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Modelling income group differences in the health and economic impacts of targeted food taxes and subsidies

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Objective To examine the effects, by income group, of targeted food taxes and subsidies on nutrition, health and expenditure in the UK.

Methods A model based on consumption data and demand elasticity was constructed to predict the effects of four food taxation-subsidy regimens. Resulting changes in demand, expenditure, nutrition, cardiovascular disease (CVD) and cancer mortality were estimated.

Data Expenditure data were taken from the Expenditure and Food Survey; estimates of price elasticities of demand for food were taken from a report based on the National Food Survey 1988–2000. Estimates of effect on CVD and cancer mortality of changing fat, salt, fruit and vegetable intake were taken from previous meta-analyses.

Results (i) Taxing principal sources of dietary saturated fat is unlikely to reduce cardiovascular disease (CVD) or cancer mortality. (ii) Taxing 'less healthy' foods (defined by the WXYfm nutrient profiling model) could increase CVD and cancer deaths by 35–1300 yearly. (iii) Taxing 'less healthy' foods and subsidising fruits and vegetables by 17.5% could avert up to 2900 CVD and cancer deaths yearly. (iv) Taxing 'less healthy' foods and using all tax revenue to subsidize fruits and vegetables could avert up to 6400 CVD and cancer deaths yearly. Few obesity-related CVD deaths are averted by any of the regimens. All four regimens would be economically regressive and positive health effects will not necessarily be greater in lower-income groups where the need for dietary improvement is higher.

Conclusions A targeted food tax combined with the appropriate subsidy on fruits and vegetables could reduce deaths from CVD and cancer.

Keywords Junk-food tax, chronic disease prevention, fiscal policy

Introduction

There are concerns about the effect of diet on major chronic diseases, in particular cardiovascular disease (CVD) and cancer.[1] As governments seek strategies to improve the national diet, the use of fiscal policy measures has gained increasing attention.[1,2]

Fiscal instruments, such as taxation, have been used widely to influence health. The UK, for example, has a policy to increase alcohol duty by 2% yearly in real terms.[3] Internationally, a wide variety of taxes is

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levied on food, but the intention is normally to raise revenue rather than change diet to improve health.[4] Countries such as Denmark, Finland and Norway are considering modifying taxes on foods as part of efforts to improve nutrition and combat obesity,[5–7] but there remains little research on the effects of food taxes and subsidies on behaviour and health.[8] One criticism commonly directed at proposed food taxes is that they are regressive—that is, that persons in low-income households would pay a greater percentage of their income on food taxes than those in higher income households.[9] However, the effects of taxes and, in particular, subsidies, on food expenditure in different income groups has not been looked at in any great detail. Furthermore, the health effects of food taxes and subsidies on different income groups have not been examined at all.

This article extends a recent study[8] on the potential impact of a tax on unhealthy foods in the UK. A value added tax (VAT) in the UK is currently charged at a standard rate of 17.5% on a limited range of foods, principally foods bought in catering establishments, 'luxury' and/or snack foods such as confectionary, ice cream and most drinks. The somewhat erratic nature of the VAT system and its poor link to national health priorities are reflected, for example, in the fact that healthy food sold in catering establishments will attract the standard rate of VAT, but most biscuits, cakes and high-fat processed meat products not supplied in the course of catering are VAT free. This article estimates the potential dietary and health effects of changing VAT in the UK to support national health objectives. Most crucially, we use empirical economic and dietary data to estimate the effects of alternative ways of doing this—including both taxing and subsidising different foods—on different income groups. We further investigate the regressive nature of food-related taxes and the expected impacts on CVD and cancer mortality for different income groups.

Methods

We developed a spreadsheet-based model to analyse the effects of different taxation-subsidy regimens in the UK. We tested the effects of extending VAT at 17.5% to certain food items with or without a subsidy on fruits and vegetables. We refer to the four taxation-subsidy regimens as scenarios and describe them as follows.

(i) 'Saturated fats' scenario: taxing foods that are the major sources of saturated fat in the diet

Taxing principal sources of dietary saturated fat (whole milk, butter, cheese, biscuits, cakes and pastries)[10] has been a popular suggestion.[8,11] This proposal is re-explored by testing the income group-specific effects of a 17.5% VAT on these foods.

