between population groups, the direct monetary incidence of the reforms that we have considered appears to be mildly regressive. However, our estimation results suggest that the price elasticities for sugary products as well as for fish are higher among individuals with a low socioeconomic status. We also find some evidence that the overall health effects, which take into account differences in elasticities as well as original consumption patterns, are also highest for them. Since it is well-known that overweight and the associated diseases are more prevalent among these groups, health-based food taxation can be an effective instrument for reducing health inequality. Interestingly, we also find that benefits from the sugar tax are more pronounced for women than for men. This finding has some significance, since earlier studies have shown that the adverse impact of both type 2 diabetes and coronary heart disease may be greater for women (Forssas et al 2010).

The paper proceeds by first discussing, in Section 2, commodity demand estimation methods and the corresponding results. Section 3 introduces the tax reforms that we consider. Section 4 describes the methods for assessing the health impacts and their confidence intervals. Section 5 concludes.

2. Demand system estimation

2.1 Data and descriptive analysis

To estimate the food demand system, we use repeated cross sections of the Household Budget Survey of Statistics Finland from four years (1995-6, 1998, 2001, 2006). Consumption expenditure is classified according to the national COICO-HBS classification (around 900 headings) that has 12 main categories of consumption; we concentrate on food expenditure (category 1). The sample size varies somewhat from year to year. The number of households in our final estimations is around 17,000.

The consumption data are combined with independent price information from consumer price index data, collected by Statistics Finland. The list of available prices closely matches the food categories in the Household Budget Survey data set. The prices are measured monthly, and as we have information on the date of the budget survey for the households in the data, we can match households with month-specific price data. The price variation used to estimate commodity demand stems therefore from cross-sectional and yearly changes in the relative prices of various types of foodstuff.

We first present some descriptive statistics of food demand. Table 2.1 below shows how consumption of some food categories depends on the educational background of the household. As expected, there are large differences in the eating habits so that the expenditure share of fish and fruit and vegetables are greatest in highly-educated households, whereas households with a basic educational level have a higher share of fat purchases.

There are also similar demographic differences in food consumption with respect to the income level of the households. This can be seen from the Engel curve figures below, which depict the share of the overall food expenditure for fish, fruit and vegetables, sugar and sweets and fat. These Engel curves (Figures 2.1, 2.2, 2.3 and 2.4) are drawn for a particular type of family (two-parent households with children) ï to obtain a reliable comparison ï using non-parametric techniques (quadratic Kernel estimation). The expenditure share of fish as well as fruit and vegetables appears to increase moderately with income, and the expenditure share of fat decreases. For the expenditure share of sugar and sweets there is no monotonic pattern.

2.2 Regression analysis

We follow Deaton (1985), Blundell et al. (1993) and Banks et al. (1997) and estimate a quadratic version of the almost ideal demand system (QAIDS) for different categories of food and drinks consumption. The food categories used in the estimation are bread and cereals, meat products, fish, milk products, fats, fruit and vegetables, and sugar, sweets and sweet drinks. Together with the rest of consumption (to which we have also allocated small food items such as coffee and tea that do not contain energy), this forms a demand system of eight categories.

The system is estimated using three-stage least squares. The estimated equations are of the following type:

$$w_i^h = \alpha_i + X^h \beta_i + \sum_j \gamma_{ij} \ln p_j^h + \delta_i m^h + \phi_i (m^h)^2 + e_i^h ,$$

where w_i^h refers to the budget share of food category *i* for household *h,* which is explained by household-specific prices ($\ln p_i^h$), household real expenditure (m^h) and its square. The model also includes a set of control variables, X^h. The control variables include the following indicator variables: the socioeconomic background of the household (10 categories), the size of the household, the number of children of different ages, the area code (4 categories), the sex of persons in single-person households, the mean age of the adults in the household (5 categories) and the season of the year.

Expenditure is measured in real terms: the expenditure variable used in the estimations is $m^h = \ln M^h / n^h - \ln a(p)^h$, where *M* denotes the nominal outlays of the household, *n* refers to the number of OECD equivalent consumption units, and $\ln a(p)^h$ is a household-specific price index approximated with the Stone index, $\sum_i w_i^h \ln p_i^h$.

Using the standard procedure in demand analysis, we instrument for the endogenous overall expenditure and its square by using household income and a quadratic household income term as instruments. One of the benefits of structural consumption analysis is that one can impose the restrictions set by consumer optimisation on the estimates, and therefore we also set the following restrictions: adding-up (the sum of different types of expenditure must equal the overall expenditure), zero-degree homogeneity (multiplying all prices and total expenditure with a constant does not affect the choice set and demand) and symmetry (the cross-price elasticities of compensated demand are symmetric).

