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Socio-economic characteristics and the effect of taxation as a health policy instrument

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Abstract

This paper analyses the quantitative effects of using economic instruments in health policy on the basis of price elasticities calculated from estimated demand systems. The nutritional effects of various taxation schemes are compared for households in different age groups and social classes. Focusing on the consumption of saturated fats, fibre and sugar; it is generally found that the impact of price instruments is stronger for lower social classes than in other groups of the population. With regard to age groups, it is mostly the youngest that decrease their demand for saturated fat in response to price changes, while it is mostly the middle-aged who exhibit price responsiveness in their demand for sugar. These groups are however not considered as key target groups for dietary regulation; thus tax instruments may be effective in improving diets on average, but the design of the instruments and the targeting of vulnerable groups with special needs should be done with care. It should be noted that a tax on a single nutrient or food may have undesired effects on the demand for other food components, though this may be avoided by introducing taxes/subsidies on several food products simultaneously.

JEL classification: I12; P36; Q18

Keywords: Nutrition; Food taxes; AIDS model; Socio-demographic differences

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Introduction

Globally, there are more than 1 billion overweight adults, and at least 300 million of these are obese.[2] Furthermore, there are 17.6 million children under five who are estimated to be overweight (WHO, 2003). Although obesity should be considered a disease in its own right, it is, together with smoking, one of the key determinants for other lifestyle-related chronic diseases. Obesity is estimated to account for 2–6% of the total health care costs in several developed countries, but the true costs are undoubtedly much greater, as not all obesity-related conditions are included in the calculations (WHO, 2003). Both in countries with publicly financed health services and in countries with privately financed health services but with equally distributed rates of payment for everybody, this means that the unhealthy eating or lack of exercise of one citizen may impose economic burdens, externalities, on other citizens (tax-payers, employers, colleagues). A range of incentive-based economic instruments may be useful to adjust economic incentives in such a way that these externalities are internalised. Direct instruments such as a BMI tax or BMI-graduated health care costs (see for example Bhattachary and Sood, 2003) might be effective, but probably politically unacceptable. The present study analyses the effects of introducing taxes that change the relative prices of food (making healthy foods cheaper relative to unhealthy foods). This is a more indirect measure, as it targets overweight and future health through changes in the demand for foods.

The use of taxes and subsidies on foods as a means of improving the health of the population has been on the political agenda for a long time in several countries, including the UK and Denmark. The issue has also been a subject of theoretical interest (see for example Aronsson and Thunström, 2005, Cash et al., 2005, or Scroeter et al., 2005). The effect of income and prices on nutrient intake is not a new issue in empirical economics either. Two approaches have been taken: a "direct" approach where the demand for specific nutrients is regressed on relevant variables (see for example Subramanian and Deaton, 1996 or Chesher, 1998) and an "indirect" approach where changed nutrient intake is calculated through changes in food demand. The latter requires that in the first stage an estimation of a food demand system is made, and then in a later stage the effect of changed prices and/or income on food demand is translated into changed nutrient consumption. This approach is followed in, for example, Angulo et al. (2003), Ramezani et al. (1995), and Huang (1999). In this paper, we choose the "indirect approach". This is due to the fact that food is bought of other reasons than pure nutritional value and we therefore assume that consumers purchase decisions is between products and not between nutrients. While earlier studies show changes in *average* nutrient demand due to changed prices, this study compares changes in nutrient demand due to changed prices across age groups and social classes. This means that the analysis provides new insight into whether the social bias in diet composition will increase or decrease through the application of a tax instrument.

The rest of the paper is organised as follows sections: the trends in food consumption and obesity in Denmark; the model applied in the study and the scenarios selected; the data and estimation procedures in more detail; and the results. Last section contains a conclusion and a discussion of policy implications.

[2] BMI is calculated as: $\frac{\text{Weight in kg}}{(\text{Height in m})^2}$ Obesity is defined as having a Body Mass Index (BMI) = 30, with a BMI 25–30 people are defined as overweight.

Trends in Danish food consumption and obesity

About 10% of the Danish population were obese in 2000, a figure which is at the lower end of the scale in comparison with the figures for obesity in most other European countries (OECD, 2004). With an increase of about 6% points since the late 1980s (a doubling), Denmark is also fairly representative with regard to trends in obesity rates. Research show that the level of obesity depends on the socio-demographic characteristics of households for example, there are more obese people among the unskilled (no training or only short-term training) and low income groups. The rate of increase in obesity is also greater among the unskilled groups (Richelsen et al., 2003). This is similar to findings in other countries (Nichéle, 2003; Anderson et al., 2003). To a large extent, these differences can be explained by differences in diets. Nichéle (2003) finds that households where the main income provider has lower-level or no education have diets that are higher in fats and cholesterol and lower in vegetables and fruits than an average household. The elderly in Denmark more often eat traditional meals that are high in fats, since they are typically strongly bound by traditions and react slowly to new trends (Larsen, 2003; Smed, 2002; Groth and Fagt, 2003). More alarming is the growth in obesity among children and teenagers. This development may be caused by the consumption of unhealthy fast food and a high sugar intake in combination with too little exercise (Larsen, 2003; Groth and Fagt, 2003).