(ii) 'Less-healthy food' scenario: taxing foods defined as 'less healthy' by the nutrient profiling model WXYfm

The WXYfm nutrient profiling model was developed for use in regulating broadcast advertising of unhealthy foods to children. It rates individual foods on a scale from −15 (most healthy) to +40 (least healthy) based on: energy, saturated fat, total sugars, sodium, protein, fibre and fruit/vegetable/nut content per 100 g. It categorizes foods as 'less healthy' if they score ⩾4 or 'healthier' if they score <4. Drinks are 'less healthy' if they score ⩾1 and 'healthier' if they score <1.[12]

Foods classified as 'less healthy' (yoghurt, cheese, bacon and ham, butter and margarine, sugar and preservatives, processed potatoes, pastries/cakes/biscuits and breakfast cereals) by the model were all taxed in this scenario. Soft drinks and confectionery are classified as 'less healthy', and already attract VAT in the UK, so no further tax was imposed.

(iii) 'Tax plus 17.5% subsidy' scenario: taxing foods defined as 'less healthy' by the nutrient profiling model WXYfm and subsidising fruit and vegetables

In this scenario, VAT on foods classified as 'less healthy' were combined with a 17.5% subsidy on fruits and vegetables.

(iv) 'Tax plus more subsidy' scenario: taxing foods defined as 'less healthy' by the nutrient profiling model WXYfm and subsidising fruit and vegetables to neutralize tax revenue

In this revenue-neutral scenario, it was calculated that a fruit and vegetable subsidy of 32.5% would fully offset the tax revenue generated from the proposed taxes on 'less healthy' foods.

The summary of the model framework is shown in Figure 1. Estimating changes in food expenditure and disease mortality involved a number of spreadsheet calculations (Microsoft Excel 2003). Using this spreadsheet, it was possible to alter the amount of tax placed on specific food items and observe the effects on outcomes of interest by income group. Figure 2 summarizes the effects of diet on health in the model. The detailed assumptions made at each stage of the model are described below.

Price changes and changes in food expenditure and consumption

We based our model on consumption and expenditure data from the Expenditure and Food Survey (EFS)[13] 2003–06. Income quintiles in the EFS were based on gross weekly household income with the first quintile containing the lowest-income households. We also used National Food Survey (NFS 2000)[14] estimates of the own and cross-price elasticity of demand of food items to model changes in food expenditure and consumption by income quintile when selected foods are taxed or subsidized in different ways. Only own and cross-price elasticities that were significant ($P < 0.05$) in the NFS report were used. We assumed that tax and subsidy changes are transmitted fully to consumer prices.

Own and cross-price elasticity data predict changes in consumption in response to price changes and are

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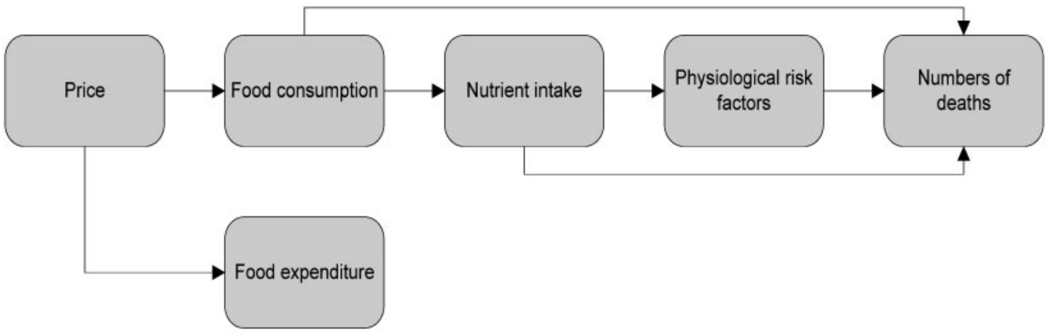

Figure 1 Summary of analyses of the economic and health effects of tax/subsidy instruments