The compensated price elasticities, $\varepsilon_{i,j}$, in this model are given by $\varepsilon_{i,j} = -1 + \overline{w}_j + \gamma_{i,j} / \overline{w}_i$ if *i=j* and $\varepsilon_{i,j} = \overline{w}_j + \gamma_{i,j} / \overline{w}_i$ otherwise. Here, $\overline{w}_i$ refers to the budget share of market demand, which is a weighted average of individual budget shares, with survey weights and share of the individual demand from overall consumption of good i used as weights. The expenditure elasticity is given by $\eta_i = 1 + (\delta_i + 2\phi_i \overline{m}) / \overline{w}_i$, where $\overline{m}$ refers to weighted mean expenditure (with similar weights as above). The uncompensated price elasticities can be calculated using the Slutsky equation $\tilde{\varepsilon}_{i,j} = \varepsilon_{i,j} - \eta_i \overline{w}_j$. Since the elasticities are functions of many estimated parameters, we use both bootstrapping and the delta method to calculate the standard errors of the elasticities.[7]

2.3 Regression results

Table 2.2 presents the compensated price elasticities for the 8X8 demand system. Most of the own-price elasticities seem fairly reasonable and we will discuss them in more detail below when presenting our final specification. However, the elasticity of demand for fat is very imprecisely estimated. It is rather common for price data to include common trends and suffer from near multicollinearity. Therefore the price parameters tend to be estimated quite imprecisely in complete systems of demand equations. However, in our case the most likely reason for the imprecise estimation of the fat demand elasticity is associated with the standard practice of using expenditure data on food categories (e.g. fat) aggregated over individual food items (e.g. butter,

[7] We mainly report below bootstrapped standard errors (with 200 repetitions). The standard errors derived by the delta method are very similar but somewhat smaller.

different types of margerine) for demand estimation. That is, the consumption survey data only measures expenditure on fat, but it cannot account for the quality change within fat consumption: many consumers have moved, for example, from cheap margarine to more expensive varieties with a greater share of unsaturated fats. This can give rise to biased price estimates. A similar phenomenon can have taken place in the consumption of dairy products, where, at this aggregate level, quality improvements that are not observable for the econometrician may drive the price estimates upwards.

For these reasons, we proceed to a smaller, 6X6 demand system, where fat and dairy products are allocated to the final, ÷otherô category. The estimates of this system are presented in Table 2.3. Moving the two food categories to the omitted, ÷otherô, category does not greatly affect the elasticity estimates of the remaining categories. Hence, we decided to base the simulations analysis on this reduced modelling of food demand.

The expenditure elasticities, expressed in Table 2.4, are very reasonable. All the food items appear to be necessities, with fish products having the greatest expenditure elasticity. Finally, the uncompensated price elasticities, which will be the basis for our simulation analysis, are presented in Table 2.5. These are very close to the compensated elasticities, since the expenditure elasticities that are added to the compensated elasticities to obtain the uncompensated elasticities are multiplied with the expenditure shares (see section 2.2); and as they are measured out of overall outlays, they are small for single food categories. With the exception of meat products, all the estimated own-price elasticities are negative and statistically significant. Fish products and sugar and sweets, especially, appear to be quite price-elastic. This suggests that tax reforms targeted to affect the consumption of these items have potentially large effects on consumption patterns. Many of the cross-price elasticities are, as we expected, statistically insignificant.

While fairly large, the elasticity for sugary products is still within, for example, the confidence interval reported in US studies (see Andreyeva et al 2010). We have also examined the robustness of this price elasticity by estimating single-equation models for sugar demand (both with and without instrumenting for total expenditure), where the cross-equations restrictions are not present and cannot drive the results, and by estimating the system as a seemingly unrelated model. All these different modelling techniques yield quantitatively large and statistically significant own-price elasticities for sugary products in our model.[8]

Finally, it is of interest to examine whether the elasticities differ with respect to the householdsô socioeconomic backgrounds. To study this possibility, we estimated the system separately for three different income classes, where the division has been made on the basis of household disposable income. The estimated own-price elasticities from these models are presented in Table 2.6. They convey the plausible message that demand for many food categories appears to be more price-elastic among low-income households. This holds true, for example, for fish, but most notably for sugary products. Some of the health effects simulations below will be based on these, income-dependent, elasticities.

3. The tax reforms

As mentioned in the introduction, we analyse the following tax reforms:

- Sugar tax: a tax of one euro per kilogram of added sugar applied to each food category based on its sugar content.
- Cut in VAT: Abolition of the current VAT on fresh fruit, vegetables and fish
- Combined reform: both of the reforms above.

A one ú tax per added kilogram of sugar would raise the consumer price of the foods in the sugar and sweets category by 9.2 per cent and the price of the foods in the bread category by 1.7 per cent (since this category includes sweet pastry). This can be calculated, as we have information about both the purchases in euros and the purchased quantities for the latest consumption survey, 2006, as well as about the average nutrition content of the food categories listed in the consumption survey. The current VAT on all foodstuffs is 13%, and its abolition would lead to an 11.5% reduction in the consumer price of fruit, vegetables and fish. Here we assume for convenience that the tax changes are fully passed on to the prices.

[8] However, since our method of calculating elasticities, which is standard in the literature, is not based on actual physical quantities, quality changes may blur the estimation results, as discussed above. For example Irz (2010) obtains much smaller elasticities (around -0.5) for different types of sugary products, using a very different approach including multi-stage budgeting and macro-level data. There is therefore a need to interpret the actual point estimates cautiously.

The impact of these tax reforms on the food expenditure of households of different socioeconomic backgrounds is illustrated in Tables 3.1 and 3.2. These tables confirm the intuition that those households with a lower educational background and/or a lower income level benefit relatively less financially from tax cuts on healthy food. Thus, health-motivated food tax reforms appear to be mildly regressive if one only considers the monetary incidence (not the health benefits) of the taxes.

The impact of the tax changes on consumption demand can be calculated by multiplying the uncompensated demand matrix with a vector containing the percentage changes in consumer prices. The demand changes are reported in Table 3.3. In the health analysis below, we only take into account those demand changes that are statistically significant.

