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The demand for food and beverages in Norway

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Abstract

The demand for food and beverages is estimated within a three-stage demand model. The separability structure of the model is checked by nonparametric tests. Some generalized axiom of revealed preference (GARP) violations are detected in one of the subsystems. However, they are removed by small adjustments in the quantities of fish, and the violations are interpreted as results of measurement errors. The almost ideal demand system is used in the static and a dynamic version. The results of various specification and misspecification tests suggest that the static version performs poorly as compared with the dynamic version. Norwegian demand elasticities for disaggregate food commodities have rarely been estimated within a system framework, so the results are of intrinsic interest. The elasticities estimated by using the dynamic model are of the expected signs and reasonable magnitudes. The values are stable over time for most commodities. Elasticities estimated within a subsystem are conditional on the goods included in that system, and they may differ from the more policy relevant unconditional elasticities estimated within a system including all goods. Adjustment formulas are used to approximate the unconditional elasticities from the estimated conditional elasticities. There are considerable differences between the numerical values of the conditional and unconditional elasticities for several of the foods. The unconditional own-price elasticities are in the interval −0.20 to −0.89. The own-price elasticities for hot drinks and for milk are most inelastic. The unconditional expenditure elasticities for food-away-from-home, fish, soft drinks, and alcoholic beverages are above one, while the expenditure elasticity for hot drinks is about zero. Published by Elsevier Science B.V.

Keywords: Conditional and unconditional elasticities; Disaggregate food commodities; Multistage budgeting; Nonparametric analysis

1. Introduction

Demand elasticities are of considerable interest for policy purposes. Market demand for various foods is an important component in the formation of agricultural as well as other public policies in most industrialized countries. Demand functions are, for example, used to evaluate the effects of changes in target prices on farmers' income. Market demand is also of interest for forecasting. Farmers, food processors, and retailers need to forecast demand to plan their production and sales, and demand elasticities are of crucial importance.

In this study, demand elasticities for food commodities are estimated. Relatively few studies have used demand systems to model the demand for disaggregated food commodities in Norway. Previous studies include Vale (1989) who applied household data, Edgerton et al. (1996) who estimated demand elasticities for each of the Nordic countries, Rickertsen et al. (1995) who estimated the demand for various vegetables, and Rickertsen (1996) who estimated the demand for meats and fish.

The elasticities for various foodstuffs are usually estimated under a weak separability assumption

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within a system excluding many goods. Some interconnections are then neglected. Following the terminology in Pollak and Wales (1992), demand functions within a subsystem are called conditional and the corresponding elasticities are called conditional elasticities. They will, in general, differ from the unconditional elasticities that are estimated from a demand system including all goods. The unconditional elasticities are usually of most interest. In this study, conditional elasticities are estimated within a three-stage model. Approximate adjustment formulas, which are proposed in Edgerton (1992, 1997) are then applied to calculate the corresponding unconditional elasticities. Considerable differences between the values of the conditional and unconditional elasticities are found for several goods.

The outline of the paper is as follows. First, the almost ideal demand system and a dynamic version of this system are presented. Second, weak separability and the relationship between conditional and unconditional elasticities are described. Third, the separability structure of the model is checked by nonparametric tests. Fourth, the estimation procedure and tests for specification and misspecification of the subsystems are described. Finally, the demand elasticities from the almost ideal model are discussed in more detail.

2. The almost ideal demand system

In the almost ideal demand system of Deaton and Muellbauer (1980a), the expenditure share of good i, w_i, is given by

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln \frac{x}{P} \tag{1}$$

where $\ln P$ is a price index defined by

$$\ln P = \alpha_0 + \sum_{k=1}^{n} \alpha_k \ln p_k + \frac{1}{2} \sum_{k=1}^{n} \sum_{j=1}^{n} \gamma_{kj} \ln p_k \ln p_j \tag{2}$$

In Eqs. (1) and (2), p_j denotes the per unit price of good j and x is the total per capita expenditure on all goods included in the system.

