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The effect of food prices and household income on the British diet

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Non-technical summary

The effects of obesity on current and future health and health costs are evident from growing number of cases of diseases related to excessive body weight, the rise in the number of medical treatments for conditions associated with obesity and the increase in indirect costs of obesity. Researchers have raised concerns about the future as they forecast that if the average rate of increase in the prevalence of obesity between 1980 and 1998 continues, almost half of all children in Britain will be overweight by 2050 (UK Dept. of Health, 2004; 2006). Most recently, rising food prices and shrinking incomes driven by the recent financial and economic crisis have affected food choices resulting in higher consumption of fatty foods and lower purchases of fruit and vegetables. Therefore understanding how economic factors may affect consumers decision is particularly important from a policy and public health perspective. This paper investigates the effect of changes in food prices and household income on the demand for food and diet composition of British households in the period 1975-2000.

It explores the role of food prices and income over time on consumers food choices and it studies their indirect impact on diet composition in term of nutrients such as calories, fats, carbohydrates and proteins. In fact when a food i becomes more expensive, consumers are expected to respond by decreasing their demand for food i and, where possible, substituting it with another food relatively less expensive. Other foods consumption may also change if they are complementary to food i (if consumers buy less bread they may buy also less butter). Furthermore, because different foods provide different nutrients, it is likely that also diet composition changes as a consequence of food i 's price rising. Similarly, variations of household's income may also affect demand for food and nutrients.

This work contributes to the existing literature linking the economic determinants of food choices, such as food prices and household income, with changes in the composition of the British diet expressed by changes in nutrient intakes. Own- and cross- prices and expenditure elasticities of food are compared over time and they are used to calculate nutrient elasticities, which are also examined over time.

The findings suggest that as households become richer, the substitution between foods is quicker than the variation of diet through substitution of nutrients. Indeed there is little evidence of changes through time in income elasticities for nutrient intake, although there are some effects of family income variation on food consumption. Price changes would leave expenditure almost unchanged as demand for food falls and rises at a similar rate as prices increase and decrease. This is reflected in the demand for nutrients indicating that the average daily individual caloric intake would change very slowly following changes in food prices.

The effect of food prices and household income on the British diet

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Abstract

This paper investigates the effect of price variations on the diet composition in Britain. It describes the dynamics of food demand in relation to food prices over time using data from the British National Food Survey (NFS) covering the period 1975-2000. Demand elasticities with respect to price elasticities are estimated by solving a quadratic almost ideal demand system (QUAIDS) model controlling also for total expenditure on food, region of residence, household size, age of head of household, whether women are working, number of time in which the household buys ready food, household type and income quartiles. Focusing on the "consumption technology" function, effects of food price variation on calories intake, energy from fats and energy from carbohydrate have been explored deriving nutrients elasticities with respect to variation of food prices.

Keywords: time-series of cross-section household survey data, food and nutrient demand and elasticities, prices, total food expenditures.

JEL codes: D1, D12, H31, I18

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1 Introduction

This paper investigates the effect of changes in food prices and expenditure on the diet composition of Britain from 1975 to 2000. This is particularly important from a policy and public health perspective in relation to the high and fast-rising obesity rate observed in Britain since the middle of the 1980s. Indeed the effects of obesity on health and health costs are evident from growing number of cases of diseases related to excessive body weight (WHO and FAO, 2002), the rise in the number of medical treatments for conditions associated with obesity (Health Committee, 2004) and the increase in indirect costs of obesity related to a fall in productivity, inability to work, low self-esteem and discrimination (Pagan and Davila, 1997; Cawley, 2004; Finkelstein et al., 2005; Atella et al., 2007). Furthermore, particular concern arises about the future as researchers have forecast that if the average rate of increase in the prevalence of obesity between 1980 and 1998 continues, almost half of all children will be overweight by 2050 (UK Dept. of Health, 2004; 2006). Thus it is urgent to find an answer to the following question: what could be done to reverse the obesity trend?

With the aim of gaining some insight into the origin of the upward trend of obesity, this study explores the role of food prices and expenditure over time on consumers food choices and it studies their indirect impact on diet composition in term of nutrients. In fact when the price of one food i goes up, consumers will probably respond by decreasing the demand for that food and increasing the demand for another that is relatively less expensive. Consumption of other foods could also change if they are complementary to food i . Furthermore, because different foods provide different nutrients, it is likely that also diet composition changes with variations in food prices and expenditure.

Over the last few decades, the literature on consumer demand theory and its linkage with econometric methods have stimulated much empirical analysis of consumer behaviour (Deaton and Muellbauer, 1980b; Blundell, 1988; Browning and Meghir, 1991; Blundell et al., 1993, 1994; Dhar et al., 2005; Moro and Skokai, 2000; Farrell and Shields, 2007; Blundell and Stoker, 2005) and a large number of econometric specifications have been proposed for the representation of consumer preferences (Stone, 1954; Jorgenson et al., 1980, 1982; Deaton and Muellbauer, 1980a; Blundell, 1988; Banks et al., 1997).

Although most of the studies on expenditure patterns of British households focus on quite general good categories, and food is usually considered as one aggregate class of items as well as clothes, entertainment, etc. (Blundell et al., 1993, 1994; Blundell and Stoker, 2005), a few studies have looked at food in more detail. For example Blundell and Robin (2000), examining latent separability among commodities, consider, among other goods, six categories of food (i.e. bread, dairy, meat and fish, vegetables and fruit, other food and eating out). Alternatively Lechene (2000) estimates patterns of expenditure on meat, meat products and fish using data from the NFS 1979-1999. However only a few studies have attempted to estimate demand for nutrients (Pitt, 1983; Behrman, 1988; Subramanian and Deaton, 1996; Behrman and Deolalikar, 1990; Strauss and Thomas, 1990; Huang, 1996, 1999; Huang and Lin, 2000). Most of them describe demand equations for specific nutrients as functions of income or total expenditure and socio-demographic characteristics. Others derive the effects of prices and income on nutrients demand using elasticities. However, to the best of my knowledge, no research has been conducted yet on income and the price elasticities of nutrients for the UK.

This work contributes to the existing literature deriving nutrient elasticities for the UK linking the economic determinant of food choices, such as food prices and expenditure, with changes of nutrient intake. In addition, changing effects over time are also studied, showing the trend of prices and income elasticities.

The data used are the 1975-2000 National Food Survey (NFS) for the UK covering 130,728 households

over a 26-year period. The main advantage of using these instead of diet and nutritional individual data is that people are asked about what they buy and not directly about what they eat, so that they feel the interview less invasive and they have less incentive to misreport (Chesher, 1997). Moreover, data on quantity and expenditure of food purchased for more than 200 foods are recorded, allowing the derivation of unit values for each household. The energy value and nutrient content of each food are also provided by the NFS. Here I focus on nine nutrients, such as calories, fat, proteins, carbohydrate, animal proteins, vegetable proteins, iron, calcium, vitamin C as well as energy from fat, protein and carbohydrate.

The empirical results are based on a Quadratic Almost Ideal Demand System (QUAIDS) (Banks et al., 1997) that relates the household share of expenditure on six food groups (dairy products, meat and fish, fat and sugar, vegetables and fruit, cereals and other food) with food prices, total food expenditure and household characteristics, such as region of residence, household size, age of head of household, presence of children by three age groups, women's participation in the labour market, number of time per week in which the household buys ready food and household composition. Own- and cross- prices and expenditure elasticities of food are compared over time and they are used to calculate nutrient elasticities, which are also examined over time.

The facts that the "relevant income" in demand estimation is total expenditure rather than total income (Gorman, 1959¹) and that there may have been errors in the measurement of expenditure (Pudney, 1989) raise the issue of the endogeneity of total expenditure. The usual practice is to treat expenditure as exogenous (Dhar et al., 2005), however in this paper I address this issue by applying instrumental variables estimation for the logarithm of total food expenditure instrumented by household income (Blundell and Robin, 2000).

The paper is organized as follows: section 2 surveys the demand models available in the literature. Section 3 describes the demand model applied in this particular case and derives price and expenditure elasticities for nutrients, section 4 describes the empirical application focusing in particular on the data description and reporting the results. Section 5 concludes.

2 General Framework

The main questions that I want to address are the following: how do households allocate their expenditure across different food groups? how does this affect diet composition? and, has this effect changed over time?

Since income varies across individuals and income elasticities vary across goods, the study of the relationship between expenditure and income (the Engel curve) has been the object of many applied microeconomic works (Deaton and Muellbauer, 1980b). The linear functional form of Engel curves relating budget shares to logarithm of expenditure is known as the Working-Leser form after the two researchers who first proposed and applied it in 1943 and 1963 respectively:

$$w_i = \alpha_i + \beta_i \ln x$$

where adding up condition implies that $\sum_i w_i = 1$, thus $\sum_i \alpha_i = 1$ and $\sum_i \beta_i = 0$.

However, a complete description of consumer behaviour requires a specification of both the Engel curve and relative price effects. Thus, over the last few decades, the literature on consumer demand

¹This is the two-stage budgeting process, for which total income at the first stage is divided between consumption and saving, while at the second stage it is divided across the expenditure categories.

theory and its linkage with econometric methods have stimulated the empirical analysis of consumer behaviour (Browning and Meghir, 1991; Blundell et al., 1994; Dhar et al., 2005; Moro and Skokai, 2000; Farrell and Shields, 2007; Chesher and Lechene, 2002) and a large number of econometric specifications have been proposed for the representation of consumer preferences (Stone, 1954; Jorgenson et al., 1980, 1982; Deaton and Muellbauer, 1980a; Blundell, 1988; Banks et al., 1997).

The empirical problem is to characterize budget allocation to several categories of commodities (Blundell and Stoker, 2005) in order to explain how category expenditures relate to prices and the distribution of household income. The basic approach involves estimating Marshallian demand functions, expressing quantities consumed as functions of prices and household expenditure $q_i = f(p, m)$.

The first applications were based on the *Linear Expenditure System* model of Stone (1954). Stone's model starts from a general linear formulation of demand and mathematically imposes the theoretical restrictions of adding up, homogeneity and symmetry. His study models commodity demands equation by equation, so that, if necessary, the functional form can be varied and special explanatory variables could be introduced in each equation. According to Deaton and Muellbauer (1980a), this approach has the great advantage of flexibility and is the best way of modelling the demand for an individual commodity. However, they also point out that only the homogeneity restriction has any immediate consequence for a single equation so that the theory plays a relatively minor role.

At the beginning of the 1980s two models of demand have been proposed. One considers the budget shares in semi-log form and is known as the *translog models* of Jorgenson et al. (1980, 1982). The other, proposed by Deaton and Muellbauer, is known as the *Almost Ideal Demand System (AIDS)* and adopts a flexible functional form for the indirect utility function developed from a general class of Price-Independent Generalized Logarithmic (PIGLOG) models to avoid non-linearity in the share equations (Blundell, 1988).

All of these specifications possess some attractive characteristics, such as homotheticity, homogeneity and symmetry. However, they restrict preferences to be linear with respect to the logarithm of income. In this direction of functional form specifications Banks, Blundell and Lewbel in 1997 investigate a higher order of income terms, generalizing the AIDS model from Deaton and Muellbauer adding a quadratic logarithmic income term. Their model is known as the *Quadratic Almost Ideal Demand System (QUAIDS)*. Imposing particular restrictions on the parameters of this model, it can be reduced to either the Almost Ideal model of Deaton and Muellbauer and the Translog model of Jorgenson et al. (1982).

The empirical application presented in this paper is based on the QUAIDS model estimated on six food groups. Thus the following section will explain in detail the theoretical derivation of this model, considering also some typical econometric issues.

3 Demand Model

Let $U^h(q)$ be the direct utility function for a household h , representing a joint utility function for all members of the household, increasing monotonically, continuously twice differentiable and strictly quasi-concave over a bundle of n goods (foods) $q = (q_1, q_2, \dots, q_n)$. The basic behavioural hypothesis of the economic theory of consumer demand is that households choose the basket of n goods that maximizes their utility given a vector of prices p and subject to their budget constraint².