4. Calculating the health effects of the tax reforms

4.1 Methods

The health benefit calculations are based on nutrition-epidemiological meta-analyses on the linkages between the nutrition content of different foods, energy intake, weight gain, and the incidence of two overweight-related illnesses, type 2 diabetes and coronary heart disease (CHD). We consider both changes in illness incidence that stem from weight changes, as well as effects that stem from changes in nutritional intake (holding weight constant).

We utilise detailed data on the nutrient intake of Finnish individuals, derived from the Health 2000 Survey of the National Institute of Health and Welfare.[9] The survey was a representative survey of 10,000 individuals with information on different aspects of health (including their body mass index (BMI)) and detailed information on their eating habits. The data on eating habits are then combined with information on the average nutrition content of different foods, also based on data at the National Institute for Health and Welfare (Food Composition Database Fineli[R], www.fineli.fi).

[9] For more information on this survey, see http://www.terveys2000.fi/indexe.html.

In more detail, the procedure that we use to calculate the health effects is the following. First, the individual level data from the Health 2000 survey is used to evaluate the corresponding change in energy intake due to changes in food consumption. The food frequency questionnaires and the corresponding average portion sizes yield information on food intake as grams per day. We then calculate the changes in food intake at the individual level, using the relative demand changes reported in Table 3.3, and on energy intake, using the average energy contents of different types of food.

Second, the new weight and the corresponding new BMI are then calculated based on the old weight and the estimated change in weight. The effect of changes in energy intake on body weight was estimated in Dall et al. (2009). During a long follow-up, a daily reduction of 20 kcal for men and 12 kcal for women was associated with a one kilogram reduction in body weight.

Third, higher body weight is associated with increased incidence of type 2 diabetes and coronary heart disease: for diabetes, the risk ratio (RR) of an obese person (BMI >30) compared with a person with normal weight is 7.2 (Abdullah et al. 2010). For coronary heart disease, the RR is 1.8 (Bogers et al 2007). As the risk ratios in the studies that we have used were reported for a categorical BMI classification with $S = 4$ categories based on the threshold values 25, 30 and 35, we calculate the old (O) and new (N) prevalence figures, p_s^O and p_s^N, of each BMI category $s = 1,...,S$ before and after a particular tax reform.

The effects of the change in the distribution of BMI are assessed using the population attributable risk (PAR) statistic. The PAR combines the individual-level hazardousness of the risk factor, given by the risk ratio, and the population-level prevalence of the risk factor. We apply a version of the PAR developed for a comparison of two different populations (Spiegelman et al. 2007, Laaksonen 2005); in our case the populations before and after the reform:

$$PAR_{2C} = \frac{\sum_{s=1}^{S} p_s^O RR_s - \sum_{s=1}^{S} p_s^N RR_s}{\sum_{s=1}^{S} p_s^O RR_s} \qquad (1)$$

The PAR_{2C} demonstrates the potential change in disease incidence, if the distribution of the risk factor was transformed from p_s^O and p_s^N, $s = 1,...,S$ and individuals moving from a high risk (high BMI) category to a low risk (low BMI) category would become similar to individuals who are already in the low risk category.

A key benefit of carrying out both demand estimation and a simulation of the health effects of tax reform in one paper is that we are able to account for the uncertainty involved in all stages of the analysis, and combine these to obtain confidence intervals for the overall health effects that we report below. There are several sources of uncertainty in the estimates. Firstly, the uncertainty involved in the demand system estimation is embodied in the standard errors of the demand changes reported in Table 3.3. Secondly, the estimated covariance matrices of the RR estimates, which are obtained from the literature, reflect another source of uncertainty. Thirdly, the estimated prevalences of the BMI distributions are based on the Health 2000 survey, which involved a complex sampling design (Laiho et al. 2008). The effects of missing data and the oversampling of people aged 80 or over were accounted for using post-stratification weights (Djerf et al. 2008). These sources of uncertainty are accounted for using the one-stage bootstrap method described by Ogden and Tarpey (2006), which can handle externally estimated parameters. The complex sampling design is also accounted for in the bootstrap algorithm (Korn and Graubard 1999). The procedure for obtaining the standard errors for the health effect estimates is described in more detail in an appendix.

We also take into account the impact of the nutritional content of food consumption on the incidence of CHD. These effects materialise even if body weight remains unchanged. On the basis of the meta analysis of Mozaffarian and Rimm (2006), the intake of fish fat is associated with a reduced risk of death due to CHD: Eating on average 29 grams of salmon or other fatty fish or 48 g of less fatty fish per day, from which one obtains 250 mg of EPA and DHA fatty acids per day, reduces the risk of coronary death by 36% compared with individuals whose intake of these fatty acids is zero mg per day. On the other hand, a daily intake of fish fats exceeding this level is not associated with any additional reduction in risk. Similar positive effects can also arise from a larger intake of fruit and vegetables. According to the meta-analysis of Dauchet et al. (2006), one additional portion (106 grams) of vegetables and fruit reduces the risk of cardiovascular mortality by 26%, and the risk of CHD by 4% (fruit and vegetable intake) and 7% (fruit intake). Again, we use these coefficients of CHD incidence together with the estimated demand changes to obtain estimates of the health effects of the tax reforms that we consider.

4.2 Results regarding a tax on sugar

We first consider the impacts of the sugar tax on body weight, the incidence of type 2 diabetes and coronary heart disease. There are large movements towards lower BMI classes as a response to the sugar tax (Table 4.1).