Adding up, homogeneity of degree zero in prices and total expenditure, and Slutsky symmetry imply the following restrictions on the parameters

$\Sigma_i \alpha_i = 1, \Sigma_i \beta_i = 0, \Sigma_i \gamma_{ij} = 0 \, \forall j$ (adding up)

$\Sigma_j \gamma_{ij} = 0 \, \forall i$ (homogeneity)

and

$$\gamma_{ij} = \gamma_{ji} \; \forall \, i,j \text{ (symmetry)} \tag{3}$$

The own-price, e_{ii}, cross-price, e_{ij}, and expenditure elasticities, E_i, are given by

$$e_{ii} = -1 + \frac{\gamma_{ii}}{w_i} - \frac{\beta_i}{w_i} \times \left\{ \alpha_i + \frac{1}{2} \Sigma_k (\gamma_{ki} + \gamma_{ik}) \ln p_k \right\}$$

$$e_{ij} = \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i} \left\{ \alpha_j + \frac{1}{2} \Sigma_k (\gamma_{kj} + \gamma_{jk}) \ln p_k \right\}$$

and

$$E_i = 1 + \frac{\beta_i}{w_i} \tag{4}$$

where $\gamma_{kj} = \gamma_{jk}$ when symmetry is imposed.

Dynamic effects have been introduced into this system in different ways. The model has been estimated in difference form (e.g., Moschini and Meilke, 1989), lagged consumption has been included (e.g., Chen and Veeman, 1991), a general dynamic framework has been used (e.g., Anderson and Blundell, 1983), and the vector of lagged expenditure shares has been included in each equation (e.g., Alessie and Kapteyn, 1991; Assarsson, 1991). The last approach is quite simple and preserves the adding-up property. It is followed here and dynamic effects are introduced in Eqs. (1), (2) and (4) by defining

$$\alpha_i = \alpha_{i0} + \sum_{j=1}^{n} \theta_{ij} w_{j(t-1)} \tag{5}$$

where $w_{j(t-1)}$ is the lagged expenditure share of good j. Good i's expenditure share in period t is then given by

$$w_{it} = \alpha_{i0} + \sum_{j=1}^{n} \theta_{ij} w_{j(t-1)} + \sum_{j=1}^{n} \gamma_{ij} \ln p_{jt} + \beta_i \ln \frac{x_t}{P_t} \tag{6}$$

where the price index $\ln P_t$ is defined by

$$\ln P_t = \alpha_0 + \sum_{k=1}^{n} \alpha_{k0} \ln p_{kt} + \sum_{k=1}^{n} \sum_{j=1}^{n} \theta_{kj} w_{j(t-1)} \ln p_{kt} + \frac{1}{2} \sum_{k=1}^{n} \sum_{j=1}^{n} \gamma_{kj} \ln p_{kt} \ln p_{jt} \quad (7)$$

Adding up requires $\Sigma_i \theta_{ij} = 0\ \forall j$ besides the restrictions given by Eq. (3) where α_i is replaced by α_{i0}. Since the expenditure shares sum to one for every observation, some restrictions must be imposed to enable identification of the system. The restrictions $\Sigma_j \theta_{ij} = 0\ \forall i$ are imposed. [1] The short-run own-price, cross-price, and expenditure elasticities are given by Eq. (4) where the α_i's are replaced by Eq. (5).

Eqs. (6) and (7) will be referred to as the dynamic almost ideal system. This model may be given a habit-persistence or partial-adjustment interpretation. Because of habits, the consumer only gradually adjusts his consumption in response to changes in prices and income.