The numbers in Table 1, which are from a large Danish food consumption survey (Groth and Fagt, 2003 and Andersen et al., 1996), show large differences in food consumption patterns. For example, the consumption of fish is greatest amongst the elderly and the upper social classes. More sugar is eaten by the youngest households and the middle and lower social classes. The middle-aged have the largest consumption of meat, fruit and vegetables, while the lowest consumption level of these items is found in the lowest social class.

The diet of the Danish population has improved during recent years, which partly is due to various public information campaigns promoting healthy food intake (e.g. increased fruit and vegetable consumption and decreased fat consumption). Despite this positive trend in diet, the aim of Danes having a diet consisting of at least 600 g of vegetable or fruits per day and a maximal share of energy from fat of 30% is still far from being achieved. Furthermore, these average measures do not take account of the large variation in diet between various groups in the population mentioned above.

Table 1
Consumption of selected food for various socio-demographic groups, g/day per person

	Social class					Age*						
	1	2	3	4	5	19–24	25–34	35–44	45–54	55–64	65–74	75–80
Fish	27	25	20	18	19	14	19	22	26	31	34	36
Sugar	44	44	52	54	50	22	22	20	15	14	14	10
Fruit and vegetables	131	133	121	135	110	69	80	90	93	83	86	77
Meat (excl. poultry)	111	106	121	134	126	96	94	106	103	105	98	87

Source: Groth and Fagt (2003) and Andersen et al. (1996).

* The definition of some groups of food (sugar, fruit and vegetables) is slightly different for the age group comparisons and the social class comparisons.

Model overview and analyses of scenarios

Model overview

The analysis of the impact of food taxes on diet quality is carried out by combining price elasticities, calculated from parameters estimated in econometric models of food demand for five social classes[3] and seven age groups,[4] with food/nutrient conversion tables. The latter are basically matrices of technical conversion coefficients reflecting the contents of various nutrients (e.g. proteins, fats, carbohydrates, sugar) in different food products, and are equivalent to the consumption technology matrix in characteristics models.[5] As in Huang (1999), we assume the total quantity of a nutrient can be expressed as the sum of nutrients from various foods: $\theta_k = \sum_i a_{ki} q_i$, where θ_k is the total amount of nutrient k in the diet, a_{ki} is the amount of nutrient k per unit of food i and q_i is the amount of food i. The full model is illustrated in Fig. 1.

The figure illustrates the operation of tax instruments on two different levels: taxes/subsidies levied directly on food commodities (a), and taxes/subsidies levied on the nutrients contained in foods (b). In the first case, the tax or subsidy directly affects the prices of the commodities concerned (e.g. as changed Value Added Tax (VAT) on vegetables and/or fruit). The resulting change in demand for each socio-demographic group is then predicted from the price elasticities calculated from the estimated food-demand models. The changes in quantities demanded can then be converted into changes in demand for nutrients by means of the food/nutrient conversion table. If the tax/subsidy is levied on nutrients contained in foods (e.g. a tax per gram of saturated fats), the first step of the analysis is to convert these taxes into commodity price changes using the food/nutrient conversion table. Since a change in the price of one food affects the demanded level of all types of food, a full system of price elasticities is needed in order to translate changes in food prices into changes in demand for nutrients. On the basis of the household data it is not possible to predict the consumption of nutrients on individual level, but throughout the rest of paper we will assume that family purchases are equal to family consumption. We assume that this is reasonable, provided there is no waste, since we estimate demand at a monthly level so storage is a minor problem.

Analyses of scenarios

On the basis of recommendations from WHO (2003), Willett (2001a,b) and Nordic Council of Ministers (1996), we have chosen to focus on three diet recommendations

[3] Social class membership is determined from consumers' self-classification in terms of job position, education, etc. Social classes 1 and 2 represent owners of larger companies, people in leading positions in society and people with higher education; social class 3 represents owners of small firms and white-collar workers with a small number of subordinates or with specialist skills; social class 4 represents white-collar workers without subordinates and skilled blue-collar workers; and social class 5 consists of unskilled blue-collar workers, the unemployed, pensioners, etc.

[4] The households are divided into age groups according to the age of the main income provider.

[5] Characteristics models have as their main feature that utility is based on consumption of non-market goods such as nutrients in foods. The conversion between market goods and non-market goods is made through the technology matrix.

