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HEALTHIER EATING AND RISING OBESITY IN THE UK: EXPLAINING THE PARADOX

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Abstract

Promotion of healthier eating choices and adherence to recommended dietary norms are important elements of the UK Government's food strategy to combat the rising incidence of obesity. This paper explores the paradox of rising incidence of obesity over the last two decades even as consumers have moved towards healthier dietary choices. We analyse data from the UK's National Diet and Nutrition Surveys over this period using quantile regression and counterfactual decompositions to identify the main elements underlying this paradox. We find that adherence to individual dietary norms in isolation has only very modest impacts on the obesity profile of the population. Efforts to promote compliance with some of the norms may have the unintended consequence of increasing excessive calorie consumption, leading to increased obesity. The effects of improved adherence to dietary norms may be offset by the changes in the impact of adherence to norms on excessive energy intake. Our results suggest that nutrition and policy and interventions need to focus on the simultaneous compliance with a range of dietary norms to have a significant impact on the incidence of obesity.

Keywords: Obesity incidence, adherence to dietary guidelines, impact assessment

Introduction

The Cabinet Office report *Food Matters* (1) identifies the promotion of healthier dietary choices by consumers as a key element in the UK Government's food strategy for the 21st century. This follows from the recognition of the enormous health gains that would accrue to the UK if diets matched nutritional guidelines on fruit and vegetable consumption, saturated fats, added sugars and salt intake. The Cabinet Office report estimates that adherence to nutritional guidelines would reduce the risks related to cancer, heart disease and other illnesses leading to 70,000 fewer people dying prematurely every year. Improved dietary choices are also crucial for meeting the challenge of obesity, with a quarter of adults and 10% of children in the UK already classified as "obese". In addition to the social impacts, the economic burden of diet related ill-health is estimated at almost £6 billion a year by way of additional National Health Service costs alone.

Promoting adherence to recommended dietary norms is an important element of the strategy for promoting healthier eating. It provides the rationale for a variety of dietary interventions such as the "Eat well, be well" campaign, the "five a day" campaign, initiatives for nutritional labelling etc. The desirability of conforming to recommended dietary norms also underpins many proposed regulatory interventions to combat obesity such as "fat" taxes and "thin" subsidies. In this paper, we develop a framework for assessing the contribution that adherence to recommended dietary norms can make to reduce the incidence of obesity. An empirical assessment of the impact of conformity to dietary norms is attempted for the UK.

Obesity and Adherence to Dietary Norms in the UK

Figure 1 shows the changing Body Mass Index (BMI) profile of the UK adult population based on data from the Diet and Nutritional Survey of British Adults 1986-87 (2) and the National Diet and Nutritional Surveys of 2000-01 (3) and 2008-09 (4). Table-1 summarises the quantiles of the BMI distribution in the three time periods. While the average BMI has steadily increased, what is significant and of greater concern is the rightward shift of the BMI distribution. The proportion of adult individuals who are overweight (BMI>25) has increased from 40% to 62%, while the proportion of individuals who are obese (BMI>30) has increased from 10% to 27%.

This rising trend in the incidence of obesity has been associated with significant deviations from the recommended dietary guidelines prescribed by the Department of Health (5) and also from the dietary norms suggested by the World Health Organization (6) (Table-2). These dietary norms are related to the share of energy derived from macronutrients (fats and sub-components, sugars and protein) and the absolute intake levels of fruits and vegetables, fibre, salt and cholesterol. Information on trends in adherence to key dietary norms over last the two decades is summarised in Table-3. For 2008-09, the average contribution to energy intake from all fats (35.1%), saturated fats (13.2%) and non-milk extrinsic sugars (13.5%) is clearly in excess of the prescribed norms, while the contribution of polyunsaturated fatty acids (PUFA) to energy (5.18%) and average cholesterol consumption are within the acceptable range. Average fruit and vegetable consumption falls well short of the recommended intake (400 grams per day), as does the intake of dietary fibre. The average consumption of salt remains considerably higher than the recommended norm (less than 2.36 grams of sodium per day). The average figures, however, mask the true extent and severity of non-compliance with the recommended guidelines. From an obesity perspective, it is the large proportion of non-compliers in the population whose dietary choices are a matter of concern. However, the trends in Table-3 show that while significant deviations from dietary norms persist, compliance with many important dietary norms (e.g., saturated fat consumption, fruit and vegetable consumption etc) has steadily improved over the last two decades – as may be seen from the declining proportion of the non-conforming population for most norms.

The dietary norms suggested by the Department of Health (DoH) and the World Health Organization (WHO) are based on an extensive review of medical and nutrition literature examining the relationship between dietary choices/nutrient intakes and the prevalence of chronic disease and ill-health. They are intended to reduce the incidence of a range of chronic diseases such as diabetes mellitus, cardiovascular disease, hypertension, stroke, certain types of cancer and also combat obesity. It is no doubt true that not all of the dietary norms are aimed at combating obesity. However, the promotion of diets derived from these norms (such as the US Department of Agriculture's MyPyramid and the UK Food Standard Agency's "Eatwell Plate") is a crucial element of the strategy to improve the dietary patterns of the population. The reduction in the incidence of obesity that can be achieved through adherence to the recommended dietary norms remains an empirical question. It is this question, which could be of considerable interest to those designing dietary interventions, that we address in this paper. We attempt to develop a framework to assess the potential changes in the obesity profile if adherence to prescribed dietary norms is successfully achieved.

In assessing the impact of adherence to dietary norms on obesity, it is tempting to model BMI (or other obesity indicators) as a function of intakes of nutrients or adherence to norms. However, using such an approach with cross-sectional data sets (which comprise the majority of nutrition data sets) raises a number of problems and issues which have been well recognised in the literature. Jebb (7) notes that "cross-sectional studies are confounded by post-hoc effects in which dietary differences between individuals arise as a consequence of obesity rather than as a causal factor" (p. 93). Variyam (8) observes that nutrition studies using self-reported data intakes fail to find a strong positive association with between energy intake and obesity. This is attributed to the under-reporting of intakes by overweight persons and also to the possibility that at any point in time, a proportion of overweight persons may be on weight-loss diets. Rosenheck (9) finds "discrepant associations between frequent fast food consumption, increased energy or overweight in terms of BMI" (p. 535), with a number of studies finding a negative correlation between BMI and fast food consumption. Therefore, relating BMI directly to dietary intakes in a cross-sectional setting may not be a useful approach for assessing the obesity impact of adherence to dietary norms[1].

A second issue to be addressed is that the impact of adherence to dietary norms may vary along the distribution of BMI (or other obesity indicators). For instance, the impact of a unit increase in the share of energy derived from saturated fats may be very different for an obese individual as compared to an underweight individual. A number of studies in the literature have used multiple linear or logistic regressions to analyse the impact of dietary intakes on BMI. These approaches assess the *mean* response of the outcome variable to changes in explanatory variables. In these approaches, the effect of the covariates is same along the whole range of outcomes – for instance, the impact of a unit increase in fat consumption on BMI would be the same for an underweight or obese individual. In designing interventions, we are more interested in the impact of adherence to norms in the upper tails of the outcome variable (denoting obesity). The heterogeneity of response to adherence to different dietary norms at different levels of overweight/obesity is a key element of interest. We would like to explore the hypothesis that the impact of adherence to dietary norms could vary along the whole BMI distribution and could be significantly different from the mean response values in the upper tail of the obesity distribution. The impact of compliance could be very different for obese and non-obese individuals.

The third issue is that in assessing the impact of adherence to dietary norms, we are more interested in how the obesity profile would change as a result of compliance, rather than in the average effects of compliance with dietary norms. Even if the entire population were to conform to the recommended dietary norms, there would still be substantial variation across individuals in the degree of conformity. We are interested in the obesity profile that can be expected in a population of compliers.