²The traditional model describes household decisions making in a unitary fashion where all household members are assumed to maximize jointly a household utility function. Essentially, the household is treated as if it acts as a single individual or as if one member of the family acts as a dictator; hence,

$$\max U^h = u^h(q_1, q_2, \dots, q_n)$$

subject to:

$$m = \sum_{i=1}^n p_i q_i$$

$$q_i \geq 0$$

From which, given a predetermined total food expenditure m (Gorman, 1959), the optimal quantity demanded is $q^* = (q_1^*, q_2^*, \dots, q_n^*)$ where each component $q_i = f(p_1, \dots, p_n, m)$ is the set of Marshallian demand functions for food i corresponding to $U^h(q)$.

3.1 How to Derive the QUAIDS Model

Define the indirect utility function $V^h(p, m)$ corresponding to U^h to be:

$$V^h(p, m) = \left[\left(\frac{\ln m - \ln a(p)}{b(p)} \right)^{-1} + \lambda(p) \right]^{-1} =$$

$$= \left[\frac{b(p)}{\ln m - \ln a(p)} + \lambda(p) \right]^{-1} =$$

$$= \frac{\ln m - \ln a(p)}{b(p) + \lambda(p)[\ln m - \ln a(p)]}$$

where $\frac{\ln m - \ln a(p)}{b(p)}$ is the indirect utility function PIGLOG and $\lambda(p)$ is a function of prices p differentiable and homogeneous of degree zero, whilst $\ln a(p)$ and $b(p)$ are price indexes from the AIDS model:

$$\ln a(p) = \alpha_0 + \sum_k \alpha_k \ln p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj}^* \ln p_k \ln p_j$$

$$b(p) = \prod_i p_i^{\beta_i} = \exp\left(\sum_i \beta_i \ln p_i\right)$$

$$\lambda(p) = \sum_i \lambda_i \ln p_i$$

that substituted into the QUAIDS indirect utility function $V^h(p, m)$ gives:

$$V^h(p, m) = \left[\left(\frac{\ln m - (\alpha_0 + \sum_k \alpha_k \ln p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj}^* \ln p_k \ln p_j)}{\prod_i p_i^{\beta_i}} \right)^{-1} + \sum_i \lambda_i \ln p_i \right]^{-1} \quad (1)$$

which corresponds to the following cost function:

all resources are pooled and then reallocated according to some common rule. In contrast, in 1988 Chiappori proposes the collective family behaviour model that represents the household as maximizing a social welfare function that depends on single individual utility functions (one for each member of the household) (Chiappori, 1992; Browning et al., 2006). That could be implemented in a future work.

$$\ln c(u, p) = \alpha_0 + \sum_k \alpha_k \ln p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj}^* \ln p_k \ln p_j + \frac{u \prod_i p_i^{\beta_i}}{1 - u \sum_i \lambda_i \ln p_i}$$

$$\ln c(u, p) = \ln a(p) + \frac{ub(p)}{1 - u\lambda(p)} \quad (2)$$

In the case that all $\lambda_i = 0$ the above equation reduces to the AIDS cost function.

Applying Shephard's Lemma³ to [2] and substituting u for the indirect utility function [1] in the cost function [2] Banks, Blundell and Lewbel obtain the QUAIDS budget shares equations.

$$w_i = \alpha_i + \frac{1}{2} \sum_k \gamma_{kj}^* \ln p_k + \beta_i \left[\ln \frac{m}{a(p)} \right] + \frac{\lambda_i}{b(p)} \left[\ln \frac{m}{a(p)} \right]^2 \quad (3)$$

Shephard's Lemma. The budget share equation is the log price derivative of the consumers expenditure function:

$$\frac{\partial \ln C(u, p)}{\partial \ln p_i} = \frac{p_i q_i}{C(u, p)} = w_i$$

thus

$$\begin{aligned} w_i &= \alpha_i + \frac{1}{2} \sum_k \gamma_{kj}^* \ln p_k + \frac{u\beta_i \exp(\sum_k \beta_k \ln p_k) (1 - u \sum_k \lambda_k \ln p_k) - u \exp(\sum_k \beta_k \ln p_k) (-u\lambda_i)}{[1 - u \sum_k \lambda_k \ln p_k]^2} \\ &= \alpha_i + \frac{1}{2} \sum_k \gamma_{kj}^* \ln p_k + \frac{u\beta_i b(p) (1 - u\lambda(p)) + u^2 b(p) \lambda_i}{[1 - u\lambda(p)]^2} \end{aligned}$$

and substituting u with $V^h(m, p)$ one obtains the QUAIDS budget shares equations.

3.1.1 Properties of Demand:

Adding up: The total value of demands is total expenditure. That is,

$$\sum_i p_i h_i(u, p) = \sum_i p_i q_i(m, p) = m$$

where $h_i(u, p)$ represents the Hicksian demand quantity and $q_i(m, p)$ the Marshallian demand quantity. From the condition above it derives that $\sum w_i = 1$, where $w_i = \frac{p_i q_i}{m}$.

Homogeneity: The cost function $C(u, p)$ is linear homogeneous of degree one on the vector of prices p_i . Hence the Hicksian demands h_i are homogeneous of degree zero⁴. From the Euler equation this implies that always

$$\sum_i \frac{\partial \ln C(u, p)}{\partial \ln p_i} = 1 \Rightarrow \sum_i w_i = 1$$

Thus using the QUAIDS cost specification:

³Or Roy's identity.

⁴Because they are the derivatives of a function homogeneous of degree one.

$$\frac{\partial \ln C(u, p)}{\partial \ln p_i} = w_i = \alpha_i + \frac{1}{2} \sum_k \gamma_{kj}^* \ln p_k + \beta_i \left[\ln \frac{m}{a(p)} \right] + \frac{\lambda_i}{b(p)} \left[\ln \frac{m}{a(p)} \right]^2$$

then the homogeneity restrictions give:

$$\alpha_i + \frac{1}{2} \sum_k \gamma_{kj}^* \ln p_k + \beta_i \left[\ln \frac{m}{a(p)} \right] + \frac{\lambda_i}{b(p)} \left[\ln \frac{m}{a(p)} \right]^2 = 1$$

for all p_i and u this implies that:

$$\begin{aligned} \sum_i \alpha_i &= 1 \\ \sum_k \gamma_{kj}^* \left(= \sum_j \gamma_{jk}^* \right) &= 0 \quad \forall j = 1, \dots, N \\ \sum_i \beta_i &= 0 \\ \sum_i \lambda_i &= 0 \end{aligned}$$

Symmetry: The matrix of second derivatives with respect to prices $\frac{\partial^2 \ln C(u, p)}{\partial (\ln p)^2}$ should be symmetric. Based on the above QUAIDS cost function specification, this implies that

$$\gamma_{ij} = \gamma_{ji} \quad \forall i \neq j, i, j = 1, \dots, N$$

thus this condition generates $\frac{(N^2 - N)}{2}$ symmetric restrictions.

Negativity: the n -by- n matrix formed by the elements $\frac{\partial h_i(u, p)}{\partial p_j}$ is negative semi-definite, that is, for any n vector ξ , the quadratic form

$$\sum_i \sum_j \xi_i \xi_j \frac{\partial h_i(u, p)}{\partial p_j} \leq 0$$

For convenience the matrix of $\frac{\partial h_i(u, p)}{\partial p_j}$ is usually denoted by S to indicate the *substitution matrix* or *Slutsky matrix* of compensated price responses. By the last two properties, S is symmetric and negative semi-definite. The diagonal elements must be non-positive for all i . Thus, an increase in price with utility held constant must cause demand for that good to fall or at least remain unchanged.

3.2 Household Food Demand

The optimal household food demand $q_i^* = f(p_1, p_2, \dots, p_n, m)$ in the QUAIDS model (Banks et al., 1997) is determined solving the following system of n equations:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln \left(\frac{m}{a(p)} \right) + \frac{\lambda_i}{b(p)} \left[\ln \left(\frac{m}{a(p)} \right) \right]^2 \quad (4)$$

where $a(p)$ and $b(p)$ are respectively a price index defined as:

$$\ln a(p) \equiv \alpha_0 + \sum_i \alpha_i \ln p_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j$$

and the Cobb-Douglas price index:

$$b(p) = \prod_i p_i^{\beta_i}$$

w_i represents shares of expenditure on food i :

$$w_i = \frac{p_i q_i}{\sum_i p_i q_i} = \frac{p_i q_i}{m}$$

and m is the total expenditure on all foods in the demand system. Economic theory imposes the following constraints on the parameters deriving from the fact that $\sum_i w_i = 1$ and that the cost function should be homogeneous of degree 1:

$$\sum_i \alpha_i = 1 \quad \sum_i \beta_i = 0 \quad \sum_i \lambda_i = 0 \quad \sum_i \gamma_{ij} = 0 \quad \forall j$$

and, since demand functions are homogeneous of degree zero in (p, m) , also:

$$\sum_j \gamma_{ij} = 0 \quad \forall j$$

Finally, Slutsky symmetry implies that:

$$\gamma_{ij} = \gamma_{ji}$$

3.3 Expenditure Endogeneity and Measurement Errors

There are two important empirical issues that need to be addressed. The first is the possible endogeneity of total expenditure (Blundell and Robin, 2000; Blundell et al., 1994; Dhar et al., 2005; Farrell and Shields, 2007). The second is the possible measurement error occurring in household expenditure data (Pudney, 1989; Kedir and Girma, 2003; Lewbel, 1996).

3.3.1 Endogeneity of Total Expenditure

Demand theory assumes that income is exogenous to expenditure, but in the empirical specification, to ensure that the sum of budget shares equals one, income is defined as the sum of total expenditures across the food groups.

Households choose their consumption pattern subject to a budget constraint. Considering the two-stage budgeting process (Gorman, 1959) under which consumers allocate expenditure first to broad commodity groups and then to detailed within-group demands, it enables allocations within groups to be determined solely by the within-group relative prices and the allocation of expenditure to that group. Thus the relevant income is total expenditure (not total income) as total income also takes into account savings. Hence total expenditure ($m = \sum_i m_i$) is endogenous with the budget share w_i in the QUAIDS model.

The obvious solution to endogeneity is to employ instrumental variables estimation.

3.3.2 Measurement Error

Recent studies on British data report that the observed mean household total expenditure over-estimates the mean of the "true" total expenditure (Hikaru and Kozumi, 2001).

The presence of measurement error has been recognized in the literature of Engel curves estimation (Pudney, 1989; Lewbel, 1996). Household expenditure usually suffers from survey errors such as interviewer's errors and errors due to respondents. Moreover they involve positive as well as zero purchases. As pointed out by Pudney (1989), "the behavioural information provided from zero expenditure observations has significant econometric and economic implications as they may represent a choice that needs to be explained. In fact zeros may represent infrequent purchases, choice of not consuming particular goods given current prices and households budget constraint, as well as, they may represent misreporting or mis-measurement". Another source of error could also derive from the difference between purchases and consumption due to storage or waste, as noticed by Lewbel⁵ (1996).

When expenditure data are contaminated with measurement errors, the most common solution of the problem is to use instrumental variables to address the regressor-error correlation arising in an endogeneity problem (Hikaru and Kozumi, 2001; Newey, 2001; Hausman et al., 1994; Lewbel, 1996).

Thus the instrumental variable approach will help to solve both the potential endogeneity and the measurement error issues in the total expenditure variable. Identification requires that the vector of instruments, z , should be correlated with total expenditure but not with the error term. Following the existing literature (Blundell and Robin, 2000; Blundell et al., 1998), the estimated reduced form equation for the logarithm of total food expenditure in addition to all the exogenous variables in the model, contains the total household income as instrument. Indeed total income at the first stage of the budgeting process is highly correlated with total expenditure at the second stage of the budgeting process, but it is exogenous to the specific expenditure on a certain food i .