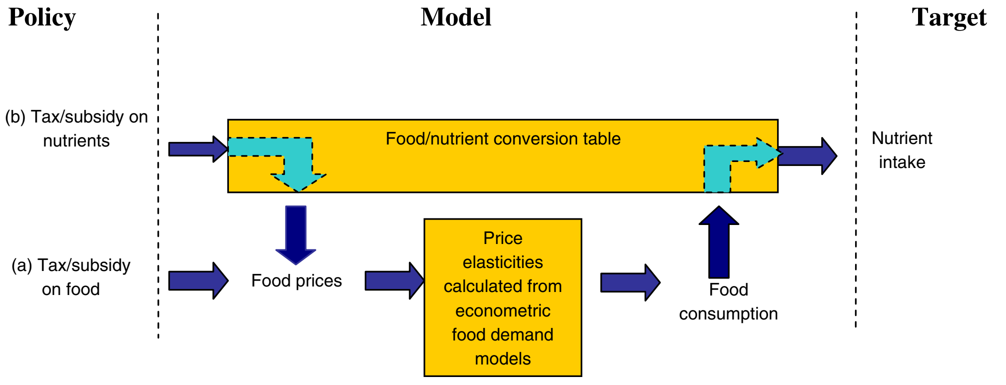

Fig. 1. Model (a) tax/subsidy on food and (b) tax/subsidy on nutrients.

that are the object of general consensus: (1) eat more fibre, (2) cut the amount of sugar, and (3) eat less saturated fat. The set of tax scenarios comprises adjustments to the taxes on individual foods or nutrients, as well as revenue-neutral combinations of adjustments. These three nutritional recommendations are addressed by both the indirect and the direct approaches. For example, the third recommendation is approached either by a tax on food commodities with a large content of saturated fat (scenario 1 in Table 2), or directly as a tax on the content of saturated fats in foods (scenario 3 in Table 2). All the scenarios which target single nutrients (scenarios 1–5) are scaled equally in the sense that the aggregate economic welfare loss is identical across scenarios, in order for comparisons across scenarios to make sense (the aggregate welfare loss corresponds to around 0.3% of the total food budget in all these scenarios). This welfare loss is defined as the net loss of consumers' surplus – calculated as an approximation to the

Table 2
Scenarios targeting single nutrients and combined scenarios targeting several nutrients

Scenario no.	Schemes aimed at food products
1	Tax on fatty meats (beef and pork), butter and cheese (5% increase in price)
2	VAT reduction on fresh fruit and vegetables, potatoes and grain-based products from 25 to 22% (2% decrease in price)
	Schemes aimed at specific nutrients
3	Tax on saturated fats, 7.89 DKK/kg
4	Subsidies on fibres, 18.00 DKK/kg
5	Tax on sugar, 10.30 DKK/kg
	Revenue-neutral scenarios
6	Combination of scenario 1 and scenario 2. The tax on beef, pork, fats and cheese is the same, the decrease in VAT on fruits, vegetables, potatoes and grain-based products is scaled in order to give a revenue-neutral scenario
7	Combination of scenario 3 and scenario 4. The tax on saturated fats is the same, the subsidy on fibre is scaled in order to give a revenue-neutral scenario
8	As 7, but the scenario includes a tax on sugar. This means that the subsidy on fibre is scaled in order to give a revenue-neutral scenario

equivalent variation[6] – plus the net loss of tax revenue. This calculation is based only on the direct welfare economic cost, since we do not consider the benefits from potential positive health effects of a change in the diet. This gives the tax/subsidy rates 1–5 shown in Table 2. In order to address cross-effects between regulations, these five scenarios are supplemented with three combinations of tax modifications, reflected in scenarios 6–8, which are scaled so that they are revenue-neutral for the authorities. This means that as a general rule the tax is kept at the same level, while the subsidy is adjusted to make the taxation revenue-neutral.

The welfare economic costs in the three last scenarios differ, but all are around three times as large as those in scenarios 1–5. The results from the combined scenarios can therefore not be compared with the results from other scenarios, but within any one scenario the results can be compared across socioeconomic groups.

Estimation of food demand model and data description

Food demand model

The food demand model is based on economic demand theory, which assumes that consumers maximise utility subject to a budget constraint. Assuming standard properties of the utility function, this implies that the demand for individual commodities can be derived as a function of the price of the commodity under consideration, the prices of other commodities, and the budget available for consumption. In the empirical study below, the Almost Ideal Demand System (AIDS) model (Deaton and Muellbauer, 1980) is used as functional form. Dynamics in consumer behaviour (e.g. habit formation or storage effects) are introduced by lagged budget shares in the AIDS model, as suggested by, for example, Alessie and Kapteyn (1991) and Assarson (1991). Furthermore, a trend variable is used to reflect changes in preferences not captured by the explanatory variables. Dummies for seasonality reflect seasonal differences in demand. According to this augmented AIDS specification, commodity i's share, w_i, of the total budget is assumed to be a function of prices of all commodities j ($i, j =$ milk, cheese, ... etc),[7] lagged consumption of all commodities j and the budget. This can be specified as (seasonality is left out of this specification for ease of notation):

$$w_{it} = \alpha_i + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i(\ln y_t - \ln P_t) + \sum_j \theta_{ij} w_{j,t-1} + \varepsilon_{it} \tag{1}$$

where p_{jt} is the price of commodity j at time t, y_t is the total food demand budget at time t, α_i, β_i, θ_{ij}, γ_{ij} are parameters to be estimated, and $\ln P_t = \alpha_0 + \sum_j (\alpha_k + \theta_k w_{kt-1}) \ln p_{kt} + 1/2 \sum_k \sum_j \gamma_{ij} \ln p_{kt} \ln p_{kt}$ is an aggregate food price index, which can reasonably well be approximated by the Törnquist index (Moschini, 1995):

$\ln P_t - \ln P_0 = \sum_i 1/2(w_{i0} + w_{it}) \cdot (\ln p_{it} - \ln p_{i0})$. For theoretical consistency, the system of budget share equations is required to satisfy the properties of adding-up, linear homogeneity and Slutsky symmetry.