The average reduction in body weight is 3.2 kilograms (Table 4.2). The effects appear larger for females than males. Further, if income-dependent elasticities are used, the weight loss is higher for individuals in low-income households than for those living in households with a higher disposable income. As individuals with lower incomes respond more to changes in prices, the health benefits of a sugar tax are greatest for them. It should be noted, however, that the income-dependent elasticities are rather imprecisely estimated and the results based on these should therefore be regarded with some caution. Indeed, when income-specific elasticities are used, the reduction in body weight appears to be significant only for low-income individuals.

Since type 2 diabetes is strongly associated with weight changes, these weight reductions can lead to sizable reductions in diabetes incidence (Table 4.3). The point estimate of the reduction on incidence is 13.4%, and again, in line with the pattern on weight changes, the effects are larger for females and those with a low-income background.[10] Since the coronary heart disease risk ratios increase less rapidly with body weight, the associated reduction in coronary heart disease incidence is smaller (3.0% on average, see Table 4.4).

4.3 Results regarding other tax changes

Consider next the impacts of VAT cuts on coronary heart disease. There are potentially two conflicting effects: on the one hand, increased consumption of fish, fruit and vegetables tends to increase body weight. Since most of the cross-price elasticities in our analysis were not significant and some are close to zero in any case, according to our results people would not reduce the consumption of other types of food when they increase the consumption of fish, fruit

[10] Notice that the calculations are based on average elasticities for different sexes and educational groups. Differences across these groups, therefore, only arise from differences in eating habits. However, income-dependent elasticities are used for the breakdown of health effects according to household income. These changes reflect both different price elasticities and differences in eating habits.

and vegetables.[11] Using the same kind of procedure as in the case of the sugar tax, VAT cuts could lead to a 0.9% increase in the incidence of CHD via weight gain, but this increase is not significant (95% CI -0.8, 2.8).

On the other hand, the beneficial nutrition content of fish, fruit and vegetables helps prevent deaths resulting from CHD. In the Health 2000 survey, the average daily intake of fish was 36.7 grams. If one only takes into account those individuals whose initial intake of EPA+DHA fatty acids is less than 250 mgs per day, one finds that their intake of these nutrients would increase by 10 mgs a day. Such an increase would help to avoid 1.8% (95% CI 0.6-3.1) of coronary deaths, based on the results of Mozaffarian and Rimm (2006). The health benefits of VAT cuts also apply to fruit and vegetables: as a response to the VAT cut that we have considered, people would start to consume 0.2 additional portions of these food items, thereby reducing the risk of cardiovascular mortality by 4.4% (95% CI 2.2-6.7) and the risk of CHD by approximately 0.9% (95% CI 0.2-1.7) on the basis of the results of Dauchet et al. (2006).

To conclude, the changes in food consumption caused by the VAT cuts that we have considered appear to have direct beneficial effects for health, measured in terms of CHD incidence, early deaths and cardiovascular mortality. The indirect health effects of the reform through weight changes, on the other hand, were found to be insignificant.

Consider finally the combined reform of a sugar tax plus VAT reductions. Such a tax reform leads to decreased body weight (average change -2.34 kg with 95% confidence interval from -4.78 to -0.26) and to an associated reduction in diabetes 2 incidence of 9.7 per cent (CI 0.8, 18.7). In comparison to merely imposing a sugar tax, a combined tax reform including VAT cuts on fruit, vegetables and fish leads, therefore, to smaller reductions in the incidence of diabetes. But it also brings about the beneficial direct impacts via an increased intake of healthy nutrients in fish, fruit and vegetables, leading to reductions in mortality due to CHD.

[11] It may be the case that the aggregate reactions hide simultaneous quality changes (e.g. if fish becomes cheaper, people may respond by buying more expensive and perhaps more healthy types of meat, thereby not reducing the overall amount of money allocated to meat).

5. Conclusion

This paper examined the potential health impacts of health-based food taxation in Finland by, first, estimating a complete demand system for different types of food, then using the demand system to simulate the impacts of a tax increase on sugary products and a tax reduction on fresh fish, fruit and vegetables on food demand, and finally by assessing the effect of these demand changes on energy and nutrient intake. The results indicate that the demand for sugar and sweets appears to be very price elastic, and therefore a sugar tax of 1 ú / kg has a sizable effect on the incidence of obesity and overweight, causing, on average, an approximately 13% reduction in the incidence of type 2 diabetes and a smaller reduction in coronary heart disease. Reduced VAT rates for fresh fish, fruit and vegetables have a small positive effect on the incidence of coronary heart disease and cardiovascular mortality. Further, we find some evidence that the health effects are most pronounced for low-income individuals, and the reforms may therefore reduce health inequality.

We would like to stress that the exact magnitude of the health impacts needs to be taken cautiously, because of the substantial uncertainty the estimates involve, and because of a common caveat associated with the standard type of commodity demand analysis that we use: this type of analysis utilises data where outlays are observed but unit prices are not. The analysis thus cannot account for potential changes in the quality of food consumption, which can affect the estimates. Nevertheless, our main results concern the consumption of sweets and other sugary products, where quality changes are likely not to be very pronounced. Further, it is important to note that the health impacts of smaller sugar consumption are so substantial that even a much smaller elasticity for consumption of sugary products would still generate sizable health benefits.

