Modelling physical quantities of food and nutrients consumed from aggregate data – with an application to Finland

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Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009

Abstract

Anticipating the impact of changes in economic incentives on dietary quality and nutritional health requires knowledge of how physical quantities of food consumed respond to price and income variations. A problem arises, however, because physical quantities are: 1- not consistent aggregates in demand models; and 2- not measured at final/retail level in national statistics. The paper develops a solution by establishing explicitly the theoretical link between composite demand and physical quantities, from which a novel empirical approach to the estimation of nutrient elasticities is derived. It is applied to Finnish aggregate data from the National Accounts and Food Balance Sheets over the 1975-2006 period, and the results are used to assess the potential effectiveness of several incentive-based nutritional policy instruments.

Key words: Demand analysis; aggregation theory; physical consumption; nutrition; nutrient elasticity; Finland; fat tax; nutritional policy.

JEL Codes: I10; Q18; Q11

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1. Introduction

It is necessary to understand how the physical quantities of food demanded by consumers respond to economic incentives in order to tackle a whole range of policy issues. Hence, this paper is motivated by the need to inform policy aimed at improving nutritional health and tackle the obesity epidemic in Finland by means of fiscal or redistributive measures (e.g., adjustments in VAT rates of particular foods, fat taxes, thin subsidies, or allocation of vouchers for the purchase of healthy foods). However, the relationship between physical demand and economic variables has broader relevance, for instance in environmental economics where the environmental impact of food consumption and its potential responsiveness to a green tax have received attention.

In empirical work, however, a first problem relates to the nature of the available data on the physical quantities of food consumed in a given country, which are derived through accounting relationships in so-called "food balance sheets" (FBS). Those are typically recorded at the level of primary or intermediate commodities (e.g., wheat), which often are not purchased as such by consumers, or enter the composition of a multitude of final food products – in other words what is measured is the derived demand for primary or intermediate commodities, as opposed to final food demand. It is therefore difficult, artificial, and ultimately unsatisfactory to define consumer prices for those commodities, which prevents estimation of an ordinary system of demand based on that type of data.

A second problem arises because physical quantities, from which nutrient intakes can be derived by applying constant transformation coefficients, are not consistent aggregates in demand models, unless the underlying goods are perfectly substitutable on a one-to-one basis (Nelson, 1991). Consequently, there is no reason to believe that a system of demand for food expressed in physical terms should satisfy the restrictions (e.g., symmetry, homogeneity) implied by consumer theory, and, more generally, theory provides little guidance to estimate and interpret such a system.

Although recognised by some in the empirical literature (Reed et al., 2003), the aggregation problem has so far been ignored by researchers analysing demand for nutrients, who have either tested the restrictions implied by theory (Beatty & Lafrance, 2005; Smed et al., 2007), and/or imposed them in the course of estimation (Huang, 1996; Allais et al., 2008). Further, to the best of our knowledge, the fact that FBS data measure derived rather than final demand for food has not been addressed anywhere in the literature. The contribution of the paper is therefore to build a theoretical model of derived demand for commodities as recorded in FBS data, from which a novel empirical approach to the estimation of nutrient elasticities follows naturally. That approach involves three steps: 1- Estimation of a complete system of demand based on the consistent aggregates measuring food consumption (i.e., consumption volumes) in the Finnish national accounts; 2- Estimation of the relationship between physical quantities of commodities recorded in Food Balance Sheets and consumption volumes; and 3- Combining the relationships estimated in steps 1 and 2, we obtain how derived demand for food commodities measured in physical terms responds to consumer food prices and income. Although developed in the Finnish context, the proposed approach can be implemented in virtually any country as it relies on official national statistics that are easily, and freely, available. Another advantage of the approach lies in the fact that food availability data cover both food consumed within the home and food consumed in the catering sector. Hence, the estimated nutrient elasticities truly reflect the response of the entire diet to exogenous changes.

Of course, the problem inherent in the nature of FBS data outlined above could be circumvented by using household-level data, as has often been done in recent years in the economic analysis of nutritional health issues (Allais et al., 2008; Smed et al., 2007; Arnoult et al., 2008). However, while household-level data present the undeniable advantage of allowing analysis of how the determinants of demand for food vary across socio-demographic groups, they also present some undesirable characteristics (e.g., zero values, limited coverage of the diet both in terms of physical quantities and prices) that cause a whole range of econometric problems when estimating elasticities of demand for nutrients. Further, in the case of Finland, only the latest household budget survey (2006) records data on food quantities with any degree of accuracy, but the lack of price variability in a single year of data makes the estimation of price elasticities difficult.

The paper is organised as follows: the next section presents the theoretical and empirical models together with the data; section 3 reports the estimated elasticities of demand for food and nutrients as well as the results of simple policy simulations; and, finally, section 4 offers some tentative conclusions.

2. Theory of derived demand for commodities and estimation strategy

We start by developing a model of demand for food commodities derived from the consumption of food products at retail level. It is first noted that observations do not exist at the level of the numerous individual food products available to consumers, which typically number thousands in high-income countries with well developed food-processing and retail sectors[1]. Instead, statistical agencies always report data on much more aggregated groups, or composite goods. Hence, in the case of Finland, the National Accounts report consumption data on only 51 food and drink aggregates, while the corresponding number for the Household Budget Survey, although larger, is still modest at 215. Taking into account this feature of the data, we denote by x_{Gi} the unobserved quantity of the perfectly-homogenous final good *i* in composite good *G*.

Focusing on country-level data, consumption of each composite good *G* is observed both in terms of current-price expenditure E_G and constant-price expenditure, or consumption volume, Q_G. However, no information is available on the physical quantities of composite good *G*, which raises several problems when attempting to derive demand for nutrients and infer the response of dietary quality to economic changes. Consumption volumes Q_G are in themselves not informative about physical quantities, because, as demonstrated by Nelson (1991), they also have a quality component that reflects the within-group mix of goods consumed. Formally, Theil's quality index is defined for composite good *G* by $v_G = \sum_{i \in G} p^0_{Gi} x_{Gi} / q_G$, where q_G denotes the physical quantity of composite good *G*, i.e. $q_G = \sum_{i \in G} x_{Gi}$. It follows from simple algebra that $Q_G = v_G q_G$, which implies that there is no straightforward relationship between physical quantity q_G and consumption volume Q_G of a composite good. In particular, it is entirely possible for composite demand to increase while physical quantity decreases if consumers choose to reallocate consumption towards higher-quality goods as a result of an exogenous change, such as a rise in income. The same obviously applies to the nutrient content of food group *G*, which is proportional to q_G under the assumption of nutritional homogeneity of within-group goods. Further, in developed countries at least, there is convincing evidence that changes in composite demand are in fact driven primarily by changes in quality rather than physical quantity (Nelson, 1990; Reed et al., 2003). Altogether, this means that aggregate expenditure data are not, on their own, suitable to analyse the economic determinants of diet quality.