[6] The equivalent variation is calculated as an approximation to the expression given by Diewert (1989), i.e. the relative change in aggregate quantity multiplied by the initial budget for food.

[7] For a full specification of the food groups that i and j run through see appendix and note.[8]

Purchase data

The data for the present analysis consist of weekly household panel data from a representative panel of Danish food consumers (approximately 2000 households) from Gfk Consumerscan, spanning the period from January 1997 to December 2000. Weekly shopping reports were collected, reporting the households' purchases in terms of quantity, price, brand, special product characteristics, place of purchase, etc. The weekly shopping reports have been aggregated into 23 broader food categories.[8] Unfortunately, the data do not include purchase of alcoholic and non-alcoholic beverages and expenditures on food-away-from-home, and cover only to a certain extent ad hoc purchases in nearby shops by family members other than the diary keeper.[9] This means that there might be some bias in the results. We assume this bias to be of minor significance, since the costs of ingredients often constitute only a minor share of the price of goods purchased in kiosks and restaurants.[10] Consequently, the major changes can be expected to occur in the purchases covered by the data in this analysis. A wide range of background information has been recorded for each household in the panel, including family type, age, social class and geographical location.

Econometric estimation of the food demand model

In principle, the data might enable the use of panel data methods for analysing the demand for food, if the panel structure of the data were to be exploited fully. However, in this respect the data have one shortcoming: they only contain price information on the commodities purchased, whereas information concerning the prices of commodities not chosen by the individual household is either non-existent or imperfect. The main problem here is not the missing data but that of consistently modelling the many corner solutions that would appear at the household level. For reasons of parsimony we have chosen to model the representative aggregate consumer and the data have been aggregated to pure time-series data for different groupings of households: seven age groups[11] and five social classes.[3] These two socio-demographic characteristics, together with family type and location of the household, have been found to have major influences on dietary choices (Smed, 2002; Angulo et al., 2003). Provided that each commodity type has been purchased every week by at least one household within each group, which is the case in these data, the aggregated data will contain weekly observations on expenditure, quantity and average price for all commodities.[12] The demand systems are estimated separately for each of the groups using maximum likelihood.[13] Adding up is inherent in the system, and the system

[8] Beef, biscuits and cakes, butter, cheese, curdled milk products, fish, fresh fruit, fresh vegetables, grain-based products, margarine, milk, other dairy, other food, other meat, pork, potatoes, poultry, processed fish, processed fruit and vegetables, processed meat, rice and pasta, sugar and sugar products, eggs.

[9] This is because other family members have to tell the diary keeper about purchases they make over and above the household shopping.

[10] This is for example the case for many kinds of soft drinks, where the price is mainly based on brand names.

[11] The households are divided into age groups according to the age of the main income provider.

[12] It should be noted that if a group's purchase of a commodity type within a week has been low, the resulting calculated average price observations for that week will be based on few observations and hence become relatively uncertain.

[13] The separation of the panel into separate groups instead of introducing socioeconomic variables by, for example, translation, scaling or Lewbel's modifying functions approach is similar to Raper et al. (2002), Park et al. (1996) and Huang and Lin (2000), for example.

is tested for the properties of linear homogeneity and symmetry.[14] Homogeneity is accepted for all the demand systems, while symmetry is accepted for most systems (but is imposed for all socio-demographic groups). Tests were applied for multicollinarity (condition index) and for misspecification (White and Breusch–Pagan tests for heteroscedasticity and Godfrey's test for autocorrelation). There are indications of multicollinarity between total food demand and the intercept. This problem is handled by demeaning the variables and thereby omitting the intercept. There are no signs of heteroscedasticity or autocorrelation.

