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## Estimation of Price Elasticities from Norwegian Household Survey Data

**Abstract:**

In this paper, a subsystem of demand equations is estimated using data from the Norwegian survey of household expenditures 1989-1991. One objective has been to obtain substantial knowledge of Norwegian household demand for a set of food groups, with emphasis on price responses, using two different approaches, namely, the method proposed in Deaton (1990), which utilises unit values instead of market prices, and an alternative approach, which relies on market prices. Comparing the two approaches, we conclude that they produce significantly different results. Possible explanations of this finding and implications for further research are discussed.

**Keywords:** Consumer demand, price elasticities, unit values, quality.

**JEL classification:** C3, C5, D1

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## 1. Introduction

For the purpose of policy design, e.g. tax or subsidy reforms, it is important for policy makers to know how consumers change their behaviour in response to changes in prices. The estimation of price elasticities in consumer demand has received considerable attention in the literature. However, it seems fair to say that there are still many unsolved problems. The standard approach relies on time-series data, or time-series of cross-sections, assuming that there exists no spatial variation in prices. However, this assumption is not very realistic. Unpublished figures for Norway, provided to the author by the Norwegian Competition Authority, indicate that there might exist significant spatial price variation for a number of commodities.

In a series of papers, Deaton (1987, 1988, 1990) developed a methodology for estimating price elasticities from household survey data in the case where no exogenous price data are available. His technique relies on spatial price variation, and information on the spatial distribution of prices is obtained from observed unit values, defined as expenditure divided by quantity. Hence, this method is restricted to household surveys where both expenditure and quantity are reported. In the annual Norwegian household expenditure survey, quantities are reported for foods and beverages.

Although tempting, substituting unit values in the place of market prices in a regression of budget shares on e.g. market prices and total expenditure would not be appropriate. First, we would run the risk of simultaneity bias because unit values are not exogenous. A second, and possibly more important problem arises from the fact that unit values may change less than proportionately to price changes. Since the commodity groups for which we have data typically will be heterogeneous, due to different qualities, households can respond to a general price increase by altering both quantity and quality. If we define a price increase of a commodity group as a proportionate increase in the prices of all the different qualities, unit values may change less than proportionately because households respond to a price increase by choosing less expensive qualities. Thus, it is likely that parameter estimates will be biased when running a regression of e.g. budget shares on unit values.

In this paper, we estimate a subsystem of demand functions for the commodities meat, fish, vegetable, fruit and potato based on data from the Norwegian household survey. Two different approaches are

used, namely, the one proposed by Deaton (1990)<sup>1</sup> and an alternative one, which utilises exogenous price information. Although the estimation procedure for the two approaches differs, the basic model is the same. An important objective of this paper is to obtain knowledge on price elasticities for the foods in question. In addition, it will be interesting to compare the results from Deatons approach to the results obtained when direct observation of market prices are used.

The paper is organised as follows. The next section gives a brief discussion of the theoretical model and how it can be estimated under two different information sets. First, we show how parameters can be estimated when no exogenous price information is available and second, we discuss the estimation procedure when prices are observed. Data are described in Section 3 while the estimated price and Engel elasticities for the five commodities, using both Deatons approach and the alternative approach, are presented in Section 4 and Section 5, respectively. In Section 6, we compare the results from the two different approaches. Section 7 concludes the paper.

## **2. The model**

### **2.1. The model spesification**

The model describes a situation where consumers choose both quality and quantity. Commodities are defined as groups of heterogeneous goods which vary with respect to both quality and price. The expenditure per unit of the commodity, or unit value, will depend on the choice of quality, and thus on income and demographic variables due to variation in preferences. To estimate the model, data are required both on household expenditures and physical quantities. Furthermore, households must be geographically «clustered» within the sample. Clustering is important because it means that households within each cluster can be assumed to face approximately the same set of market prices. In addition, for this assumption to hold, households within a cluster must be interviewed at approximately the same time (in this study, a «cluster» is defined as a set of households who live in the same area and who do their accounts in the same quarter). We do not, however, need exogenous price information which means that price elasticities can be estimated without having direct observations of market prices.

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<sup>1</sup> Two other studies using Deatons approach are Laraki (1988) and Nelson (1990).

In Deaton (1990), the following regression functions are postulated for the budget share and unit value of commodity  $j$  for household  $i$  in cluster  $c$

$$(1) \quad w_{jic} = \alpha_j^0 + \beta_j^0 \ln x_{ic} + \gamma_j^0 \cdot z_{ic} + \sum_{k=1}^J \theta_{jk} \ln P_{kc} + (f_{jc} + u_{jic}^0)$$

and

$$(2) \quad \ln v_{jic} = \alpha_j^1 + \beta_j^1 \ln x_{ic} + \gamma_j^1 \cdot z_{ic} + \sum_{k=1}^J \psi_{jk} \ln P_{kc} + u_{jic}^1$$

for  $j=1, \dots, J$ ,  $i=1, \dots, N$   $c=1, \dots, C$ . Equation (1) gives the budget share,  $w_{jic}$ , of good  $j$  as a function of total expenditure (measured in nominal prices),  $x_{ic}$ , household characteristics,  $z_{ic}$ , commodity prices,  $P_{kc}$ , and a cluster-fixed effect,  $f_{jc}$ . The logarithm of the unit value,  $v_{jic}$ , is postulated to be a function of the same set of explanatory variables that appear in the share equation, with the exception of the cluster-fixed effect. The  $\alpha$ 's,  $\beta$ 's,  $\gamma$ 's,  $\theta$ 's and  $\psi$ 's are all parameters.

Under the assumption that market prices are not observed, including a cluster-fixed effect in the unit value equation would preclude identification of price elasticities, because the unit value would no longer provide useful information about the true prices. This point will be discussed in more depth below. For the moment, we simply note that the exclusion of a cluster-fixed effect in (2) is a crucial assumption.

Eq. (1) looks very much like the Almost Ideal Demand System (AIDS) of Deaton and Muelbauer (1980). However, the model here is different. As recognised by Deaton (1990), the equations (1) and (2) should not be taken as a direct representation of preferences, but rather as the regression functions of budget share and unit value conditional on the right-hand-side variables. Zero expenditure is allowed for so that expectation is taken over purchasers and nonpurchasers alike. It should be noted that there is no guarantee that there exist preferences that would generate regression functions of the form (1) and (2).

The inclusion of equation (2) is motivated from the fact that consumers choose not only quantity, but also quality. We now show how both expenditure share and unit value depend on the choice of quality. By definition, we have that the expenditure share and unit value of commodity  $j$  (household  $i$ , cluster  $c$ ) are given by

$$(3) \quad w_{jic} = \frac{P_{jc} \cdot q_{jic}}{x_{ic}}$$

and

$$(4) \quad v_{jic} = \frac{P_{jc} \cdot Q_{jic}}{Q_{jic}},$$

respectively, where  $p_{jc}$  and  $q_{jic}$  are vectors of the prices and quantities of the individual goods that define commodity  $j$  and  $Q_{jic}$  denotes the total physical quantity of commodity  $j$  measured in kilos (i.e. we have that  $Q_{jic} = o \cdot q_{jic}$ , where  $o$  is a column vector of ones). We can now rewrite (3) and (4) as follows

$$(5) \quad w_{jic} = \frac{P_{jc} \rho_{jc} Q_{jic}}{x_{ic}}$$

and

$$(6) \quad v_{jic} = P_{jc} \rho_{jic}$$

where

$$\rho_{jic} = \frac{p_j^* \cdot q_{jic}}{Q_{jic}}$$

is the quality indicator introduced by Deaton (1988),  $P_{jc}$  is the price index of commodity  $j$  used in (1) and (2), and  $p_j^*$  denotes a vector of relative prices<sup>2</sup> where the  $m$ th element is given by  $\frac{P_{mjc}}{P_{jc}}$ . Note that equation (2) relies on equation (6) and the assumption that the choice of quality can be explained by prices, expenditure and demographic variables.