The results from regressing the logarithm of total expenditure on the instrument as well as the other explanatory variables in the models, are statistically significant in each year considered⁶.

3.4 Demographic Translating of the QUAIDS Model

Demand for food may depend on many things, such as "the shape of Engel curves, the amount of substitution between goods, demographic composition of the household and the labour market status of the household" (Blundell et al., 1994). This subsection considers the way in which observable heterogeneity (demographics in this case) can enter into the demand model. Indeed, household preferences differ depending on its size and composition, as well as the age and needs of household members. If no socio-demographic variables were included in the model, it would be like making the assumption that all households behave in the same manner in choosing the foods, in order to maximize their utility (Betti, 2000). Indeed this is not the case.

There are different ways in which researchers have introduced household demographic characteristics into the utility function. The Appendix contains a summary.

⁵Lewbel (1996) dealt with the expenditure measurement errors on both the left- and right-side variables of the Working-Leser specification of Engel curves applying an efficient estimator, which is constructed from a generalized method of moments (GMM) estimator. He shows that correction for measurement error can change parameter estimates by more than 15 percent.

⁶Full estimates for each year of survey are available on request.

This study applies the demographic translating method to incorporate socio-demographic characteristics of the household (Dhar et al., 2005). Those the above QUAIDS specification can be modified, assuming that the intercepts $\alpha_i(d^h)$ takes the form $\alpha_i(d^h) = \alpha_i + \sum_{s=1}^S \alpha_{is} d_s^h$ for each food $i = 1, \dots, N$; where d is a vector of socio-demographic variables affecting household preferences and consumption behaviour. Then, household preferences are given by the utility function $U(q, d)$, that now varies both with the vector of consumption goods (foods in this case) and household characteristics d . As before, the household faces the budget constraint $pq \leq m$, where m is household total food expenditure, and p is a vector of prices for q . The household decisions are given by the maximization problem:

$$\max U^h = u^h(q_1, q_2, \dots, q_n, d^h)$$

subject to:

$$\begin{aligned} m &= \sum_{i=1}^n p_i q_i \\ q_i &\geq 0 \end{aligned}$$

Thus the budget share equations for the QUAIDS model, including socio-demographic variables, become:

$$w_i = \alpha_i(d^h) + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln \left(\frac{m^h}{a(p, d^h)} \right) + \frac{\lambda_i}{b(p)} \left[\ln \left(\frac{m^h}{a(p, d^h)} \right) \right]^2 \quad (5)$$

where

$$\alpha_i(d^h) = \alpha_i + \sum_{s=1}^S \alpha_{is} d_s^h$$

so that also the price index changes:

$$\ln a(p, d^h) \equiv \alpha_0 + \sum_i \left(\alpha_i + \sum_s \alpha_{is}(d_s^h) \right) \ln p_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j$$

while the Cobb-Douglas price index remains as before because it does not depend on α_i :

$$b(p) \equiv \prod_i p_i^{\beta_i}$$

The theoretical restrictions consequently vary. The symmetry restriction remains the same as before

$$\gamma_{ij} = \gamma_{ji} \quad \forall i \neq j, i, j = 1, \dots, N$$

Whilst the adding up and homogeneity restrictions require that for all p_i and u :

$$\begin{aligned} \sum_i \alpha_i &= 1 & \sum_i \alpha_{is} &= 0 \\ \sum_k \gamma_{kj}^* (= \sum_j \gamma_{jk}^*) &= 0 & \forall j &= 1, \dots, N \\ \sum_i \beta_i &= 0 \\ \sum_i \lambda_i &= 0 \end{aligned}$$

3.5 Price and Income Elasticities of Food Demand

Expenditure elasticities of share are defined as⁷:

$$\mu_i \equiv \frac{\partial w_i}{\partial \ln m} = \beta_i + \frac{2\lambda_i}{b(p)} \left[\ln \left(\frac{m}{a(p)} \right) \right]$$

Own and cross price elasticities of share are:

$$\mu_{ij} \equiv \frac{\partial w_i}{\partial \ln p_j} = \gamma_{ij} - \mu_i \left(\alpha_j + \frac{1}{2} \sum_i \gamma_{ij} \ln p_i \right) - \frac{\lambda_i \beta_i}{b(p)} \left[\ln \left(\frac{m}{a(p)} \right) \right]^2$$

From which the elasticities of demand with respect to expenditure and prices are respectively:

$$\epsilon_i = \frac{\mu_i}{(w_i + 1)}$$

$$\epsilon_{ij}^u = \frac{\mu_{ij}}{w_j} - \delta_{ij}$$

with $\delta = 1$ if $i = j$ and $\delta_{ij} = 0$ if $i \neq j$. Where e_{ij}^u is the uncompensate (from Marshallian demand) Slutsky elasticity.

Income elasticity expresses the proportionate change in quantity of a food demanded due to a unit proportionate change in household income, prices and household characteristics held constant. For "normal" goods, elasticity is usually positive, ranging between 0 and 1, indicating that the quantity demanded (and therefore also expenditure) increases as income rises but less than proportionally to the rate at which income increases. However, some goods may show demand rising faster than income as income increases ($\epsilon_i > 1$). These are called luxury goods. Conversely, demand for "inferior" goods decreases when income increases ($\epsilon_i < 0$).

Price elasticity indicates proportional changes in demand for a good in relation to 1% variation of its own price or other goods' prices. Its own price elasticities are expected to be negative, indicating that an increase in the price of a good leads to a decrease in the demand for that good. When $\epsilon_{ii} = -1$, 1% variation in p_i leaves the expenditure unchanged as the quantity demanded also changes by 1%. In this case the demand is said to be unit elastic. Conversely, demand is said to be inelastic when $\epsilon_{ii} = 0$ and the quantity demanded does not vary with price.

Cross price elasticities can be negative, positive or zero, depending on whether the increase in the price of one good decreases, increases or leaves the demand for another good unchanged. In the first case the two goods are said to be complements ($\epsilon_{ij} < 0$), in the second case they are called substitutes ($\epsilon_{ij} > 0$), and in the last case they are unrelated ($\epsilon_{ij} = 0$).

3.6 Demand for Nutrients and Elasticities

In the literature there are only a few studies attempting to estimate demand for nutrients, most of which fit demand equations for specific nutrients as a function of income or total expenditure and socio-demographic characteristics (Behrman, 1988; Subramanian and Deaton, 1996; Behrman and Deolalikar,

⁷When one introduces socio-demographics and household characteristics into the model, these variables affect elasticities in the same way that α_i does and indirectly through their impact on $a(p)$.

1990; Strauss and Thomas, 1990). Others derive the effects of prices and income on nutrients demand using elasticities (Huang, 1996, 1999; Huang and Lin, 2000; Pitt, 1983). This paper follows this second approach. The main idea here is that consumers altering their food purchases in response to prices and income variations, also change their consumption of nutrients as different foods provide a different amount of nutrients. Thus, from the previous section, a household demands quantity $q^* = (q_1^*, q_2^*, \dots, q_n^*)$ of foods that maximizes its utility function and indirectly it also demands a certain combination of K nutrients corresponding to $q^* = (q_1^*, q_2^*, \dots, q_n^*)$. As each unit q_i^* of food i provides the amount a_{ik} of nutrient k . The total amount of nutrient k obtained by the household purchasing various types of foods can be expressed as $\varphi_k = \sum_i \varphi_{ik} = \sum_i a_{ik} q_i$. Thus the household demands directly q^* and indirectly it also demands a certain combination of K nutrients corresponding to q^* , $\varphi^* = (\varphi_1^*, \varphi_2^*, \dots, \varphi_K^*)$. In other words, the total quantity of nutrient k entering the household is the total amount of nutrient provided by the total amount of food purchased. This relation is known as "consumption technology" and was first introduced by Lancaster in 1966.

Hence, if consumers respond to a decline in the price of fruit, due for example to a wider supply thanks to the modern food chain distribution that makes available a larger quantity of food in all seasons, purchasing more fruit and reducing consumption of fish and chips, then the change in demand would have an impact also on the amount of nutrients intake such as vitamin C and proteins.

Thus, the main question that this section is going to address is: how does demand for nutrients change when food demand changes? As q_i and φ_k are not independent, but related through the "consumption technology" function, we can derive the total differential for φ_k as:

$$d\varphi_k = \sum_{i=1}^n a_{ki} dq_i$$

where dq_i is the total differential of q_i :

$$dq_i = \sum_{j=1}^n \frac{\partial q_i}{\partial p_j} dp_j + \frac{\partial q_i}{\partial m} dm$$

from which multiplying and dividing by p_j and m

$$dq_i = \sum_{j=1}^n \frac{\partial q_i}{\partial p_j} \frac{p_j}{p_j} dp_j + \frac{\partial q_i}{\partial m} \frac{m}{m} dm$$

and dividing all by q_i :

$$\frac{dq_i}{q_i} = \sum_{j=1}^n \frac{\partial q_i}{\partial p_j} \frac{p_j}{q_i} \frac{dp_j}{p_j} + \frac{\partial q_i}{\partial m} \frac{m}{q_i} \frac{dm}{m}$$

where $\frac{\partial q_i}{\partial p_j} \frac{p_j}{q_i} = e_{ij}$ and $\frac{\partial q_i}{\partial m} \frac{m}{q_i} = e_i$ and finally

$$\frac{dq_i}{q_i} = \sum_{j=1}^n e_{ij} \frac{dp_j}{p_j} + e_i \frac{dm}{m}$$

where e_{ij} and e_i represent respectively own- and cross-prices and income elasticities for food.

As we are interested in what happens to diet composition in term of nutrients when food demand

changes in response to a variation in prices and/or income, let us consider the "consumption technology function" $\varphi_k = \sum_{i=1}^n a_{ki} q_i$. Thus, using the direct relation between φ_k and q_i , the total differential of φ_k depends directly on the total differential of q_i : $d\varphi_k = \sum_i a_{ki} dq_i$. And thus,

$$\frac{d\varphi_k}{q_i} = \sum_{i=1}^n \frac{\partial \varphi_k}{\partial q_i} \frac{dq_i}{q_i}$$

substituting for $\frac{dq_i}{q_i}$

$$\frac{d\varphi_k}{q_i} = \sum_{i=1}^n a_{ki} \left[\sum_{j=1}^n e_{ij} \frac{dp_j}{p_j} + e_i \frac{dm}{m} \right]$$

$$\frac{d\varphi_k}{q_i} = \sum_{i=1}^n \sum_{j=1}^n a_{ki} e_{ij} \frac{dp_j}{p_j} + \sum_{i=1}^n a_{ki} e_i \frac{dm}{m}$$

take q_i on the right hand side:

$$d\varphi_k = \sum_{i=1}^n \sum_{j=1}^n a_{ki} q_i e_{ij} \frac{dp_j}{p_j} + \sum_{i=1}^n a_{ki} q_i e_i \frac{dm}{m}$$

divide all by φ_k :

$$\frac{d\varphi_k}{\varphi_k} = \sum_{i=1}^n \sum_{j=1}^n \frac{a_{ki} q_i}{\varphi_k} e_{ij} \frac{dp_j}{p_j} + \sum_{i=1}^n \frac{a_{ki} q_i}{\varphi_k} e_i \frac{dm}{m}$$

The ratio $\frac{a_{ki} q_i}{\varphi_k}$ represents the share of nutrient k produced by food i , and the price and income elasticities of each nutrient can be formalized as follows:

$$\pi_{kj} = \frac{\partial \varphi_k}{\partial p_j} \frac{p_j}{\varphi_k} = \frac{a_{ki} q_i}{\varphi_k} e_{ij}$$

and

$$\rho_k = \frac{\partial \varphi_k}{\partial m} \frac{m}{\varphi_k} = \frac{a_{ki} q_i}{\varphi_k} e_i$$

Thus to compute the effect of food prices and household income changes on the demand for nutrients one needs to know food prices and income elasticities for food and the share of nutrients provided by each food.