First, we assume that food demand is weakly separable from the demand for other goods and services. In order to retain sufficient degrees of freedom to include lagged variables, the system of demand equations is nested in a two-stage budgeting system. The two different separability structures shown in Appendix 1 are each tested against a system of no structure according to the test procedure developed by Moschini et al. (1994) and Moro and Moschini (1996). For all socio-demographic groups structure 1 was rejected, while the hypothesis that structure 2 is just as good as no structure cannot be rejected for most groups.[14] Hence, the systems are estimated in a two-stage procedure. In the first step, demand for the six aggregates dairy and eggs, fats, processed meat and fish, meat and fish, fruit, vegetables and potatoes, and other foods is estimated, working on the assumption that the joint price changes for these aggregates can be reasonably well approximated by an aggregate price index (Törnquist index). In the second step, demand for the components in each of these subgroups is estimated. On the basis of estimated coefficients and average budget shares, conditional own-price and cross-price elasticities were calculated for each of the socio-demographic groups, according to the following formulas (where δ_{ij} is the Kronecker delta) (Edgerton et al., 1996).

$$E_i = 1 + \frac{\beta_i}{w_i} \tag{2}$$

$$\varepsilon_{ij} = \frac{\gamma_{ij} - \beta_i \cdot [\beta_j \cdot \ln(y/P) - w_j - 1/2 \cdot (\gamma_{ij} + \gamma i_{ji}) \cdot \ln(p_i)]}{w_j} - \delta_{ij} \tag{3}$$

Full matrices of unconditional[15] elasticities for the 23 food groups are calculated from the elasticities in the first stage according to the formulas in Edgerton (1997). Asymptotic standard errors for the calculated elasticities are approximated using first order Taylor-series expansions. The full matrices of own-price and cross-price elasticities are not shown here due to space limitations, but selected own-price elasticities for the socio-demographic groups are shown in Table 3 (standard errors in parentheses).

For most commodities, greater price sensitivity is found for social classes 4 and 5. The average levels of income and education in those two segments are lower than for the rest of the social classes. The elasticities for these two groups can therefore be compared to elasticities found for low-income or less-educated groups in other studies. Jones (1997) found greater price sensitivity for breakfast cereals for low-income groups using scanner data. Lennernas et al. (1997) found a greater level of importance for price amongst the less well educated, the unemployed and the retired. Cost constraints are also found to be a barrier to healthy eating in low-income groups in France (Darmon et al., 2002) and

[14] Due to space limitation, estimation and test results from the 12 demand systems are not shown, but can be obtained from the author upon request.

[15] Unconditional in the sense that food consumption is assumed to be separable from other consumption.

Table 3
Selected own-price elasticities for socio-demographic groupings

	Butter	Margarine	Beef	Pork	Poultry	Sugar	Fruit	Vegetables
Age (yrs)								
<26	−1.10	−1.25	−1.92	−2.02	−1.26	−1.01	−1.60	−1.41
	(0.03)	(0.00)	(0.00)	(0.06)	(0.06)	(0.00)	(0.05)	(0.00)
26–29	−1.04	−1.01	−1.01	−1.52	−1.97	−0.55	−0.93	−0.94
	(0.00)	(0.01)	(0.00)	(0.01)	(0.11)	(0.00)	(0.00)	(0.00)
30–39	−3.92	−2.78	−1.61	−1.57	−1.28	−1.00	−1.36	−1.35
	(0.01)	(0.04)	(0.00)	(0.06)	(0.12)	(0.00)	(0.00)	(0.04)
40–49	−1.15	−1.09	−1.46	−1.02	−1.35	−1.02	−1.40	−1.18
	(0.04)	(0.00)	(0.06)	(0.03)	(0.03)	(0.00)	(0.00)	(0.04)
50–59	−1.15	−1.12	−1.32	−1.87	−1.70	−0.77	−1.69	−1.40
	(0.16)	(0.01)	(0.07)	(0.06)	(0.02)	(0.01)	(0.06)	(0.06)
60+	−0.17	−0.75	−1.60	−1.29	−1.93	−1.33	−0.82	−1.12
	(0.08)	(0.00)	(0.10)	(0.03)	(0.08)	(0.07)	(0.05)	(0.07)
Social class								
1	1.10	1.56	−0.73	−1.11	−0.87	−0.87	−0.37	−1.03
	(0.04)	(0.09)	(1.42)	(1.30)	(1.42)	(0.15)	(0.06)	(0.07)
2	−1.58	−1.86	−0.59	−0.37	−0.76	−1.02	−0.84	−1.21
	(0.01)	(0.11)	(0.03)	(0.03)	(0.03)	(0.00)	(0.05)	(0.08)
3	−1.20	−1.76	−0.89	−1.05	−0.86	−1.01	−1.20	−1.18
	(0.00)	(0.00)	(0.10)	(0.08)	(0.08)	(0.03)	(0.05)	(0.07)
4	−1.38	−2.07	−1.87	−1.43	−1.42	−1.02	−1.27	−1.30
	(0.00)	(0.07)	(0.07)	(0.04)	(0.02)	(0.00)	(0.00)	(0.05)
5	−1.55	−1.98	−1.80	−2.00	−1.87	−1.03	−1.22	−1.47
	(0.03)	(0.07)	(0.01)	(0.04)	(0.01)	(0.00)	(0.06)	(0.08)

similarly in the US (Adelaja et al., 1997, who also report greater price sensitivity for the lower social classes). In contrast, Park et al. (1996) and Raper et al. (2002) report own-price elasticities for both poverty and non-poverty status households to be equal. Their studies are based on systems of 9 and 12 food groups, respectively (two of them being food-away-from-home and beverages), as compared to the 23 food groups in the present study. This might indicate that low-income households exhibit more substitution within commodity aggregates than households with higher incomes do. In general, price elasticities for all goods are lower for the upper social classes, and some price elasticities are even non-significant. Price elasticities for butter and margarine are found to have the wrong sign in social class 1. All in all, this indicates that for the wealthiest and most well educated prices are less important than for other groups. There is no specific age-dependent pattern in the price elasticities.