The quality indicator measures to what extent a consumer is choosing the more expensive varieties. More precisely,  $\rho_{jic}$  is a weighted sum of the quantity shares of the different goods (varieties) constituting commodity  $j$ , where the corresponding constant relative prices are used as weights (the elements in  $p_j^*$ ). Thus, a high  $\rho_j$  will be observed for consumers who buy relatively more of the expensive varieties that define commodity  $j$ , whereas the opposite is true for consumers buying relatively more of the cheaper varieties.

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<sup>2</sup> The relative prices of the different goods in each commodity group are assumed constant across clusters, which is indicated by the fact that  $p_j^*$  has no cluster subscript,  $c$ .

The results in this study will be presented in terms of two set of elasticities, to which we now turn. By using (1), (2), (5) and (6), we derive the following income and price elasticities of physical quantity<sup>3</sup> for commodity j (the subscripts i and c are dropped for convenience)

$$(7) \quad E_j = \frac{\beta_j^0}{w_j} - \beta_j^1 + 1$$

and

$$(8) \quad e_{jk} = \frac{\theta_{jk}}{w_j} - \psi_{jk}$$

where  $E_j$  is the income elasticity and  $e_{jk}$  denotes the price elasticity of good j with respect to price k.

As mentioned above, Deaton makes the assumption that relative prices, of goods within each commodity group, are constant across clusters. This allows us to derive the Hicksian composite good elasticities. By applying the composite good theorem (see Deaton and Muellbauer (1980, pp. 121)), we can write (3) as

$$(9) \quad w_{jic} = \frac{P_{jc} Q'_{jic}}{x_{ic}},$$

where

$$Q'_{jic} = p_{jc}^* \cdot q_{jic}$$

is the Hicksian aggregate. The corresponding income and price elasticities are given by (again the subscripts i and c are left out)

$$(10) \quad \tilde{E}_j = \frac{\beta_j^0}{w_j} + 1$$

and

$$(11) \quad \tilde{e}_{jk} = \frac{\theta_{jk}}{w_j} - \delta_{jk}$$

where

$$\delta_{jk} = \begin{cases} 1 & \text{if } j = k \\ 0 & \text{otherwise} \end{cases}$$

From this point on, the elasticities given in (7) and (8) are referred to as the «quantity elasticities» and (10) and (11) are referred to as the «demand elasticities». This corresponds to the terminology

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<sup>3</sup> Quantity is measured in kilos.



adopted by Nelson (1990). Both price elasticities are Cournot elasticities. It should be noted that Deaton (1990) only report the quantity elasticities, i.e. the elasticities given in (7) and (8).

## 2.2. Estimation when prices are unobservable

When all prices are observed the identification of the parameters in (1) and (2) is more or less straightforward. However, assuming that prices are not observed, all of the parameters cannot be identified without further prior information. The basic results that yields identification is a formula that links the effects of prices on quality choice to conventional price and total expenditure (income) elasticities. Given that preferences are weakly separable in the basic goods that comprise each commodity, it is shown in Deaton (1987) that

$$(12) \quad \frac{\partial \ln v_j}{\partial \ln p_k} = \delta_{jk} + \frac{\eta_j e_{jk}}{E_k}, \quad j, k = 1, \dots, J$$

where  $\eta_j$  denotes the quality elasticity as defined by Prais and Houthakker (1955) (which equals the elasticity of the unit value of commodity  $j$  with respect to income),  $e_{jk}$  and  $E_k$  are the price and income elasticities of quantity defined in (8) and (7), respectively and  $\delta_{jk}$  again denotes the kroneker delta ( $\delta_{jk}=1$  if  $j=k$ , 0 otherwise). In terms of the parameters in (1) and (2), we can also express (12) as follows

$$(13) \quad \psi_{jk} = \delta_{jk} + \beta_j^i \left( \frac{\theta_j / w_j - \psi_{jk}}{(1 - \beta_j^1) + \beta_j^0 / w_j} \right).$$

From (12) (or equivalently (13)), it is clear that we will tend to overstate the true own-price elasticity under normal assumptions if the own-price elasticity is measured by the relationship between the change in quantity and the change in unit value. Under normal assumptions, we will expect the last term on the right-hand side of (12) to be negative and hence, the unit value will move less than proportionate to the market price. This implies that regressing quantity on unit value will result in a larger relative price effect than when regressing quantity on the true market price.

We now present the two-stage estimation approach proposed by Deaton (1990). At the first stage, within cluster variation is used to estimate the effects of income and household characteristics on both shares and unit values, i.e. estimates of  $\beta_j^0$ ,  $\gamma_j^0$ ,  $\beta_j^1$  and  $\gamma_j^1$  in (1) and (2) are obtained. We thus start by estimating the equations obtained when cluster means of all variables are subtracted from (1) and (2), i.e.

$$(14) \quad \bar{w}_{jic} = \beta_j^0 \overline{\ln x_{ic}} + \gamma_j^0 \bar{z}_{ic} + \bar{u}_{jic}^0$$

and

$$(15) \quad \overline{\ln v_{jic}} = \beta_j^1 \overline{\ln x_{ic}} + \gamma_j^1 \bar{z}_{ic} + \bar{u}_{jic}^1$$

where  $\bar{\chi}$  indicates that we have subtracted the cluster mean from the variable  $\chi$ . The parameters in (14) and (15) can be consistently estimated using OLS.

We define  $\hat{u}_{jic}^0$  and  $\hat{u}_{jic}^1$  as the residuals from the two set of regressions above (from (14) and (15), respectively). These residuals can be used to obtain consistent estimates of the variances and covariances of the residuals in (1) and (2) as follows:

$$(16) \quad \sigma_{jk}^{00} = (n - C - k)^{-1} \sum_c \sum_i \hat{u}_{jic}^0 \hat{u}_{kic}^0$$

and

$$(17) \quad \sigma_{jj}^{11} = (n_j^+ - C - k)^{-1} \sum_c \sum_i (\hat{u}_{jic}^1)^2$$

and

$$(18) \quad \sigma_{jj}^{01} = (n_j^+ - C - k)^{-1} \sum_c \sum_i \hat{u}_{jic}^0 \hat{u}_{jic}^1$$

where  $n$  is the total number of households across clusters,  $n_j^+$  is the total number of households that have observations on both budget share and unit value of good  $j$ ,  $C$  is the number of clusters and  $k$  is the number of explanatory variables. We see that the equations (17) and (18) only estimate variances and covariances within commodities. In what follows, it will be assumed that the covariances between commodities are zero both within the unit value equations and between the two equations. Thus,  $\sigma_{jk}^{11} = 0$  and  $\sigma_{jk}^{01} = 0$  for all  $j \neq k$ . However, nothing prevent us from estimating the full matrices of inter-commodity covariances.

The second stage begins by calculating the parts of mean cluster shares and unit values that are not accounted for by the first-stage variables. These magnitudes are defined as follows

$$(19) \quad \tilde{\gamma}_{j,c}^0 = w_{j,c} - \tilde{\beta}_j^0 \ln x_{j,c} - \tilde{\gamma}_j^0 \cdot z_{j,c}$$

and

$$(20) \quad \tilde{\gamma}_{j,c}^1 = \ln v_{j,c} - \tilde{\beta}_j^1 \ln x_{j,c} - \tilde{\gamma}_j^1 \cdot z_{j,c}$$

where «.» indicates that we have taken the arithmetic mean across households in the cluster, i.e.  $w_{j,c}$  is the average budget share of good  $j$  in cluster  $c$ . We realise from (1) and (2) that the population counterparts of (19) and (20) can be written

$$(21) \quad y_{j,c}^0 = \alpha_j^0 + \sum_{k=1}^J \theta_{jk} \ln P_{kc} + (f_{j,c} + u_{j,c}^0)$$

and

$$(22) \quad y_{j,c}^1 = \alpha_j^1 + \sum_{k=1}^J \psi_{jk} \ln P_{kc} + u_{j,c}^1$$