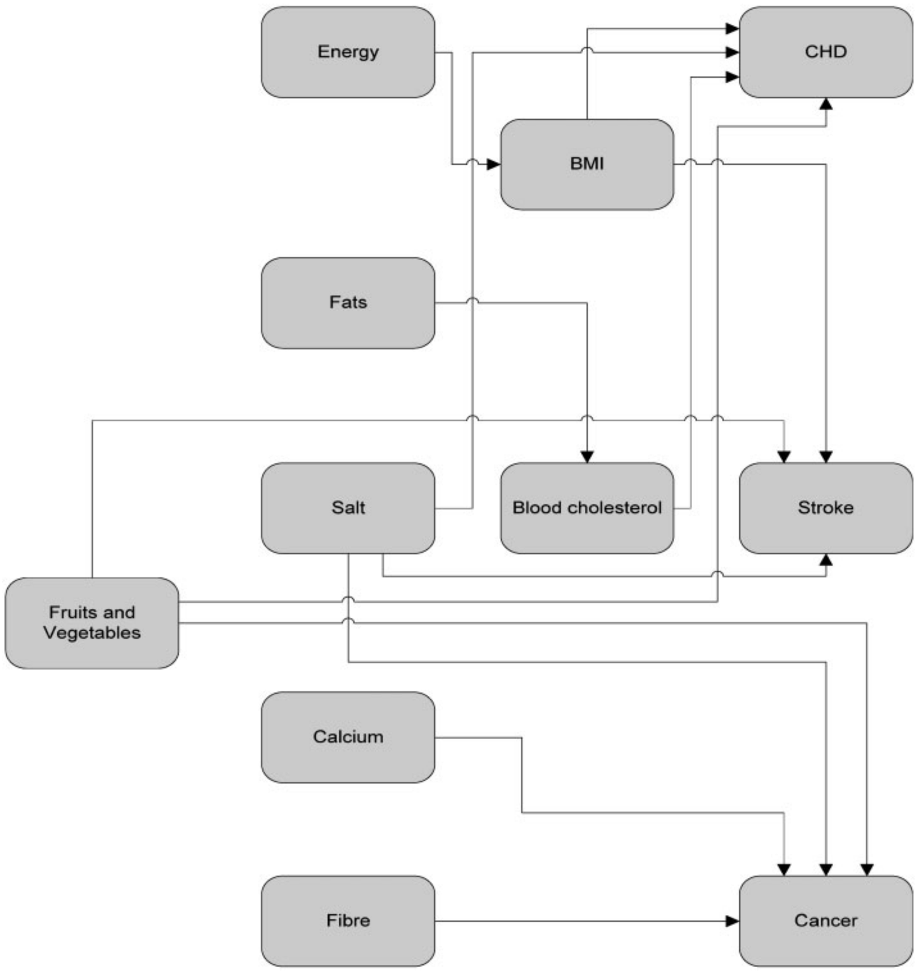

Figure 2 Specific nutrients, diseases and risk markers analysed in model. CHD = coronary heart disease; BMI = body mass index

described in more detail elsewhere.[8] We assumed that price elasticities for food items do not vary across income quintiles because such estimates do not exist.

Although intake of food items was presented in the EFS 2007, most price elasticity values were available at the 'food category' level. Items (such as soft drinks and confectionery) that already attract a VAT in the UK were not taxed in the model scenarios. However, 'Dairy desserts' such as ice cream were taxed because they were a small subcomponent (accounting for 4%) of the food category entitled 'milk and milk products, excluding cheese'.

By comparing pre- and post-tax expenditures on food in each income quintile, we worked out how much hypothesized taxation-subsidy regimens would cost, and thus what percentage of total income persons in each quintile would lose through their introduction. Potential tax revenue (to the Government)

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was the sum of tax revenues from each income quintile.

Changes in food consumption and nutrient intake

The NFS[14] provides information on the nutritional contents of specific quantities of food consumed by persons in UK households. We used this information to predict changes in nutrient intake due to changes in quantity of foods consumed in each income quintile.

Changes in nutrient intake and markers of disease risk

Serum cholesterol is a marker for CHD risk and depends on the proportion of dietary energy derived from saturated or polyunsaturated fats and to a lesser extent on dietary cholesterol. We used the Keys equation[15] and coefficients from Clarke's meta-analysis of metabolic ward studies[16] to derive upper and lower values for changes in serum cholesterol resulting from changes in dietary cholesterol intake and proportion of dietary energy from fats.