Calculation of conversions between food demand and nutrient intake

The changes in demand for nutrients due to changes in prices can be calculated via a coupling of changes in food demand due to changed prices and nutrient food/nutrition conversion coefficients from the Danish Food Database (2005), which describes the average content of a number of micro- and macro-nutrients in a large range of the most common commodities on the Danish market. For the present purpose, these coefficients have been aggregated to the level of detail in the econometric food-demand model. Examples of some of the nutrient coefficients applied are given in Table 4.

Table 4
Selected aggregate nutrient coefficients

	Fats, total g/100 g	Saturated fats g/100 g	Added sugar g/100 g	Fibre g/100 g
Milk	2.0	1.2	0.9	0.1
Fats	81.2	45.8	0	0.0
Cheese	23.9	14.8	0	0.0
Pork	14.4	5.5	0	0.0
Flour/bread/cereals	2.5	1.4	0.1	5.1
Vegetables/potatoes	0.6	0.2	0	1.7

Source: Danish Food Database (2005).

Results

Fig. 2 shows the aggregate changes in demand for saturated fats, sugar and fibre due to the taxation scenarios specified aimed at single food commodities or single nutrients. If we compare the changes in demand for nutrients brought about by direct and indirect taxation, a larger effect is seen when the tax or subsidy is levied directly on the nutrient content than when it is levied indirectly through tax or subsidy on food commodities. For example, if we wanted to increase the demand for fibre we could reduce the VAT on fruit, vegetables and grain-based products (scenario 2), which leaves the demand for saturated fat almost unchanged but increases the demand for sugar and fibre by 1.3% and 4.2%, respectively. In comparison, a subsidy on fibre (scenario 4) gives the same changes in demand for saturated fat and sugar, but a larger increase in the demand for fibre (almost 6.2%). A taxation aimed at products with a high content of saturated fat (scenario 1) gives a decrease in demand for these fats of 5.7%, while a tax aimed directly at the content of saturated fat (scenario 3) yields a decrease of 9.0%. Recall here that the tax and subsidy levels chosen have the same welfare economic cost (not including the potential derived health effects of the change in food composition).

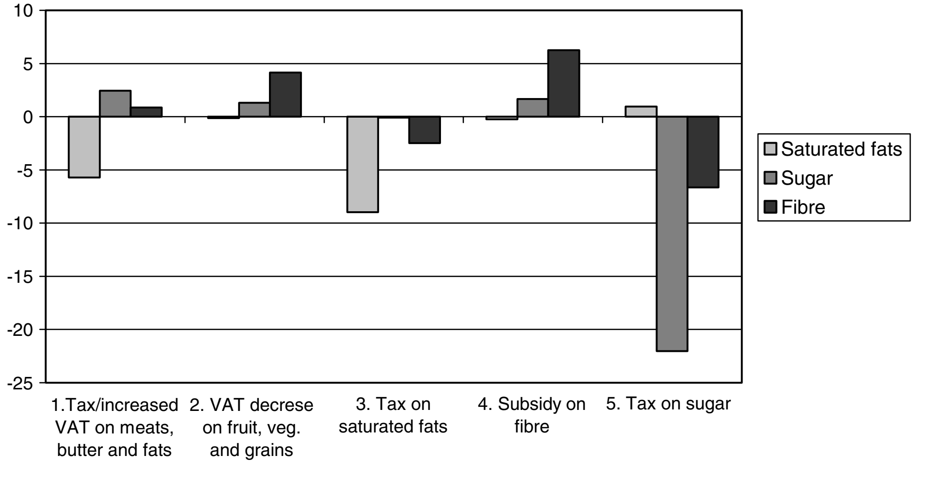

Fig. 2. Change in the demand for various nutrients as a consequence of different scenarios aimed at single nutrients.