In this context, Food Balance Sheet (FBS) data, whose characteristics are discussed by Srinivasan et al. (2006), represent the only source of information on the aggregate physical quantities of foods consumed at country level. It is therefore necessary to extend the basic model of demand for food to

[1] For instance, the Finnish Food Composition (Fineli) Database database contains information on over 3000 foods – see http://www.fineli.fi/index.php?lang=en.

explicitly take account of the link between food commodities and retail food products. To that end, we denote by $\boldsymbol{f}$ the K-vector of physical quantities of commodities as measured in the FBS data, and by $\boldsymbol{r}_{Gi}$ the K-vector of per-unit commodity contents of final good i in composite good G. Vector $\boldsymbol{r}_{Gi}$ can be understood as a "recipe" (e.g., one kilogram of pizza contains 0.5kg of wheat, 0.3kg of vegetables of different kinds, 0.1 kg of meat and 0.15kg of cheese), which typically has a large number of zeros. The total commodity content of final good i in group G is simply obtained as the product of scalar x_{Gi} and each of the coordinates of vector r_{iG}, so that the total derived demand for farm commodities is:

$$f(Y,\boldsymbol{p}) = \sum_{G=1}^{M}\sum_{i=1}^{n_G} x_{Gi}(Y,\boldsymbol{p})\boldsymbol{r}_{Gi} \qquad (1)$$

where Y is aggregate income, $\boldsymbol{p}$ denotes the vector of prices of the foods available at retail level, M is the number of composite goods in the expenditure data, and n_G denotes the number of elementary goods in composite good G. That equation, however, cannot be estimated directly as the price vector $\boldsymbol{p}$ is both too large and unobserved. We follow the usual approach to reduce the dimension of the model in price space by defining aggregates that preserve the theoretical properties of demand systems. The Hicks condition for consistent aggregation that all prices of individual goods within a composite good change proportionally is therefore assumed: $p_{Gi}=P_G.p_{Gi}^{0}$, where the only new notation, P_G, denotes the price index of composite good G, which is observed as the ratio of current-price to constant-price expenditures E_G/Q_G. The expression of the derived demand for farm commodities (1) reduces to:

$$f(Y,\boldsymbol{P}) = \sum_{G=1}^{M}\sum_{i=1}^{n_G} x_{Gi}(Y,\boldsymbol{P})\boldsymbol{r}_{Gi} \qquad (2)$$

where $\boldsymbol{P}$ denotes the M-vector of composite price indices, that can be calculated from expenditure data. This expression suggests an empirical approach to the estimation of physical quantities of food that departs fundamentally from those followed in the existing literature. First, there is no reason to expect the vector of demand for food commodities $\boldsymbol{f}$ and that of price indices of retail composite goods $\boldsymbol{P}$ to have the same dimension because commodities are typically used in a variety of retail food products. Hence, the common practice of creating a one-to-one link between the categories of food commodities of the FBS data and retail prices that influence consumers' decisions is flawed, because consumers have preferences over composite final products, not commodities. Yet, we are not aware of any previous empirical analysis of the physical demand for food that does not rely on an exact mapping of the FBS categories to the grouping of retail goods used to report expenditure and price information (a practice henceforth referred to as "exact matching"). Second, there is no reason to believe that the whole system of derived demand (2) should satisfy the usual properties implied by consumer theory.

In fact, this becomes obvious once the exact matching assumption has been relaxed, in which case even the notion of own-price elasticity, and hence the theoretical property of negativity, become meaningless when applied to commodities. Yet, those theoretical properties are commonly tested (Beatty & LaFrance, 2005) or imposed (Huang, 1996) on quantity data in the existing literature. Finally, the relaxing of the "exact matching" assumption, which is desirable from a theoretical stand point, also creates additional problems for empirical application on short time series. In that situation, the usual approach to deal with the lack of degrees of freedom is to invoke some sort of separability or multi-stage budgeting assumptions (Edgerton et al., 1996, p. 69). This facilitates the estimation of the system of final demand but does not necessarily reduce the dimension of the system of demand for farm commodities because of the technical relationships introduced by matrix $\boldsymbol{r}$ across composite goods.

We therefore need to impose additional restrictions on preferences in order to allow estimation of the model of demand for farm commodities. At that level, we draw on ideas first proposed in a rich literature concerned with the estimation of demand elasticities from household survey data (Deaton, 1987, 1988, 1990) to overcome the problem of using and interpreting unit values in demand models, as those reflect both prices and endogenous quality choices. Following Crawford (2003), we start by assuming the weak separability of preferences in the partition corresponding to the M composite goods. Thus, demand for each elementary good i in group G can be expressed as $x_{Gi} = f_{Gi}(y_G, \mathbf{p}_G)$, where $\mathbf{p}_G$ is the vector of prices p_{Gi} of all goods in group G, y_G represents expenditure on composite good G (i.e. $y_G = \mathbf{p}_G \mathbf{x}_G$, where $\mathbf{x}_G$ denotes the vector of quantities x_{Gi} for each good i in group G). Given the Hicks-condition for consistent aggregation, and the linear homogeneity of demand functions in prices, the demand functions can be re-written as $x_{Gi} = f_{Gi}(y_G / P_G, \mathbf{p}^0_G)$. The base-period price vector $\mathbf{p}^0{}_G$ is, by definition, held fixed and therefore ignored in what follows. Meanwhile, the first argument of the demand function is, by definition of the Hicks-quantity index, the composite quantity Q_G. It follows that $x_{Gi} = f_{Gi}(Q_G(Y,P), \mathbf{p}^0_G)$, which means that the physical demand for any particular good i in group G is solely a function of composite demand $Q_G(\mathrm{Y},\mathbf{P})$. Under the stated assumptions, the derived demand for farm commodities (2) therefore becomes:

$$f(Y, \boldsymbol{P}) = \sum_{G=1}^{M} \sum_{i=1}^{n_G} x_{Gi}(Q_G(Y, \boldsymbol{P}))\boldsymbol{r}_{Gi} \qquad (3)$$

Keeping in mind that the vectors $\boldsymbol{r_{Gi}}$ of unit composition of the elementary goods typically present a large number of zero values, the derived demand for a particular farm commodity *a* can be more simply expressed as:

$$f_a(Y, \boldsymbol{P}) = h(Q_G(Y,P), Q_H(Y,P), \ldots.., Q_J(Y,P)) \qquad (4)$$

The list of arguments in (4) depends on whether the manufacturing of each composite good *G* requires commodity *a* (if so, *G* is included, if not, it is left out). Altogether, by establishing an explicit link between composite demand for retail products and derived demand for farm commodities, the model suggests the following estimation strategy:

Step 1: Estimate the demand for composite goods Q_G using the standard econometric toolkit of demand analysis. In particular, the properties implied by consumer theory can legitimately be tested and/or imposed on the whole demand system. This leads to a *M* x *(M+1)* matrix *E* of price and expenditure elasticities for all *M* composite food products.