Obesity is a marker for CVD risk.[17] Trichopoulou examined a database of 14 281 adults for the mutually adjusted quantitative relationship of energy intake and expenditure with BMI. For an individual ~170 cm in height and 70 kg in weight, a reduction of 500 kcal in energy intake reduces BMI by 0.33 kg/m^2.[18] This effect estimate was used to investigate the impact of changes in dietary energy intake on obesity.

Changes in nutrient intake and CVD, cancer and obesity-related CVD mortality

Data from the Office for National Statistics[19] and the British Heart Foundation[20] were combined to yield age- and income group-specific mortality from CHD and stroke in the UK in 2005. Data on UK cancer deaths in the same year were obtained from Cancer Research UK[21] but income group-specific mortality data for cancer were not available.

Estimates of the effect of changes in nutrient intake on mortality were taken from systematic reviews containing meta-analyses. Using computerized database and hand searching for secondary references, we identified reviews providing continuous estimates of how disease risks change as food or nutrient intake changes. We used the QUORUM checklist[22] to assess the quality of reviews and used estimates from the best quality reviews. Where reviews of trials were not available, high-quality meta-analyses of observational studies were employed.

Two separate reports of a systematic review and meta-analysis of 28 trials provided summary estimates of effect of salt intake reduction on CHD and stroke mortality.[23,24] We used upper and lower values of these estimates to derive corresponding values for changes in deaths from CHD and stroke.

To examine the impact of changes in fruit and vegetable consumption on CHD and stroke mortality, measures of effect from Dauchet's meta-analyses of prospective study data[25,26] were used in combination with age- and income-group-specific mortality data.

A recent World Cancer Research Fund expert report established quantitative relationships between food nutrients and specific cancers in several meta-analyses of selected studies.[27] In that report, there was 'convincing' or 'probable' evidence that an increase in fruit and vegetable consumption was linked to a decrease in oral, oesophageal and stomach cancers; an increase in fruit consumption to a reduction in lung cancers; an increase in dietary fats to an increase in colorectal cancer; an increase in dietary calcium and fibre to a decrease in colorectal cancers and an increase in dietary salt to an increase in stomach cancer. We employed estimates from those meta-analyses to predict changes in cancer deaths.

Changes in markers of disease risk and CVD mortality

Age-specific summary measures of effect for a given reduction in serum cholesterol on CHD mortality were taken from Law's meta-analysis of 41 studies (10 prospective cohort, 3 international surveys and 28 randomized controlled trials).[28] We did not consider the relationship between serum cholesterol and stroke mortality as this is less well established.[29]

A World Health Organisation report presented data from the Asian Pacific Cohort Study Collaboration, which provided age-, sex- and outcome-specific hazard ratios for a 1 kg/m^2 change in BMI.[30] We used the upper and lower estimates of these effects to predict changes in obesity-related CVD mortality.

Obesity-related CVD mortality was excluded from numbers of total CVD deaths to avoid double counting.

Results

Changes in food consumption and nutrient intake

Our model predicts that scenarios 1 and 2 will reduce consumption of fruits and vegetables by ~3 and 1.5%, respectively (Table 1). Scenario 3 will result in about 5% increase in fruit and vegetable consumption while the revenue-neutral scenario 4 will increase fruit and vegetable consumption by ~11%. The reduction in fruit and vegetable consumption in the tax-only scenarios is due to the negative cross-price elasticities of wholemilk and fats with respect to fruit and of cheese with respect to fresh vegetables. The fruit and vegetable subsidies in scenarios 3 and 4 override these reductions to produce a net increase in intake of fruit and vegetables.

Scenarios 1, 2 and 3 will result in average reductions of 0.54% [confidence interval (CI) −0.66 to −0.41] 2.4% (CI −2.67 to −2.13) and 0.92% (CI −1.09

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Table 1 Overall and income group-specific changes in food and nutrient consumption