Furthermore, we can now express  $r_{jk} = \text{cov}(y_{j,c}^0, y_{k,c}^1)$  and  $s_{jk} = \text{cov}(y_{j,c}^1, y_{k,c}^1)$  as functions of the parameters  $\theta$  and  $\psi$ . From (21) and (22) and taking probability limits over all clusters,  $r$  and  $s$  can be expressed on matrix form as follows

$$(23) \quad \mathbf{R} = \Psi \mathbf{M} \Theta' + \Gamma \mathbf{N}^{-1}$$

and

$$(24) \quad \mathbf{S} = \Psi \mathbf{M} \Psi' + \Omega \mathbf{N}_+^{-1}$$

where  $\mathbf{M}$  is the variance-covariance matrix of the unobservable prices and  $\Gamma$  and  $\Omega$  are matrix versions of the population counterparts of  $\tilde{\sigma}_{jj}^{01}$  and  $\tilde{\sigma}_{jj}^{11}$ , respectively. Since inter-commodity covariances are assumed to be zero (i.e.  $\tilde{\sigma}_{jk}^{01} = 0$  and  $\tilde{\sigma}_{jk}^{11} = 0$ ) it follows that both  $\Gamma$  and  $\Omega$  will be diagonal matrices. Furthermore,  $\mathbf{N}_+^{-1} = \text{p lim } C^{-1} \sum_c \mathbf{D}(n_c^+)^{-1}$  where  $\mathbf{D}(n_c^+)$  is a diagonal matrix with  $n_{jc}^+$  on the diagonal ( $n_{jc}^+$  denotes the number of households in cluster  $c$  reporting a positive purchase of commodity  $j$ ), and  $\mathbf{N}^{-1} = \text{p lim } C^{-1} \sum_c \mathbf{D}(n_c)^{-1}$  where  $\mathbf{D}(n_c)$  is a diagonal matrix with the number of households in cluster  $c$  on the diagonal.

The sample counterparts of  $\Omega$  and  $\Gamma$  are obtained from (17) and (18) and the sample counterparts of  $\mathbf{R}$  and  $\mathbf{S}$  are easily calculated from (19) and (20). Substituting the sample moments for the corresponding population moments, we calculate the matrix  $\tilde{\mathbf{B}}$  according to

$$(25) \quad \tilde{\mathbf{B}} = (\tilde{\mathbf{S}} - \tilde{\Omega} \mathbf{T}_+^{-1})^{-1} (\tilde{\mathbf{R}} - \tilde{\Gamma} \mathbf{T}^{-1})$$

where  $\mathbf{T}$  and  $\mathbf{T}_+$  are the sample counterparts of  $\mathbf{N}$  and  $\mathbf{N}_+$ , respectively. As the number of clusters approaches infinity with cluster sizes remaining fixed,  $\tilde{\mathbf{B}}$  will tend to its population counterpart, i.e.

$$(26) \quad \text{p lim } \tilde{\mathbf{B}} = \mathbf{B} = (\Psi')^{-1} \Theta'$$

The basic idea is to utilise the sample covariance between shares and unit values to isolate the effect of market prices on shares. If unit values moved proportionally to market prices (implying that  $\psi=1$ ), cross-price effects were absent, and there were no measurement errors, we would have that

$$\tilde{\theta}_j = \frac{\text{cov}(\tilde{y}_{j,c}^0, \tilde{y}_{j,c}^1)}{\text{var}(\tilde{y}_{j,c}^1)}, \text{ or } S^{-1}R \text{ in matrix notation (where both } S \text{ and } R \text{ would be diagonal matrices),}$$

which is simply the OLS estimator obtained from regressing  $\tilde{y}_{j,c}^0$  on  $\tilde{y}_{j,c}^1$ . However, parts of the covariance between shares and unit values and the variance of the unit values originate from the fact that the error terms are correlated. This is taken into account by subtracting  $\tilde{\Omega}\Gamma_+^{-1}$  and  $\tilde{\Gamma}\Gamma^{-1}$  from  $\tilde{S}$  and  $\tilde{R}$ , respectively.

We can not identify both  $\Theta$  and  $\Psi$  from (26), but with the additional information from (the matrix version of) (13), we have that

$$(27) \quad \Theta = B' [I - D(\xi)B' + D(\xi)D(w)]^{-1}$$

and

$$(28) \quad \Psi = [I - D(\xi)B' + D(\xi)D(w)]^{-1}$$

where  $D(\xi)$  denotes a diagonal matrix with  $\xi_j = \frac{\beta_j^1}{[(1 - \beta_j^1) + \beta_j^0 / w_j]}$  on the diagonal.

and  $D(w)$  denotes a diagonal matrix formed by the sample mean budget shares for the different commodities on the diagonal. Estimates of  $\Theta$  and  $\Psi$  are obtained by substituting the theoretical magnitudes with first and second stage estimates and by using the sample mean budget shares for the vector  $w$ . These estimates, with corresponding standard errors can be found in Appendix B.

We can now use the equations (27) and (28) to express the price elasticities of quantity and demand in terms of the first and second stage estimates. The price elasticities of quantity and demand on matrix form,  $e$  and  $\tilde{e}$ , are given by

$$(29) \quad e = D(w)^{-1} \Theta - \Psi$$

and

$$(30) \quad \tilde{e} = D(w)^{-1} \Theta - I,$$

respectively, where  $I$  is the identity matrix. Substituting for  $\Theta$  and  $\Psi$ , we have that

$$(31) \quad e = (D(w)^{-1} B' - I) [I - D(\xi)B' + D(\xi)D(w)]^{-1}$$

and

$$(32) \quad \tilde{\epsilon} = D(w)^{-1} B' [I - D(\xi)B' + D(\xi)D(w)]^{-1} - I$$

Estimates of these elasticities together with the corresponding income elasticities are given in Section 4.

### 2.3. Estimation when prices are observed

Estimating (1) and (2), having observations on market prices, would at first glance seem quite straightforward. However, a problem arises from the fact that we do not observe the commodity (or group) prices like i.e. the price of meat. The commodity «Meat» is by construction an aggregate constituted by an array of different meat products (goods). Thus, we can not simply go out in the market and observe the price of «meat». The «obvious» solution to this, and also the common approach, is to define the commodity price as a function of the different good prices. In Deaton (1987, 1988), which also underlies Deaton (1990), the commodity price is simply taken to be some linear homogenous function of the different good prices. However, Deaton makes further restrictions on prices by assuming that relative good prices are constant across clusters, which means that differences in prices across clusters are due to differences in levels. This assumption implies that the price of good  $m$  belonging to commodity group  $j$  observed in cluster  $c$ ,  $p_{mjc}$ ,<sup>4</sup> can be written as follows<sup>5</sup>

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<sup>4</sup> For clusters where there is more than one price reported for good  $m$  in cluster  $c$ ,  $p_{mjc}$  is simply taken to be the mean price of good  $m$  in cluster  $c$ .

<sup>5</sup> The good price  $p_{mjc}$  can be decomposed as follows

$$(i) \quad p_{mjc} = \lambda_{jc} p_{mj}^*$$

where the relative price  $p_{mj}^*$  is defined by

$$(ii) \quad p_{mj}^* = \frac{p_{mjc}}{\lambda_{jc}}$$

and  $\lambda_{jc}$  denotes the price level. Note that the relative price has no subscript  $c$  since it is assumed constant across clusters. Taking the mean across clusters in (i), we have that

$$(iii) \quad \bar{p}_{mj} = \bar{\lambda}_j p_{mj}^*$$

where  $\bar{\lambda}_j$  is the mean price level across clusters. Given (iii), we can now write (i) as

$$p_{mjc} = P_{jc} \bar{p}_{mj}$$

where

$$P_{jc} = \frac{\lambda_{jc}}{\bar{\lambda}_j}.$$

$$(33) \quad p_{mjc} = P_{jc} \cdot \bar{p}_{mj}$$

or equivalently

$$(34) \quad \frac{p_{mjc}}{\bar{p}_{mj}} = P_{jc},$$

where  $P_{jc}$  denotes the commodity price level (index) and  $\bar{p}_{mj}$  is the arithmetic mean of good  $m$  in commodity group  $j$  across clusters. The assumption that relative prices are constant across clusters is of course rather strong and would probably have to be abandoned when confronted with extensive data on relative prices within clusters. Thus, in the following we will relax this assumption somewhat by including an error term in (34), i.e

$$(35) \quad \frac{p_{mjc}}{\bar{p}_{mj}} = P_{jc} + \varepsilon_{mjc},$$

where  $\varepsilon_{mjc}$  is a zero mean error term. Since (35) must hold for all  $m$  in commodity group  $j$  cluster  $c$ , a consistent estimate of the commodity price index,  $P_{jc}$ , would be the following

$$(36) \quad \hat{P}_{jc} = \frac{1}{N_{jc}} \sum_{m \in J} \frac{p_{mjc}}{\bar{p}_{mj}},$$

where  $N_{jc}$  denotes the total number of price observations of goods belonging to commodity group  $j$  in cluster  $c$  and  $J$  is the set of goods in commodity group  $j$ . We recognise (36) as the «mean of price ratios» index or Sauerbeck index (with equal weights), which has been widely used in applied index work.<sup>6</sup> This is the definition of the group price index which will be applied in the following.