Such an approach does not require knowledge of the average "price of nutrient", but the proportional contribution of each food to the total amount of each nutrient. This is useful because one of the main problems when estimating the demand for nutrients is in fact the derivation of prices (Crawford, 2003).

4 Empirical Application

4.1 Maximum Likelihood Estimation

The model presented in 5 is estimated by maximum likelihood. The error term $\epsilon \equiv [\epsilon_1, \dots, \epsilon_N]$, added to each equation in 5, captures the unobservable and it is usually assumed to be multivariate normal distributed $\epsilon \sim N(0, (\Sigma_N \otimes I_H))$ with variance-covariance matrix $\Sigma \equiv \Sigma_N \otimes I_H$, N is the number of equations (foods) and H the number of households observed. As the additivity conditions imply that the variance-covariance matrix is singular ($\det \Sigma = 0$), one of the N equations must be dropped from the system. The remaining $(N - 1)$ equations are estimated by maximum likelihood, and the parameters of the last equation are recovered using the parameters constraints imposed on the system.

The log-likelihood function for the $(N - 1)$ equations with $\epsilon^{*'} \equiv [\epsilon_1, \dots, \epsilon_{N-1}] \sim N(0, (\Sigma_{N-1}^* \otimes I_H))$ is:

$$\ln L = -\frac{H(N-1)}{2} \ln 2\pi - \frac{1}{2} \ln |\Sigma_{N-1}^* \otimes I_H| - \frac{1}{2} \epsilon^{*'} [\Sigma_{N-1}^* \otimes I_H]^{-1} \epsilon^*$$

where Σ_{N-1}^* is the variance-covariance matrix of the $(N - 1)$ equations expressed in terms of ϵ^* and it is defined as $\Sigma^* = \frac{1}{H} \sum_{h=1}^H e_h^*(\theta) e_h^{*'}(\theta)$ where h indexes households and $e_h^*(\theta) \equiv [w_{1h} - \hat{w}_{1h}, \dots, w_{N-1,h} - \hat{w}_{N-1,h}]$.

Substituting the expression of Σ_{N-1}^* into the above log-likelihood function, the function to be maximized with respect to the vector of parameters θ , is:

$$\ln L = -\frac{H}{2} \{(N-1)[1 + \ln 2\pi + \ln |\Sigma^*|]\}$$

4.2 Delta Method

The procedure described in the previous section estimates only $(N - 1)$ equations. Thus we need to recover the full approximate probability distribution for the parameters in the demand system. Thus, while the parameters for the $N - th$ equation are recovered using the constraints imposed by the demand properties, the variance-covariance matrix provided by the maximum likelihood estimation is also not complete and the full matrix needs to be recovered. To do so Poi (2002) suggests applying the delta method. This statistical procedure computes the approximate probability distribution for an asymptotically normally distributed statistical estimator of whose variance we have only limited knowledge.

So, let $\{\hat{\theta}_n | n = 1, \dots, N\}$ be a sequence of estimators of the $P \times 1$ vector of parameters θ asymptotically normally distributed as $\sqrt{N}(\hat{\theta}_N - \theta) \rightarrow N(0, V)$ where V is a positive definite matrix representing the asymptotic variance of $\sqrt{N}(\hat{\theta}_N - \theta)$. Then, for any non-stochastic matrix R ($Q \times P$) with $Q < P$ and $\text{rank}(R) = Q$

$$\sqrt{N}R(\hat{\theta}_N - \theta) \underset{a}{\rightsquigarrow} N(0, RVR')$$

where $R = C(\theta) \equiv \nabla_{\theta} c(\theta)$ is the $Q \times P$ Jacobian of a continuous and differentiable function of parameters c . Then the transformation of θ through c is distributed as follows:

$$\sqrt{N}(c(\hat{\theta}_N) - c(\theta)) \underset{a}{\rightsquigarrow} N(0, C(\theta)VC(\theta)') \quad (6)$$

And

$$\{\sqrt{N}(c(\hat{\theta}_N) - c(\theta))\}' [C(\theta)VC(\theta)']^{-1} \{\sqrt{N}(c(\hat{\theta}_N) - c(\theta))\} \sim^a \chi_Q^2$$

Define $\hat{C}_N \equiv C(\hat{\theta}_N)$. Then, $\text{plim}\hat{C}_N = C(\theta)$. If $\text{plim}\hat{V}_N = V$, then

$$\{\sqrt{N}(c(\hat{\theta}_N) - c(\theta))\}' [\hat{C}_N V \hat{C}_N']^{-1} \{\sqrt{N}(c(\hat{\theta}_N) - c(\theta))\} \sim^a \chi_Q^2$$

The equation 6 is useful for obtaining asymptotic standard errors for non-linear functions of $\hat{\theta}_N$. The appropriate estimator of the asymptotic variance (*Avar*) of $c(\hat{\theta}_N)$ is $\hat{C}_N \frac{\hat{V}_N}{N} \hat{C}_N' = \hat{C}_N [Avar(\hat{\theta}_N)] \hat{C}_N'$. Thus once $Avar(\hat{\theta}_N)$ and the estimated Jacobian of c are obtained, we can compute the full asymptotic variance-covariance matrix of $\hat{\theta}_N$:

$$Avar[c(\hat{\theta}_N)] = \hat{C}_N [Avar(\hat{\theta}_N)] \hat{C}_N'$$

4.3 Data

The analysis reported in this paper is based on the UK National Food Survey (NFS) from 1975 to 2000⁸. The NFS is a set of cross-sectional surveys that has run continuously since 1942. Its initial aim was to monitor the diet of the urban "working class" during the war years. In 1950 it was extended to the whole population in Britain to collect data on food consumption and expenditures. Since 1992 the NFS has collected information also on confectionery, alcohol and soft drinks; and since 1996 it has been extended to Northern Ireland.

The NFS collects weekly data on household food acquisition from roughly 7,000 households in the UK every year (corresponding to a response rate of 65 percent). It contains specific information about physical quantities of food entering the household among more than 200 food items listed, and expenditure in British pence. Moreover, the surveys record some socio-demographic characteristics, as for example the age and sex of household members, the number of males and females working, region of residence, household size and weekly net family income. From these surveys I exclude households residing in Northern Ireland because they were included in the survey only from 1996 and also households for which missing values could not be recovered using any other information provided by the household members.

For the purpose of this paper, food items have been classified into six macro-food groups (although not all households buy every product) as follows: dairy products, meat and fish, fats and sugar, vegetables and fruit, cereals and other food (miscellaneous and beverages). Most of the categories are self-explanatory, but some require a little more clarification. The dairy products category records milk, cream, cheese and yogurt purchases. Fats and sugars include different types of oils and butters, fat spreads, lard, sugar, jams, jellies, fruit curds, marmalade, syrup and honey. Vegetables and fruit include all types of fresh, frozen and canned vegetables and fruit. Cereals represent expenditure on bread, flour, cake and pastries, biscuits, muesli, rice, pasta and pizza. Other food mostly consists of beverages such as coffee, tea, drinking chocolate, and miscellaneous (mineral water, soups, salad dressings and other dressings, ice creams, artificial sweeteners and salt). This excludes soft drinks, confectioneries and alcohol because they have been included in the survey only from 1992. Finally, my selected sample consists of 130,728 households observed between 1975 and 2000.

⁸From 2001 the NFS has been merged with the Family Expenditure Survey (FES), becoming the Expenditure and Food Survey (EFS).

Descriptive statistics of the principal variables used in the demand system are provided in Tables 1 and 3. Households spend on average 27 pounds per week on the six food groups, with the maximum amount spent being £295.55. On average 16 percent (£3.70) of the total weekly food expenditure is spent on dairy products, 32 percent (£8.93) on meat and fish, 21 percent (£5.86) on vegetables and fruit, 18 percent (£4.68) on cereals, 5 percent (£1.31) on fats and sugar and 8 percent (£2.21) on other food. This average pattern of expenditure corresponds to an average purchase of 6.5 kilograms of dairy products, 3 kilograms of meat and fish, 1.4 kilograms of fats and sugar, 8.15 kilograms of vegetables and fruit, 4.05 kilograms of cereals and 1 kilogram of other food.

Table 1: Descriptive statistics: food consumption and expenditure (1975-2000) - Households obs. 130,728

	Weekly qty purchased (kg)		Prices per kg		Weekly expenditure (£)		Budget share of expenditure	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Dairy products	6.51	<i>4.51</i>	0.70	<i>0.31</i>	3.77	<i>3.06</i>	0.16	<i>0.12</i>
Meat and fish	3.01	<i>2.93</i>	3.39	<i>1.28</i>	8.93	<i>8.64</i>	0.32	<i>0.16</i>
Fats and sugars	1.40	<i>1.57</i>	1.27	<i>0.50</i>	1.31	<i>1.38</i>	0.05	<i>0.05</i>
Vegetables and fruit	8.15	<i>6.95</i>	0.87	<i>0.42</i>	5.86	<i>5.67</i>	0.21	<i>0.11</i>
Cereals	4.05	<i>3.30</i>	1.28	<i>0.56</i>	4.68	<i>4.44</i>	0.18	<i>0.10</i>
Other food	1.07	<i>1.50</i>	3.38	<i>1.31</i>	2.21	<i>2.65</i>	0.08	<i>0.07</i>

4.3.1 Food Prices

The NFS does not record data on food prices, however, in empirical studies the most common approach for recovering this information when prices are not observed directly, is to compute unit values by dividing total expenditure by the total amount of food purchased by the household in a certain period of time (Deaton, 1987, 1997; Huang, 1999; Dhar et al., 2005; Lechene, 2000). This method presents both advantages and disadvantages. The advantage is that prices can be directly recovered from the data observed on any good purchased. The disadvantages are 1) they could be affected by measurement error due to misreporting of either quantity or total expenditure (Kedir and Girma, 2003; Chesher, 1991) and 2) they usually result different for each household in the survey because they reflect the average market price and consumers' choice of food quality and nutritional characteristics (Huang and Lin, 2000; Crawford et al., 2002; Crawford, 2003).

An alternative to overcome these issues could be to use some aggregate prices derived from outside the main dataset as, for example, the Retail Price Index (RPI) provided by the National Statistics Office (Chesher and Lechene, 2002), however also this approach is not free of issues. In fact, RPI may not be available for the complete bundle of goods considered in the analysis and it is usually computed for the whole country, so that variability across geographical locations is lost, while households living in different regions might be facing different prices at the same point in time.

Thus, this paper uses unit values for food i derived as the ratio between total expenditure on food i and total quantity of food purchased i by household h ($\nu_i = \frac{p_i q_i}{q_i}$). To harmonize the prices across regions

and over time I average up unit values by food groups, region of residence and month of interview⁹. Table 1 shows average unit prices for each food group considered in this work. The most expensive food group is meat and fish (£3.40 per kg). Fats and sugar cost on average £1.27 per kg, while vegetables and fruit cost 87 pence per kilo.

Table 2: Descriptive statistics: household characteristics (1975-2000) - Households obs. 130,728

Variable	Mean	Std. Dev.	Min	Max
Total food expenditure (£)	26.77	20.16	0.05	295.55
Net weekly family income (£)	195.55	186.64	1.9	5500.00
Age of head of household	49.45	17.52	16	99
Household size	2.61	1.37	1	13
Number of children in age:				
00–05	0.26	0.59	0	7
06–11	0.26	0.59	0	5
12–17	0.22	0.56	0	7
Female works	0.40	0.49	0	1
Number of ready meals bought	1.83	1.53	0	12

Table 3: (Ctd.) Descriptive statistics: household characteristics (1975-2000) - Households obs. 130,728

		Freq.	Percent	Cum.
Region of residence				
	Scotland	11,719	8.96	8.96
	Northern England	36,145	27.65	36.61
	Central, SW England and Wales	39,600	30.29	66.91
	London & SE England	43,264	33.09	100
Household composition				
	Single	29,706	22.72	22.72
	Lone parents	5,501	4.21	26.93
	Couple without children	50,098	38.32	65.25
	Couple with children	45,423	34.75	100
Total		130,728	100	

⁹Browning et al. (2006) use the *weighted geometric mean of the component prices* (a Stone price index) with budget share averaged across the strata.