Quintiles (average weekly income)	Percent change in calorie intake			Percent change in saturated fat intake			Percent change in salt intake			Percent change in fruit/veg intake		
	Avrg	LCL	UCL	Avrg	LCL	UCL	Avrg	LCL	UCL	Avrg	LCL	UCL
Scenario 1 (saturated fat scenario)												
Q1 (£134)	−0.53	−0.65	−0.41	−2.54	−4.69	−0.4	0.28	−2.37	2.93	−2.81	−3.65	−1.98
Q2 (£281)	−0.57	−0.70	−0.44	−2.53	−4.68	−0.38	0.23	−2.18	2.64	−2.79	−3.60	−1.20
Q3 (£475)	−0.49	−0.61	−0.37	−2.37	−4.52	−0.23	0.26	−2.35	2.87	−2.69	−3.50	−1.88
Q4 (£736)	−0.50	−0.63	−0.38	−2.14	−4.23	−0.04	0.25	−2.35	2.86	−2.63	−3.44	−1.81
Q5(£1468)	−0.59	−0.73	−0.46	−2.41	−4.65	−0.17	0.17	−1.99	2.33	−2.71	−3.48	−1.94
Average	−0.54	−0.66	−0.41	−2.40	−4.55	−0.24	0.24	−2.25	2.73	−2.73	−3.53	−1.76
Scenario 2 (less-healthy food scenario)												
Q1 (£134)	−3.08	−3.38	−2.78	−3.66	−6.25	−1.07	−2.29	−9.94	5.36	−1.54	−2.16	−0.91
Q2 (£281)	−2.51	−2.78	−2.24	−3.06	−5.43	−0.68	−1.76	−8.51	4.98	−1.53	−2.12	−0.93
Q3 (£475)	−2.28	−2.55	−2.02	−2.96	−5.36	−0.56	−1.75	−8.58	5.07	−1.43	−2.03	−0.84
Q4 (£736)	−2.11	−2.37	−1.85	−2.89	−5.33	−0.45	−1.77	−8.76	5.22	−1.37	−1.97	−0.78
Q5(£1468)	−2.02	−2.28	−1.77	−3.00	−5.51	−0.49	−1.71	−8.66	5.24	−1.43	−1.99	−0.87
Average	−2.40	−2.67	−2.13	−3.11	−5.58	−0.65	−1.86	−8.89	5.17	−1.46	−2.05	−0.87
Scenario 3 (tax plus 17.5% subsidy scenario)												
Q1 (£134)	−1.53	−1.74	−1.32	−1.36	−2.92	0.20	−1.50	−7.67	4.67	4.75	3.67	5.83
Q2 (£281)	−0.98	−1.15	−0.82	−0.87	−2.13	0.38	−0.99	−6.01	4.04	4.79	3.76	5.83
Q3 (£475)	−0.82	−0.98	−0.66	−0.85	−2.12	0.42	−1.00	−6.14	4.14	4.85	3.78	5.93
Q4 (£736)	−0.69	−0.84	−0.54	−0.85	−2.16	0.46	−1.04	−6.39	4.30	4.86	3.76	5.95
Q5(£1468)	−0.58	−0.72	−0.45	−0.98	−2.41	0.44	−0.97	−6.20	4.26	4.75	3.75	5.76
Average	−0.92	−1.09	−0.76	−0.98	−2.35	0.38	−1.10	−6.48	4.28	4.80	3.74	5.86
Scenario 4 (tax plus 32.5% subsidy scenario)												
Q1 (£134)	−0.21	−0.28	−0.13	0.61	−0.42	1.65	−0.83	−5.39	3.74	11.43	9.816	13.04
Q2 (£281)	0.32	0.23	0.42	1.00	−0.33	2.33	−0.32	−3.18	2.54	10.97	9.449	12.48
Q3 (£475)	0.44	0.32	0.55	0.96	−0.38	2.31	−0.35	−3.40	2.69	11.11	9.533	12.68
Q4 (£736)	0.53	0.40	0.66	0.90	−0.44	2.24	−0.42	−3.80	2.96	11.09	9.491	12.69
Q5(£1468)	0.65	0.51	0.79	0.74	−0.48	1.97	−0.34	−3.44	2.75	10.16	8.735	11.59
Average	0.35	0.24	0.46	0.84	−0.41	2.10	−0.45	−3.84	2.94	10.95	9.40	12.50

Avrg = average; LCL = lower confidence limit; UCL = upper confidence limit.