Step 2: Estimate equations (4) by regressing demand for farm commodities on demand for the relevant composite goods. This gives a *K* x *M* matrix *Ω* of pseudo-elasticities of demand for farm commodities with respect to demand for composite goods (with constituent elements denoted by $\gamma_{aG} = \partial \ln f_a / \partial \ln Q_G$).

Step 3: Combine the results of Steps 1 and 2 to derive the *K* x *(M+1)* matrix *Σ* of elasticities of demand for farm commodities with respect to the prices of all composite food products as well as expenditure. It follows directly from (4) that *Σ= Ω. E*

Data

The physical quantity data from 1975 to 2006 for 35 commodities are derived from the food balance sheets published annually by the Finnish Ministry of Agriculture (Tike, 1975-2006). Some items are not included because they are only reported over a very short time period and, while most of those are quantitatively insignificant in the Finnish diet, we note the omission of important items such as sausages and other meat products. Discussions are on-going with the Ministry of Agriculture in order to try to resolve the issue. The National Accounts of the Finnish Government provide information on consumption volumes (i.e., expenditure at constant prices) as well as current price expenditure. Price indices for all food composites are then constructed as the ratio of current to constant-price expenditure on a particular composite group.

Empirical model

Stage 1 – Estimation of a complete system of demand

Given the small data set and the large number of elasticities to estimate, we assume a priori a simplified structure in the consumers' preferences whereby resources are allocated sequentially according to a three-stage budgeting procedure represented schematically in Figure 1. In total, this structure allows us to undertake the estimation of the economic determinants of demand for 25 food composites consumed at home, six food groups, and four high-level expenditure categories (including the relevant Food Away From Home (FAFH)).

The Almost Ideal Demand System (AIDS) developed by Deaton and Muellbauer (1980) is chosen for each of the eight sub-systems, as it presents several desirable properties that probably still makes it the most popular model with demand analysts (Arnoult, Tiffin & Traill, 2008). Following Deaton & Muellbauer (1980), Moschini & Moro (1993), and Bouamra-Mechemache et al. (2008), the empirical estimation of the systems is carried out on the basis of a first-difference linearised AIDS, where the regression equations take the following form

$$\Delta w_i = \alpha_i + \sum_j \gamma_{ij} \Delta \ln p_j + \beta_i \Delta \ln(Y_G / P_G^S) \qquad (5)$$

In the above equation, Δ denotes the first-difference operator, w_i is the expenditure share of food composite i in group G, p_j denotes the price index of composite good j, Y_G is total expenditure on the composites included in sub-system G, while α, β, γ represent vectors of parameters to be estimated[2]. The constant term α_i is introduced to capture any potential linear trend. Finally, $P^S{}_G$ denotes a price index of all the composites in group G and, in the linearised version of the model, is approximated by the Stone price index ($\ln P_G^S = \alpha_0 + \sum_{k \in G} w_k \ln p_k$). Estimation of the model requires one share equation to be dropped to avoid singularity of the variance-covariance matrix of the residuals, and it follows that adding-up holds automatically, while homogeneity and symmetry are easily testable.

[2] For notational convenience, time subscripts are omitted.

The price and expenditure elasticities of demand for each composite in the system are calculated at the sample mean using the formulae of Green & Alston (1990)[3], and the related but unconditional elasticities, which allow variations in group-level expenditure, are then derived as in Carpentier and Guyomard (2001). We then extend the formulae of Edgeton et al. (1996) to derive the elasticities relating to the FAFH group:

$$\begin{aligned} e_{i,FAFH} &= E_{(r)i} E_{(FAH)(r)} e_{(FAH)(FAFH)} \\ e_{FAFH,i} &= e_{(FAFH)(FAH)} w_{(stage2)r} w_{(r)i} \end{aligned} \qquad \text{(6a-b)}$$

The first (second) equation expresses the elasticity of demand for composite *i* (FAFH) with respect to the price of FAFH (commodity *i*). $E_{(r)i}$ denotes the within-group expenditure elasticity of composite *i* in group *r*; $E_{(FAH)(r)}$ denotes the elasticity of expenditure on food group *r* with respect to the total food-at-home (FAH) budget; $e_{(FAH)(FAFH)}$ is the elasticity of the FAH budget with respect to the price of FAFH, and $w_{(r)(i)}$ is the expenditure share of composite *i* in group *r*.

Step 2 – relationship between physical demand for commodities and consumption volumes of composite foods.

Theory provides no guidance on the form of relationship (4), and given the small size of the available time series, we estimate simple log-log relationships with the list of regressors presented in Table 2. Note that all regressions include FAFH because food eaten away from home is diverse enough to make use of all 35 commodities.

3. 1. Results – Demand elasticities (Step 1)

Estimation of the demand system is carried out by maximum likelihood maximisation and the results are therefore invariant to the choice of the share equation that is dropped. Each of the six sub-systems in stage three (see Figure 1), as well as the two systems in stages 1 and 2 were estimated separately and subjected to likelihood-ratio tests of specification. The results reported in Table A1 (Appendix) indicate that the model is consistent with the properties of homogeneity and symmetry implied by microeconomic theory, and those properties are therefore imposed in what follows. The tests also show that trends are present for some of the subsystems. The constant terms α_i were therefore kept in all sub-systems for consistency.

Table 1 reports the unconditional elasticities derived from the estimation of the eight systems defined in Figure 1, and overall conform to prior expectations. Most own-price elasticities are negative,

[3] Standard errors follow from application of the delta method.

significantly different from zero, and less than unity in absolute value, with the exception of those corresponding to flour & groats (positive but insignificant) as well as rice/other grains, processed meat, and sour milk products (negative but not statistically significant). Turning to the elasticities with respect to total private expenditure on non-durables, FAFH is identified in Stage 1 as a luxury with a large elasticity (2.1), while FAH is an inferior good, which is in line with intuition as well as Engel's law. In stage 3, most composites are normal goods, although the expenditure elasticity of demand for margarine & oils is negative and not significantly different from zero. Also conform to prior expectations, demand for alcoholic drinks is found to be relatively expenditure elastic. Finally, Table 1 reports statistically significant cross-price elasticities in most of the estimated demand systems, hence indicating the presence of strong complementarity and substitution relationships across commodities, and confirming the need to model the response of the entire diet to changes in economic incentives.