[1] The confounding "post-hoc" effects are also evident in the NDNS data set used in this paper. A regression of BMI on nutrient intakes yields a negative coefficient for the share of fat in energy intake – giving the misleading implication that an increase in the share of fat in energy intake will lower BMI.

Methods

Given the poor correlation between BMI and dietary intakes in a cross-sectional context, we develop a proxy indicator for potential obesity relying on one of the few facts about obesity that are not controversial –"that weight is only gained when energy intake exceeds energy needs over a prolonged period"(7, p.98). We build a measure of "excess calorie consumption" (ECC)[2] and model it as a function of the nutrient composition of diet. The impact of adherence to dietary norms is seen as being mediated through the impact on ECC. We use a measure of ECC because it clearly signals obesity risk and at the same time appears to be well-explained by the nutrient composition of diets available from cross-sectional data. To assess calorie need, we rely on the predictive equations for resting energy expenditure proposed in the literature (10, 11). These predictive equations are all based on empirical studies that relate an individual's resting energy requirement to age, gender and anthropometric characteristics. In this paper we have based our measure of ECC on the Harris-Benedict (HB) equation[3]. The BMR derived from the HB equation is multiplied by a factor reflecting a person's level of physical activity to arrive at the total calorie requirement[4].

With a measure of ECC derived from the HB equation, we use a quantile regression (QR) (12) approach to explore how dietary composition and intakes (linked to the dietary guidelines), physical activity and a set of health related lifestyle choices (smoking and alcohol consumption) influence ECC. The QR method allows us to understand how the effect of adherence to dietary norms in groups with the highest levels of ECC differs from that in other groups. This can provide insights into the impact of adherence to dietary norms in groups with the highest risk of obesity. The QR technique allows the impact of the explanatory variables to vary along the whole range of the outcome variable – ECC in this case. The relevance of QR in diet and nutrition analysis arises from the interest in the tails of the dietary outcome distributions – characterised by inadequate/excessive energy intake. An

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[2] ECC is computed as (Total calories consumed/Total calorie need)*100. If total calories consumed = total calorie need, then ECC=100. ECC <100 actually denotes deficient calorie consumption.

[3] The Harris-Benedict equation estimates the Basic Metabolic Requirement (BMR) as:

$$BMR_{MALE} = 66+13.7 \text{x} weight\ (kgs) + 5 \text{x} height\ (cms) - 6.8 \text{x} age\ (years)$$

$$BMR_{FEMALE} = 655+9.6 \text{x} weight(kgs)+1.8 \text{x} height(cms) - 4.7 \text{x}\ age(years)$$

The Harris-Benedict equation is, perhaps, the oldest of such predictive equations and is believed to overestimate energy requirements in the context of current day lifestyles. However, the measure of excess calorie consumption based on it gives a better fit when regressed on nutrient composition of diet compared to some other equations (such as the Miffin-St. Jeor equation).

[4] The BMR derived from the HB equation is generally multiplied by a factor ranging from 1.2 to 1.9 depending on a person's level of physical activity to arrive at the total calorie requirement. The National Diet and Nutrition Survey data set used in this paper records average physical activity scores that range from 33 to 100, with those having a score above 40 considered to have a relatively active lifestyle. The multiplicative factors used to derive the total calorie requirement were based on these scores.

increasing number of applications of QR are emerging in diet and nutrition analysis (13, 14). A recent application examined the impact of socio-economic determinants on fruit and vegetable intakes in the UK (15).

The QR results are used to carry out a "counterfactual decomposition" to assess the impact of adherence to dietary norms on the distribution of excess calorie intake. We use the technique used by Machado and Mata (16) which allows changes in the distribution of the outcome variable to be decomposed into "co-efficient" and "covariate" effects. For instance, if obesity is related to fat consumption, then a change in obesity over two time periods could be due to an increase (or decrease) in fat consumption (covariate effect) and/or due to a change in the impact of fat consumption on obesity (co-efficient effect). The same technique can also be used to assess how the distribution of the outcome variable would change if the distribution of one the covariates were to change, other covariates remaining the same. We use this counterfactual decomposition technique to assess how the distribution of ECC would change if the entire population were to conform to individual dietary norms or combinations thereof.

Data and Variables

This paper uses data from the UK's National Diet and Nutrition Survey (NDNS) for 2000-01 which collected diet and nutrition information from a nationally representative sample of 2251 adults aged 19-64. The survey collected detailed information on foods consumed (at home and outside the home) based on food diaries maintained by respondents. The survey also collected social and demographic information at the household level and data on anthropometry, health parameters and physical activities of the respondents. The data set provides nutrient conversion factors for each food item covering a total of 51 macro and micro nutrients. A number of "derived variables" are also provided such as the total energy intake, share of different macro nutrients in energy intake, consumption of fruit and vegetables, salt, fibre, cholesterol etc which are related to the recommended dietary norms. After omitting respondents with incomplete responses/data and further omitting respondents who reported that their eating had been affected by ill-health, there were observations on 1342 individuals.

The variables used in this paper are summarised in Table-4. The measure of ECC is derived by subtracting the calorie requirement as estimated from the HB equation from the total calories consumed. The dietary composition/intake variables included are those related to the DoH's prescribed dietary norms and include the share of energy from macronutrients[5],

[5] Share of food energy from carbohydrates was omitted as it was treated as a "residual" after energy from all other macronutrients has been taken into account.

intakes of fruits and vegetables, fibre, salt and cholesterol. Cigarette smoking and alcohol consumption were included as "lifestyle" factors affecting excess calorie intake. In addition to the average physical activity score for each individual, the occupational category (manual or non-manual) was included as a factor influencing energy expenditure. Age, gender and ethnicity were the demographic variables included in the model. Ethnicity was included to assess whether the impact of adherence to dietary norms varies across ethnic groups (possibly as a result of genetic differences).

It is well-recognised in the literature that large-scale nutrition surveys such as the NDNS are subject to significant under-reporting of nutrient/food intakes. The extent of under-reporting may vary with respondent characteristics (e.g., BMI) and could be different for different nutrients. Rennie *et al.* (17) estimate that the extent of under-reporting of energy intake in the NDNS could be as high as 25%, with under-reporting being higher in obese men and women. This is an important caveat to be kept in mind in interpreting the figures on ECC. The counterfactual decomposition method used in this paper assesses the impact of a *change* in adherence to dietary norms (relative to existing patterns) on ECC. The results can, therefore, still provide useful insights into the potential impact of changes in nutrient intakes on obesity, notwithstanding the under-reporting that may be prevalent in the data set.

Quantile Regression Results

The linear QR model was estimated was:

$$ECC_{\tau}= \alpha_{1\tau} + \beta_{1\tau} fesat + \beta_{2\tau} fepufa + \beta_{3\tau} femono + \beta_{4\tau} fenmes + \beta_{5\tau} feprot + \beta_{6\tau} festar + \beta_{7\tau} fvgms + \beta_{8\tau} fibregms + \beta_{9\tau} sodium + \beta_{10\ \tau} cigsaday + \beta_{11\tau} alcogms + \beta_{12\tau} chol + \beta_{13\tau} phyactscore + \beta_{14\tau} respage + \beta_{15\tau} respsex + \beta_{16\tau} ethnic + \beta_{17\tau} scresp$$

where the dependent variable ECC denotes excess calorie consumption, the explanatory variables are as described in Table-4 and τ denotes quantiles. All the continuous explanatory variables were centred at the median for convenience of interpretation. Conditional quantiles were estimated for the dependent variable at 90 different quantiles from 5^{th} to 95^{th} – and the results for five quantiles -the 5^{th}, 25^{th}, 50^{th} (median), 75th and 90^{th} - are presented. The estimation was done using the 'quantreg' module in the R statistical software package. Standard errors and confidence intervals were computed using the bootstrap procedure described in Koenker (12) which is incorporated in the "quantreg" module in the R statistical package.