to −0.76) in calorie intake, respectively, whereas scenario 4 will produce an average increase in calorie intake of 0.35% (CI 0.24 to 0.46). For salt intake, an average increase of 0.24% (CI −2.25 to 2.73) in scenario 1 and average reductions of 1.86% (CI −8.89 to 5.17), 1.10% (CI −6.48 to 4.28) and 0.45% (CI −3.84 to 2.94) are predicted in scenarios 2, 3 and 4, respectively. In scenarios 1, 2 and 3, average reductions in saturated fat intake are predicted of 2.4% (CI −4.55 to −0.24), 3.1% (CI −5.58 to −0.65) and 0.98% (CI −2.35 to 0.38), respectively. Scenario 4 will result in an average increase in saturated fat intake of 0.84% (CI −0.41 to 2.10). Scenario 2 will produce the largest reductions in calorie, saturated fat and salt intakes across all income quintiles.

Scenarios 2, 3 and 4 will produce greater reductions in calorie intake in quintile 1 than in quintile 5. All other changes in food or nutrient intake will not differ between income quintiles 1 and 5.

Changes in household expenditure

Table 2 shows the economic impact of the instruments in the different scenarios. The tax in scenario 1 will raise the weekly personal food expenditure by 8% (CI 6.8–9.2%) for people in income quintile 1 and 4.5% (CI 3.7–5.4%) for those in income quintile 5. This increase is equivalent to an extra 150 pence/person/week for persons in quintile 1 and 109 pence/person/week for those in quintile 5. Food expenditure changes in other scenarios are shown in Table 2.

In all four scenarios, persons in households in income quintile 1 will lose a significantly higher

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Table 2 Economic impacts of different tax scenarios

	Scenario 1		**Scenario 2**		**Scenario 3**		**Scenario 4**	
	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5
Percent change in weekly food expenditure (CIs)	8.0 (6.8–9.2)	4.5 (3.7–5.4)	5.4 (4.4–6.4)	5.0 (4.2–5.9)	4.7 (3.7–5.7)	4.0 (3.3–4.8)	6.1 (5.0–7.2)	5.3 (4.4–6.2)
Percent of weekly income lost to tax (CIs)	1.12 (0.95–1.3)	0.07 (0.06–0.09)	0.76 (0.61–0.9)	0.08 (0.07–0.10)	0.66 (0.52–0.80)	0.07 (0.05–0.08)	0.86 (0.70–1.01)	0.09 (0.07–0.10)
Post-tax increase in food expenditure (pence/person/week)	151	110	106	121	88	98	115	128
Potential tax revenue (billions)	£5.1		£18.3		£10.6		Nil	

Table 3 Income group-specific changes in health outcomes

	Change in annual CHD deaths		**Change in annual stroke deaths**		**Change in annual cancer deaths**		**Change in annual obesity-related CVD deaths**		**Total deaths (excluding obesity-related CVD deaths)**	
Quintiles	Worst case	Best case	Worst case	Best case	Worst case	Best case	Worst case	Best case	Worst case	Best case
Scenario 1 (saturated fat scenario)										
Q1	−124	−158	271	267	307	102	−1	−16	454	211
Q2	−92	−120	246	243	334	109	−1	−15	488	232
Q3	−90	−114	224	220	307	101	0	−11	440	208
Q4	−67	−87	199	196	295	98	0	−11	427	207
Q5	−66	−87	215	213	354	115	0	−11	503	241
Total deaths									**2312**	**1098**
Scenario 2 (less-healthy food scenario)										
Q1	−52	−192	146	110	190	42	−5	−96	284	−41
Q2	−46	−131	141	117	202	52	−2	−65	296	37
Q3	−61	−142	127	106	184	47	−2	−54	250	10
Q4	−68	−137	111	89	177	45	−1	−46	219	−3
Q5	−72	−133	125	106	215	58	0	−39	268	32
Total deaths									**1318**	**35**
Scenario 3 (tax plus 17.5% subsidy scenario)										
Q1	−183	−288	−105	−129	−39	−210	−2	−48	−327	−627
Q2	−185	−243	−91	−104	−37	−231	−1	−26	−313	−579
Q3	−179	−236	−85	−97	−35	−219	−1	−19	−299	−552
Q4	−190	−241	−77	−90	−34	−210	0	−15	−302	−541
Q5	−207	−251	−79	−89	−37	−231	0	−11	−323	−571
Total deaths									**−1563**	**−2870**
Scenario 4 (tax plus 32.5% subsidy scenario)										
Q1	−324	−392	−372	−383	−124	−635	3	0	−821	−1410
Q2	−322	−353	−318	−321	−123	−654	13	0	−763	−1329
Q3	−298	−330	−296	−299	−117	−620	15	1	−710	−1249
Q4	−314	−346	−265	−269	−114	−597	16	0	−694	−1212
Q5	−326	−355	−256	−260	−119	−621	13	0	−702	−1236
Total deaths									**−3689**	**−6435**