3. Two-stage budgeting, weak separability and elasticities

Studying the demand for disaggregated food commodities, the number of parameters in a flexible demand system becomes very large. The usual way to reduce the number of parameters in applied studies is to impose more structures on the preferences. Weak separability and two-stage budgeting are frequently made assumptions. Let us assume there are k goods. The demand function for good i, q_i, can be written as

$$q_i = f_i(p_1, p_2, \ldots, p_k, x) \quad (8)$$

where p_i is the price per unit of good i and x is the total expenditure. Two-stage budgeting assumes that the allocation of total expenditure can be divided into two separate stages. Divide the k goods into two groups, group A consisting of n food items and group B consisting of other goods. In the first stage, the total expenditure is allocated to our two weakly separable groups of goods. In the second stage, the group expenditures are allocated between the goods in each group.

The first stage must be based on an approximation since it is usually not possible to replace the prices and quantities with a single price and a single quantity index. However, an approximation is proposed in Deaton and Muellbauer (1980b), pp. 129–132. Let the first-stage demand function for expenditure on all of the goods in group A be

$$q_A = g_A(P_A, P_B, x) \quad (9)$$

where q_A is expressed as real expenditure on the entire group and the P's are true cost-of-living indices, which are proportional to expenditure functions. The group expenditure for group A, x_A, is next allocated between the food items, resulting in the second-stage demand function for good i

$$q_i = g_i(p_{A1}, p_{A2}, \ldots, p_{An}, x_A) \quad (10)$$

Given weak separability, the demand functions for all goods in group A are affected in the same manner by a price change of any good in group B, and the effect of the price change works only through the expenditure term. For example, let us consider the change in bread consumption caused by a change in the price of some nonfood good, say, clothes. The change in the price of clothes will cause the consumer to change his total expenditure on food and this change in total expenditure on food will cause a change in the bread consumption. Next, let the price of another nonfood item, say, books change. Suppose this price change and the price change of clothes have the same effect on food expenditure. Then, the change in the price of clothes and the change in the price of books will have the same effect on the consumption of bread. Following Pollak and Wales (1992, p. 47), the demand functions Eq. (10) are called *conditional* and the demand functions Eq. (8) *unconditional.*

The two-stage procedure where stage one is given by Eq. (9) and stage two by Eq. (10) will approximate the results of the allocation made in one step, i.e., Eq. (8). This approximation will be good if the preferences are weakly separable and the price indices used to approximate the true cost-of-living

[1] An alternative set of restrictions is $\alpha_i = 0\ \forall i$. The choice of normalization does not affect the other results.

indices at stage one do not vary too much with the expenditure level (Edgerton, 1997).

Edgerton (1992, 1997) shows how to calculate unconditional elasticities from estimated conditional elasticities. Let, E_{AiA} denote the conditional expenditure elasticity for good i within group A, E_A the group expenditure elasticity for group A, E_{Ai} the unconditional expenditure elasticity for good i within group A, e_{Aij} the (uncompensated) conditional price elasticity between goods i and j within group A, e_{AA} the own-price elasticity for group A, and e_{AiAj} the unconditional cross-price elasticity between goods i and j within group A.

The unconditional expenditure elasticity for good i within group A is approximated by using Eqs. (8)–(10) such that

$$E_{Ai} = \frac{\partial \ln f_i}{\partial \ln x} = \frac{\partial \ln g_i}{\partial \ln x_A}\frac{\partial \ln x_A}{\partial \ln x} = \frac{\partial \ln g_i}{\partial \ln x_A}\frac{\partial \ln g_A}{\partial \ln x}$$
$$= E_{AiA}E_A \tag{11}$$

where $\ln x_A = \ln P_A + \ln g_A(P_A, P_B, x)$. The Eq. (11) is an approximation since it is assumed that $\partial \ln P_A / \partial \ln x = 0$, i.e., the price index does not vary with the expenditure level. The relationship Eq. (11) is previously suggested in, for example, Manser (1976), p. 887.