These findings suggest that society could achieve significant savings in health care costs if the sugar tax was introduced. The current excess costs of treating diabetes in Finland amount to 800 million euros annually or 2,800 euros per patient with diabetes (Jarvala et al 2010); and a 13 per cent reduction in diabetes incidence could lead to cost savings of the order of 100 million euros annually. Needless to say, this figure does not involve any valuation for the changes in the loss of or quality of life if diabetes cases are prevented. Further, a tax on sugar is a prevention mechanism that affects the overall population at the same time, which makes it potentially a very powerful mechanism in comparison to individual health-counselling policies.

A major part of the motivation behind our paper lies in the behavioural justification for heavy taxation of ñsin goodsò such as unhealthy food. From the point of view of this behavioural justification, the result that the health benefits of the tax reforms that we have considered are likely to be concentrated on low-income individuals is of importance for two reasons. Firstly, the theoretical literature on behavioural economics has raised the concern that while sin taxes are beneficial for individuals who suffer from problems such as obesity, they cause distortions for individuals who do not suffer from such problems. The overall desirability of sin taxes hinges on the balance of these benefits and distortions. Our results suggest that the demand responses and the resulting health effects of the reforms that we have studied are strongest for the group which has the most severe health problems to start with. Secondly, this finding is significant from the point of view of the behavioural modification of traditional incidence analysis: even though the burden of high taxation of unhealthy food is in percentage terms heaviest for low income individuals, the health effects are likely to be most positive for them, which counteracts the traditional regressivity argument against sin taxes ï overall, taking into account not only the monetary but also the health effects of taxation, sin taxes may lead to a more equal distribution of welfare.

Appendix: The method for calculating the confidence intervals of the health effects

1. Set the number of bootstrap samples to 400.
2. For each bootstrap sample, log (RR) is generated from the multinormal distribution defined by the point estimates and standard errors obtained from the literature.
3. Relative demand changes corresponding to each particular tax reform are generated from the multinormal distribution using the point estimates (Table 3.3) and estimated covariance matrix.
4. A bootstrap sample is generated from the Health 2000 Survey data by sampling primary sampling units (PSUs), which were individuals in the 15 largest Finnish towns and health centre districts in the remaining part of continental Finland.
5. The BMI prevalence estimates for p_s^O are calculated based on the bootstrapped data and the post-stratification weights.

6. The individual weight and BMI changes are then calculated as described in the text, using the relative demand changes (step 3). The new BMI prevalence estimates p_s^N are calculated based on the new BMI values.
7. The PAR estimate is then calculated according to equation (1), using the RR, p_s^O and p_s^N, values obtained in steps 2, 5 and 6.
8. Steps 2 to 7 are then repeated 400 times, and the procedure yields 400 point estimates of PAR and average weight changes.
9. The point estimates, which we report, are the point estimates obtained using the original Health 2000 Survey data, and point estimates of RR and relative changes without bootstrapping. The 95% confidence intervals (CI) are based on the 2.5% and 97.5% quantile points of the 400 point estimates obtained using the bootstrap.

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Table 2.1: Share of certain foods from food expenditures by level of education.

Education[1]	Fish	Fruit & veg	Sugar & sweets	Butter & margarine
1 = lowest	3.7%	15.9%	8.0%	2.6%
2	4.4%	17.0%	8.0%	2.2%
3	4.8%	17.4%	7.3%	1.8%
4 = highest	5.2%	19.4%	7.5%	1.7%

[1] 1 = both spouses have basic or secondary education; 2 = at least one spouse has tertiary education; 3 = one spouse has higher education; 4 = both spouses have higher education. (Households with only one adult have been excluded.)

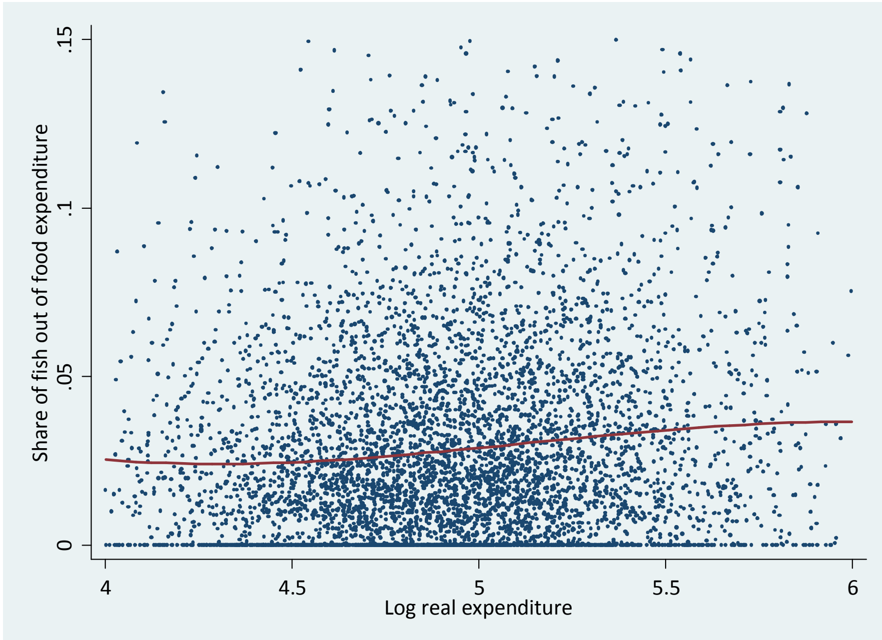

Figure 2.1 Non-parametric Engel curve for fish.