Having defined the commodity prices we are in a position to estimate (1) and (2). However, an identification problem arises from the presence of both a cluster-fixed effect,  $f_c$ , and a cluster-fixed price. This can be seen considering the analogous standard fixed-effect model for panel data. If we have a fixed-effect model with individual-specific intercepts and constant slope coefficients it is not possible to separately estimate the effects of individual-specific variables (variables that vary across individuals, but are constant over time, i.e. sex, race etc.) and the individual-specific intercepts (see Hsiao (1986), pp. 50). In this study, the role of the individuals is represented by the clusters and the time-series observations are represented by the individual household within each cluster. Hence, we cannot separately estimate the price effects, the  $\theta$ 's, and the fixed effect  $f_c$ . A possible solution to this problem is to define  $f_c$  as a function of some variables that are likely to explain inter-cluster differences. In this study, a cluster is defined as a set of households who live in the same area and who

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<sup>6</sup> See e.g. Dalén (1992).

make their purchases in the same quarter (season). We assume that the cluster fixed effect can be accounted for by including seasonal and regional dummies. Thus, we have that

$$(37) \quad f_{jc} = \mu_j + \sum_{s=2}^4 \eta_{sj} D_{sc} + \sum_{i=2}^6 \nu_{ij} L_{ic} + \sum_{d=2}^3 \pi_{dj} PO_{dc}$$

where  $D_{sc}=1$  if households in cluster  $c$  are observed in season (quarter)  $s$  and zero otherwise (relative to season one),  $L_{ic}=1$  if cluster  $c$  is in region  $i$  and zero otherwise (relative to region one) and  $PO_{dc}=1$  if cluster  $c$  falls into population density category  $d$  and zero otherwise (relative to population density category one) denotes an index for population density in cluster  $c$ . If (40) is inserted into (1) we obtain the following equation

$$(1') \quad w_{jic} = (\alpha_j^0 + \mu_j) + \beta_j^0 \ln x_{ic} + \gamma_j^0 \cdot z_{ic} + \sum_{k=1}^J \theta_{jk} \ln P_{kc} + \sum_{s=2}^4 \eta_{sj} D_{sc} + \sum_{i=2}^6 \nu_{ij} L_{ic} + \sum_{d=2}^3 \pi_{dj} PO_{dc} + u_{jic}^0$$

The system given by (1') and (2) could be consistently estimated using OLS. However, given that the error term in the share equation and the error term in the unit value equation are correlated for a given commodity, OLS would not provide us with efficient estimates. Furthermore, for the sake of comparison between the two approaches, it would be desirable to avoid, to the extent possible, differences in the estimated parameters that could be contributed to final sample bias. Based on these considerations, the following two-stage estimation approach was chosen: On the first stage we followed Deaton and estimated income and demographic effects having first removed the cluster mean from all variables, i.e. we estimated (14) and (15). Analogous to Deaton, we then calculated the part of mean cluster shares and unit values not accounted for by the first stage explanatory variables to arrive at the system of equations given by the sample counterparts of (21) and (22), where (37) was used to substitute for the cluster specific effect. On the second stage, we conducted a pairwise estimation of the share and unit value equations for each commodity using Seemingly Unrelated Regression (SUR). This approach makes efficient use of the before mentioned assumption employed by Deaton, namely that the error term in the share equation of commodity  $j$  is correlated with the error term in the unit value equation of commodity  $j$ .

In what follows, we shall refer to both (1) and (2) and (1') and (2) as «Deatons model». The estimation of (1) and (2) using the two-stage estimation procedure outlined in Section 2.2 will be referred to as «Deatons approach» (or «Deatons method»). The two-stage approach described above, which requires that market prices are observed, will be termed «the alternative approach».

As mentioned above, the estimation results obtained from the two approaches are presented in terms of the income and price elasticities of both quantity and demand (the Hicksian aggregate) and they can be found in Section 4 and Section 5, respectively. Note that only the price elasticities can be expected to differ between the two approaches since the first stage of the procedure, determining the income parameters, is identical.

### 3. Data

The consumption data used in this study are taken from the annual Norwegian household expenditure survey for the years 1989-1991 (see Statistics Norway (1993)), where households report their private consumption expenditure over a fourteen days period. However, all data on expenditure and quantity are translated into annual figures by multiplying the reported fourteen days figures by twenty-six. For the whole period, we have a total sample of 3657 households. We have utilised information on expenditure, quantity (measured in grams), demographic variables (the number of adults and the number of children in the household) and total consumption expenditure. The commodities used in this study are: meat, fish, vegetables, fruit and potatoes. Data for the commodities vegetables and fruit are obtained by adding data for the aggregates «Cabbage and carrots» and «Other vegetables» and «Apples, pears, and plums» and «Citrus fruits, bananas and grapes», respectively. The corresponding prices are constructed from monthly collected price data from the Division for Economic Indicators at Statistic Norway, which are used to compute the Norwegian consumer price index (see Statistics Norway (1991)).

Roughly, the households of the sample are grouped into 105 potential geographical areas. However, data for these distinct areas are not collected at the same time. First, we have data for three different years. Second, households in a given area are not necessarily interviewed at the same time. Because prices vary over the years and also over seasons, and since the estimation method described in this paper assumes that all households within a cluster face the same set of prices, it would not be appropriate to simply group households from the same area into one cluster. We define a cluster as households from the same area interviewed in the same year and also the same quarter, which leaves us with a sample of 1137 clusters.<sup>7</sup> This grouping is possible since we for every household have information on geographical location, year, and when the account was kept. The price data also include information concerning where (in which area) prices are collected (corresponding to the

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<sup>7</sup> Potentially, we have 1260 (105x4x3) clusters. However, there are quarters where no accounts were kept leaving us with 1137 clusters.



regions in the household survey) and when they are collected (in which month and year), which allow us to compute prices for each cluster.

## 4. Estimation results using Deatons approach

In this section we present the estimation results obtained when using the approach described in 2.2. When estimating (1), zero expenditures are included, so that the conditional expectation is taken over purchasers and nonpurchasers alike. However, for some clusters it might be the case that no households record a positive purchase of the commodity in question. These clusters are excluded because it would not be possible to calculate unit values for them. As mentioned in the preceding section, there are 3657 households divided on potentially 1137 clusters. In the third column of table 4.1, we report the number of clusters were at least one household is making a positive purchase. The first column show the total number of households in such clusters and the second column show the number of households which make positive purchases. In the last column the expenditure shares of the different foods are shown. As can be seen, the chosen foods only account for about 7.5 per cent of total expenditure. However, they account for around half the expenditure on foods and beverages.

**Table 4.1. Sample sizes and budget shares for Norway<sup>a</sup>**

	Numbers of:			
	Shares	Un. values	Clusters	Exp. shares
Meat	3642	3504	1132	0.0439
Fish	3580	2856	1084	0.0118
Vegetable	3600	3144	1097	0.0064
Fruit	3600	3139	1096	0.0079
Potato	3341	2148	946	0.0029

<sup>a</sup>The first three columns are numbers of households in clusters with some households purchasing the good, numbers of households recording purchases and numbers of such clusters. The final column show average budget shares (the arithmetic mean) for the different goods.

Table 4.2 report some of the results from the first-stage estimation, i.e. the estimation of (14) and (15). At the first stage, the expenditure shares and the logarithm of unit values were regressed on the logarithm of total expenditure and some demographic variables (the number of adults and children in the household), having first removed the clusters means from all variables. The first two columns show the effects of total expenditure on budget shares and logarithm of unit values, respectively, with the corresponding t-values in parenthesis. The last two columns report the calculated total expenditure (income) elasticities of quantity and demand, respectively.