3.2. Results - Step 2 (pseudo-elasticities)

The regressions in step 2 are estimated by instrumental-variable techniques, where the instruments are: the log of private expenditure on non-durables (a proxy for income); all log-prices and the corresponding price index in Stage 1 of the utility tree, which is justified by the inclusion of FAFH in all estimated equations; and the logarithm of all "relevant" prices and corresponding indices in Stage 3 (i.e., if the consumption volume of composite "bread" appears as explanatory variable, all log-prices of the "Starches" group are included, together with the corresponding price index). The model is then estimated either in level or in first difference, with or without a trend variable, and the best specification is then selected by focusing on goodness of fit, overall significance of the model, plausibility of results, and serial independence of the error term. The corresponding pseudo-elasticities, which describe matrix Ω introduced in the theory section, are presented in Table 2, together with other summary statistics. With a few exceptions, most notably in relation to beverages, the physical quantities are statistically significantly linked to some composites and the regressions have a reasonable fit.

3.3. Results – Step 3 (nutrient elasticities and policy simulations)

Elasticities of physical quantities of food demand

By multiplying matrix E of unconditional demand elasticities derived in Step 1 to the matrix of pseudo-elasticities Ω derived in Step 2, one obtains a matrix of elasticities Σ that describes the responsiveness of the physical quantities of food commodities to changes in consumer food prices and income. That matrix is difficult to present because of its size (35 X 26), but Table A2 (Appendix) reports the results obtained when assuming that all prices in each of the six composite groups in Stage 3 (e.g., all starches) change proportionally. The last three columns of the table describe the responsiveness of food demand in physical terms to a change in the price of all FAH foods, all foods consumed away from home, as well as income. What is striking in the results is the fact that each column contains a large number of positive and negative values, which stands in sharp contrast to the pattern of unconditional elasticities (partially) presented in Table 1 with reference to consumption volumes. This is an attractive aspect of the results, as it seems intuitive that, in a developed country such as Finland, in physical terms an increase in the consumption of one food should be offset by a decline in the consumption of another food, regardless of the determinant. This sort of trade-off is better explored by calculating the elasticities of demand for nutrients and other nutritionally-relevant quantities in the next section.

Elasticities of demand for energy, nutrients and other nutritionally-relevant quantities

As shown by Huang (1996), the elasticity of demand for any given nutrient is the weighted average of the quantity elasticities reported in Table A2, using the shares of total nutrient intake as weights. Table 3 reports the results for total energy as well as the three macro-nutrients available in the data, namely fat, proteins, and carbohydrates. Further, because most nutritional recommendations also contain quantitative targets for the intake of sugar as well as fruits and vegetables, the related elasticities are also reported in the table. Although many important nutrients (e.g., saturated and polyunsaturated fats) are missing from this analysis due to the unavailability of the related nutritional coefficients, Table 3 gives a broad assessment of how diet quality responds to changes in price and income signals, and helps judge the plausibility of the estimated elasticities.

Starting with the effect of income on dietary quality, Table 3 establishes that total demand for energy is virtually unaffected by income level (elasticity of -0.01). This finding is intuitive in the context of a developed country where standards of living are high enough for the entire population to meet its energy needs. It is also in line with much of the evidence gathered from the analysis of household level data in developing countries. For instance, Bhargava (2007, p. 180) concludes from several rigorous empirical studies that the elasticity of demand for energy in developing countries such as India, the Philippines or Bangladesh is typically in the neighbourhood of 0.10, with higher values possible only during periods of food shortages[4]. Yet, our finding stands in sharp contrast to the results reported in the literature based on aggregate US data, with both Huang (1996) and Beatty & LaFrance (2005) estimating large elasticities of demand for energy[5]. Knowing that the "obesity epidemic" can be explained by an increase in calorie intake of only 100-150 calories (Cutler et al., 2003), which represents less than 7% of average energy needs[6], those large elasticities seem hardly plausible. Further, our results are consistent with those of Böckerman et al. (2007), who found no evidence that the severe recession that affected Finland in the early 1990s had reduced the incidence of obesity, which contrasts with the conclusion of similar studies for the US (Ruhm, 2000).

If income does not affect calorific intake, it has a large impact on several important aspects of dietary quality. Table 3 shows that for any 10% rise in income, fat and sugar intakes reduce by 4.9% and 7.2% respectively, while intake of fruits & vegetables, in particular of the nutrient-rich fresh variety, increase significantly (by 3.9% for the former, and 5.3% for the latter). Overall, the results therefore imply that income growth improves diet quality in Finland, a finding that is consistent with the micro-evidence on the determinants of nutritional health inequality (e.g. Lalluka et al., 2007)[7].

Regarding the effect of prices on diet quality, most of the reported elasticities are relatively small in absolute value. In line with a priori expectation, an increase in the price of all composites belonging to the fruits and vegetables group results in a decrease in consumption of fruits and vegetables, but the decline is only marginal (elasticity of -0.02). Similarly, the decrease in fat intake resulting from a rise in the price of foods high in fat and sugar is very limited (elasticity of -0.03), while the corresponding decrease in sugar intake is also small (elasticity of -0.17). Altogether, Table 3 shows that changes in group prices of the foods consumed at home have little influence on the macronutrient content of the Finnish diet[8].

Finally, the results indicate that the price of food away from home has a significant influence on nutritional outcomes in Finland. Higher FAFH prices raise total energy intake (elasticity equal to 0.08),

[4] The author reports an elasticity of demand for energy equal to 0.39 in Kenya, which he relates to the effect of a drought on the surveyed households.
[5] Huang (1996) reports a value of 0.266. The corresponding figure for Beatty & LaFrance (2005) is not reported as such but Figure 3, which is difficult to read, suggests that it is in the range of 0.30 for the 1990s period.
[6] This is a rough calculation, based on an average energy need of 2300 kCal per person per day. That approximate figure is inferred from Table 1 of the Finnish Nutritional Recommendations (VRN, 2005).
[7] KTL (2006b, p. 31) also states that 'Financial hardship adversely affects the diet of some segments of the population'.
[8] Note that even for the meat group, nutrient intake changes in proportion to energy intake, so that the nutrient composition of the diet is not affected.

with fat intake contributing most to that increase (elasticity equal to 0.23). At the same time, sugar intake increases and fruits and vegetable consumption decreases, which exacerbates the worsening in diet quality. This result might seem surprising given that the increase in availability and decrease in price of FAFH (particularly in relation to its fast food segment) are often presented as causal factors in the obesity epidemic (Chou, 2004). However, most FAFH in Finland is not fast food because workers traditionally eat a warm lunch in a staff canteen or cafeteria (KTL, 2006a, p. 21). Further, there is evidence that having lunch at a staff canteen is associated with recommended food habits (Roos, 2004), and more generally Pietinen et al. (1996) report that the catering sector in Finland has been instrumental in improving dietary quality over the 1972-1992 period[9]. In this context, our results are plausible if we accept that the average dietary quality of FAFH in Finland exceeds that of food eaten at home.