It should be noted that the model incorporates two different types of dietary norms. The norms in the first set are related to macronutrients and are expressed as shares of food energy intake. An increase in the share of food energy for one macronutrient (e.g., saturated fats) implies a decrease in the share of some other macronutrient. The coefficients of macronutrients in energy intake in the above model can be interpreted as the net effect of a unit (percentage point) increase in the energy share of the macronutrient on ECC. The macronutrient composition of diet may affect calorie intake through energy density effects and through the differing impacts of macronutrients on appetite control and satiety (18). The second set of norms are expressed in terms of the absolute level of intake – for fruit and vegetable, fibre, sodium (salt) and cholesterol consumption. The consumption of fibre, salt and cholesterol can generally increase only as a result of increased consumption of foods in which they are constituents. The "impact" of increased consumption of these nutrients on calorie consumption arises from the increase in consumption of the associated foods. We would, therefore, expect the coefficients of these nutrients to be positive unless there are large offsetting effects. For instance, increased consumption of foods containing fibre would add to calorie consumption- so we would expect the coefficient of fibre to be positive. A negative coefficient would arise only if increased fibre consumption were to cause a reduction in calorie intake from other foods through the satiety effect, offsetting the increase in calories from fibre-rich foods. The effects of smoking and alcohol consumption may arise from their effects on behavioural, sensory and physiological processes influencing the ingestion of calories from all other foods. Alcohol, however, is itself a source of calories, therefore, its coefficient will reflect the net effect of a unit increase in alcohol consumption arising from its own calorie content and its effect on consumption of other foods.

Table-5 presents the results for QR estimates. The ordinary least squares (OLS) estimates are also presented in the first column of the table to facilitate comparisons. The table presents the coefficients and p-values for all the explanatory variables for the selected set of quantiles from 5th to 90th. Figures 2A and 2B present the graphs for each explanatory variable showing the coefficients estimated at each of the selected quantiles. The shaded areas in the graphs show the 95% percent confidence intervals associated with the co-efficient estimates. The OLS estimates and the associated 95% confidence intervals, shown as the red line and dotted lines respectively, are superimposed on the quantile regression graphs. Each graph shows how the co-efficient of the explanatory variable changes as we move from the lower quantiles to the higher quantiles of the outcome variable (ECC) with all other continuous variables held at their median values and categorical variables held to the base category. For instance, the graph for the intercept term shows how ECC varies across quantiles for white males who are non-manual workers, when age, nutrient consumption, lifestyle factors and physical activity are at their median values.

The graphs in Figure-2 highlight the differences between the QR coefficients and OLS coefficients at different quantiles. These differences are marked in the upper quantiles which represent high levels of ECC. The divergence of QR estimates from the OLS estimates in the top quantiles of ECC suggests that the OLS estimates may provide a somewhat misleading representation of the effects of nutrient composition of diets for the segment of the population that faces the highest risk of obesity. The implications of the QR results for the impact of nutrient composition and other factors are discussed below.

An increase in the share of energy derived from saturated fats increases calorie consumption. The OLS results suggest that a 1% increase energy share from saturated fats leads to a 0.66 percentage point increase in ECC. But this effect is not significant in the top quantiles of ECC. The coefficient of the share of food energy from PUFA varies in sign across quantiles but is not significant in any of them. The coefficient of the share of food energy from monounsaturated fats is negative in all quantiles suggesting that an increased share reduces ECC, but the effect is significant only in the lower quantiles. Increased cholesterol consumption is associated with higher levels of ECC in all quantiles (in interpreting the cholesterol coefficient, note that units for cholesterol are milligrams).

An increase in the share of food energy derived from non-milk extrinsic sugars (NMES) has the effect of increasing ECC. The magnitude of the effect increases as we move up the quantiles and is highly significant in the upper quantiles. The results suggests that reducing the share of energy derived from NMES (e.g., by avoiding fizzy drinks) does have a significant effect on reducing ECC. The share of energy from NMES appears to have a stronger effect on ECC than the share of energy derived from fats. An increase in the share of energy derived from proteins has a large negative effect of reducing ECC – an effect which is significant in all quantiles. A one percent increase in the food energy share from proteins leads to a two percentage point decline in excess calorie intake – a result which may provide some support for the use of protein rich diets (e.g., the Atkins diet) in weight loss programmes.

The coefficient of fruit and vegetable consumption suggests that increased consumption has a small effect of raising ECC, but the effect is generally not significant. The coefficients of salt and fibre are expectedly positive and significant in all quantiles and increase as we move to the higher quantiles. There is no evidence in the estimates of large "offsetting" effects arising from salt or fibre consumption. Cigarette smoking does not appear to have a significant effect on ECC in any of the quantiles[6]. However, increased alcohol consumption clearly has

[6] An inverse relationship between smoking behaviour and body weight and a rebound weight gain on cessation of smoking have been observed in a number of studies. However, it is not clear whether this is because of lower calorie consumption by smokers relative to non-smokers (due to palatability and taste effects, inhibition of intakes of certain types of foods (e.g., sweet or salty food) or impact on appetite) or whether smokers may consume more calories than non-smokers and yet have lower

the effect of reducing ECC- an effect which is consistent and significant across all quantiles and is more pronounced in the higher quantiles of ECC. This suggests that the increase in calories from a unit of alcohol is more than offset by reduced intake of calories from other foods[7].

ECC increases with the age of the respondents. This effect is small but significant across quantiles and increases as we move up the ECC quantiles. The gender of the respondent has a much larger effect on ECC. The OLS results suggest that ECC of females is lower by 4.8 percentage points in relation to that of males. The effect of gender declines (from 8 percentage points in the 5^{th} quantile) as we move to the higher quantiles but is still substantial (3.5 percentage points) and significant in the 90^{th} quantile. Asian ethnicity is associated with substantially higher ECC (3 to 12 percentage points higher) compared to Whites (the base group). This effect is much more pronounced in the lower quantiles than in the higher quantiles of ECC. A similar effect is seen in the case of Black ethnic groups although the effects are smaller and not significant in many of the quantiles.

As expected, increased levels of physical activity reduce ECC. The effect of physical activity is largest in the top quantiles of ECC. Thus, individuals who are most prone to obesity through excess calorie intake will benefit the most from increased physical activity. However, it should be noted that the effect of physical activity is much smaller compared to the effect of age, gender and ethnicity. The occupational category (manual or non-manual) has an interesting effect on ECC. In the lower quantiles, a manual occupation reduces ECC. But in the higher quantiles a manual occupation has the opposite effect and sharply increases excess calorie intake in relation to those in non-manual occupations. These results have certain interesting implications for targeting dietary interventions. An intervention designed to reduce excess energy intake to combat the risk of obesity may need to focus on older males in manual occupations. Similarly, Asian and Black ethnic groups may have to be prioritised for intervention, even though their average calorie consumption patterns may not be very different from those of the White ethnic group.

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weight gain as a result of (smoking-induced) changes in metabolism (19). The coefficient of smoking in the model gives us only the effect on ECC.

7 Excessive alcohol consumption has been found to be associated with reduced intake of energy from fat and carbohydrates (20). However, excessive alcohol consumption causes liver and health disorders and reduced energy intake may be attributable to the effects of the health condition rather than to a diminution of appetite caused by alcohol. Moderate alcohol consumption has been found to provide short term stimulation of energy intake in a number of studies (21, 22). However, this short term stimulation of energy intakes can be offset by lower energy intakes in later meals or on alcohol free days. NDNS data provide the average consumption over a 7 day period based on respondent diaries. An overall negative impact of alcohol consumption on ECC can be consistent with the short term stimulation of energy intake provided by moderate alcohol consumption.