4.3.2 Household Demographic Characteristics

The NFS also provides information on households' demographic characteristics. This study considers four geographical areas, age of head of household, household size, whether women are working and the number of times per week households buy ready meals and four types of household composition.

As shown in Table 2, on average the head of household is 49 years old, in 40 percent of the households women work and at least one meal purchased is ready made¹⁰. The geographical areas are Scotland, northern England (including north-east and north-west England, York and Humberside), central, south-west England and Wales (including East and West Midlands, Wales and south-west England), London and the south-east (including the south-east and East Anglia). Households are further aggregated in four classes according to their composition: single, lone parents, couple with children and couple without children. Descriptive statistics for these variables for the whole sample are shown in Table 3. Those these are the variables for the vector d^h in the model.

4.3.3 Nutrients from Food

As every food provides nutrients in some amount, one can derive the combination of nutrients provided by the food combination purchased. Using the intake content factor tables provided by the Department for Environmental Food and Rural Affairs (DEFRA, 1999), the full detail of reported food purchases (apart from soft drinks, confectioneries and alcohol) is used to compute the amount of nutrient intakes entering each household during the period of study. The DEFRA table reports 47 nutrient intakes. This paper focuses on 10 of them: total amount of energy, fat, proteins, carbohydrate, animal and vegetable proteins, fatty acids, calcium, iron and vitamin C. In addition, fat, proteins and carbohydrate are converted into energies at 9, 4 and 3.75 kcal per gram respectively.

Summary statistics on household consumption of nutrients are reported in table 4. The contribution over time of each food category to the composition of the British diet in terms of energies, energy from fat, proteins and carbohydrate intake at the household level is shown in Figure 1. Some changes over time are visible at the aggregate level from Figure 1. For example there seems to be a higher contribution to total energies from vegetables, fruit and cereals and a lower contribution from fat and sugar. Moreover the main variation seems to arise from changes in the amount of energy from fat (panel b), which in 2000 was provided more by vegetables and fruit rather than fat and sugar as was the case in 1975. Fat and sugar seems also to contribute less to energy from carbohydrate (panel d).

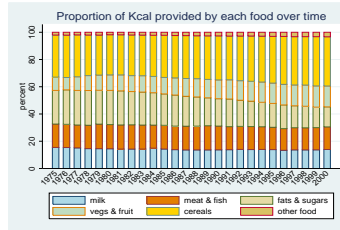
Table 5 reports the average proportions of nutrient provided by each food group that will be used for the derivation of nutrients elasticities. Cereals provide on average 32% of a British household total energies, while fat and sugar supply 21%, dairy products contribute 14%, while meat and fish provide 17%. The larger provider of energy from fat, on average, remains fats and sugar, and the larger providers of carbohydrate and protein are cereals and meat and fish respectively.

¹⁰I classified as a ready meal each minor food group from the NFS that is labelled "takeaway ready to be eaten" or "precooked, processed or canned". The minor food groups coded as takeaway are 5903, 5904, 12103, 12303, 12304, 12305, 9408, 9409, 9410, 18802, 18803, 20203, 20601, 20604, 29912 and 29602. Those coded as precooked or processed are: 5901, 5903, 5904, 5801, 6601, 7101, 7102, 8301, 8302, 8303, 9409, 9410, and those between 11401 and 12701.

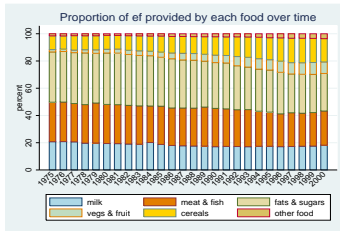
Table 4: Descriptive statistics: nutrient intakes (1975-2000) - Households obs. 130,728

Variable	Mean	Std. Dev.	Min	Max
Energies (Kcal)	36147.99	25185.90	0	1256682.00
EP (Kcal)	4750.03	3137.82	0	134812.60
EF (Kcal)	14744.80	11284.27	0	354736.10
EC (Kcal)	16620.06	12768.61	0	985761.60
Protein (gr)	1187.51	784.46	0	33703.14
Fat intake (gr)	1638.31	1253.81	0	39415.12
Carbohydrate (gr)	4432.02	3404.96	0	262869.80
Vegetable Protein (gr)	466.19	347.58	0	19488.43
Animal Protein (gr)	721.32	528.11	0	22838.50
Fatty Acids (gr)	693.54	505.60	0	12108.13
Calcium (mg)	15953.36	9951.86	0	227094.30
Iron (mg)	186.96	129.94	0	2713.41
Vitamin C (mg)	998.71	905.21	0	23834.62

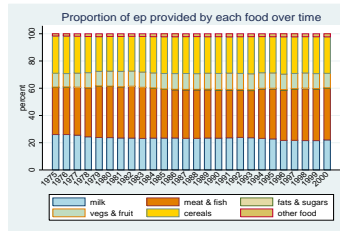
Figure 1: Proportion of nutrients provided by each food over time.



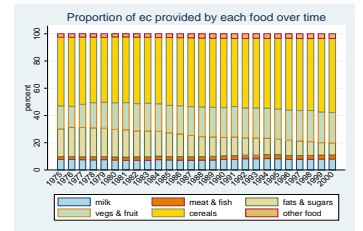
(a) Energies.



(b) Energy from fat.



(c) Energy from protein.



(d) Energy from carbohydrate.

4.4 Effect of Income and Prices on Demand for Food

The parameters of the demand system are estimated separately for each year from 1975 to 2000. I drop the last equation (other foods) to accommodate adding up and I impose homogeneity and symmetry directly when estimating the model with STATA¹¹. I consider here six food groups: dairy products, meat and fish, fats and sugars, vegetables and fruit, cereals and other food. As household expenditure varies substantially with the demographic composition of households (Blundell and Stoker, 2005; Browning,

¹¹In order to include the six food equations and household socio-demographic characteristics, I modified the routine originally created by B. Poi in STATA (2002) for 4 goods and no demographic variables.

Table 5: Food share of nutrients (1975-2000) - Households obs. 130,728

	Dairy products	Meat & fish	Fats & sugars	Vegs & fruit	Cereals	Other food	Total
Energy	14.19	17.06	21.34	12.88	32.02	2.50	100.00
EP	23.41	36.30	0.38	11.13	26.69	2.08	100.00
EF	18.52	27.30	34.25	4.86	12.96	2.11	100.00
EC	7.62	2.56	15.86	20.50	50.50	2.96	100.00
Protein	23.41	36.30	0.38	11.13	26.69	2.08	100.00
Fat intake	18.52	27.30	34.25	4.86	12.96	2.11	100.00
Carbohydrate	7.62	2.56	15.86	20.50	50.50	2.96	100.00
Vegetable Protein	0.16	3.49	0.08	28.31	65.07	2.88	100.00
Animal Protein	38.44	57.50	0.58	0.03	1.88	1.57	100.00
Fatty Acids	26.83	25.05	31.25	3.17	12.05	1.66	100.00
Calcium	58.86	4.62	0.84	8.11	24.87	2.69	100.00
Iron	3.02	21.90	1.45	21.62	46.84	5.18	100.00
Vitamin C	6.68	2.31	1.20	87.28	1.35	1.18	100.00

1992), I also control for age of head of household, household size, presence of children of different ages, region of residence and household composition (distinguishing by single, lone parents, couple with and without children). For reasons of space, the estimated parameters for each year are not reported here, however they are available from the author on request. I now examine price and income elasticities.

Table 6 presents expenditure and price elasticity estimates. The numbers reported refer to the average points of the distribution of uncompensated price elasticities ϵ_{ij} and expenditure elasticities ϵ_i for the whole period. On average the estimates of expenditure elasticity for all food are very close to zero, suggesting that income variations (or total expenditure allocated to food) leave demand for food relatively unchanged¹².

Although on average there seems to be no effect of total expenditure on demand (elasticities very close to zero), this might be the result of some compensation over time, as could be the negative sign associated with the elasticity of dairy products, fat and sugar and cereals. Figure 2 shows expenditure elasticity over time for the six food groups considered. Expenditure elasticities seem to change slowly through time only for cereals. Instead trends in demand for dairy products, meat and fish, fats and sugars, vegetable and fruit and other food remain quite stable over all the period. In particular, for cereals there is a tendency for expenditure elasticities to move toward zero through time, suggesting that as total food expenditure increases demand for cereals decreases (inferior good) as the elasticity is negative throughout the period. Moreover, demand becomes less sensitive to income variation over time (upward trend).

Own price elasticities are, as expected, negative, indicating that an increase in the price of a good leads to a decrease in the demand for that good. On average the demand for some of these food categories is nearly unit elastic (that is $\epsilon_{ii} \rightarrow -1$). In this situation, price changes leave expenditure approximately unchanged, as the demand falls and rises at a similar rate as price increases and decreases. For example,

¹²These results suggest that the food quantity demanded remains unchanged although total food expenditures may change. A possible drivers of such effects might be sought in changes through time in the nature of foods. Indeed if consumers spend more buying the same amount of food, it might be due to a switch from lower to higher quality food. Further analyses would be need to study this issue.

Table 6: Estimated income (ϵ_i), own (ϵ_{ii}) and cross-price (ϵ_{ij}) elasticities from the QUAIDS model with 6 food groups (average period 1975-2000) - standard errors in parenthesis

Elasticity	Prices						Expenditure
	Dairy	Meat & fish	Fats & sugars	Veg. & fruit	Cereals	Other food	
Diary	-0.898 (0.150)	0.488 (0.388)	3.283 (4.120)	1.094 (0.575)	0.643 (0.486)	2.026 (1.512)	-0.022 (0.030)
Meat & Fish	0.265 (0.550)	-0.856 (0.121)	0.792 (1.035)	-0.060 (0.394)	0.041 (0.310)	0.564 (1.031)	0.029 (0.036)
Fats & Sugars	0.164 (0.101)	0.032 (0.090)	-0.753 (0.344)	-0.120 (0.127)	0.027 (0.101)	0.039 (0.197)	-0.017 (0.021)
Veg. & Fruit	0.522 (0.349)	-0.043 (0.127)	0.943 (2.338)	-0.619 (0.379)	0.165 (0.260)	0.289 (0.911)	0.054 (0.025)
Cereals	0.114 (0.205)	-0.009 (0.098)	-0.089 (0.335)	-0.093 (0.165)	-0.515 (0.140)	-0.013 (0.246)	-0.054 (0.031)
Other foods	0.090 (0.110)	0.004 (0.049)	0.021 (0.173)	-0.100 (0.163)	-0.002 (0.053)	-0.853 (0.313)	0.005 (0.023)

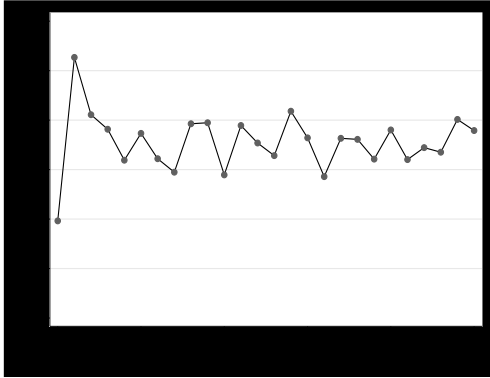
meat and fish demand is estimated to rise by 0.8% when there is a 1% decrease in price and demand for vegetables, fruit, fat and sugar declines by about 0.76% and 0.63% when their own-prices increase by 1%. Conversely, cereals result relatively inelastic ($\epsilon_{ii} \rightarrow 0$) as a 1% decrease in price results in only around 0.5% decrease in demand for pasta, bread, rice and pizza in average throughout the period¹³.