**Table 4.2. First stage estimates: Quality and quantity effects<sup>a</sup>**

	B0	B1	EQ	ED
Meat	-0,020546 (14,652)	0,04859 (4,2)	0,48343 (11,129)	0,53202 (16,694)
Fish	-0,007779 (13,685)	0,09072 (4,437)	0,25182 (3,715)	0,34254 (7,237)
Vegetable	-0,003404 (15,652)	0,12678 (7,340)	0,33725 (6,311)	0,46403 (12,83)
Fruit	-0,004843 (17,875)	0,03879 (3,617)	0,35108 (7,872)	0,38987 (11,509)
Potato	-0,002210 (11,462)	0,05922 (3,655)	0,16902 (4,634)	0,22824 (6,006)

<sup>a</sup>B0 and B1 denotes the estimated effects of total expenditure on budget shares and the logarithm of unit value, respectively. T-values in parenthesis. EQ and ED denote the total expenditure elasticity of quantity and demand, respectively.

It can be seen from the first column that all goods are necessity goods; all the  $\beta^{0i}$  s are significantly negative. Hence, we should not be surprised to find that both Engel elasticities, displayed in the third and fourth column, are less than one for all goods. Turning to the income effects on the choice of quality, given in the second column, we find that higher income make household choose higher quality. We note that the quality effect seems to be somewhat stronger for fish and vegetables than for meat, fruit and potatoes. The demand elasticities are obtained by adding the quality effect to the quantity elasticities, i.e. adding the second and third column. All Engel elasticities are significantly positive and, as would be expected, both Engel elasticities of meat are higher than the same elasticities of fish.<sup>8</sup> We note that for all commodities the demand elasticities are higher than the corresponding quantity elasticities (this will of course always be the case when the quality effects are positive). The hypothesis that the Engel elasticity for consumption measured in weight (the Engel elasticity of quantity) is lower than the Engel elasticity for consumption measured in expenditure at constant prices (the Engel elasticity of demand) has found much support in the literature, see e.g. Wold and Jureen (1952), Prais and Houthakker (1955), Cramer (1971) and Aasness (1979).

The study by Aasness (1979) is based on the Norwegian household survey for the years 1975-1976. Although his framework is slightly different, the reported Engel elasticities are comparable to the

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<sup>8</sup> Meat is more of a luxury good than fish in Norway.

ones in table 4.2. The general impression is that the Engel elasticities reported by Aasness correspond quite well to those reported here, with quantity elasticities ranging from 0.19 (potatoes) to 0.68 (meat) and demand elasticities ranging from 0.31 (potatoes) to 0.65 (meat). Evaluated at the standard errors of this study, only the elasticities of meat can be said to be significantly different. Interesting to note, the ranking of both the quantity and demand elasticities are identical.

**Table 4.3. Own- and cross-price quantity elasticities<sup>a</sup>**

	Meat	Fish	Vegetab	Fruit	Potato
Meat	-1,15753 <sup>b</sup> (5,23303)	-0,15629 (1,17605)	0,018997 (0,104841)	-0,64546 <sup>b</sup> (2,0886)	-0,14348 (0,82224)
Fish	-0,17939 (0,5398)	-0,26629 (1,28795)	0,165 (0,608899)	0,012076 (0,026479)	-0,17692 (0,67317)
Vegetab	0,282245 (1,022954)	0,069112 (0,41795)	-0,07754 (0,34433)	0,058829 (0,156204)	0,205212 (0,901144)
Fruit	0,105156 (0,477906)	0,085247 (0,643009)	-0,02516 (0,14177)	-1,14074 <sup>b</sup> (3,8205)	-0,14052 (0,81943)
Potato	0,025749 (0,062261)	0,029146 (0,116987)	0,844051 <sup>b</sup> (2,456074)	-0,33541 (0,58338)	-0,69272 <sup>b</sup> (1,98236)

<sup>a</sup>The column indicates the good whose price is changing and the row is the good affected. T-values are given in parenthesis

<sup>b</sup>Significantly different from zero at the 5 per cent level.

Table 4.3 reports the estimated own- and cross-price quantity elasticities for Norway. T-values are calculated using the ‘Delta-method’ (see Fuller (1987, p.108)), and is described in detail in Deaton (1990, p. 302-308). It should be noted that all own-price elasticities are negative. The own-price elasticities of fish and vegetables are not significantly different from zero at the 5 per cent level. Maybe with the exception of vegetables, none of the own-price point estimates seem unreasonable. The price elasticity of meat is higher than the same elasticity for fish, which would be expected. Turning to the cross-price elasticities, we note that there seems to be a significantly positive impact on the consumption of potatoes from an increase in the price of vegetables. Furthermore, we find evidence of a negative cross-price effect between fruit and meat.

Deaton (1990) report price elasticities of quantity based on Indonesian data for eleven different commodities, including meat, fresh and dried fish, vegetables and fruit. For the groups meat and fruit, Deaton reports own price elasticities of 1.09 and 0.95, respectively. The direct price elasticity for

vegetables is estimated to be 1.13, which is far above the corresponding estimate in table 4.3. The reported direct price elasticities for fresh and dried fish are 0.76 and 0.24, respectively.

**Table 4.4. Own and cross-price demand elasticities<sup>a</sup>**

	Meat	Fish	Vegetab	Fruit	Potato
Meat	-1,27388 <sup>b</sup> (5,26888)	-0,172 (1,17642)	0,020906 (0,104835)	-0,71034 <sup>b</sup> (2,09213)	-0,1579 (0,82289)
Fish	-0,24402 (0,54011)	-0,36223 (1,27479)	0,224444 (0,60695)	0,016427 (0,026479)	-0,24066 (0,67493)
Vegetab	0,388349 (1,020015)	0,095093 (0,418193)	-0,10669 (0,34462)	0,080944 (0,156175)	0,282358 (0,895093)
Fruit	0,116774 (0,478016)	0,094665 (0,643186)	-0,02795 (0,14181)	-1,26678 <sup>b</sup> (3,81296)	-0,15604 (0,82111)
Potato	0,034771 (0,062242)	0,039358 (0,117009)	1,139791 <sup>b</sup> (2,465372)	-0,45293 (0,58557)	-0,93543 <sup>b</sup> (2,04578)

<sup>a</sup>The column indicates the good whose price is changing and the row is the good affected. T-values are given in parenthesis

<sup>b</sup>Significantly different from zero at the 5 per cent level.

Turning to the demand elasticities reported in table 4.4, we note that all own-price elasticities are negative. Again, for fish and vegetables these elasticities are not significant at the 5 per cent level.<sup>9</sup> Relative to table 4.3, all direct price elasticities are increased, which implies that unit values respond less than proportional to price changes. Another way to state this is that households choose cheaper qualities when prices increase. Note that the ranking of the direct price elasticities is unchanged from Table 4.3. Analogous to the cross-price quantity elasticities, we find evidence of a negative impact of an increase in the price of fruit on meat consumption and a positive effect of an increase in the price of vegetables on the consumption of potatoes.

## 5. Estimation results using the alternative approach

In table 5.1 we report the quantity elasticities obtained from estimating (1') and (2) by the two-stage procedure outlined in 2.3. Leaving the comparison for the next section, we note that only the direct price elasticities of vegetables, fruit and potatoes have the expected negative sign. The corresponding

<sup>9</sup> See appendix A for some comments on the calculation of t-values.

elasticities of meat and fish are positive. However, note that none of own-price elasticities are significantly different from zero at the 5 per cent level. This also applies for the cross-price elasticities.