Counterfactual Decompositions

The QR results presented in the previous section give us the conditional quantile effects of changes in nutrient consumption patterns on ECC. The coefficient of any variable (e.g., share of saturated fats in food energy) at different quantiles gives us the effect of a unit change in the variable on the outcome variable (ECC) at the relevant quantile of the outcome variable, *holding all other covariates constant at their median level*. The QR coefficients do not convey the "unconditional" quantile effects, i.e., the effect of a unit change in the variable when the covariates are distributed as in the sample or when their distribution changes in a particular way (e.g., when the entire population adheres to a particular dietary norm). It is this "unconditional" quantile effect that we are interested in while assessing the impact of dietary interventions or nutrition policies. In this section we present the results from a counterfactual decomposition exercise using the method suggested by Machado and Mata (2005)[8] to examine the changes in the distribution of ECC if (1) individual dietary norms are adhered to and (2) a combination of dietary norms are adhered to.

Table-6 summarises the results of the counterfactual decomposition exercise. It shows the mean and quantiles of the distribution of ECC that would prevail under adherence to individual dietary norms or combinations thereof. The last column shows the percentage of adults not consuming excess calories under each of the scenarios. The first row shows the distribution of ECC for a random sample from the population (based on the QR model and data from the NDNS 2000-01) and provides a benchmark for comparison. Figure 3 shows the shift in the cumulative density function of ECC as a result of adherence to individual dietary norms compared to the benchmark distribution, whereas Figure 4 shows the shift in the cumulative density function of ECC as result of adherence to a combination of norms. The benchmark figures from the NDNS 2000-01 suggest that nearly 38% of the adult population are deficient in calorie consumption relative to need. This appears to be inconsistent with the worsening obesity profile of the population. However, in interpreting the figures we need to take into account the under-reporting of energy intakes in dietary

[8] The counterfactual decomposition following Machado and Mata (16) involves the following steps:

1. Generating a random of sample of size m from a uniform distribution U(0,1), u_1 to u_m.
2. Estimating the QR model at each of the m quantiles, yielding m estimates of QR coefficients.
3. Generation of a random sample of size m from the rows of the covariates and computing m predicted values of the outcome variable using the m QR coefficients (which yields a random sample of ECC in the population based on the estimated QR model)
4. Generating a random sample of size m from a subset of the population that adheres to a particular dietary norm (or a combination of dietary norms) and computing m predicted values of the outcome variable using the m QR coefficients (this yields the distribution of ECC that would prevail if a particular dietary norm were to a adhered to).
5. Comparison of the distributions of ECC estimated in steps 3 and 4 above, - i.e., comparison of the distribution of ECC from the (model based) random sample from the population with the distribution of ECC that would prevail if a particular dietary norm were to be adhered to – to assess the impact of adherence to the norm.

surveys, as discussed earlier. In assessing the impact of adherence to dietary norms on ECC, it may, therefore, be useful to focus on the percentage point *change* in ECC rather than on the implied level of calorie consumption which is subject to considerable under-reporting.

Table-6 shows that in the case of macronutrients, adherence to individual norms leads to a downward shift in the distribution of ECC except in the case of proteins and poly-unsaturated fatty acids (PUFAs) where it has the opposite effect. In the case of proteins we have seen that the QR coefficients of the share of food energy from proteins are all negative. Adherence to the protein norm involves a reduction in the average share of proteins in food energy and, therefore, shifts the ECC distribution to the right. The largest impact on ECC from adherence to an individual norm arises in the case of adherence to the saturated fats norm – which reduces ECC by 6-10 percentage points in different quantiles compared to the benchmark and increases the percentage of adults not consuming excess calories to 52% from the benchmark figure of 38%. Adherence to the NMES norm also has a large effect on ECC, increasing the percentage of the conforming adult population to over 50%. The impact of conforming to the norm for food energy from all fats (<33%) is much more modest, reducing ECC only by 4-6 percentage points in different quantiles. For all the macronutrients, the impact on ECC is generally larger in the top quantiles of ECC compared to the median quantiles. This suggests that the impact of adherence to norms is greater for those at the highest levels of ECC and consequently at the highest risk of obesity.

The impact of adherence to the norms for fruit and vegetable, fibre, sodium and cholesterol consumption need to be interpreted somewhat differently. As already noted, these norms are specified in terms of absolute levels of intake rather than in terms of their contribution to food energy. Table-6 shows that adherence to the fibre norm would increase ECC and would substantially increase the share of the population consuming excess calories. As may be seen from Table-3, average fibre consumption in UK adults is much lower than the prescribed norm with 84% of the population not conforming to the norm in 2000-01. Adherence to the norm will call for substantial increases in fibre consumption and consequently for increased consumption of fibre containing foods. The QR model is anchored in the consumption patterns of the respondents in the NDNS 2000-01. The effect of adherence to the fibre consumption norm in Table-6 is the effect of adherence to this norm in "isolation", through adoption of consumption patterns of those who met the norm in NDNS 2000-01. The impact of adherence to the fibre norm on ECC may be much less if adherence were to be brought about through consumption of fibre-rich foods different from those in the consumption basket of NDNS 2000-01. The main insight here is that in promoting adherence to norms (specified in terms of levels of intake) the choice of foods through which adherence is brought about is very important. Increased fibre consumption may have health benefits, but achieving the fibre norm may also have the undesirable consequence of increasing ECC. A similar point may be made about adherence to the fruit and vegetable norm. Achieving adherence to the norm in isolation by "imitating" the consumption patterns of compliant individuals may have the effect of increasing ECC. In the case of sodium (salt) and cholesterol, adherence to the norms requires a reduction in consumption through reduced consumption of associated foods. Achievement of norms related to salt and cholesterol would substantially reduce ECC and may well have a large impact on obesity. The above results show that targeting the achievement of individual dietary norms in isolation could have very different effects and may have unintended adverse effects on ECC in certain cases.

The second half of Table-6 shows the effect of adherence to different combinations of dietary norms – the ones shown have the largest effect on ECC. Combined adherence to the saturated fats and NMES norms produces much larger reductions in ECC (18-19 percentage points) than adherence to individual norms. Interestingly, the effect of joint adherence to the saturated fats and NMES norms is attenuated (and even changes sign in the 95th quantile) when it is combined with the fruit and vegetable norm. When joint compliance with the saturated fats and NMES norms is combined with the fibre norm, ECC increases in all the quantiles. The ECC reducing effects of joint compliance with the saturated fats and NMES norms are considerably enhanced when combined with the norms for sodium intake.

Implications for Combating Obesity

We have modelled ECC as function of nutrient composition of diets, lifestyle factors, physical activity and demographic variables. Persistent excessive energy intake in relation to need unambiguously signals obesity risk. If the impact of nutrient composition of diets on obesity is mediated predominantly through its impact on calorie consumption, then our results provide a number of insights into how compliance with dietary norms is likely to influence the obesity distribution of the population. Effects of adherence to individual dietary norms vary considerably- thus, the obesity reduction gains or "returns" from adherence to different norms can be quite different. In general, adherence to individual macronutrient dietary norms in isolation (i.e., independently of other norms) is likely to produce relatively small impacts on the obesity distribution. This is because compliance with individual norms is not necessarily associated with significant reductions in excess calorie intakes. The high shares of fats and sugars in food energy intakes have been implicated as major factors responsible for the obesity "epidemic". However, our results suggest that compliance with fat and sugar norms may not lead to a large movement in the obesity distribution. The counterfactual decomposition exercise demonstrates that a large proportion of the population that complies with the norms continues to consume excessive calories. Compliance with the norms will not result in large changes in the obesity distribution, if as our analysis suggests, consumers are able to comply without significantly reducing calorie intake. In the case of proteins, the average share of energy derived from proteins is currently in excess of the norm and is inversely related to ECC. Compliance with the norm would call for a reduction in the share of energy derived from proteins and lead to an increase in ECC, with adverse effects for the obesity distribution. We recognise that compliance with individual macronutrient norms may have substantial health benefits related to the prevention of chronic disease – but from an obesity perspective, compliance with the norms is likely to have a limited impact.