Effect of policy changes

The previous set of elasticities is used to simulate several policy scenarios corresponding to the different columns of Table 4. The first two scenarios concern changes in fiscal policy with no particular public health objective but that are relevant because they will come into place in the near future. We start with a decrease in the VAT rate applied to all foods at retail level from the current level of 17% to 12% in October 2009. The results indicate that the change would improve diet quality: the share of energy from fat and sugar would decrease, and consumption of fruits and vegetables would rise. However, the magnitude of the consumption changes is extremely small, and overall energy intake would rise, with a potentially negative effect on the incidence of obesity. Overall, it is unlikely that the change in VAT rate on foods consumed at home will have any major nutritional health impact in Finland.

The second scenario considers the reduction in VAT rate applied to purchase of FAFH that is likely to be implemented following recent legislative change at EU level. In line with scenario 1, we assume a 5% decrease in the VAT rate, and the results indicate an unambiguously positive, but small, effect on diet quality, with in particular decreases in fat and sugar intakes in the range of 1% coupled with a limited increase in fruits and vegetables consumption.

[9] For instance, the catering sector quickly switched from whole fat milk to low-fat milk and increased its offering of vegetables, and a free salad was introduced in the late 1970s.

Turning to nutritional health policies, we first consider the impact of a 10% fat tax applied to all food composites in the group labelled "foods high in fat and sugar" to which we add cheese and cream/ice-cream. The changes in nutrient intakes are consistent with an improvement in diet quality, but their magnitude is disappointingly small: total energy, fat and sugar intakes would shrink by only 0.14%, 0.51%, and 1.07% respectively. Besides, consumption of fruits and vegetables, although not directly taxed, would be negatively impacted as well (0.48% decline) because of the relationships of substitutability and complementarity captured by the model. Finally, the simulation demonstrates that the fat tax would raise total food expenditure by less than 1%.

Next, the effect of a 10% thin subsidy applied to all fruits and vegetables is summarised in the fourth column of Table 4. The policy would achieve its primary objective of raising fruits and vegetables consumption, but only by a modest 0.23%. The fat content of the diet would also decrease, but here again we observe undesirable adjustments in other dimensions of the diet, with a relatively large increase (1.44%) in sugar consumption. Expenditure on food at home would decrease by 0.77%, but because some of the released resources would be spent on FAFH (0.48% increase), the total reduction in food bill would only amount to 0.42%.

Finally, the last column of Table 4 combines the fat tax and the thin subsidy in a revenue neutral way, which would require raising the rate of the subsidy to 18.5% (while keeping the tax rate at 10%). The policy would be most successful in reducing fat intake (by 1.26%), but would have almost no impact on total calorific intake and therefore obesity. Further, the overall effect on diet quality is ambiguous because the model also suggests that sugar intake would rise by 1.60%, and consumption of fruits and vegetables would decrease somewhat.

4. Conclusion

This paper has developed a new approach to the estimation of nutrient elasticities from national aggregate statistics on value and physical quantities of food consumed. The model, unlike those available in the literature, recognises explicitly that physical quantities are always recorded on primary/intermediate food products rather than the final goods that enter a consumer's utility function. This feature implies that it is not possible to relate each quantity to a single price, which prevents estimation of an ordinary demand system. An empirical analysis of demand for food and nutrients in Finland demonstrates the applicability of the approach, which should be relevant more broadly to the analysis of other economic problems involving physical quantities of food consumed.

The paper will also contribute to the policy debate on how to improve nutritional health in developed countries as the policy simulations lead to several broad conclusions. First, we find that the response of diet quality to price and tax changes is quantitatively very small. Second, manipulating the price of large food groups often leads to undesirable "side effects", with diet quality improving in one dimension but worsening in another. Altogether, the results support the view that fat taxes and thin subsidies represent rather blunt instruments to tackle nutritional health problems, even without considering the differential responses of various socio-economic groups in the population. Whether that conclusion still holds when taxes and subsidies are applied to nutrients rather than foods remains to be established in the case of Finland.

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Table 1: Unconditional elasticities