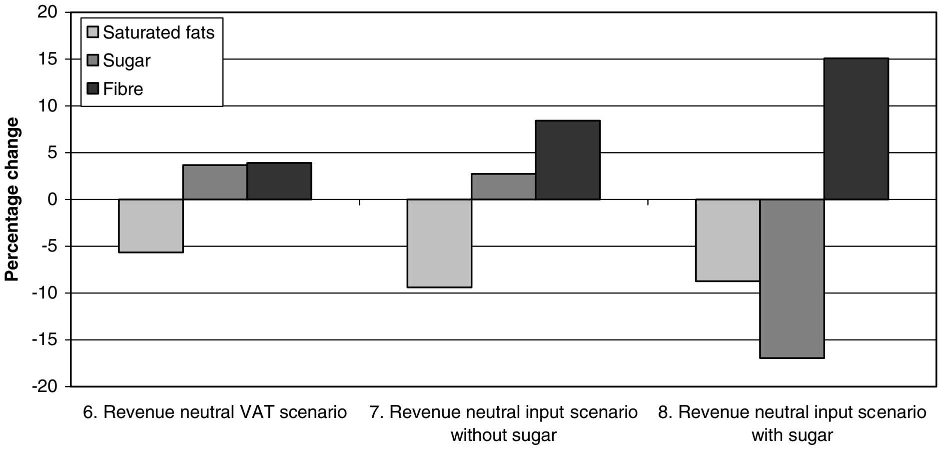

Fig. 3. Changes in the demand for various nutrients as a consequence of revenue-neutral scenarios.

The above results show that single-food or nutrient taxes tend to have the desired effects on the demand for the nutrient in question, but at the same time seem to have undesired effects on the demand for other nutrients (due to substitution or income effects). Furthermore, the regulations induce changes in overall food taxation levels and tax revenues which may also be undesirable from a fiscal-policy point of view. In order to address these concerns, scenarios 6–8 are constructed as revenue-neutral for the government and their effects on the demand for saturated fats, sugar and fibre are displayed in Fig. 3.

For the revenue-neutral VAT scenario (scenario 6) and the equivalent input scenario (scenario 7), an unwanted increase is seen in the demand for sugar. This undesirable side effect stems either from a budget effect or from goods being complementary in some sense. This can be avoided by combining the scenario with a tax on sugar, as shown in the last three columns in Fig. 3 (scenario 8).

Table 5 shows the results from the revenue-neutral scenarios (scenario 6–8) for various age groups and social classes.[16] The largest decrease in the demand for saturated fat is observed for younger consumers (<39 years) in all three scenarios. For fibre, the increase in demand is more evenly distributed, although the younger consumers also tend to be favoured in this respect. The demand for sugar increases as an undesired side effect (an effect also tending to be stronger for younger consumers) in those scenarios where only saturated fat and fibre are taxed/subsidised. In the last scenario, where a tax on sugar is included, it is the demand of the 30–59-year-olds which decreases the most.

For all three scenarios, social classes 4 and 5 exhibit the largest decreases in the demand for saturated fat. This result is in accordance with Jones (1997), for example, who found that rising food prices cause low-income consumers to change their demand far more than high-income consumers do. Social classes 2 and 3 have the largest increase in the demand for fibre. According to the simulations, social class 1 reacts counter-intuitively, as demand for the taxed nutrient increases in some scenarios. This is due to the fact that some of the elasticities have the wrong sign and others have large standard errors for this group,

[16] At an aggregate level, these three scenarios are neutral in terms of net tax revenue, but not necessarily for the respective socio-demographic segments, a fact which might have some appeal from a political perspective.

Table 5
Changes in nutrient demand for various socio-demographic groups, combined scenarios

	6 Combined VAT-adjustment			7 Combined nutrient tax, excl. sugar			8 Combined nutrient tax, inc. sugar		
	Saturated fat	Fibre	Sugar	Saturated fat	Fibres	Sugar	Saturated fat	Fibre	Sugar
< 26 yrs	−6.0	10.0	6.5	−16.4	21.9	8.1	−20.0	36.9	−10.4
26–29 yrs	−5.2	4.4	4.2	−14.0	13.7	5.4	−12.8	24.3	−3.0
30–39 yrs	−13.8	2.0	0.0	−40.1	11.9	0.0	−23.1	17.4	−21.3
40–49 yrs	−4.9	2.7	2.3	−13.3	11.9	5.3	−8.3	22.7	−15.2
50–59 yrs	6.8	1.0	−0.1	−0.6	7.3	−14.3	9.7	15.1	−26.1
60 yrs +	−1.9	−0.9	4.3	−1.3	11.9	18.6	7.1	19.6	−7.7
Social class 1	−0.3	−1.1	19.6	39.0	8.5	−2.7	52.2	12.4	0.6
Social class 2	−5.2	5.6	12.9	−13.4	14.1	16.1	−10.6	30.3	2.1
Social class 3	−5.2	5.6	12.9	−13.3	14.1	16.1	−10.8	26.2	−4.4
Social class 4	−14.7	3.9	8.2	−23.9	8.3	12.9	−19.8	22.5	−3.2
Social class 5	−10.4	3.3	8.8	−22.5	9.1	12.2	−13.4	24.1	−2.5

Table 6
Percentage change in monthly expenditure on food for various socio-demographic groups

	6 Combined VAT adjustment	7 Combined nutrient tax, excl. sugar	8 Combined nutrient tax, inc. sugar
Social class 1	1.33	9.40	31.23
Social class 2	−0.12	−0.18	−0.39
Social class 3	−0.30	−0.42	−0.97
Social class 4	−1.08	−3.81	−3.37
Social class 5	−0.57	−1.97	−3.97
< 26 yrs	−0.27	−0.48	−1.08
26–29 yrs	0.14	0.31	−0.27
30–39 yrs	−0.54	−3.40	−8.83
40–49 yrs	−0.30	−0.65	−1.41
50–59 yrs	0.35	4.09	4.48
60 +	−0.32	0.37	6.31

indicating that food demand choices are independent of prices (this group has the highest income on average).[17]