Adherence to norms for fruit and vegetable and fibre consumption (where the current average consumption falls below the recommended norm) may have the impact increasing ECC, worsening the incidence of obesity. Dietary interventions targeting fruit and vegetable consumption (e.g., provision of free fruit to school children to meet the five-a-day norm) and fibre intake need to take into account these unintended consequences. The choice of the basket of foods through which compliance is achieved (their calorie content and the presence of other "unwanted" nutrients) is an important factor influencing obesity impacts. In the case of salt consumption, achievement of the norm can have a large effect on ECC and consequently on the obesity distribution. It should be noted that the ECC reducing effects of compliance with the salt norm may be (ironically) dampened by the efforts of the food industry to develop and market healthier product options (with lower salt content). This is because healthier option products make it easier for consumers to comply with the norm without substantially reducing calorie consumption.

It is only simultaneous compliance with dietary norms that can potentially have a large effect on ECC and make a significant contribution to combating obesity. For changing the obesity distribution of the population, dietary interventions will have to target combinations of dietary norms that potentially have the largest impact on ECC and hence on the risk of obesity. It is important to recognise that even when simultaneous compliance with all the recommended dietary norms is achieved, the ECC-reducing effects of compliance with certain norms may be (partially) offset by the ECC-increasing effect of compliance with other norms.

The foregoing results show that adherence to individual dietary norms, even if successfully achieved, has only a limited potential impact on the obesity profile of the population. Dietary interventions targeting individual dietary norms may not be effective in combating obesity. This provides an important clue to resolving the paradox of increasing obesity incidence even as the population moves towards healthier dietary choices. The other potentially important element explaining the paradox – the movement in opposite directions of the covariate effects (improved adherence to norms) and the co-efficient effects (effects of improved adherence) - is something that we propose to examine in future research using data previous comparable rounds of NDNS and data from the NDNS rolling programme from 2008-09 when it becomes available.

Conclusions

The promotion of healthier dietary choices and adherence to recommended dietary norms are important elements of the UK Government's efforts to combat the rising incidence of obesity. A range of dietary interventions are aimed at achieving compliance with individual dietary norms. These interventions may be undertaken by different agencies and may involve separate campaigns focusing exclusively on particular elements of healthy eating guidelines. Our results suggest the conformity with individual dietary norms, even if successfully achieved, is likely to have a relatively small impact on the emerging obesity profile of the population. In order to have significant impact on the incidence of obesity, dietary interventions need to adopt a more co-ordinated approach focusing on the simultaneous compliance with the range of dietary norms. In promoting compliance with dietary norms, dietary interventions need to explicitly consider the impact of compliance on excessive energy intakes to mitigate some of the unintended consequences of healthier dietary choices.

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Table-1: Recommended Dietary Intake Norms – UK and WHO

UK Dietary Norms[5]	
Nutrient	**Recommened amount**
Share of energy from:	
Total fat	<33%
Saturated fatty acids (SFAs)	10%
Monounsaturated fatty acids (MUFAs)	12%
Polyunsaturated fatty acids (PUFAs)	6-10%
Trans fatty acids (TFAs)	<2%
Glycerol	3%
Protein	10-15%
Free Sugars	<10%
Total carbohydrates	50%
Other nutrients	
Cholesterol	<300 mg/day
Fruit and Vegetables	>= 400 gms per day
Salt	<6 gms/day
Sodium equivalent	<2.36 gms/day
Total dietary fibre	>=18 gms/day
WHO Dietary Norms [6]	
Dietary factor	**Goals**
Total fat	15-30% energy
Saturated fatty acids	<10% energy
Polyunsaturated fatty acids (PUFAs)	6-10% energy
n-6 Polyunsaturated fatty acids (PUFAs)	5-8% energy
n-3 Polyunsaturated fatty acids (PUFAs)	1-2% energy
Transfatty acids	<1% energy
Monosaturated fatty acids (MUFAs)	By difference [a]
Total carbohydrate [b]	55-75% energy
Free sugars [c]	<10% energy
Protein	10-15% energy
Cholesterol	<300 mg/day
Sodium chloride (sodium)	<5 g/day
Fruits and vegetables	>= 400 g/day
Total dietary fibre	From foods

[a]This means “total fat – (saturated fatty acids + polyunsaturated fatty acids + trans fatty acids)”

[b]The percentage of total energy available after taking into account that consumed as protein and fat, hence the wide range.

[c]The term “free sugars” refers to all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey syrups and fruit juices.

Table-2: Trends in BMI Distribution of UK Adults

	Mean	25th percentile	Median	75th percentile	95th percentile	Percentage of adults overweight (BMI>25)	Percentage of adults obese (BMI>30)
1986-87[1]	24.74	21.80	24.07	26.69	32.48	40%	10%
2000-01[2]	26.85	23.30	26.19	29.40	36.01	61%	22%
2008-09[3]	27.36	23.32	26.58	30.11	37.53	62%	27%

[1] Computed from the Diet and Nutrition Survey of British Adults -1986-87(2)
[2] Computed from the National Diet and Nutrition Survey 2000-01(3)
[3] Computed from the National Diet and Nutrition Survey 2008-09(4)

Table-3: Trends in Adherence to Recommended Dietary Norms in the UK

	Year[1]	Mean	25th percentile	Median	75th percentile	95th percentile	Percentage of adults not conforming to UK guidelines
Share of food energy (%) from							
All fats	1986-87	40.35	37.44	40.52	43.59	47.94	93.1
	2000-01	35.37	31.48	35.63	39.39	44.91	67.6
	2008-09	34.80	31.21	35.10	38.48	43.08	64.7
Saturated fats	1986-87	16.76	14.69	16.70	18.76	21.93	98.4
	2000-01	13.32	11.28	13.27	15.24	18.40	85.0
	2008-09	13.24	11.19	13.10	15.13	18.42	86.6
Poly-unsaturated fats	1986-87	6.12	4.59	5.72	7.25	10.08	5.2
	2000-01	6.32	5.08	6.15	7.29	9.44	2.6
	2008-09	5.18	4.62	5.65	6.84	8.72	1.9
Mono- saturated fats	1986-87	12.30	10.99	12.25	13.53	15.72	54.0
	2000-01	11.75	10.18	11.75	13.36	15.71	45.2
	2008-09	12.34	10.70	12.31	13.98	16.38	55.6
Non-milk extrinsic sugars	1986-87[2]	19.3	14.99	19.08	23.27	29.61	69.9
	2000-01	12.77	8.26	11.74	12.77	15.98	62.5
	2008-09	13.5	8.89	12.63	17.04	25.15	69.5
Protein	1986-87	14.46	12.64	14.17	16.06	20.30	36.7
	2000-01	16.45	14.26	16.14	18.25	22.53	64.8
	2008-09	15.92	13.64	15.41	17.68	21.88	55.7
Consumption of							
Fruit and Vegetables (gms)	1986-87	216.6	-	-	-	-	-
	2000-01	276.8	133.59	231.64	382.29	647.69	77.6
	2008-09	300.6	175.63	273.69	395.32	610.26	75.8
Fibre (gms)	1986-87	21.71	15.8	20.57	26.33	36.50	66.4
	2000-01[3]	13	9	12	16	23	84.3
	2008-09[3]	12.09	8.71	11.39	14.51	21.05	88.6
Sodium (gms)	1986-87	2.85	2.18	2.73	3.43	4.73	66.9
	2000-01	2.76	2.08	2.60	3.32	4.53	62.4
	2008-09	2.13	1.54	2.02	2.57	3.68	34.3
Cholesterol (mg)	1986-87	334.1	235.35	313.07	410.02	590.16	53.9
	2000-01	255.6	172.2	236.7	319.42	479.37	29.6
	2008-09	-	-	-	-	-	-

Notes:
[1] Figures computed from the Dietary and Nutrition Survey of British Adults 1986-87(2) and from the National Diet and Nutrition Surveys for 2000-01(3) and 2008-09(4).
[2] Figures for 1986-87 are for share of food energy derived from all sugars.
[3] Figures for 2000-01 and 2008-09 are based on the Englyst method.