	Price						
System	**Good 1**	**Good 2**	**Good 3**	**Good 4**	**Good 5**	**Good 6**	**Expenditure**
Stage 1							
FAFH	**-0.59**	-0.44	-0.10	-1.00			**2.14**
	(-2.4)	(-2.4)	(-0.8)	(-4.6)			**(7.7)**
FAH	-0.03	**-0.41**	-0.08	-0.21			**0.73**
	(-0.5)	**(-3.9)**	(-1.4)	(-1.9)			**(4.8)**
Non-durables	0.05	-0.16	**-0.33**	-0.47			**0.91**
	(0.8)	(-1.9)	**(-4.1)**	(-3.9)			**(5.6)**
Services	-0.06	-0.16	-0.16	**-0.60**			**0.98**
	(-2)	(-3.3)	(-5.1)	**(-8.7)**			**(11.5)**
Stage 31 (Starches)							
Rice/other grains	**-0.20**	0.05	-0.09	0.13			**0.23**
	(-0.8)	(0.6)	(-0.6)	(0.4)			**(0.7)**
Potatoes	0.02	**-0.26**	-0.10	-0.11			**0.85**
	(0.4)	**(-3.5)**	(-2.6)	(-1.3)			**(2.7)**
Flour & groats	-0.07	-0.14	**0.06**	-0.11			**0.49**
	(-0.6)	(-2.5)	**(0.4)**	(-0.6)			**(1.9)**
Bread	0.02	-0.04	-0.03	**-0.26**			**0.58**
	(0.4)	(-1.2)	(-0.6)	**(-2.5)**			**(3.2)**
Stage 32 (Meat)							
Fresh meat	**-0.26**	0.10	-0.04	0.01	0.09	-0.01	**0.84**
	(-2)	(0.8)	(-0.4)	(0.3)	(1.6)	(-0.5)	**(3.4)**
Sausages	0.13	**-0.62**	0.12	0.09	0.08	0.07	**0.87**
	(0.8)	**(-2.1)**	(0.6)	(1.1)	(1.2)	(2.2)	**(3.4)**
Processed meat	-0.13	0.16	**-0.23**	0.24	-0.18	-0.04	**1.37**
	(-0.6)	(0.5)	**(-0.7)**	(1.8)	(-1.8)	(-1)	**(3.5)**
Other meat prod.	0.12	0.57	0.94	**-1.57**	-0.09	-0.04	**0.50**
	(0.4)	(1.1)	(1.8)	**(-4.1)**	(-0.6)	(-0.7)	**(1.8)**
Fish	0.22	0.15	-0.20	-0.03	**-0.31**	0.04	**0.88**
	(1.7)	(1.2)	(-1.7)	(-0.7)	**(-2.9)**	(1.2)	**(2.9)**
Eggs	-0.07	0.37	-0.12	-0.04	0.13	**-0.36**	**0.64**
	(-0.4)	(2.3)	(-0.8)	(-0.7)	(1.2)	**(-4.8)**	**(2.1)**
Stage 33 (Milk & dairy)							
Milk and powder	**-0.29**	-0.04	0.21	0.12			**0.44**
	(-1.9)	(-0.3)	(2.2)	(1.1)			**(2.7)**
Sour milk products	-0.10	**-0.21**	0.07	0.24			**0.66**
	(-0.4)	**(-0.6)**	(0.3)	(1.2)			**(2.6)**
Other dairy	0.44	0.07	**-0.45**	-0.05			**0.61**
	(2.1)	(0.3)	**(-1.9)**	(-0.3)			**(2.5)**
Cheese	0.15	0.14	-0.03	**-0.26**			**0.40**
	(1.1)	(1.2)	(-0.2)	**(-1.7)**			**(2.6)**
Stage 34 (Fruits & vegetables)							
Fresh/frozen fruits	**-0.45**	-0.06	-0.02	0.02			**0.52**
	(-4.4)	(-2.2)	(-0.4)	(0.5)			**(2.2)**
Fruit preparations	-0.39	**-0.50**	0.03	0.04			**0.82**
	(-2.3)	**(-5)**	(0.3)	(0.4)			**(2.2)**
Fresh vegetables	-0.04	0.01	**-0.52**	0.06			**0.49**
	(-0.4)	(0.4)	**(-5.3)**	(1.5)			**(2.1)**
Vegetable prep.	0.07	0.02	0.14	**-0.61**			**0.38**
	(0.5)	(0.5)	(1.6)	**(-6.8)**			**(1.9)**
Stage 35 (Foods high in fat/sugar)							
Cakes & pastries	**-0.54**	-0.04	0.08	-0.04	0.12		**0.88**
	(-3.9)	(-0.4)	(1.2)	(-0.7)	(1.6)		**(3.5)**
Butter	-0.10	**-0.37**	0.17	-0.07	-0.21		**1.21**
	(-0.5)	**(-1.5)**	(1.2)	(-0.5)	(-1.4)		**(2.6)**
Margarine & oils	0.31	0.28	**-0.55**	-0.07	0.18		**-0.32**
	(1.4)	(1.3)	**(-2.8)**	(-0.5)	(1.4)		**(-1.1)**
Sugar, honey etc.	-0.10	-0.07	-0.07	**-0.38**	0.18		**0.89**
	(-0.6)	(-0.5)	(-0.7)	**(-2.6)**	(1.5)		**(2.6)**
Confectionary	0.14	-0.10	0.04	0.09	**-0.61**		**0.92**
	(1.6)	(-1.4)	(1)	(1.5)	**(-6.9)**		**(3.3)**
Stage 36 (Beverages)							
Non-alcoholic	**-0.20**	0.02					**0.41**
	(-3.3)	(0.2)					**(1.9)**
Alcoholic	-0.03	**-0.37**					**0.94**
	(-1)	**(-3.2)**					**(3.4)**

Table 2: Step-2 regression results

Commodity	Model Type	Composites (pseudo-elasticities)	R^2	D-W
Wheat	Level, no trend	Rice/other grains (0.096)**; flour (-0.232); bread (0.354)*; Cakes & pastries (0.116); FAFH (-0.114)**	0.78	2.02
Rye	Level, trend	Rice/other grains (0.147); flour (0.089); bread (0.544)***; FAFH (0.22)	0.83	1.52
Other grains	Level, no trend	Rice/other grains (-0.178); flour (1.169); bread (-0.608); FAFH (0.413)*	0.43	1.41
Rice	Level, no trend	Rice/other grains (0.219)*; FAFH (1.107)***	0.52	1.85
Potatoes	First difference, no trend	Potatoes (0.294); FAFH (-0.226)	0.10	2.39
Sugar	Level, no trend	Preserves (0.309)***; Cakes (0.143); Sugar/other (0.357)**; confectionary (0.191); soft drinks (-0.689); FAFH (-0.615)**	0.60	2.04
Fresh tomatoes	Level, no trend	Fresh vegetables (0.446)***; FAFH (0.160)	0.90	1.48
Other fresh veg	Level, trend	Fresh vegetables (0.149); FAFH (-0.162)	0.68	1.63
Process veg	First difference, trend	Fresh vegetables (-0.575); FAFH (-0.476)	0.07	2.07
Citrus fruits	Level, no trend	Fresh/frozen fruits (-0.525)*; FAFH (-388)	0.47	1.77
Other fresh fruits	Level, trend	Fresh/frozen fruits (0.200)**; FAFH (0.476)***	0.72	2.02
Processed fruits	Level, no trend	Fresh/frozen fruits (0.556)***; sugar/jam (-0.258); FAFH (0.647)*	0.86	2.53
Fruit juice	Level, no trend	Soft drinks (1.651)***; FAFH (-0.141)	0.50	1.01
Berries	Level, no trend	Fresh/frozen fruits (1.579)**; fruit preserves (-1.115)***; sugar/jam (1.353)***; FAFH (0.878)**	0.73	1.52
Beef & veal	Level, no trend	Fresh meat (-0.089); sausages (0.509)***; processed meat (-0.380)***; other meat (0.077); FAFH (0.415)*	0.86	1.49
Pork	First difference, no trend	Fresh meat (0.439); sausages (-0.698)**; processed meat (0.537)***; other meat (0.247); FAFH (-0.578)**	0.25	1.56
Other meat	Level, no trend	Fresh meat (-0.623); sausages (1.163); processed meat (-2.171)***; other meat (2.790)***; FAFH (-4.534)***	0.91	2.12
Poultry	First difference, no trend	Fresh meat (-0.693); sausages (-1.227)*; processed meat (1.136)***; other meat (0.192); FAFH (0.179)	0.18	1.49
Eggs	Level, no trend	Eggs (0.678)***; cakes (-0.538)***; FAFH (0.148)**	0.84	1.70
Fresh fish	Level, trend	Fish (-0.381); FAFH (0.613)*	0.70	1.35
Processed fish	Level, no trend	Fish (-0.11); FAFH (1.59)***	0.59	1.51
Milk	First difference, trend	Milk (0.583); confectionary (-0.026); FAFH (-0.215)	0.03	2.00
Sour milk products	First difference, trend	Sour milk (0.276); FAFH (0.318)*	0.18	1.67
Cream	First difference, no trend	Cream/ice-cream (0.175)*; confectionary (0.142); FAFH (-0.126)	0.30	2.48
Ice-cream	Level, trend	Cream/ice-cream (1.036)***; FAFH (-0.401)***	0.90	1.54
Milk Powder	Level, no trend	Milk (2.758)*; cakes (-2.614); confectionaries (-1.676); FAFH (3.993)***	0.83	1.85
Cheese	First difference, no trend	Cheese (0.938)***; FAFH (0.068)	0.35	2.35
Butter	Level, no trend	Cakes (0.026)*; butter (0.609)***; confectionary (0.132); FAFH (-0.663)***	0.95	2.66
Margarine	First difference, no trend	Cakes (0.202); butter (-0.060); margarine/oils (0.525)**; confectionary (-0.090); FAFH (-0.222)	0.24	2.07
Vegetable oil + other	Level, no trend	Potatoes (2.043)**; cakes (3.566)***; margarine (2.648)***; confectionary (-1.718)**; FAFH (-2.807)***	0.78	1.97
Sugary soft drinks	Level, trend	Soft drinks (1.331); FAFH (-2.214)**	0.69	1.52
Other soft drinks	First difference, no trend	Soft drinks (0.454); FAFH (0.298)	0.01	1.78
Beer	First difference, trend	Alcoholic drinks (0.088); FAFH (0.093)	0.07	1.18
Wine	First difference, trend	Alcoholic drinks (0.658)**; FAFH (-0.129)	0.17	1.12
Other alcoholic drinks	Level, trend	Alcoholic drinks (1.073); FAFH (1.592)	0.07	2.11