Estimated own-price elasticities are also shown graphically over time by Figure 3. Most of the food reveals a quite stable trend of demand over time with respect to own-price variations. The only evident exception is vegetables and fruit that shows a quite clear downward trend over the period. Thus, while in 1975 a 1% rise in price is estimated to decrease the demand for vegetables and fruit by 0.4%, in 2000 the same variation of price generates a decline of demand for vegetables and fruit of about 0.9%.

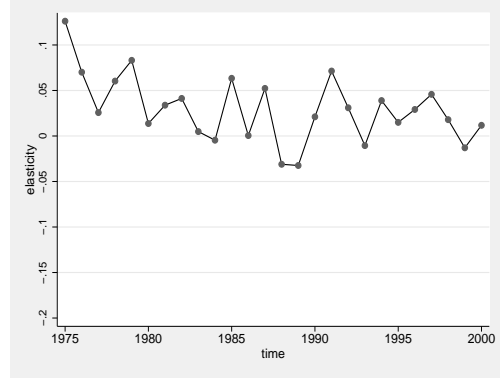
The analysis carried on in this paper also allows the computation of cross-price elasticities shown in the off-diagonal cells of Table 6. However, the average estimated cross-price elasticities, indicate rather non-existent cross-price sensitivity as none are statistically different from zero. Indeed, this is true also when looking at cross-price elasticities trends over the period of the study. There are two possible explanations for this result: first, the accuracy of these estimates depends on the variation in the relative prices of the food groups, that in general have changed very little from 1975 to 2000; second, the food categories considered are quite broad (they combine all similar foods such as all cheese, all meats, all fruit etc.) leaving little space for capturing substitution and complementarity between macro-groups. In fact, while one could expect to find that consumers substitute beef with pork and chicken in response to a change in the price of beef, it is not surprising that neither substitution nor complementarity arise between such wide categories as meat and fish and cereals for example.

¹³It is important to notice that the high price elasticity values on the main diagonal might be the effect of prices' endogeneity (Crawford, 2003). Future analysis should take this into account for example instrumenting regional prices for each food with their lag value.

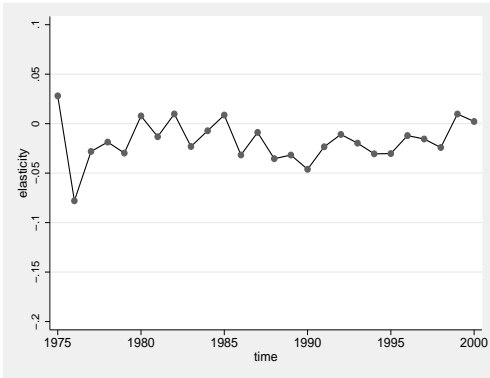
Figure 2: Food income elasticity over time.



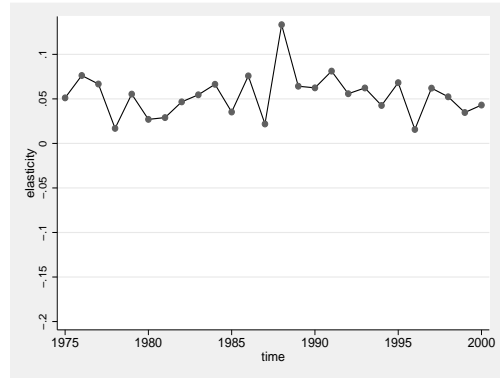
(a) Dairy products.



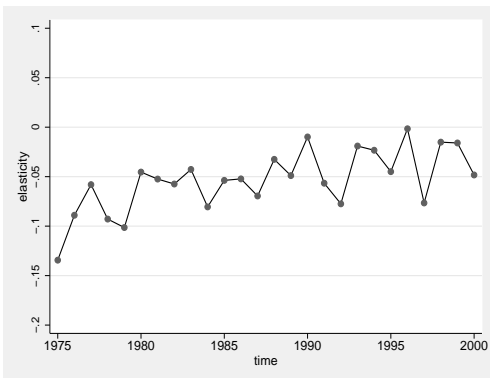
(b) Meat and fish.



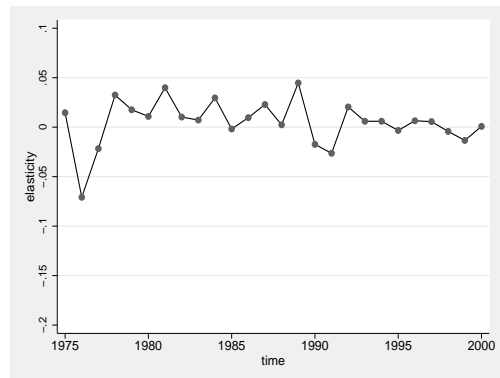
(c) Fats and sugars.



(d) Vegetables and fruit.

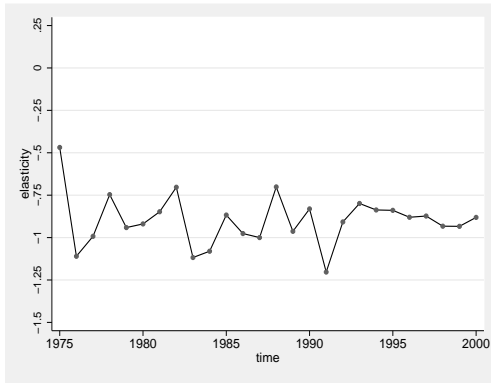


(e) Cereals.

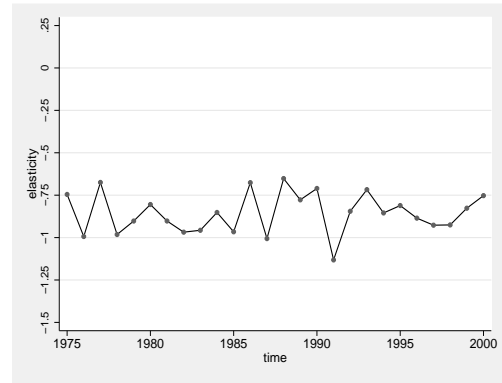


(f) Other food.

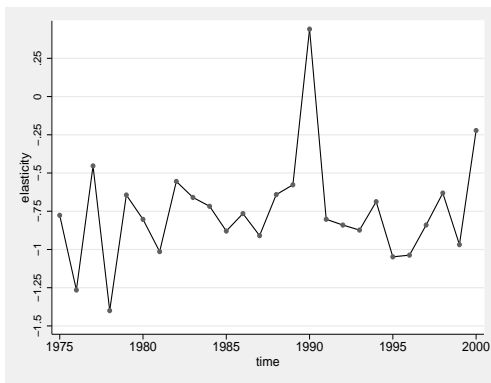
Figure 3: Food own-price elasticity over time.



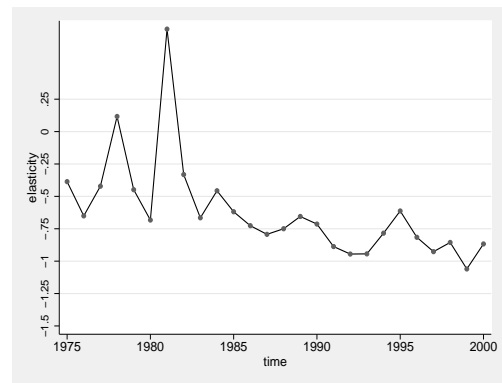
(a) Dairy products.



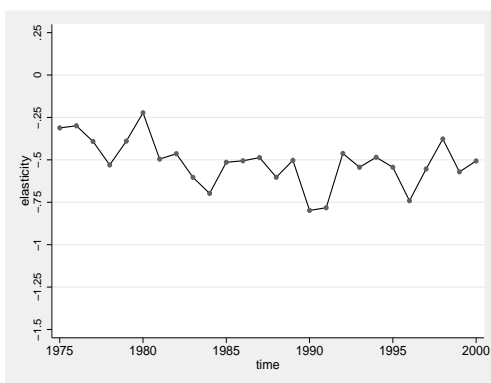
(b) Meat and fish.



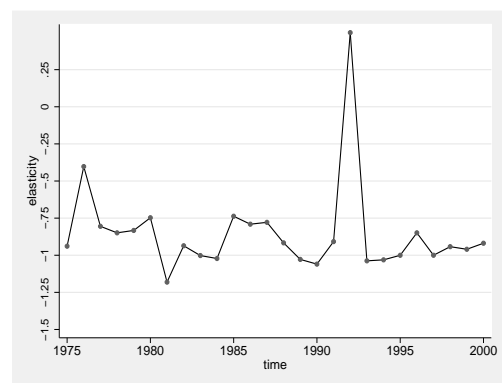
(c) Fats and sugars.



(d) Vegetables and fruit.



(e) Cereals.



(f) Other food.

4.5 Effect of Income and Prices on Demand for Nutrients

To derive the effect of total food expenditure and food prices on the diet composition of Britain I use the food demand elasticities reported in the previous section and the share of nutrients contained in Table 5. Computation of nutrient elasticities is based on the equations reported above.

Average elasticities for nutrients are computed and reported in Table 7 and show the proportional change of demand for nutrients in response to changes in the six food prices and food expenditure. For example, a 1% increase in the price of meat and fish will affect the amount of all food consumption through the interdependent demand relationships shown in Table 6. These changes in food consumption will affect the household demand for total energies by 0.07%, energy from fat by 0.13%, energy from protein by 0.18% and energy from carbohydrate by 0.02%, and iron by 0.18%.

Table 7: Estimated food price (ϕ_{kj}) and income (ρ_k) elasticities for nutrients derived from the QUAIDS model with 6 food groups (average period 1975-2000) - standard errors in parenthesis

Elasticity	Prices						Tot. Exp. ρ
	Dairy	Meat & fish	Fats & sugars	Veg. & fruit	Cereals	Other food	
Energies	0.030 (0.086)	-0.072 (0.064)	0.785 (1.595)	0.007 (0.078)	-0.027 (0.104)	0.752 (1.464)	-0.013 (0.006)
EF	-0.046 (0.138)	-0.134 (0.109)	0.948 (2.034)	0.125 (0.144)	0.091 (0.138)	0.841 (1.562)	-0.008 (0.007)
EP	-0.050 (0.157)	-0.178 (0.105)	1.435 (2.115)	0.157 (0.155)	0.059 (0.150)	1.010 (1.528)	-0.006 (0.008)
EC	0.111 (0.144)	0.018 (0.058)	0.472 (1.038)	-0.126 (0.080)	-0.156 (0.099)	0.563 (1.442)	-0.020 (0.016)
Fat intake	-0.046 (0.138)	-0.134 (0.109)	0.948 (2.034)	0.125 (0.144)	0.091 (0.138)	0.841 (1.562)	-0.008 (0.007)
Protein	-0.050 (0.157)	-0.178 (0.105)	1.435 (2.115)	0.157 (0.155)	0.059 (0.150)	1.010 (1.528)	-0.020 (0.016)
Carbohydrate	0.111 (0.144)	0.018 (0.058)	0.472 (1.038)	-0.126 (0.080)	-0.156 (0.099)	0.563 (1.442)	-0.006 (0.008)
Animal Proteins	-0.240 (0.287)	-0.251 (0.194)	2.212 (3.163)	0.434 (0.279)	0.285 (0.253)	1.314 (1.815)	0.003 (0.018)
Vegetable Proteins	0.243 (0.177)	-0.047 (0.079)	0.302 (0.846)	-0.256 (0.213)	-0.277 (0.111)	0.092 (0.272)	-0.019 (0.021)
Fatty Acid	-0.136 (0.116)	-0.069 (0.135)	1.254 (2.554)	0.230 (0.183)	0.148 (0.162)	0.954 (1.634)	-0.010 (0.006)
Calcium	-0.426 (0.110)	0.226 (0.210)	2.198 (2.978)	0.551 (0.322)	0.260 (0.286)	1.426 (1.635)	-0.021 (0.019)
Iron	0.177 (0.112)	-0.179 (0.039)	0.512 (0.697)	-0.161 (0.162)	-0.166 (0.101)	0.536 (1.417)	-0.007 (0.008)
Vitamin C	0.347 (0.296)	-0.014 (0.135)	1.230 (2.274)	-0.377 (0.297)	0.201 (0.218)	0.830 (1.385)	0.038 (0.020)

On the other hand, nutrient expenditure elasticities reflect the combined effect of all combine food expenditure elasticities in the food demand system. Thus an increase of 1% in household income (expenditure) will also reflect on food demand (even though with very little effect, as already discussed above) and through them, it will affect the demand for total energies by -0.01%, energy from fat by -0.008%,

energy from proteins by -0.006% and energy from carbohydrate by -0.02% . Thus these results suggest that those households increasing total food expenditure (or those, if the extension can be accepted, with higher income) tend to switch toward foods providing lower energies (maybe higher quality). However further interpretations of these results seems quite speculative as most of the elasticities estimated results not significantly different from zero.