When prices increase, the original group of goods will become more expensive. A major advantage of the use of economic instruments is that consumers are able to minimise the costs induced by regulation by adjusting their demand according to the new prices. The economic consequences of the scenarios for groups of households are illustrated in Table 6, which shows the percentage changes in monthly expenditure on food. In general, the scenarios show a decrease in expenditure for all groups apart from social class 1, which supports the conclusion that prices are unimportant for this class. This is also the group with the smallest adjustments in demand. The largest decreases in expenditure are seen in social classes 4 and 5, which show the largest adjustments in demand. For the different

[17] Furthermore, this is the group in the panel with the lowest number of observations (only 6% of the households are in this group, equal to 120 households), and this may decrease the reliability of the parameter estimates.

age groups the patterns are less clear, but for the two input scenarios expenditure increases for households aged 50 and up, while expenditure decreases mostly in households below 50 years of age. Again the increases or decreases in expenditures reflect the willingness to adjust food demand in the short term.

Conclusion and policy implications

This paper analyses the use of incentive-based instruments in nutritional policy by quantitative calculations, where the nutritional effects of a food tax levied either directly on nutrients or indirectly through taxes on food commodities are compared for different age groups and social classes. Across socio-demographic groups, social classes 4 and 5 generally have the greatest improvements in diet composition in the scenarios considered. This is in accordance with our initial target groups. With regard to age groups, it is mostly the younger groups that decrease their demand for saturated fat in the scenarios considered. These are not exactly the groups that were aimed at, as it is the older age groups that have the largest consumption of saturated fat. As far as sugar is concerned, it is mostly the middle-aged who decrease their demand, whereas the principal target groups for sugar reduction are the youngest, which have the largest initial consumption. With respect to expenditure, the predicted changes suggest a larger decrease for social classes 4 and 5 than other social classes and an increase in expenditures for households above 50 years of age. In principle, the introduction of economic regulation would result in the same changes in conditions for all consumers, and thus does not provide the possibility of targeting specific consumer segments, as can be done with other instruments, e.g. campaigns. But other economic research[18] shows that prices may be a barrier to healthy eating, especially for groups with low education and low income. This is in line with our findings. One possible route for further research is to see if it is possible to optimise the various scenarios to better reach specific target groups in the population.

Undesirable side effects are observed in some of the scenarios. These can to some extent be avoided when all the critical nutrients are included in a combined tax-subsidy package, as has been demonstrated with sugar. New scenarios with additional nutrients and various combinations thereof will give more insight into how to design the most appropriate taxation scenario for healthy eating. Furthermore, these new scenarios must be designed so that they are comparable across scenarios in order to be able to detect the most appropriate regulation mechanism.

The study also shows that the positive effect on diet composition with regard to the nutritional variables considered is higher in the case of regulations targeting the critical nutrients (saturated fats, fibers and sugar) than in the scenarios where food types are targeted (VAT changes).

In this analysis, it has been assumed that the effect of a price change is fully transmitted to the consumers, but there may be a number of barriers to consumer reactions. It is for example assumed that a potential VAT change or input taxation is not used to increase profits in various stages of the supply chain. A tax is more likely to be transmitted fully to consumers, while it is possible that a subsidy is partly captured as extra profit. This would hamper the effect of the subsidy instrument. New taxes or subsidies may further give rise to border trade issues and circumventions in the form of increased farm-gate

[18] See for example Darmon et al. (2002), Cade et al. (1999) or Lennernas et al. (1997).

sales, etc. The average share of farm-gate sales varies for different food items (14% for eggs, 6% on average for meat, 2% for fruit and vegetables, virtually zero for milk and totally non-existent for products such as butter and grain-based products). Furthermore, producers may be encouraged by new taxes or subsidies to invest in the development of more healthy alternative food products; a fat tax, for example, may induce producers to develop low-fat versions of food originally high in fat content.

A general conclusion based on this study is that taxation scenarios have an effect on food-choice behaviour, and that it is even possible to design scenarios which are revenue-neutral for the authorities. In order to know whether a tax on nutrients is more effective than a VAT change on food items from the point of view of society, we have to include in the calculations the administrative costs of the two different instruments. The use of direct input taxes and subsidies, the measure which are found in the study to be the most effective, without doubt places a larger administrative burden on the authorities compared to changing VAT regimes. Furthermore, the effectiveness of the economic instruments has to be compared with the effectiveness of other types of regulation. Economic instruments interact with other types of regulation, e.g. information campaigns or rule-based regulation. It should be considered whether information can contribute to enhancing the effectiveness of economic instruments – and also vice versa. These two last aspects also indicate routes for further research.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.foodpol.2007.03.002.

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