**Table 5.1. Quantity elasticities using the alternative method<sup>a</sup>**

	Meat	Fish	Vegetab	Fruit	Potato
Meat	0,281611 (0,64314)	0,229952 (0,512624)	0,173145 (0,665428)	-0,30149 (-1,36252)	-0,11563 (-0,66157)
Fish	0,56514 (0,869703)	0,391413 (0,589271)	-0,09638 (-0,24766)	-0,28846 (-0,89237)	0,131293 (0,505896)
Vegetab	0,276185 (0,63522)	0,242803 (0,545979)	-0,46409 (-1,78628)	0,133073 (0,613815)	0,281138 (1,590607)
Fruit	0,483983 (1,190398)	-0,05575 (-0,13364)	0,082371 (0,339019)	-0,1445 (-0,71053)	-0,25507 (-1,59198)
Potato	-1,25187 (-1,29591)	1,439191 (1,464307)	-0,1319 (-0,22616)	0,356738 (0,755842)	-0,45008 (-1,18832)

<sup>a</sup>The column indicates the good whose price is changing and the row is the good affected. T-values are given in parenthesis.

<sup>b</sup>Significantly different from zero at the 5 per cent level.

The positive own-price elasticity of meat and fish deserves a comment. As discussed in Aasness (1990), it is possible to obtain a positive direct price elasticity for a linear consumption aggregate despite the fact that the Engel elasticities are positive (as would be the case for meat and fish). This requires that the direct Slutsky elasticity is positive. However, we find it hard to believe that the positive own-price elasticities for meat can be explained by a positive direct Slutsky elasticity which outweighs the negative income effect (resulting from a positive Engel elasticity). It might be more rewarding to question the model specification. This issue will be discussed in Section 6.

In table 5.2, we report the demand elasticities obtained using the alternative method. All direct price elasticities are negative and the magnitudes seem plausible. However, the direct price elasticities of meat and fish are not significantly different from zero at the 5 per cent level. Turning to the cross-price elasticities, we find that an increase in the price of potatoes has a significantly negative effect on the consumption of fruits. Comparing Table 5.1 and Table 5.2, we note that the ranking of the direct price elasticities is changed.

**Table 5.2. Demand elasticities using the alternative method<sup>a</sup>**

	Meat	Fish	Vegetab	Fruit	Potato
Meat	-0,54913 (-1,3853)	0,094282 (0,232799)	0,133036 (0,558394)	-0,14542 (-0,73157)	-0,17133 (-1,09305)
Fish	0,577244 (0,93437)	-0,69989 (-1,10994)	-0,36063 (-0,96806)	-0,12511 (-0,40869)	0,127698 (0,520034)
Vegetab	0,30501 (0,79243)	0,190913 (0,486038)	-0,89146 (-3,82089)	0,15731 (0,827719)	0,253292 (1,63741)
Fruit	0,59036 (1,505547)	-0,07785 (-0,19373)	0,217058 (0,921897)	-0,87464 (-4,47215)	-0,32662 (-2,12138)
Potato	-1,42735 (-1,48103)	1,321801 (1,348155)	0,273165 (0,46933)	0,359655 (0,763957)	-1,19288 (-3,15767)

<sup>a</sup>The column indicates the good whose price is changing and the row is the good affected. T-values are given in parenthesis.

<sup>b</sup>Significantly different from zero at the 5 per cent level.

The large differences between the direct price elasticities in table 5.1 and table 5.2 indicate large quality effects for all goods, i.e. households respond to an increase in the commodity price level mainly by choosing cheaper goods. As mentioned, if there were no quality effects the relative change in unit values would equal the relative change in price levels. As can be seen from table B6 in appendix B, the direct price elasticities of unit values lie significantly below one for all commodities.

## 6. A comparison of the results obtained from the two approaches

In this section, we compare the results obtained using Deatons method (discussed in Section 4) with the results obtained using what we have termed the alternative approach (found in Section 5). This cannot be seen as a way of testing Deatons approach in a strict sense, which in this case would be difficult, since the two approaches used to identify the parameters are quite different. However, assuming that (1) and (2) can be taken as the true representation of consumer behaviour, and that (37) is a valid decomposition (so that equivalently (1') and (2) specify the true model), we can use the variability of the estimates in Section 5 to give a rough evaluation of the difference between the two set of estimated elasticities.

We start by comparing the price elasticities of demand displayed in table 4.4 and 5.2, respectively. Concentrating on the own-price elasticities, the general impression is that the two approaches produce quite different estimates. However, in terms of the standard deviations of the direct price elasticities

in table 5.2, only the elasticities of vegetables and fruit are significantly different. However, it should also be noted that the ranking of the two sets of elasticities are different. From table 5.2, we find that potatoes has the highest direct price elasticity (in absolute value) followed by vegetables, fruit, fish and meat. The corresponding ranking in table 4.4 is: Meat, fruit, potatoes, fish and vegetables.

The impression that the two approaches produce quite different own-price elasticities does not change when we compare the corresponding elasticities of quantity displayed in table 4.3 and 5.1, respectively. However, due to the rather low precision of the demand elasticities, only the own-price elasticities of meat and fruit are found to be significantly different when evaluated at the standard deviations of the estimates in table 5.1.

Based on the comparison above, it seem fair to say that the two approaches produce significantly different price elasticities in an «economic» sense. However, it should be stressed that this conclusion is not statistically founded in the sense that it is derived on basis of a distribution of the differences. The question is now how to explain the apparently different set of price elasticities obtained from the two approaches. Let us for a moment assume that (1) and (2) represent the true model and furthermore, that (1') is also a valid representation. It is then clear that there are only two possible main sources of divergence, namely: (i) the fact that the two approaches apply different estimation methods, and (ii) the use of additional information (data on market prices) when applying the alternative approach. Given that market prices are not encumbered with measurement errors, the alternative approach provides consistent estimates of the different elasticities. This is also true for Deatons method, given that the second stage of his two-stage procedure is valid. On the second stage, Deaton employs a generalised method of moments type of estimator for the elements of the matrix  $(\psi')^{-1}\theta$ . As mentioned in Section 2.2, this estimator is partly based on the correlation between the part of mean cluster shares and unit values that are not accounted for by the first stage variables, which corresponds to the matrix R given by equation (23). One possible problem, which is assumed away in Deatons (1987) paper (however, not mentioned in Deaton (1990)), is that (23) leaves out a potential correlation between prices and the cluster specific effect. Deaton (1990) asserts that «it is very important that the fixed effects be permitted to be correlated with the included exogenous variables, particularly income, and it is this feature that rules out the use of a 'random' effect for each cluster». However, when the fixed effect is correlated with prices this should be reflected in (23).<sup>10</sup>

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<sup>10</sup> As mentioned, this correlation is assumed to be zero in Deaton (1987).

Ignoring this correlation will potentially bias the estimated price elasticities. The problem with Deaton's method is that allowing for the covariance between prices and the fixed effect in (23) introduces an identification problem, unless the cluster fixed effects are known. However convenient, the assumption that the fixed effects are uncorrelated with prices may not be very realistic. The fixed effect could among other effects represent «season» (i.e. in what season the account was kept), a variable that would be expected to be correlated with prices.

Another assumption employed by Deaton, which indirectly concerns the estimation procedure, relates to equation (12) (or equivalently (13)), which provides the additional information needed for identification. This equation is derived under the assumption that preferences are weakly separable in the set of goods comprising each commodity. Within Deaton's framework, the consistency of the estimated elasticities rests upon the validity of this assumption. The consistency of the estimates obtained from the alternative method, however, is independent of this assumption.

The consistency of the estimates obtained from the alternative approach obviously requires that the price data employed reflect the prices actually faced by the households. When this is not fulfilled, the alternative approach will produce biased estimates. Another crucial assumption concerning prices is that relative good prices are constant across clusters. This is of course a very strong assumption and it would probably not hold in a strict sense, which was also the motivation for including an error term in (35). However, for both approaches to make sense it is important that this assumption holds to a reasonable degree of approximation. If this is not fulfilled, the estimated price elasticities would not be valid and any comparison between the two approaches based on these elasticities would be meaningless.

The above remarks were made conditional on the validity of (1), (1') and (2). However, when the model is misspecified, there is no reason why the two estimation procedures should give the same results. As mentioned, the estimated price elasticities of quantity obtained using the alternative method are far from satisfactory. It is for example hard to believe that the direct price elasticity of meat and fish is positive. On the other hand, the corresponding elasticities of demand seemed quite reasonable. Note from (11) that there is no direct dependence between the demand elasticities and the parameters in the unit value equation. Thus, one interesting hypothesis would be that equation (2) is wrongly specified. Including seasonal and regional dummies in (2) had a quite significant effect on the estimated price parameters, and an F-test for the hypothesis that the joint effect of these variables



were equal to zero was rejected for all commodities at the 5 per cent level. However, the qualitative impression concerning the price elasticities reported in table 5.1 was not changed.