Table-4: Variable Description

Variable	Acronym	Units
Food energy from saturated fats	fesat	(%)
Food energy from polyunsaturated fats	fepufa	(%)
Food energy from monounsaturated fats	femono	(%)
Food energy from non-milk extrinsic sugars	fenmes	(%)
Food energy from proteins	feprot	(%)
Food energy from starch	festar	(%)
Fruit and vegetable consumption per day	fvgms	gms
Fibre consumption per day	fibregms	gms
Sodium consumption per day	sodium	gms
Cigarettes smoked per day	cigsaday	number
Alcohol consumption per day	alcogms	gms
Cholesterol consumption per day	chol	mg
Average daily physical activity score	phyactscore	Scores range from 33 (inactive) -100 (very highly active)
Age of respondent	respage	years
Gender of respondent	respsex-Female	Base category= Male
Ethnicity of respondent	ethnic-Asian	Base category= Whites
	ethnic-Black	
	ethnic-Others	
Occupational category of respondent	scresp-Manual	Base category= Non-manual

Table-5: Determinants of Excess Calorie Consumption: OLS and Quantile Regression Results

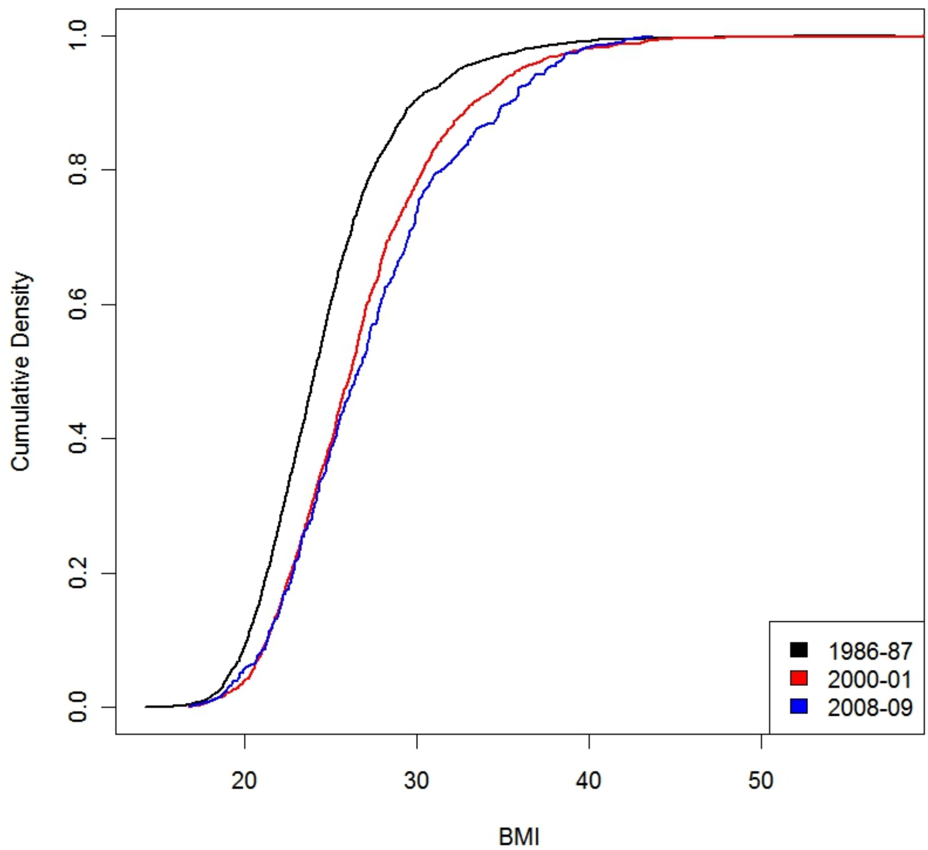
	OLS			QUANTILE REGRESSION														
Variable				**Tau=0.05**			**Tau=0.25**			**Tau=0.5**			**Tau=0.75**			**Tau=0.9**		
	Coeff	Std. Error	Pr(>|t|)	Coeff	Std. Error	Pr(>|t|)	Coeff	Std. Error	Pr(>|t|)	Coeff	Std. Error	Pr(>|t|)	Coeff	Std. Error	Pr(>|t|)	Coeff	Std. Error	Pr(>|t|)
Intercept	80.15	4.90	0.00***	89.89	9.89	0.00***	90.41	5.03	0.00***	90.58	4.42	0.00***	98.20	6.50	0.00***	112.76	6.39	0.00***
fesat	0.67	0.28	0.02**	0.65	0.50	0.19	0.55	0.28	0.05*	0.70	0.26	0.01***	0.92	0.36	0.01**	0.41	0.36	0.26
fepufa	0.12	0.35	0.74	-0.50	0.64	0.44	-0.08	0.33	0.81	0.03	0.30	0.92	0.04	0.49	0.94	-0.08	0.45	0.86
femono	-0.81	0.33	0.01**	-1.14	0.68	0.09*	-0.70	0.33	0.03**	-0.18	0.30	0.56	-0.30	0.42	0.48	-0.47	0.47	0.32
fenmes	0.76	0.19	0.00***	0.21	0.36	0.57	0.68	0.19	0.00***	0.94	0.18	0.00***	0.97	0.26	0.00***	0.89	0.24	0.00***
feprot	-2.20	0.27	0.00***	-2.30	0.48	0.00***	-1.88	0.27	0.00***	-1.85	0.25	0.00***	-1.95	0.35	0.00***	-2.24	0.34	0.00***
festar	-0.17	0.20	0.40	-0.59	0.36	0.11	-0.19	0.20	0.34	0.01	0.17	0.96	0.07	0.27	0.80	-0.22	0.24	0.35
fvgms	0.01	0.00	0.11	0.00	0.01	0.95	0.01	0.00	0.16	0.01	0.00	0.09*	0.01	0.01	0.21	0.00	0.01	0.45
fibregms	1.38	0.13	0.00***	1.04	0.24	0.00***	1.38	0.13	0.00***	1.47	0.15	0.00***	1.69	0.19	0.00***	1.83	0.20	0.00***
sodium	12.97	0.68	0.00***	11.17	1.51	0.00***	12.24	0.82	0.00***	13.05	0.69	0.00***	12.97	0.98	0.00***	12.80	1.09	0.00***
cigsaday	0.09	0.06	0.12	-0.15	0.14	0.29	0.07	0.07	0.32	0.10	0.07	0.15	0.11	0.07	0.13	0.16	0.13	0.22
alcogms	-0.20	0.02	0.00***	-0.10	0.06	0.09*	-0.14	0.03	0.00***	-0.20	0.03	0.00***	-0.21	0.04	0.00***	-0.24	0.03	0.00***
chol	0.08	0.01	0.00***	0.07	0.01	0.00***	0.08	0.01	0.00***	0.07	0.01	0.00***	0.07	0.01	0.00***	0.09	0.01	0.00***
phyactscore	-0.64	0.06	0.00***	-0.55	0.15	0.00***	-0.49	0.07	0.00***	-0.57	0.04	0.00***	-0.76	0.06	0.00***	-0.81	0.06	0.00***
respage	0.31	0.04	0.00***	0.19	0.09	0.03**	0.26	0.04	0.00***	0.33	0.04	0.00***	0.39	0.06	0.00***	0.34	0.07	0.00***
respsex-Female	-4.83	1.15	0.00***	-7.21	2.37	0.00***	-3.94	1.09	0.00***	-4.23	1.19	0.00***	-5.08	1.59	0.00***	-3.36	1.71	0.05**
ethnic-Asian	8.55	3.68	0.02**	12.34	3.70	0.00***	11.48	1.85	0.00***	8.75	1.95	0.00***	6.47	2.70	0.02**	2.89	1.81	0.11
ethnic-Black	3.76	3.70	0.31	5.79	3.35	0.09*	5.12	3.82	0.18	-0.42	2.45	0.86	6.05	2.58	0.02**	0.29	2.16	0.89
ethnic-Others	7.44	3.40	0.03**	15.87	2.77	0.00***	9.74	1.18	0.00***	7.11	1.64	0.00***	0.78	7.34	0.92	7.57	2.05	0.00***
screspManual	-0.92	1.00	0.36	-2.99	1.92	0.12	-4.45	1.13	0.00***	-2.36	1.09	0.03**	3.05	1.50	0.04**	2.25	1.38	0.10
	R^2 =0.72			Pseudo R^2 =0.71 Cells with significant p-values are highlighted. (***)= significant at 1%, (**)=significant at 5% and (*)=significant at 10% p-values of 0.00 represent very small values														