*Note: coefficients statistically different from zero are identified with stars (*10%; **5%; ***1%).*

Table 3: Elasticities of demand for nutrients and other nutritionally-relevant quantities

	Prices							Income
	Starches	Meat etc.	Milk/ dairy	F&V	Sugar/ fat	Bever.	FAFH	
Macronutrients								
Energy	-0.02	-0.08	0.00	-0.01	-0.01	-0.01	0.08	-0.01
Proteins	-0.06	-0.06	-0.04	0.01	0.01	-0.01	0.01	0.21
Fat	0.00	-0.07	0.01	0.04	-0.03	0.02	0.23	-0.49
Carbohydrates	0.00	-0.09	0.02	-0.04	-0.01	0.01	0.06	0.03
Nutritionally relevant foods								
Sugar	0.19	-0.20	0.14	-0.14	-0.17	0.13	0.34	-0.72
F&V	0.02	-0.05	0.00	-0.02	-0.05	-0.04	-0.06	0.39
Fresh F&V	0.03	-0.08	0.01	-0.03	-0.07	-0.04	-0.10	0.53

Table 4: Results of policy simulations

	Decrease in FAH VAT	Decrease in FAFH VAT	Fat Tax	Thin subsidy	Fat tax + thin subsidy
Macronutrients					
Energy	0.49%	-0.33%	-0.14%	0.06%	-0.04%
Proteins	0.63%	-0.05%	-0.05%	-0.05%	-0.16%
Fat	0.14%	-0.92%	-0.51%	-0.41%	-1.26%
Carbohydrates	0.49%	-0.26%	0.16%	0.43%	0.96%
Nutritionally relevant foods					
Sugar	0.26%	-1.39%	-1.07%	1.44%	1.60%
F&V	0.62%	0.26%	-0.48%	0.23%	-0.06%
Fresh F&V	0.75%	0.43%	-0.68%	0.26%	-0.20%
Food Expenditure					
FAH	-2.55%	0.13%	1.31%	-0.77%	-0.11%
FAFH	1.89%	-1.67%	-0.93%	0.48%	-0.04%
Total	-1.33%	-1.21%	0.69%	-0.42%	-0.09%