The most robust conclusion of this study seem to be that the two approaches produce significantly different price elasticities. However, we can not make any inference concerning the validity of Deatons approach based on these findings alone. To reach some stronger conclusion, thorough testing of the model specification and its assumptions would be necessary. Specifically, one could directly test the constant relative price assumption based on more extensive price data. Furthermore, it would be interesting to employ different definitions of the price index, one obvious candidate being the Laspeyres' index. In addition, alternative functional forms could be tested.

## **7. Concluding remarks**

Given that there exist significant spatial variation in prices the demand model proposed in Deaton (1990) have the appealing feature that price elasticities can be estimated without exogenous price information. Instead unit values are used, calculated from household survey data. In this study, Deatons model is estimated for a five-commodity subsystem based on Norwegian data. Both the two-stage estimation technique proposed by Deaton (1990) as well as an alternative approach, requiring direct measures of market prices, were used.

The reported price elasticities obtained using Deatons approach seem plausible. However, when compared to the price elasticities obtained applying the alternative method, we conclude that the two approaches produce significantly different price elasticities for Norway. Whether this is due to a misspesification of the model or the invalidity of the assumptions underlying Deatons two-stage approach, remains to be investigated.

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### Some comments on the derivation of t-values in table 4.4

Recall from (32) that the price elasticities of demand can be expressed on matrix form as follows

$$(A1) \quad \tilde{\epsilon} = D(w)^{-1} B' [I - D(\xi)B' + D(\xi)D(w)]^{-1} - I$$

We are now interested in calculating the variances for the estimates of the elements in  $\tilde{\epsilon}$ . The procedure will be identical to the one described in the appendix of Deaton (1990), which calculates variances for the price elasticities of quantity,  $e$  (denoted  $E$  by Deaton). Rearranging (A1), we have the following

$$(A2) \quad \bar{e} = D(w)^{-1} B' [I - D(\xi)B' + D(\xi)D(w)]^{-1}$$

where

$$\bar{e} = \tilde{\epsilon} + I$$

Transposing (A2) and taking total differentials, we obtain

$$(A3) \quad [-dB D(\xi) - B dD(\xi) + D(w)D(\xi)]\bar{e}' + [I - BD(\xi) + D(w)D(\xi)]d\bar{e}' = D(w)^{-1} dB$$

which can be written as

$$(A4) \quad d\bar{e}' = GdB[D(w)^{-1} + D(\xi)\bar{e}'] + G[B - D(w)]dD(\xi)\bar{e}'$$

where  $G = [I - BD(\xi) + D(\xi)D(w)]^{-1}$ .

Thus, in vec notation, we have

$$(A5) \quad \text{vec}(d\bar{e}') = [(D(w)^{-1} + \bar{e}D(\xi)) \otimes G] \text{vec}(dB) + [\bar{e} \otimes G(B - D(w))] \text{vec}(D(d\xi)).$$

Eq. (A4) and, hence (A5), are identical to the corresponding expressions for the price elasticities of quantity reported in Deaton (1990), page 307. Hence, it follows that the expression for the variance of the elements in  $\text{vec } \bar{e}'$ ,  $V(\text{vec } \bar{e}')$ , can be obtained by substituting  $\bar{e}$  for  $E$  in eq. (A.18) in Deaton (1990). We then obtain the following equation

$$(A6) \quad V(\text{vec}(d\bar{e}')) = C^{-1}V_a + (n - k - C)^{-1} + V_{11} + V_{12} + V_{12}' + V_{22},$$

where

$$\begin{aligned}
V_a(P, H) &= [D(w)^{-1} + \bar{e}D(\xi)]P'HP[D(w)^{-1} + D(\xi)\bar{e}'] \otimes GA^{-1}JHJ'A^{-1}G' \\
V_b &= V_a(PT^{-1}, \Lambda) \\
V_{11} &= \omega[\bar{e} \otimes G(B - D(w))]L\Phi_2\Lambda\Phi_2'L'[\bar{e} \otimes (B' - D(w))G'] \\
V_{12} &= -[\bar{e} \otimes G(B - D(w))]L[e'(W'W)^{-1}MP(D(w)^{-1} + D(\xi)\bar{e}') \otimes \Phi_2\Lambda J'A^{-1}G'] \\
&\quad - [\bar{e} \otimes G(B - D(w))]L[e'(W'W)^{-1}MJ'A^{-1}G' \otimes \Phi_2\Lambda P(D(w)^{-1} + D(\xi)\bar{e}')]K \\
V_{22} &= [(D(w)^{-1} + \bar{e}D(\xi)) \otimes G]V_3[(D(w)^{-1} + D(\xi)\bar{e}') \otimes G']
\end{aligned}$$

where the symbols are as defined in Deaton (1990) with the exception of  $\bar{e}$ .

The variances of  $\Theta$  and  $\Psi$  can be found in a similar fashion. To obtain an expression for the variances of the elements of  $\Theta$ , replace all occurrences of  $D(w)^{-1}$  in (A6) by the identity matrix,  $I$ , and all occurrences of  $\bar{e}$  by the matrix  $\Theta$ . To derive an expression for the variances of  $\Psi$ , replace all occurrences of  $D(w)^{-1}$  in (A6) by the zero matrix and all occurrences of  $\bar{e}$  by  $\Psi$ .

## Parameter estimates and corresponding standard errors

In this appendix, we report the parameter estimates with corresponding standard errors from the first and second stage estimation based on Deaton's approach and the alternative approach, respectively.

### 1. First-stage estimates<sup>11</sup>

**Table B1. First-stage estimates for the budget shares<sup>a</sup>**

Parameter <sup>b</sup>	Meat	Fish	Vegetable	Fruit	Potato
$\beta_j^0$	-0,020546 (0,001402)	-0,007779 (0,000568)	-0,003404 (0,000217)	-0,004843 (0,000271)	-0,00221 (0,000193)
$\gamma_{1j}^0$	0,010346 (0,000964)	0,001805 (0,000390)	0,001225 (0,000149)	0,002216 (0,000186)	0,000704 (0,000133)
$\gamma_{2j}^0$	0,002039 (0,000830)	-0,000546 (0,000336)	0,000358 (0,000129)	0,000929 (0,00016)	0,000032 (0,000114)
N	3642	3580	3600	3600	3341
R <sup>2</sup> -adj	0,0614	0,0655	0,0626	0,0836	0,0428

<sup>a</sup> These are the estimated parameters in (14). The columns show the estimated parameters for the commodity in question with standard errors in parenthesis.

<sup>b</sup> The parameters  $\gamma_{1j}^0$  and  $\gamma_{2j}^0$  represents the marginal effect on budget shares of the number of adults and children, respectively.

<sup>11</sup> Note that the first stage is identical for the two approaches.

**Table B2. First-stage estimates for the unit-values<sup>a</sup>**

Parameter	Meat	Fish	Vegetable	Fruit	Potato
$\beta_j^0$	0,048592 (0,011569)	0,090723 (0,020448)	0,126781 (0,017273)	0,03879 (0,010725)	0,059222 (0,016201)
$\gamma_{1j}^1$	-0,029156 (0,007897)	-0,051557 (0,013881)	-0,042353 (0,011638)	-0,035442 (0,007238)	-0,06361 (0,011255)
$\gamma_{2j}^1$	-0,018476 (0,006742)	-0,028789 (0,011838)	-0,013025 (0,009887)	-0,023564 (0,006158)	0,00349 (0,009448)
N	3504	2856	3144	3139	2148
R <sup>2</sup> -adj	0,0055	0,0069	0,0168	0,0093	0,0153

<sup>a</sup>These are the estimated parameters of (15). The columns show the estimated parameters for the commodity in question with standard errors in parenthesis.

<sup>b</sup>The parameters  $\gamma_{1j}^1$  and  $\gamma_{2j}^1$  represents the marginal effect on the logarithm of unit values of the number of adults and children, respectively.