Table-6: Impact of Adherence to Dietary Norms on Excess Calorie Consumption (%)*

	Mean	25th percentile	Median	75th percentile	95th percentile	Percentage of adults not consuming excess calories
As predicted by model for dietary pattern in NDNS-2000-01	***109.40***	***89.90***	***108.00***	***127.20***	***158.77***	***38.44***
Impact of adherence to individual dietary norms						
All fats	104.10	84.91	102.82	121.13	154.12	46.02
Saturated fats	99.64	79.05	98.18	116.72	152.74	52.48
PUFA	110.70	90.16	108.12	128.60	162.44	37.86
Monosaturated fats	107.70	89.70	105.85	124.28	156.13	41.00
Non-milk extrinsic sugars	101.90	81.74	99.77	119.50	153.84	50.30
Protein	118.50	99.13	116.68	134.23	169.54	26.26
Fruit and Vegetable	122.40	102.81	120.16	139.58	175.80	21.36
Fibre	134.70	115.29	131.61	152.07	185.26	8.30
Sodium	88.84	73.13	88.78	103.53	126.70	70.04
Cholesterol	99.63	83.55	98.73	115.06	140.90	52.22
Impact of adherence to a combination of norms						
Saturated fat and non-milk extrinsic sugars	92.69	71.08	90.03	107.86	153.73	64.98
Saturated fats, non-milk extrinsic sugars and fruit and vegetables	106.30	84.57	100.84	120.86	171.23	48.72
Saturated fats, non-milk extrinsic sugar and fibre	116.90	96.59	112.84	135.04	173.67	29.26
Saturated fats, non-milk extrinsic sugars and sodium	76.81	62.40	74.11	90.90	114.11	85.74

* Computed as (Total calories consumed/Calorie requirement) x100.

Figure-1: Shifts in BMI Distribution of UK Adults 1986-87 -2008-09



Source: BMI distribution of UK adults computed from the Dietary and Nutrition Survey of British Adults 1986-87 (2) and from the National Diet and Nutrition Surveys for 2000-01 (3) and 2008-09 (4).

Figure-2A: Quantile Regression Graphs- Nutrient Intake Variables

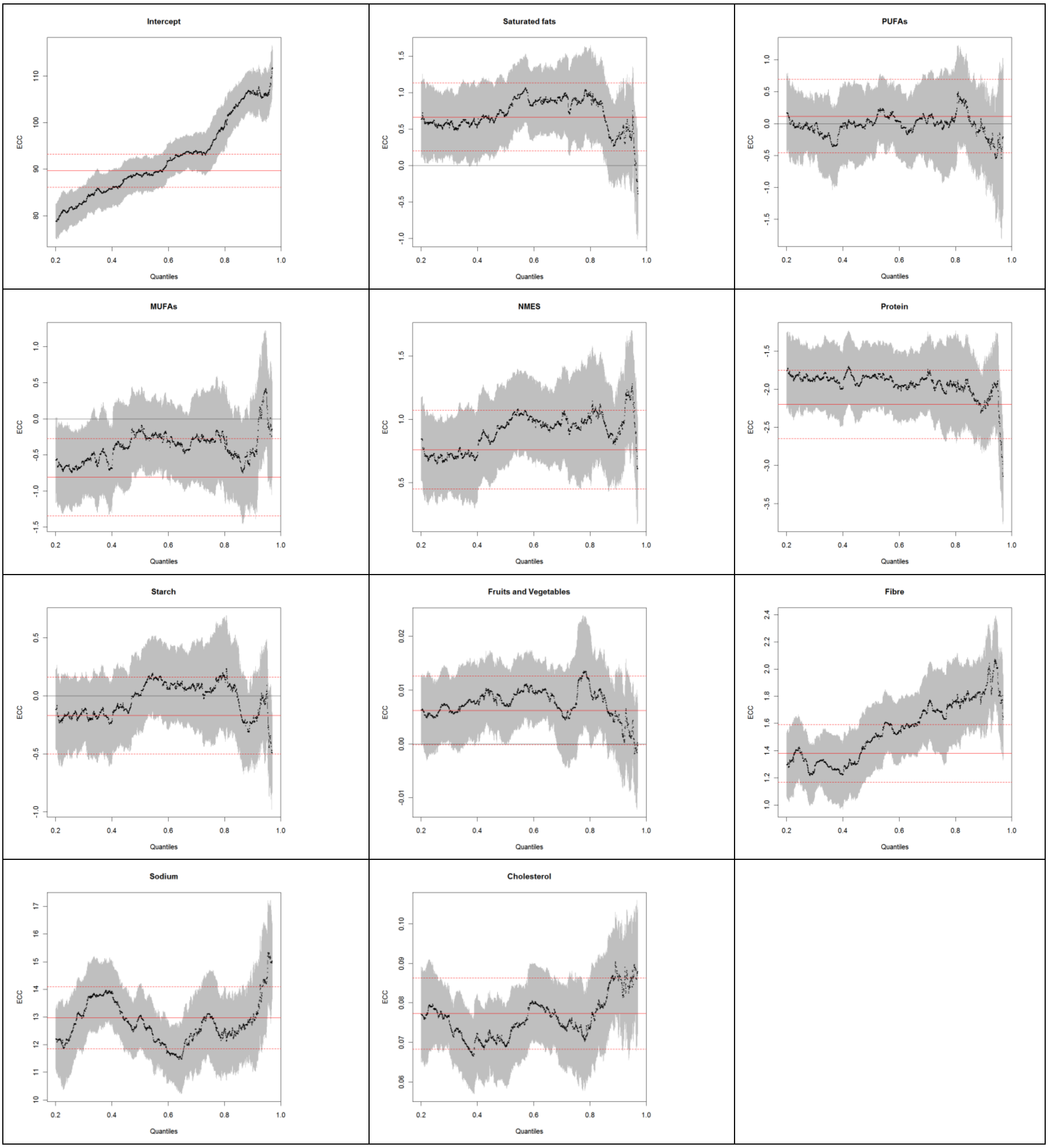


Figure-2B: Quantile Regression Graphs- Lifestyle, Physical Activity and Demographic factors