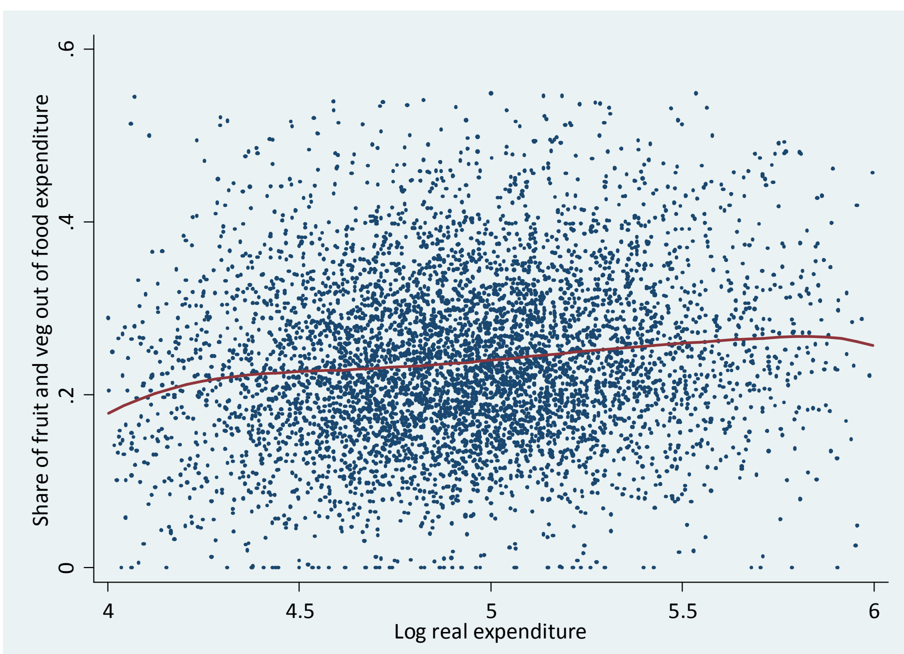

Figure 2.2: Non-parametric Engel curve for fruit and vegetables.

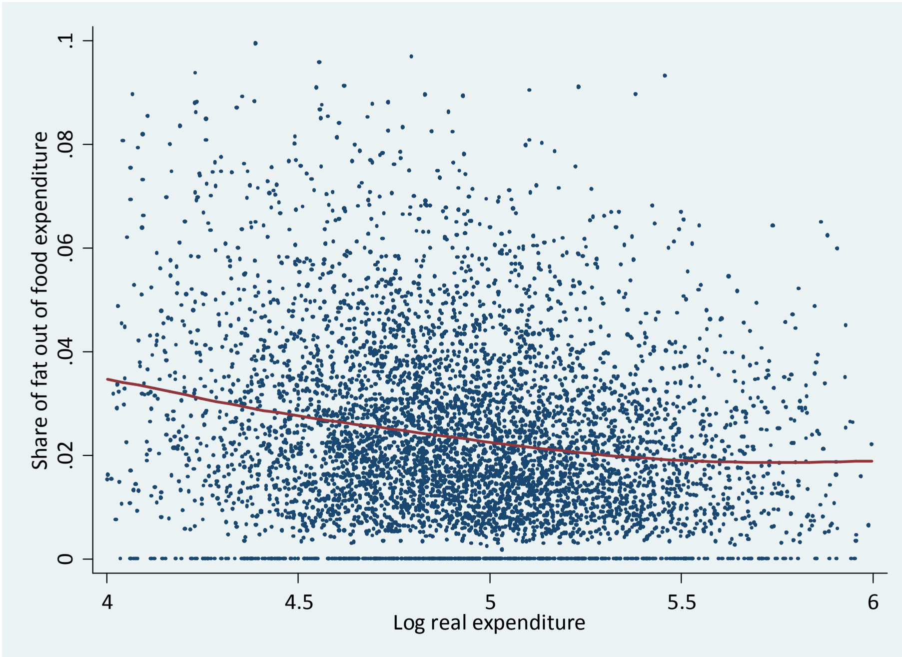

Figure 2.3 Non-parametric Engel curve for fat.

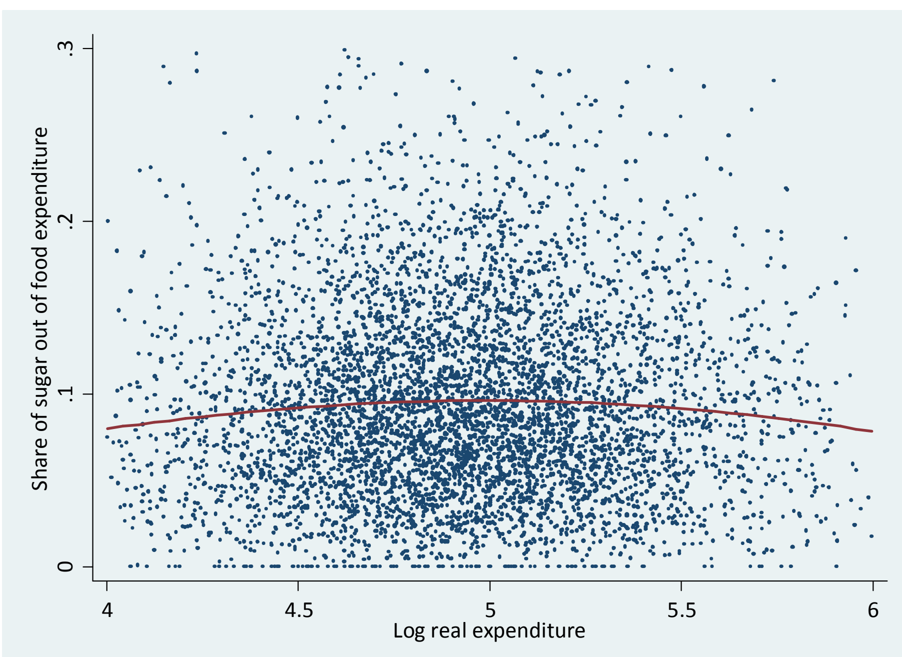

Figure 2.4: Non-parametric Engel curve for sugar and sweets.