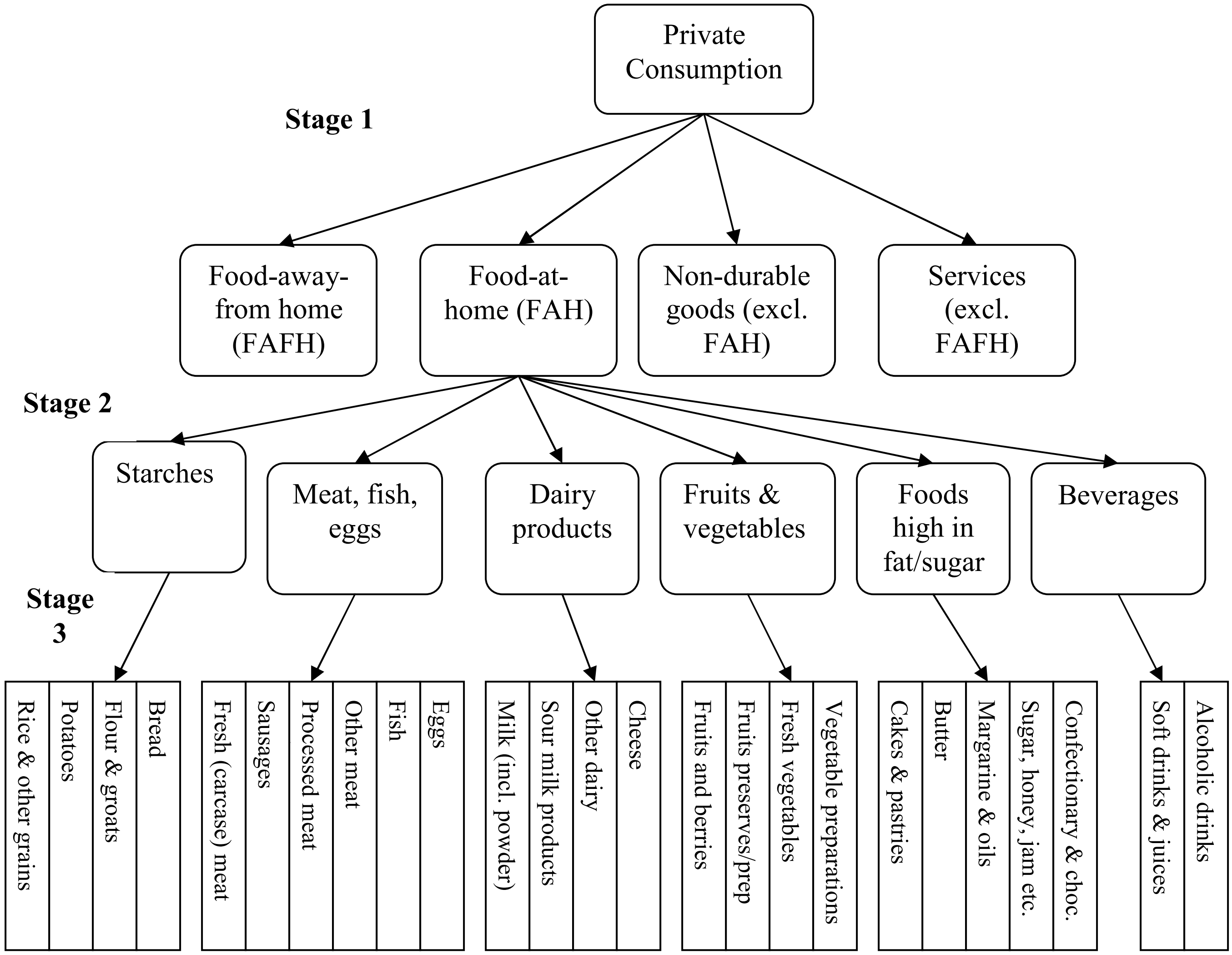

Figure 1: Utility tree

Appendix - Table A1: Specification tests

Ho System	Log-likelihood Unrestricted	Restricted	Ratio	# Restrictions	Critical Value (5%)	P-value
Homogeneity						
Stage 1	436.5	433.2	6.5	3	7.8	0.089
Stage 2	734.5	733.6	1.9	5	11.1	0.866
Starches	357.1	356.0	2.3	3	7.8	0.511
Meat	693.3	691.6	3.4	5	11.1	0.633
Milk/Dairy	365.1	363.9	2.4	3	7.8	0.487
Fruits & veg.	347.2	346.1	2.1	3	7.8	0.554
Fat / Sugar	473.7	469.6	8.3	4	9.5	0.082
Beverages	102.4	102.4	0.0	1	3.8	0.900
Homogeneity + Symmetry						
Stage 1	436.5	430.0	13.0	6	12.6	0.043
Stage 2	734.5	727.1	14.8	15	25.0	0.466
Starches	357.1	354.9	4.5	6	12.6	0.612
Meat	693.3	683.3	20.0	15	25.0	0.172
Milk/Dairy	365.1	363.7	2.9	6	12.6	0.823
Fruits & veg.	347.2	344.6	5.2	6	12.6	0.515
Fat / Sugar	473.7	466.4	14.6	10	18.3	0.149
Beverages	102.4	102.4	0.0	1	3.8	0.900
No trend						
Stage 1	436.5	434.1	4.8	3	7.8	0.188
Stage 2	734.5	724.9	19.2	5	11.1	0.002
Starches	357.1	354.5	5.3	3	7.8	0.153
Meat	693.3	688.6	9.5	5	11.1	0.092
Milk/Dairy	365.1	353.5	23.2	3	7.8	0.000
Fruits & veg.	347.2	346.7	1.0	3	7.8	0.798
Fat / Sugar	473.7	468.8	9.9	4	9.5	0.042
Beverages	102.4	102.4	0.1	1	3.8	0.744

Appendix - Table A2: Elasticities of physical quantities of food demand

	Prices								Income
	Starches	Meat	Milk/ dairy	F&V	Fat/ Sugar	Drinks	FAH	FAFH	
Wheat	**-0.03**	-0.06	0.00	0.02	0.01	-0.01	-0.07	0.06	-0.03
Rye	**-0.22**	-0.10	-0.09	0.01	0.16	-0.07	-0.32	-0.15	0.86
Other grains	**-0.23**	0.16	-0.13	-0.07	0.31	-0.02	0.01	-0.23	0.53
Rice	**-0.08**	-0.12	-0.07	-0.05	-0.05	-0.15	-0.52	-0.66	2.42
Potatoes	**-0.12**	-0.03	-0.04	0.02	0.12	0.00	-0.04	0.12	-0.24
Sugar	0.19	-0.20	0.14	-0.14	**-0.17**	0.13	-0.06	0.34	-0.72
Fresh tomatoes	0.01	0.01	-0.01	**-0.22**	0.05	-0.03	-0.19	-0.10	0.56
Other fresh veg	0.01	0.03	0.01	**-0.06**	0.03	0.02	0.03	0.09	-0.27
Process veg	0.02	-0.01	0.06	**0.25**	-0.01	0.26	0.58	0.31	-1.68
Citrus fruits	0.00	0.00	0.02	**0.29**	-0.05	0.06	0.32	0.24	-1.10
Other fresh fruits	-0.02	-0.03	-0.03	**-0.13**	0.00	-0.07	-0.27	-0.29	1.12
Processed fruits	-0.05	0.10	-0.07	**-0.51**	0.20	-0.08	-0.41	-0.39	1.61
Fruit juice	-0.02	0.05	-0.05	-0.01	-0.02	**-0.27**	-0.32	0.05	0.38
Berries	0.21	-0.64	0.11	**0.20**	-0.67	-0.22	-1.01	-0.57	2.99
Beef & veal	-0.01	**-0.02**	-0.01	-0.02	0.01	-0.06	-0.12	-0.24	0.77
Pork	-0.02	**-0.03**	-0.06	0.04	-0.14	0.11	-0.09	0.32	-0.62
Other meat	-0.15	**-0.22**	-0.43	0.34	-1.08	0.84	-0.70	2.48	-4.88
Poultry	-0.01	**-0.02**	-0.01	-0.01	-0.01	-0.02	-0.08	-0.11	0.39
Eggs	-0.14	**0.14**	-0.13	-0.05	0.09	0.05	-0.04	-0.09	0.28
Fresh fish	0.00	**-0.01**	0.01	-0.04	0.05	-0.10	-0.08	-0.35	0.98
Processed fish	-0.07	**-0.14**	-0.08	-0.08	-0.08	-0.21	-0.65	-0.94	3.32
Milk	-0.04	-0.07	**0.01**	0.01	0.10	-0.04	-0.03	0.12	-0.23
Sour milk products	-0.05	-0.10	**-0.02**	-0.01	0.03	-0.09	-0.24	-0.20	0.86
Cream	0.01	-0.09	**0.02**	0.02	-0.02	-0.02	-0.08	0.06	-0.03
Ice cream	-0.10	-0.21	**0.03**	0.02	0.20	-0.11	-0.18	0.21	-0.23
Milk Powder	-1.26	0.88	**-0.73**	-0.64	1.92	-0.45	-0.28	-2.25	5.90
Cheese	-0.08	-0.16	**0.00**	0.00	0.10	-0.10	-0.24	-0.06	0.52
Butter	0.22	-0.33	0.15	0.14	**-0.38**	0.00	-0.20	0.35	-0.54
Margarin	-0.02	0.09	-0.01	-0.01	**0.08**	0.04	0.18	0.14	-0.62
Vegetable oil/other	0.08	-0.16	0.13	0.17	**-0.07**	0.13	0.27	0.96	-2.74
Sugary soft drinks	0.09	0.24	0.08	0.09	0.12	**0.05**	0.67	1.29	-4.20
Other soft drinks	-0.02	-0.02	-0.03	-0.02	-0.03	**-0.12**	-0.24	-0.18	0.83
Beer	-0.01	0.00	-0.01	-0.01	-0.01	**-0.05**	-0.09	-0.06	0.28
Wine	-0.02	0.05	-0.04	-0.01	-0.02	**-0.25**	-0.29	0.05	0.34
Other alcoholic drinks	-0.11	-0.10	-0.18	-0.10	-0.16	**-0.63**	-1.27	-0.99	4.42