Figure 4 presents nutrients elasticities with respect to expenditure variation over time. Our findings emphasize that elasticities of nutrients remain quite stable over time and they are very close to zero (or moving toward zero by the end of the period as PEC does) : as households become richer, the substitution between foods is quicker than the variation of diet through substitution of nutrient intakes. Indeed, there is little evidence of changes through time in income elasticities for nutrient intakes, although there are some (although small) effects of family income variation on food groups consumption.

Figure 4: Nutrient demand elasticity with respect to income over time.

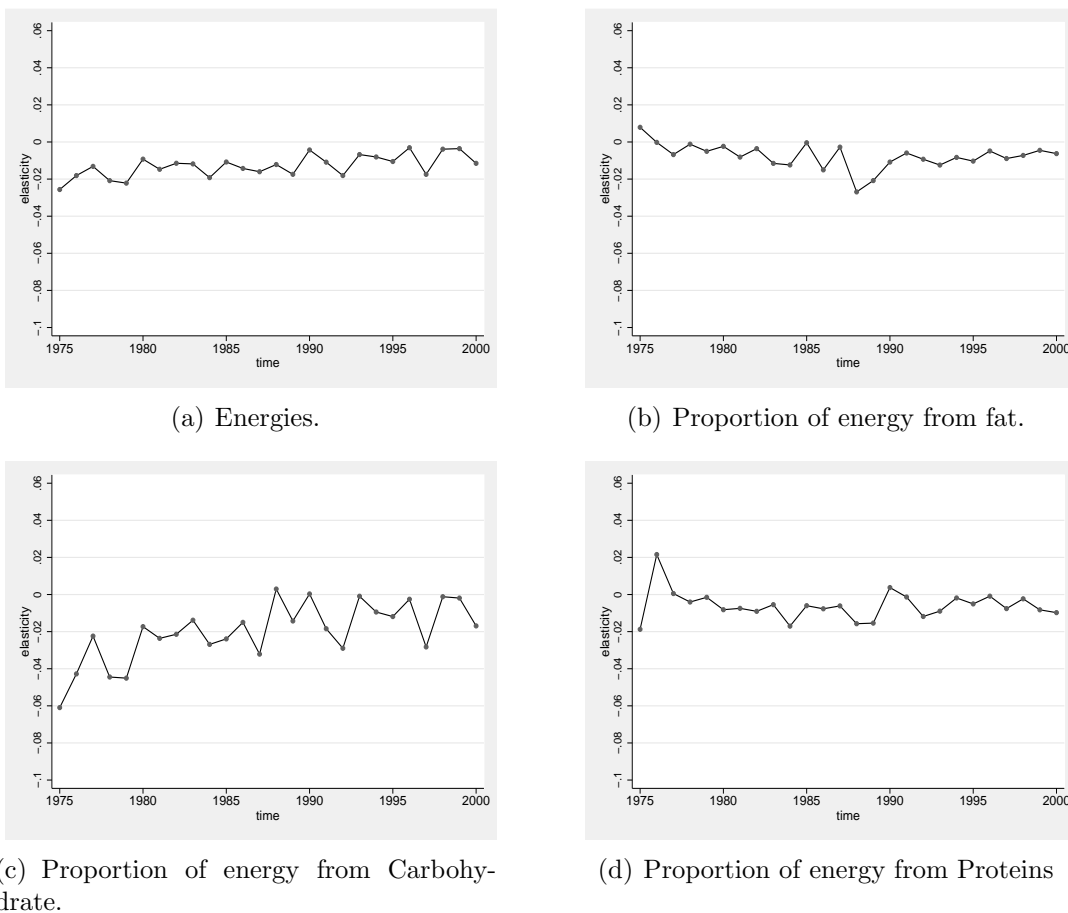


Table 8 transforms the elasticity estimates into absolute quantity variation in household weekly shopping for a 10% variation of prices. Thus a rise of 10% in the price of dairy products, according to this finding would results in a decrease in weekly demand for dairy products, that translated into nutrients, means mainly a decline of calcium intake of about 678 mgr. As noted earlier, as demand results quite inelastic, also the magnitude of changes results quite small.

Table 8: Weekly quantity change in food and nutrients in relation to a 10% increase in prices of food (on the average period 1975-2000)

Elasticity	Prices						Income ρ
	Dairy	Meat & fish	Fats & sugars	Veg. & fruit	Cereals	Other food	
Food (kg):							
Dairy products	-0.582	0.326	2.084	0.700	0.416	1.337	-0.015
Meat & fish	0.090	-0.257	0.242	-0.015	0.014	0.170	0.009
Fat & sugars	0.022	0.004	-0.107	-0.016	0.004	0.006	-0.002
Veg. & fruit	0.414	-0.035	0.700	-0.515	0.122	0.203	0.043
Cereals	0.042	-0.006	-0.032	-0.036	-0.209	-0.002	-0.021
Other food	0.009	0.000	0.003	-0.011	0.000	-0.092	0.001
Nutrients:							
Total energies	108.609	-261.842	2838.485	25.127	-96.446	2717.829	-46.591
EF	-68.425	-197.819	1397.740	184.663	133.539	1240.775	-11.233
EP	-23.798	-84.718	681.823	74.430	28.214	479.815	-2.821
EC	183.764	29.268	784.886	-210.165	-258.668	935.140	-33.315
Fat intake	-7.603	-21.980	155.304	20.518	14.838	137.864	-1.248
Protein	-5.950	-21.180	170.456	18.607	7.053	119.954	-2.380
Carbohydrate	49.004	7.805	209.303	-56.044	-68.978	249.371	-2.633
Animal Protein	-17.308	-18.084	159.554	31.329	20.563	94.772	0.197
Veg. Protein	11.324	-2.185	14.084	-11.939	-12.901	4.283	-0.866
Fatty Acids	-9.430	-4.816	86.971	15.946	10.240	66.161	-0.697
Calcium	-679.778	360.785	3505.773	878.350	414.735	2274.613	-32.948
Iron	3.304	-3.352	9.569	-3.006	-3.113	10.030	-0.130
Vitamin C	34.644	-1.427	122.841	-37.670	20.026	82.846	3.779

4.6 Other Influences on Demand

The previous section highlights that the economic determinants of demand, prices and income have little effect on the food spending behaviours of British people. This section presents the influence on food expenditure as a proportion of income, of some socio-demographic factors, such as age of head of household, household size, presence of children of different age groups, women working, number of times in a week that the household buys ready meals, region of residence and household composition.

The age of head of household has in general little, although statistically significant, effect on food spending over the time period of the study. Older head of household implies higher spending on fat, sugar and cereals as well as lower demand for vegetables and fruit. However, these effects are not constant over time. Indeed, from 1988 older households allocate larger proportions of their income to vegetables and fruit, as well as to dairy products. Conversely, they constantly reduce the proportion of expenditure allocated to meat, fish and cereals.

Household size also significantly affects household food demand. A higher number of household members increases the consumption of dairy products, fat and sugar, cereals and other food, whilst it decreases demand for meat and fish as well as that for vegetables and fruit.

During the last thirty years there was a shift upward in the number of women participating in the labour market. The effect of this change on food expenditure allocation among the six food groups examined is generally small, although statistically significant. Between 1975 and 2000 households with women working allocate lower proportions of food expenditure to fat and sugar and higher ones to vegetables and fruit compared to households in which the females are not employed. Some small shifts are also observable in the demand for meat and fish, indicating that before 1996 women's participation in the labour market had the effect of increasing the demand for meat and fish, while after 1996 this effect reverses. A possible explanation for this sudden change could be the BSE crisis.

The number of ready meals bought has also a small, but statistically significant effect on demand. In general a higher number of ready meals leads to a decline in predicted proportions of expenditure on dairy products, vegetables and fruit (even lower from 1982), and a rise in predicted proportions of expenditure on meat and fish, suggesting maybe that ready meals mostly substitute raw meat and fish.

The presence of children is also an important determinant of food demand decisions (Browning, 1992). In particular, households with children between 0-5 spend more on dairy products and less on vegetables, fruit, cereals and other food. From the beginning of the 1990s demand for fat and sugar is also affected negatively by the presence of young children. On the other hand, having children between 6 and 11 does not change significantly the food expenditure allocation of households in Britain.

Conversely, the presence of adolescents (age 12-17) results significantly different from zero, leading to an increase only in predicted shares for fat and sugar.

Some differences also arise in the demand for food by region of residence. For example Scotland compared to London and the south-east consumes significantly more fat and sugar, more vegetables and fruit, more cereals and less dairy products. Over time the proportion of expenditure on vegetables and fruit has increased from 1980. Also northern England spends significantly more than London and the south-east on fat and sugar and less on vegetables and fruit, cereals and other food. Moreover, the demand for vegetables and fruit seems to have steadily declined over time. Similarly, central England, south-west England and Wales spend more on dairy products, fat, sugar, meat and fish than London and the south-east. However, since 1990 they seem to have reduced their demand for meat and fish.

Finally I control whether the demand varies across household compositions. Household composition falls into four categories: single, lone parent, couples with and without children. The reference category

here is couple with children. On average singles allocate a lower share of food expenditure to fat and sugar and a higher one to other food (i.e. tea, coffee, etc.) compared to couples with children. Over time there seems to be a shift in preferences as they allocate more income to vegetables and fruit from 1985 onward, while before that singles used to consume less vegetables and fruit than couples with children.

Budget allocation to food by lone parents does not differ from those of couples with children, suggesting that it is the presence of children rather than the household composition that affect food choices¹⁴. However at the end of the 1980s some variations arise: a lone parent household demands more cereals and less vegetables and fruit than a couple with children.

Couples without children spend on average significantly more on milk compared with couples with children.

5 Concluding Remarks

This paper has looked at the effect of food prices and consumer income on demand for food and nutrients. Motivated by the rapid increase in the obesity rate observed in the UK from the middle of the 1980s and the consequences that this might have for individual's actual and future health, public health care costs and social costs, I estimated a Quadratic Almost Ideal Demand System (QUAIDS) using data from the British National Food Survey 1975-2000 and derive own- and cross-prices and income elasticities of demand for six food groups and the intake of ten nutrients.

I find that, on average, income elasticity for food is small suggesting that income variations leave demand for food relatively unchanged. Over time income elasticities also change quite slowly for almost all food considered, with only one exception: cereals for which, over time, demand has become less sensitive to income variations. The findings suggest that households increasing total food expenditure (reflecting higher income) tend to lower their energy sources from fats, carbohydrates and proteins, however this results in an almost unchanged total amount of energies. When looking at elasticities trends, the results suggest that as households become richer, the substitution between foods is quicker than the variation of diet through substitution of nutrients. Indeed, there is little evidence of changes through time in income elasticities for nutrient intake, although there are some effects of family income variation on food groups consumption.