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proportion of their income than those in households in income quintile 5, indicating that the taxation or taxation-subsidy regimens in all scenarios will be economically regressive. The taxation regimen in scenario 1 is the most economically regressive of all four regimens. The taxation-subsidy regimen in scenario 3 will be the least expensive to the consumer but the regimen in scenario 2 will yield the most revenue to government.

Changes in health outcome

The taxation regimen in scenario 1 is likely to contribute to between 1100 and 2300 additional deaths every year in the UK, mainly due to deaths from stroke and cancer (Table 3). The regimen in scenario 2 could contribute to between 35 and 1300 additional deaths every year in the UK, also due principally to deaths from stroke and cancer. The taxation-subsidy regimen in scenario 3 could prevent between 1600 and 2900 deaths from CHD, stroke and cancer each year. The taxation-subsidy regimen in scenario 4 could prevent the most deaths (3700–6400). Notably, very few obesity-related CVD deaths would be prevented in any of the four scenarios. Generally, additional deaths will occur because although consumption of fats decreases, fruit and vegetable intake also falls due to the effects of cross-price elasticities, the effect of the latter outweighing that of the former.

Overall effects on health by income group (Table 3) show no clear income group gradients in excess deaths in scenarios 1 and 2 and deaths saved in scenarios 3 and 4. Nevertheless, the analyses in scenarios 3 and 4 suggest that the likely deaths saved through the taxation-subsidy regimens in those scenarios may be more favourable for the poor than the rich.

Discussion

This study has modelled the potential health outcomes of targeted taxes and subsidies on foods in the UK, and shown that a tax on unhealthy foods, combined with the appropriate amount of subsidy on fruits and vegetables, could lead to significant population health gains.

Whereas previous studies have recognized that economic instruments of this nature are regressive,[5,9] this is the first study to examine specifically the health and economic effects of a food tax on different income groups. In view of the regressive nature of these instruments, a desirable outcome would be that taxation regimens compensated for regressivity by producing relatively greater health benefits in the poor, who have the greatest need for dietary improvements. Our study, however, suggests that for those taxation regimens which will produce population health gains, this comparative benefit may not be obvious.

The comparative gains for the poor are, however, likely to have been underestimated in this study for two reasons: first, although we used income group-specific data on CVD mortality, we assumed a uniform distribution of cancer burden across income groups, but cancer mortality is income related. Secondly, our model did not use income-specific elasticity data (see below).

Similar effects (sometimes persisting beyond the period of the intervention) on dietary choices have been observed in studies that test the impact of price-related interventions (taxation and/or subsidies) in more restricted populations such as users of school cafeterias.[31–33] The observed dietary behavioural changes in such settings may, however, not represent the behavioural changes that may attend a similar intervention in the general population.

The taxation-subsidy regimens in scenarios 3 and 4 place a higher financial burden on lower- than higher-income groups but also produce important population health gains. This raises an ethical dilemma for policy makers but the subsidy in scenario 4 represents a reasonable way to demonstrate explicitly that the change in tax regime aims to facilitate a change in dietary behaviour rather than generate revenue for government. In considering such a tax as a policy option, governments may, however, seek to draw on additional research that examines the impact of an increased financial burden on lower-income groups. Notably, all taxes of this nature, e.g. taxes on tobacco and alcohol,[34–36] are similarly regressive but their implementation in many countries around the world has been justified on health grounds.[37] Furthermore, the precise way in which fruit and vegetable subsidies might be implemented would require careful deliberation: subsidies have been used before, for example on a range of foods including bread, butter, milk, cheese and tea in the UK in the 1970s, but then mainly to influence the inflation rate and wage settlements rather than alter consumption patterns.[38]

It is perhaps surprising that scenario 4 is more expensive to the consumer than scenario 3 but this reflects the fact that this is a linear model with fruits and vegetables having negative cross-price elasticities with respect to whole milk, cheese and fats. Consequently, a subsidy on fruits and vegetables will likely increase the demand of these items in a linear fashion, suggesting that beyond a certain level of subsidy, the positive effects of a targeted tax on 'less-healthy food' consumption is likely to be overridden by the negative effect of a fruit and vegetable subsidy on the consumption of such foods. This suggests that even the amount of subsidy on fruit and vegetables needs to be given careful thought by policy makers considering this approach to food policy.