## 2. Second-stage estimates using Deaton's approach

**Table B3. Estimates of the price-parameters in the share equations<sup>a</sup>**

Parameter <sup>b</sup>	Meat	Fish	Vegetab	Fruit	Potato
$\delta_{1k}$	-0,01202 (0,010615)	-0,00755 (0,006419)	0,000918 (0,008755)	-0,03119 (0,014907)	-0,00693 (0,008425)
$\delta_{2k}$	-0,00289 (0,005342)	0,007546 (0,00336)	0,002656 (0,004373)	0,000194 (0,007336)	-0,00285 (0,004217)
$\delta_{3k}$	0,002466 (0,002418)	0,000604 (0,001444)	0,005673 (0,001966)	0,000514 (0,003291)	0,001793 (0,002003)
$\delta_{4k}$	0,000927 (0,001939)	0,000752 (0,001168)	-0,00022 (0,001564)	-0,00212 (0,002637)	-0,00124 (0,001509)
$\delta_{5k}$	9,96E-05 (0,0016)	0,000113 (0,000963)	0,003264 (0,001324)	-0,0013 (0,002215)	0,000185 (0,00131)

<sup>a</sup>This table corresponds to the matrix given by (27). Note that the parameters in row  $j$  ( $j=1,2,\dots,5$ ) are the price parameters in (21). The standard errors are given in parenthesis.

<sup>b</sup>we have used the following indexing of the commodity groups: 1=Meat, 2=Fish, 3=Vegetables, 4=Fruit and 5=Potatoes.

**Table B4. Estimates of the price-parameters in the unit-value equations<sup>a</sup>**

Parameter <sup>b</sup>	Meat	Fish	Vegetab	Fruit	Potato
$\psi_{1k}$	0,88365 (0,034393)	-0,01571 (0,013824)	0,00191 (0,018229)	-0,06488 (0,034151)	-0,01442 (0,017722)
$\psi_{2k}$	-0,06463 (0,120493)	0,904062 (0,080979)	0,059445 (0,099879)	0,004351 (0,164221)	-0,06374 (0,095061)
$\psi_{3k}$	0,106105 (0,106076)	0,025981 (0,062158)	0,970849 (0,084519)	0,022116 (0,141714)	0,077146 (0,088507)
$\psi_{4k}$	0,011618 (0,02445)	0,009419 (0,014821)	-0,00278 (0,01957)	0,873965 (0,04754)	-0,01553 (0,019008)
$\psi_{5k}$	0,009022 (0,145126)	0,010212 (0,087317)	0,29574 (0,162158)	-0,11752 (0,203344)	0,757285 (0,140331)

<sup>a</sup> This table corresponds to the matrix given by (28). Note that the parameters in row  $j$  ( $j=1,2,\dots,5$ ) are the price parameters in (22). The standard errors are given in parenthesis.

<sup>b</sup> we have used the following indexing of the commodity groups: 1=Meat, 2=Fish, 3=Vegetables, 4=Fruit and 5=Potatoes.

### 3. Second-stage estimates using market prices (the alternative approach)

**Table B5: Estimation results for the budget shares using the alternative method<sup>a</sup>**

Parameter <sup>b</sup>	Meat	Fish	Vegetab	Fruit	Potato
$\alpha_j^0 + \mu_j$	0,349998 (0,004344)	0,135674 (0,001911)	0,060069 (0,000583)	0,083118 (0,000801)	0,0383 (0,000714)
$\delta_{j1}$	0,019838 (0,01744)	0,006927 (0,007414)	0,00183 (0,002309)	0,004723 (0,003137)	-0,00428 (0,002891)
$\delta_{j2}$	0,004148 (0,01782)	0,003601 (0,007567)	0,001145 (0,002357)	-0,00062 (0,003215)	0,003965 (0,002941)
$\delta_{j3}$	0,005854 (0,01048)	-0,00433 (0,00447)	0,000651 (0,0014)	0,001736 (0,001884)	0,000819 (0,001746)
$\delta_{j4}$	-0,0064 (0,008746)	-0,0015 (0,003674)	0,000944 (0,00114)	0,001003 (0,001565)	0,001079 (0,001412)
$\delta_{j5}$	-0,00754 (0,006897)	0,001532 (0,002947)	0,00152 (0,000928)	-0,00261 (0,001232)	-0,00058 (0,001133)
$\eta_{2j}$	0,004013 (0,003067)	0,00084 (0,001328)	0,001519 (0,000409)	-0,00026 (0,000562)	0,000282 (0,000514)
$\eta_{3j}$	0,007799 (0,002879)	0,00102 (0,001253)	0,00135 (0,000385)	-0,00129 (0,00053)	0,001124 (0,000479)
$\eta_{4j}$	0,0162 (0,00313)	0,000833 (0,001367)	0,000133 (0,000422)	0,000191 (0,000573)	0,001409 (0,000533)
$\upsilon_{2j}$	0,004811 (0,003555)	0,000551 (0,001558)	-0,00032 (0,000476)	0,000212 (0,000657)	-4E-05 (0,000574)
$\upsilon_{3j}$	-0,00299 (0,004233)	0,000257 (0,001853)	-0,0005 (0,000565)	0,000594 (0,000776)	0,000561 (0,000689)
$\upsilon_{4j}$	0,008903 (0,004433)	0,001527 (0,001948)	-0,00085 (0,000595)	0,000839 (0,000817)	0,001414 (0,000722)
$\upsilon_{5j}$	0,00032 (0,005009)	0,000895 (0,002207)	-0,00212 (0,000672)	-0,00112 (0,000929)	-0,00081 (0,000821)
$\upsilon_{6j}$	0,008609 (0,004683)	0,008625 (0,00205)	-0,00145 (0,000627)	-0,00043 (0,000865)	0,002587 (0,00077)
$\pi_{2j}$	0,002086 (0,002475)	0,000183 (0,001085)	-9,2E-05 (0,000332)	0,000279 (0,000455)	-0,00103 (0,000417)
$\pi_{3j}$	0,004088 (0,006055)	0,000228 (0,0026)	0,00083 (0,0008)	0,00136 (0,001099)	-0,0018 (0,00094)
N	1064	1018	1029	1029	893
R <sup>2</sup> -adj.	0,0283	0,0237	0,0475	0,0045	0,0437

<sup>a</sup> Each column gives the estimated parameters of (21) where (37) is substituted for  $f_{jc}$ . Standard errors in parenthesis.

<sup>b</sup> The subscripts used for the  $\delta$ 's have the following interpretation: 1=Meat, 2=Fish, 3=Vegetables, 4=Fruit and 5=Potatoes.



**Table B6. Estimation results for the unit-values using the alternative method<sup>a</sup>**

Parameter <sup>b</sup>	Meat	Fish	Vegetab	Fruit	Potato
$\alpha_j^1$	1,170605 (0,008199)	-0,09742 (0,01466)	-1,59309 (0,01355)	-0,31208 (0,007827)	-1,80388 (0,01322)
$\psi_{j1}$	0,169261 (0,12609)	0,012103 (0,22457)	0,028825 (0,2101)	0,106378 (0,12011)	-0,17548 (0,20524)
$\psi_{j2}$	-0,13567 (0,13075)	-0,09131 (0,23272)	-0,05189 (0,21666)	-0,0221 (0,1251)	-0,11739 (0,21321)
$\psi_{j3}$	-0,04011 (0,07091)	-0,26424 (0,12555)	0,572625 (0,11876)	0,134687 (0,06706)	0,40506 (0,11464)
$\psi_{j4}$	0,156069 (0,0659)	0,163345 (0,1157)	0,024237 (0,10838)	0,269859 (0,06237)	0,002917 (0,10434)
$\psi_{j5}$	-0,0557 (0,05242)	-0,0036 (0,09363)	-0,02785 (0,08884)	-0,07155 (0,04957)	0,257197 (0,08467)
N	1064	1018	1029	1029	893
R <sup>2</sup> -adj.	0,033	0,0013	0,0359	0,0335	0,0582

<sup>a</sup> Each column gives the estimated parameters of (22). Standard errors in parenthesis.

<sup>b</sup> we have used the following indexing of the commodity groups: 1=Meat, 2=Fish, 3=Vegetables, 4=Fruit and 5=Potatoes.