Table 2.2: Estimated compensated price elasticities for 8 consumption categories with bootstrapped standard errors.

	Bread	Meat	Fish	Milk	Fats	Fruit & veg	Sugar & sweets	Other
Bread	-0.713	0.253	-0.079	-0.216	0.138	0.237	-0.160	0.539
Se	0.298	0.131	0.082	0.165	0.138	0.066	0.205	0.393
Meat	0.245	-0.034	-0.033	0.348	0.025	-0.275	0.223	-0.498
Se	0.127	0.125	0.491	0.091	0.036	0.067	0.097	0.288
Fish	-0.409	-0.177	-0.725	0.032	-0.850	0.009	1.042	1.079
Se	0.428	0.264	0.261	0.338	0.209	0.160	0.423	0.727
Milk	-0.248	0.414	0.007	0.297	0.051	0.001	-0.037	-0.485
Se	0.189	0.108	0.075	0.221	0.079	0.068	0.175	0.374
Fats	1.079	0.200	-1.280	0.345	2.502	-0.053	-3.081	0.286
Se	1.083	0.294	0.314	0.542	1.433	0.164	0.928	0.991
Fruit & veg	0.332	-0.398	0.002	0.001	-0.009	-0.415	-0.128	0.615
Se	0.092	0.097	0.043	0.083	0.293	0.084	0.084	0.273
Sugar & sweets	-0.307	0.442	0.385	-0.061	-0.736	-0.175	-2.169	2.641
Se	0.391	0.173	0.156	0.292	0.227	0.114	0.596	0.703
Other	0.016	-0.015	0.006	-0.013	0.001	0.013	0.042	-0.050
Se	0.118	0.009	0.004	0.010	0.004	0.006	0.011	0.029

Table 2.3: Estimated compensated price elasticities for 6 consumption categories with bootstrapped standard errors.

	Bread	Meat	Fish	Fruit & veg	Sugar & sweets	Others
Bread	-0.726	0.319	-0.133	0.237	-0.283	0.575
Se	0.277	0.119	0.083	0.074	0.198	0.319
Meat	0.309	-0.025	-0.049	-0.302	0.203	-0.135
Se	0.116	0.117	0.302	0.060	0.087	0.216
Fish	-0.695	-0.264	-0.932	0.003	0.591	1.297
Se	0.430	0.230	0.233	0.166	0.378	0.596
Fruit & veg	0.346	-0.439	0.001	-0.426	-0.119	0.637
Se	0.104	0.087	0.045	0.099	0.083	0.237
Sugar & sweets	-0.542	0.404	0.219	-0.163	-2.538	2.621
Se	0.381	0.174	0.140	0.113	0.557	0.576
Others	0.017	-0.004	0.006	0.013	0.040	-0.074
Se	0.009	0.007	0.000	0.005	0.009	0.019

Table 2.4. Estimated expenditure elasticities with bootstrapped standard errors in parentheses.

Bread	0.33765 (0.0356)
Meat	0.3884 (0.04208)
Fish	0.6879 (0.09056)
Fruit and veg	0.5831 (0.03756)
Sugar & sweets	0.32843 (0.04896)

Table 2.5: Estimated uncompensated elasticities with bootstrapped standard errors.

	Bread	Meat	Fish	Fruit & veg	Sugar & sweets	Others
Bread	-0.736	0.309	-0.136	0.240	-0.287	0.270
Se	0.277	0.119	0.083	0.074	0.199	0.328
Meat	0.297	-0.037	-0.051	-0.311	0.197	-0.484
Se	0.116	0.117	0.043	0.060	0.088	0.227
Fish	-0.713	-0.283	-0.935	-0.010	0.581	0.672
Se	0.430	0.229	0.233	0.166	0.378	0.628
Fruit and veg	0.330	-0.456	-0.002	-0.437	-0.128	0.111
Se	0.104	0.087	0.045	0.010	0.083	0.242
Sweets & sugar	-0.552	0.394	0.217	-0.170	-2.543	2.236
Se	0.382	0.174	0.140	0.113	0.557	0.576
Others	-0.0112	-0.033	0.002	-0.007	0.025	-1.035
Se	0.009	0.006	0.003	0.005	0.008	0.019

Table 2.6: Estimated uncompensated own-price elasticities for different income levels with bootstrapped standard errors in parentheses.