The second group of findings of this paper is concerned with the effect of prices. My results indicate that as the demand for food is nearly unit elastic with respect to own-prices, then price changes would leave expenditure almost unchanged as demand for food falls and rises at a similar rate as prices increase and decrease. Changes in demand for food are reflected in the demand for nutrients. The elasticities of nutrients with respect to the price of food (when significantly different from zero) are negative and quite small, suggesting that the average daily individual caloric intake would decline when the price of food rises.

Thus if income and price effects on the composition of diet are small, there might be other factors affecting food and thus nutrients demand. The model estimated controls also for some socio-demographic characteristics of the household. I find that households with an older head have, since 1988, allocated a higher share of expenditure to vegetables and fruit. Female employment has resulted in a lower share of expenditure on fat and sugar and higher shares of expenditure on vegetables and fruit. Availability of ready meals reduces consumption of dairy products and vegetables and fruit, while they increase share of

¹⁴As also Chesher (1997, 1998) found.

expenditure on meat and fish, suggesting that they substitute raw meat and fish. The presence of children is also important: young children reduce expenditure on fat and sugar, while adolescents increase it. Some differences also arise across geographical regions.

These findings are important from a policy perspective because they suggest 1) that income policies aiming at changing eating habits may have little impact on the national diet; 2) although the effect of price policies (subsidies or tax) could be more effective on household demand than income policies, the magnitude of the effect could still be smaller than expected.

This paper adds to the literature on UK food demand (Chesher, 1997, 1998; Lechene, 2000; Chesher and Lechene, 2002), presenting a first attempt to derive nutrient elasticities with respect to variations in food prices and consumer expenditure. Several extensions of this work would be desirable. First the empirical application uses data from the National Food Survey for Britain (1975-2000) that provides information on the total amount of food entering the household and not on the individual consumption. Thus, the household is treated as if it was a single individual that maximizes a utility function representing preferences of all household members jointly. However, as pointed out by Chiappori (1988, 1992), models of household behaviours that assume that each member has the same preferences may not be an accurate description of real life within a household. Thus future research may extend this work within the framework of the collective model.

Second, demand is likely to change continuously in ways that cannot be captured by changes in the variables considered here, for example time, education, media, food security, food quality and new foods appearing on the market may affect people choices (Becker, 1965; Blundell et al., 1994).

Third, in this paper the level of aggregation did not allow any distinction between complementarity and substitutability among food expenditure, however, considering more detailed food groups may help to gain precision in estimated cross-price elasticities (Blundell and Robin, 2000).

Fourth, a number of studies have found that intergenerational transmission of taste from parents to children in consumption of commodities such as alcohol and tobacco is positively related to the parental consumption of these commodities (Gruber, 2000; Manrique and Hensen, 2002; Farrell and Shields, 2007). It is not unreasonable to suppose that the same may apply to consumption of fat and sweet food.

Fifth, as special concerns are increasing about children's nutritional habits, particular attention should be paid to how they make their choice on food when eating out. Since 2001 the NFS has been part of the UK Expenditure and Food Survey (EFS), together with the Family Expenditure Survey (FES). This new data set provides specific information about personal expenditure on snacks, meals, sweets, and drinks consumed outside the home for each household member age 11 and over that could be used to shed some light on children's eating out habits.

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6 Appendix A

6.1 How to Introduce Socio-Demographic Characteristics into a Demand System

There are different ways used by researchers to include household socio-demographic characteristics into a demand system (Betti, 2000). We can distinguish:

- 1) the *Demographic Scaling* model (1964) considering the following utility functional form:

$$u = v\left(\frac{q_1}{m_1(d)}, \frac{q_2}{m_2(d)}, \dots, \frac{q_n}{m_n(d)}\right)$$

where $m_i(d)$ is the equivalence scale for a particular good i . The main problem with its empirical estimation derives from the evaluation of equivalence scales in goods which are not consumed in the reference household (for which all $m_i(d)$ are equal one).

- 2) *Gorman's model* (Gorman, 1976) modifies the cost function related to the previous model, adding a term representing the fixed cost associated with the demographic characteristic vector \mathbf{d} .

$$C(u, p, d) = C(u, p_1 m_1(d), p_2 m_2(d), \dots, p_n m_n(d)) + \sum p_k c_k(d)$$

- 3) The *Demographic Translating* method (Pollak and Wales, 1978) uses the following cost function:

$$C(u, p, d) = C(u, p) + \sum p_k c_k(d)$$

that is a special version of Gorman's model obtained fixing all $m_i(d)$ equal one.

- 4) The *Reverse Gorman* model (Pollak and Wales, 1981) applies the following demand function:

$$C(u, p, d) = C(u, p_1 m_1(d), p_2 m_2(d), \dots, p_n m_n(d)) + \sum p_k m_k(d) c_k(d)$$

- 5) The *Price Scaling* method (Ray, 1983) uses a multiplicative version of the cost function, as opposed to the additional version:

$$C(u, p, d) = C(u, p) m(p, d)$$

- 7) A general version incorporating all the previous ones was presented by Lewbel (1985). In this case the cost function is modified to be:

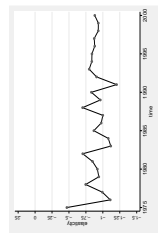
$$C(u, p, d) = f(C(u, h(p, d)), p, d)$$

7 Appendix B - Extra Tables and Figures

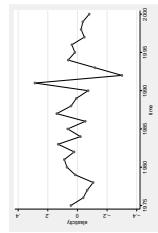
Table 9: Number of children (1975-2000) - Households obs. 130,728

		Freq.	Percent	Cum.
Number of children age 0-5				
	0	105,846	80.97	80.97
	1	16,702	12.78	93.74
	2	7,294	5.58	99.32
	3	835	0.64	99.96
	4	46	0.04	100
	5	3	0	100
	6	1	0	100
	7	1	0	100
Number of children age 6-11				
	0	106,468	81.44	81.44
	1	16,220	12.41	93.85
	2	7,049	5.39	99.24
	3	896	0.69	99.93
	4	79	0.06	99.99
	5	16	0.01	100
Number of children age 12-17				
	0	109,809	84	84
	1	13,957	10.68	94.67
	2	5,941	4.54	99.22
	3	882	0.67	99.89
	4	127	0.1	99.99
	5	9	0.01	100
	6	2	0	100
	7	1	0	100
	Total	130,728	100	

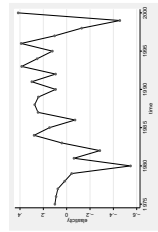
Figure 5: Food cross-price elasticities over time.



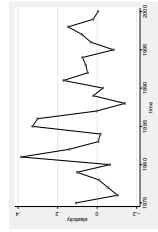
(a) Dairy products.



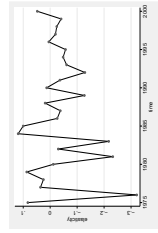
(b) Meat and fish.



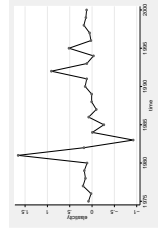
(c) Fat and sugar



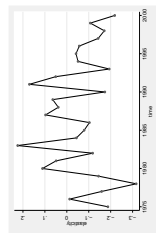
(d) Vegetables and fruit.



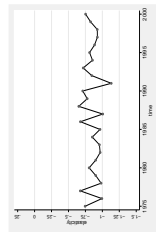
(e) Cereals.



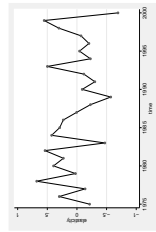
(f) Other food.



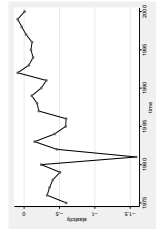
(g) Dairy products.



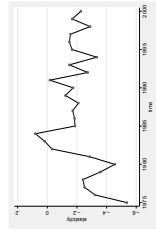
(h) Meat and fish.



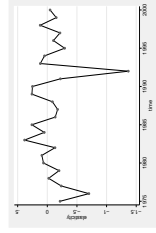
(i) Fat and sugar



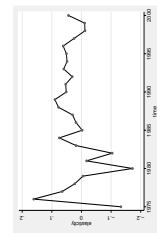
(j) Vegetables and fruit.



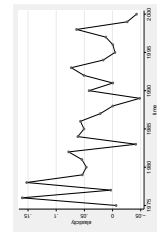
(k) Cereals.



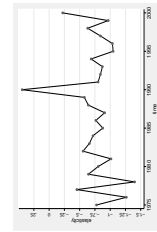
(l) Other food.



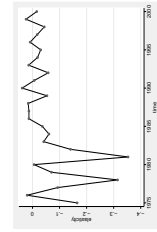
(m) Dairy products.



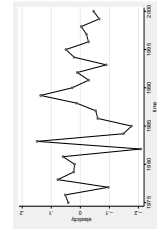
(n) Meat and fish.



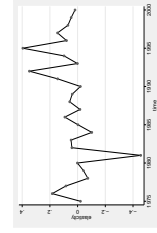
(o) Fat and sugar



(p) Vegetables and fruit.

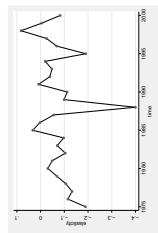


(q) Cereals.

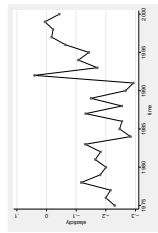


(r) Other food.

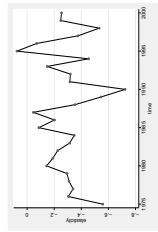
Figure 6: (Ctd.) Food cross-price elasticities over time.



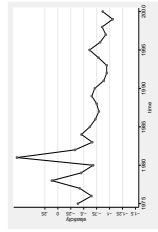
(a) Dairy products.



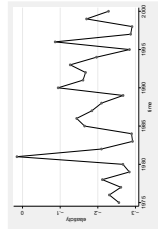
(b) Meat and fish.



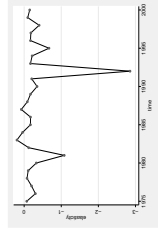
(c) Fat and sugar



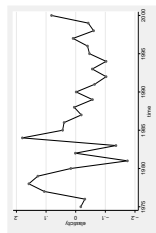
(d) Vegetables and fruit.



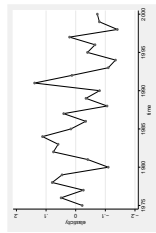
(e) Cereals.



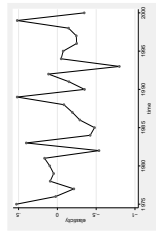
(f) Other food.



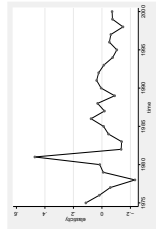
(g) Dairy products.



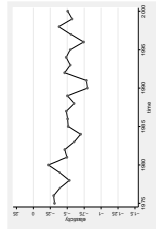
(h) Meat and fish.



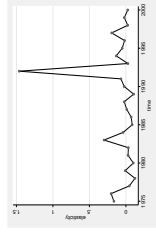
(i) Fat and sugar



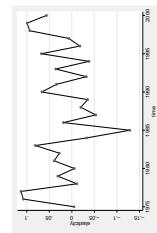
(j) Vegetables and fruit.



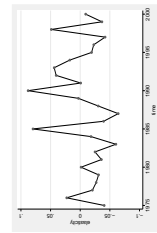
(k) Cereals.



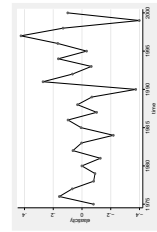
(l) Other food.



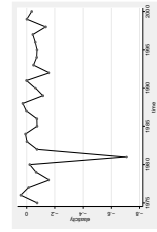
(m) Dairy products.



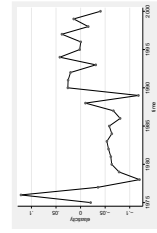
(n) Meat and fish.



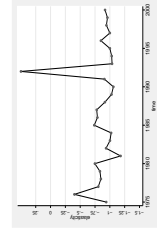
(o) Fat and sugar



(p) Vegetables and fruit.



(q) Cereals.



(r) Other food.