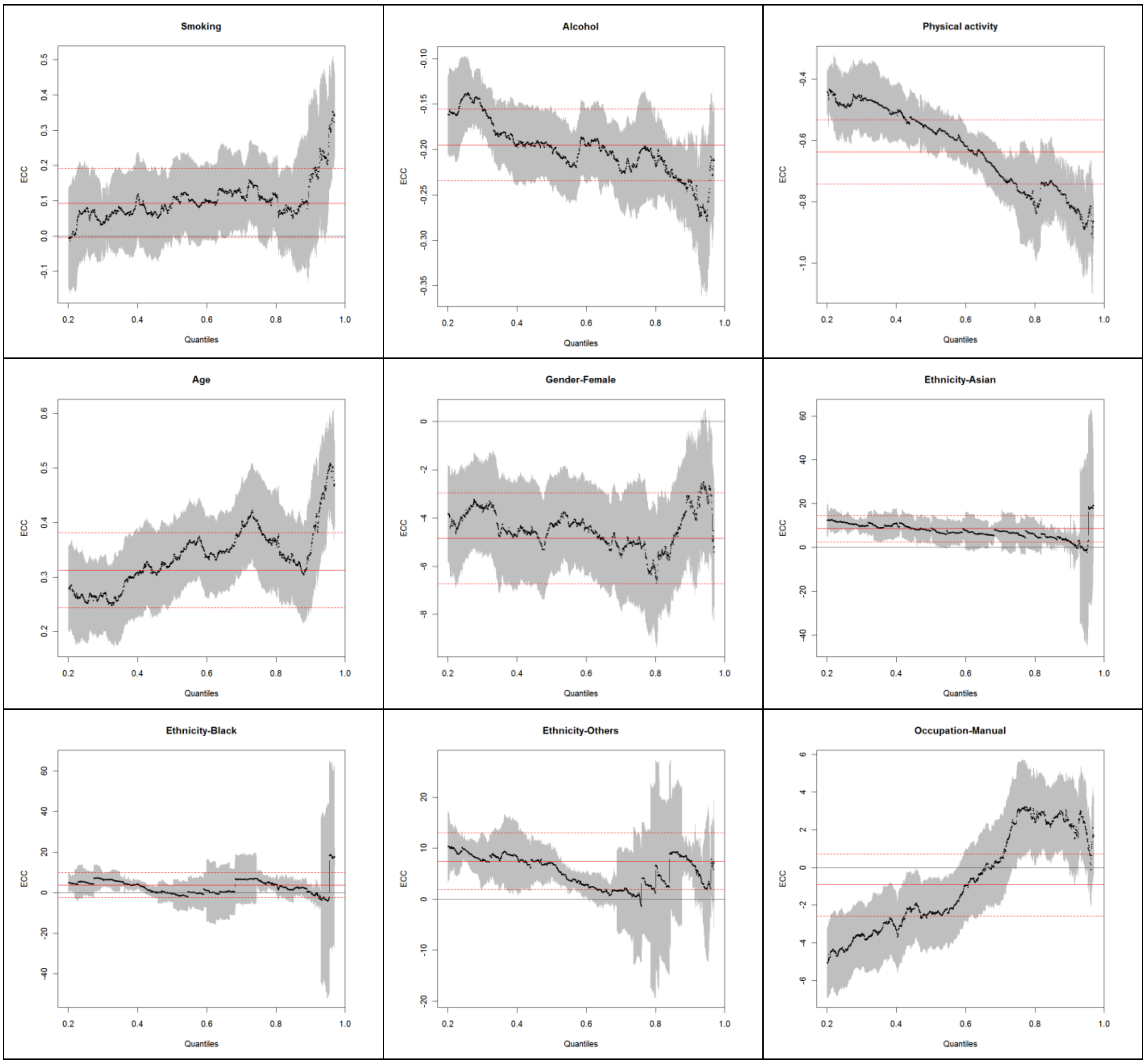


Figure-3: Impact of Adherence to Individual Dietary Norms on Excess Calorie Consumption

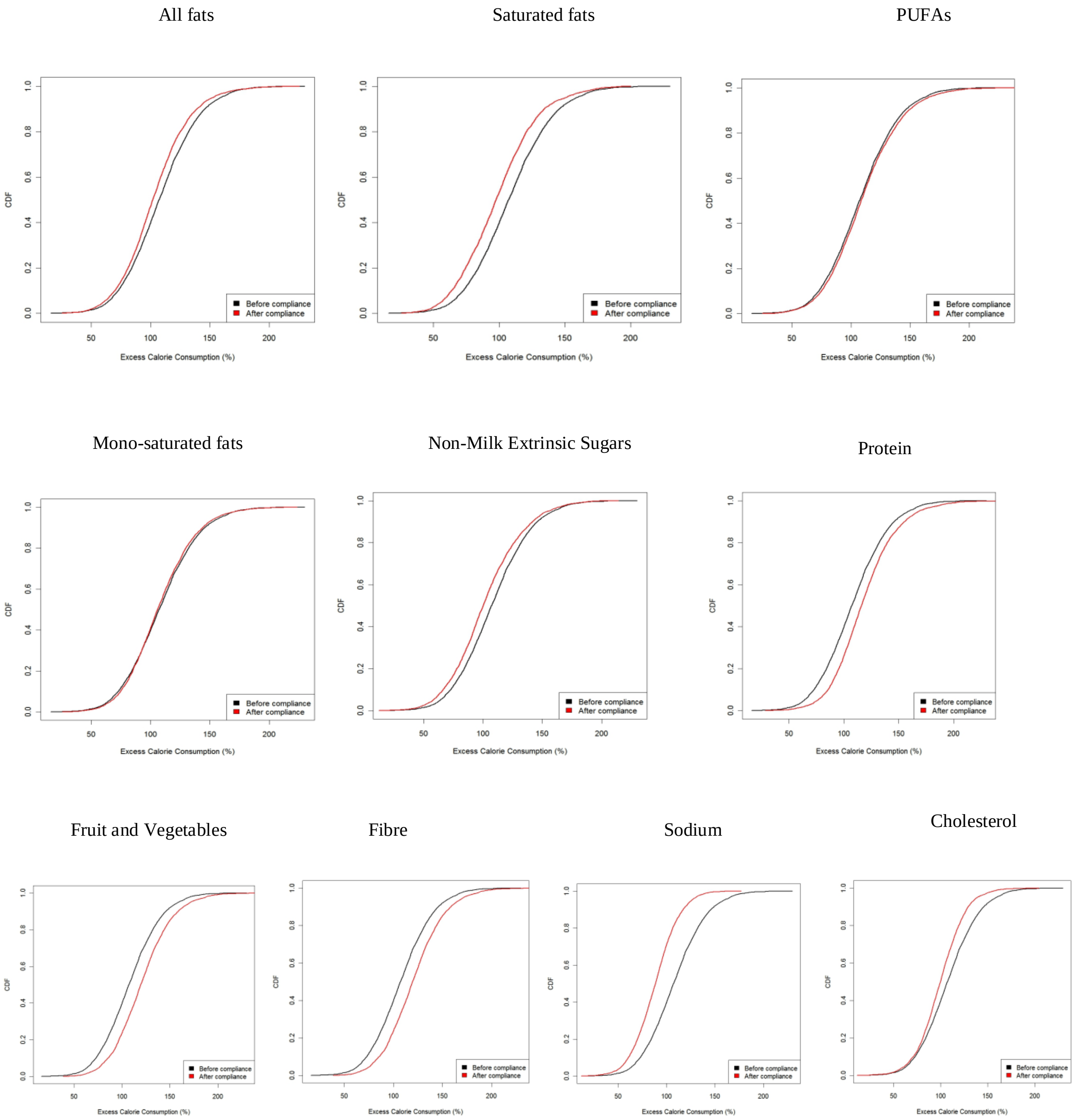


Figure-4: Impact of Adherence to Combination of Dietary Norms on Excess Calorie Consumption