	Bread	Meat	Fish	Fruit & veg	Sugar & sweets	Others
Low income (N=5139)	-0.54 (0.63)	-0.26 (0.33)	-1.00 (0.53)	-0.57 (0.23)	-3.05 (1.25)	-1.06 (0.06)
Middle income (N=6142)	-0.52 (0.67)	-0.06 (0.28)	-0.91 (0.43)	-0.35 (0.28)	-2.59 (1.04)	-0.95 (0.08)
High income (N=5912)	-0.60 (0.63)	-0.72 (0.34)	-0.72 (0.46)	-0.53 (0.18)	-1.90 (1.27)	-1.04 (0.03)

Table 3.1: The impacts of tax reforms on food expenditure at different income levels without behavioural changes.

Change in food expenditure, ú				
Decile	Sugar tax	Fish VAT down	Fruit & veg VAT down	Altogether
1	25.80	-9.84	-30.48	-14.52
5	47.63	-15.78	-61.38	-29.53
10	86.64	-31.20	-117.15	-61.71
Percentage change in food expenditure				
Decile	Sugar tax	Fish VAT down	Fruit & veg VAT down	Altogether
1	1.67 %	-0.57 %	-1.74 %	-0.64 %
5	1.59 %	-0.51 %	-2.01 %	-0.93 %
10	1.44 %	-0.54 %	-2.01 %	-1.11 %

Table 3.2: The impacts of tax reforms on food expenditure at different educational levels without behavioural changes.

Change in food expenditure, ú				
Education	Sugar tax	Fish VAT down	Fruit & veg VAT down	Altogether
Low	49.73	-15.33	-60.27	-25.87
Medium	60.21	-21.48	-81.48	-42.75
High	66.40	-28.05	-90.87	-52.52
Percentage change in food expenditure				
Education	Sugar tax	Fish VAT down	Fruit & veg VAT down	Altogether
Low	1.58 %	-0.48 %	-2.01 %	-0.91 %
Medium	1.56 %	-0.57 %	-2.13 %	-1.14 %
High	1.54 %	-0.63 %	-2.10 %	-1.19 %

Table 3.3. The impact of the tax reforms on demand, relative changes with standard errors.

Sugar tax		
	Change	Std error
Bread	-0.0377*	0.0177
Meat	0.0224*	0.0086
Fish	0.0392	0.0344
Fruit and veg	-0.0057	0.0077
Sugar and sweets	-0.2331*	0.0469
VAT cut		
Bread	-0.0128	0.0130
Meat	0.0442*	0.0100
Fish	0.1155*	0.0344
Fruit and veg	0.0537*	0.0131
Sugar and sweets	-0.0057	0.0202
Both reforms		
Bread	-0.0505*	0.0229
Meat	0.0666*	0.0131
Fish	0.1547*	0.0502
Fruit and veg	0.0480*	0.0144
Sugar and sweets	-0.2389*	0.0537

* refers to statistically significant demand changes at the 5 per cent level.

Table 4.1: Change in the BMI distribution (%) as a result of the sugar tax. The column on the right-hand side depicts the distribution of BMI classes before the intervention, the bottom row after the intervention, and the other off-diagonal entries show the changes in the BMI distribution.

	BMI<25	25<BMI <30	30<BMI <35	BMI>35	Distribution in 2000
BMI<25	40.7	0	0	0	40.7
25<BMI<30	10.1	28.4	0	0	38.5
30<BMI<35	0	4.8	11.0	0	15.8
BMI>35	0	0	1.2	3.7	4.9
Distribution after intervention	50.8	33.2	12.2	3.7	100.0

Table 4.2: Change in body weight (kgs) as a result of the sugar tax. The calculations are based on average elasticities for different sexes and educational groups and on income-dependent elasticities for households at different income levels.

All	-3.19 (-4.89, -1.44)		
By sex:	-2.54 (-3.89, -1.13) (males)	-3.79 (-5.81, -1.73) (females)	
By education:	-3.02 (-4.73, -1.30) (basic education)	-3.17 (-4.87, -1.40) (secondary)	-3.44 (-5.20, -1.63) (tertiary)
By household income:	-5.41 (-8.59, -2.53) (low income)	-0.78 (-3.7, 2.11) (middle income)	-2.63 (-5.4, 0.28) (high income)

Table 4.3: Change (negative PAR_{2c} , %) in the incidence of type 2 diabetes as a result of the sugar tax. The calculations are based on average elasticities for different sexes and educational groups and on income-dependent elasticities for households at different income levels.

All	-13.4 (-6.3, -19.9)		
By sex:	-10.8 (-5.2, -15.7) (males)	-15.9 (-7.1, -23.6) (females)	
By education:	-12.5 (-5.5, -19.0) (basic education)	-13.8 (-6.7, -20.0) (secondary)	-14.4 (-7.2, -21.3) (tertiary)
By household income:	-20.8 (-10.3, -30.5) (low income)	-3.2 (9.6, -16.0) (middle income)	-11.8 (2.3, -22.6) (high income)

Table 4.4: Change (negative PAR_{2c} , %) in the incidence of coronary heart disease as a result of the sugar tax. The calculations are based on average elasticities for different sexes and educational groups and on income-dependent elasticities for households at different income levels.

All	-3 (-1.4, -4.8)		
By sex:	-2.3 (-1.1, -3.7) (males)	-3.7 (-1.6, -5.8) (females)	
By education:	-3.2 (-1.3, -5.2) (basic education)	-3.1 (-1.5, -4.7) (secondary)	-2.8 (-1.4, -4.3) (tertiary)
By household income:	-4.9 (-2.0, -7.4) (low income)	-0.7 (1.9, -3.7) (middle income)	-2.5 (0.6, -5.2) (high income)