This study has important limitations which mean that our results should be interpreted cautiously. The first set of limitations relate to the price elasticities of demand used in the study. The demand model in the NFS 2000[14] estimated common price elasticity for wholemilk and skimmed milk. However, a tax on

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wholemilk is likely to increase the demand of skimmed milk, a substitute commodity. The fall in demand of wholemilk is therefore likely to be greater in practice than suggested by the estimated elasticity. This would in turn have resulted in lesser saturated fat intake and more deaths averted than we have estimated. Secondly, food taxes do not influence health behaviour in a linear fashion; price elasticities are econometrically derived from observed associations between price changes and demand, but attitudes of individuals or populations to specific food items may also affect demand. Indeed, in addition to cost, health concerns, convenience, access and taste similarly influence dietary choices,[31] although health concerns may be less relevant to choice than are taste and cost.[39] In addition, there is some inconsistency in estimated price elasticities across studies, such that exact effects of alternative elasticity values on our estimates are hard to predict.

Furthermore, the elasticity values in this study were estimated for the period 1988–2000, and may now have changed, for example, in response to new attitudes to healthy eating. Other limitations include the fact that our analysis relies on aggregate consumption and expenditure data that may mask important variations within different food categories and income groups. The use of aggregate data also limited the specificity with which some analyses could be performed. For example, it was necessary to treat the food category 'cereals and other cereal products' as 'healthy' despite the fact that many products within this category (e.g. most breads and some breakfast cereals) are not categorized similarly by nutrient profiling model WXYfm. Furthermore, the analysis assumes—due to lack of UK data—that the price elasticities of demand for food and drink items do not vary by income group. This assumption is supported by analysis of a large US food consumption dataset which showed that estimates of price elasticity did not vary systematically across income groups.[40] However, higher- and lower-income consumers may exhibit varying sensitivity to price changes,[41,42] and these are not captured here. Finally, the study only considers health outcomes with respect to numbers of deaths, and does not calculate disability-adjusted or quality-adjusted life-years lost or gained: in so far as these interventions alter morbidity as well as mortality, the impact of the proposed taxes on overall health outcomes may therefore have been under-estimated.

It may be important politically that all revenue raised from taxation of food is used for public health purposes e.g. education-based nutrition campaigns. If the taxation-subsidy regimen in scenario 4 was not adopted, policy makers would need to consider how revenue raised from a health-related tax would be put to use.

Future research in this area could examine the potential impact of similar taxes in other countries. The model used here could also be used to examine the impact of other policy interventions that impact on the price of food.

What this article adds

This article uses empirical consumption and economic data to model the likely wider health and economic impacts of targeted food-related taxes and subsidies by income group.

It supports the possibility that taxes of this nature, though likely to constitute a greater economic burden to the poor than to the rich, will produce important population health gains if combined with subsidies of healthy foods like fruits and vegetables.

Policy implications

Targeted food-related taxes could be optimized by combining them with a subsidy on fruits and vegetables. Adopting a revenue-neutral tax regimen where all revenue from taxing 'less-healthy foods' is used to subsidize fruits and vegetables presents the greatest opportunity in terms of health benefits. In considering such tax as a policy option, however, Governments may need to draw on additional research that examines the impact of an increased financial burden on lower-income groups.

Conflict of interest: None declared.

KEY MESSAGES

- Carefully targeted fiscal instruments are a promising intervention for the prevention of CVD and some cancers.
- Health gains are likely to be maximized and the economic effect ameliorated if taxes to less-healthy foods are combined with subsidies of fruit and vegetables.
- All modelled taxation and taxation/subsidy regimens will be regressive.
- No clear income group gradients exist in the health gains that will be produced by the combined tax-subsidy regimens.

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