In a similar way, the unconditional cross-price elasticity between goods i and j within group A is approximated by

$$e_{AiAj} = \frac{\partial \ln f_i}{\partial \ln p_{Aj}} = \frac{\partial \ln g_i}{\partial \ln p_{Aj}} + \frac{\partial \ln g_i}{\partial \ln x_A}\frac{\partial \ln x_A}{\partial \ln P_A}\frac{\partial \ln P_A}{\partial \ln p_{Aj}}$$
$$= e_{Aij} + E_{AiA}(1 + e_{AA})w_{AjA} \tag{12}$$

where $w_{AjA} = p_{Aj}q_{Aj}/x_A$. Note that $\partial \ln P_A / \partial \ln p_{Aj} = w_{AjA}$ by Shephard's lemma used on the true cost-of-living index, $\ln P_A$.

The true cost-of-living indices are approximated by Paasche indices in the empirical implementation below. If the variation of prices with the expenditure level is small, this index is a good approximation. Edgerton (1997) shows how the Eqs. (11) and (12) can be extended to any number of stages, and they are used to calculate unconditional elasticities for the three-stage model in this paper.

4. The separability structure of the model

Annual data for private consumption expenditures are used. [2] They cover the 1962–1991 period. The price data are the implicit price indices found by dividing current by real expenditures. To avoid difficulties regarding durability, durables and semidurables are excluded from the analysis. The expenditure data are published in Central Bureau Central Bureau of Statistics (1979, 1981, 1989, 1993), and the prices were calculated by the Central Bureau of Statistics. The data are described in more detail in Rickertsen (1994).

Varian (1983) suggested nonparametric methods to test for separability. His test consists of two parts. First, the data are checked for violations of the generalized axiom of revealed preference (GARP). No GARP violations is a necessary condition for the validity of the proposed separability structure. Second, the Afriat numbers are constructed to see if the subutility functions fit within an overall utility function. This is a sufficient but not necessary condition for separability, and Barnett and Choi (1989) showed that this sufficient condition is strongly biased toward rejection of the proposed separability structure.

Varian's Nonpar program was used for the separability test. As shown in Chalfant and Zhang (1995, p. 5), indices can only be used in nonparametric analysis if they leave expenditures intact. The data were therefore rescaled for the nonparametric tests such that current expenditures were intact for each observation. The structure that was finally selected for the parametric analysis is shown in Fig. 1. The group food and beverages away-from-home consists of expenditures at restaurants and cafes. The group hot drinks consists of coffee, tea, and cocoa and the

[2] In many food demand studies, disappearance data are used. This may be appealing for disaggregated goods, however, not for groups of goods such as services or beverages. There are some notable differences between disappearance and expenditure data that have implications for the interpretation of the elasticity estimates. First, public consumption is excluded from our expenditure data but is usually included in disappearance data. Second, our price series are directly derived from the expenditures while the prices of some representative items have to be used with the disappearance data. Third, expenditures include effects of quality changes. For example, expenditures may increase with the use of more processed foods while the quantities may remain unchanged.

group miscellaneous consists of edible fats and oils, sugar, confectionery, etc.

No violations of GARP were detected at stage one or two. Furthermore, there were no violations in the beverages or vegetablia systems at stage three. Three specifications of the animalia system were checked and each resulted in violations. First, meat, fish, cheese, and eggs were specified as in Fig. 1. This partitioning resulted in ten violations of GARP. Second, since cheese and eggs are of minor importance in the budget as compared with meat and fish, cheese and eggs were specified as one good. However, this grouping resulted in eleven violations. Finally milk, cheese, and eggs were aggregated into one good within the animalia subsystem. This resulted rather surprisingly in only two violations of GARP.

The violations may reflect an inappropriate separability structure or alternatively measurement errors. Measurement errors may be particularly troublesome for fish. There are substantial homeproduction of fish as well as sales that never are recorded. These missing quantities and prices are approximated before they are added to the published consumption statistics. This procedure may easily cause measurement errors.

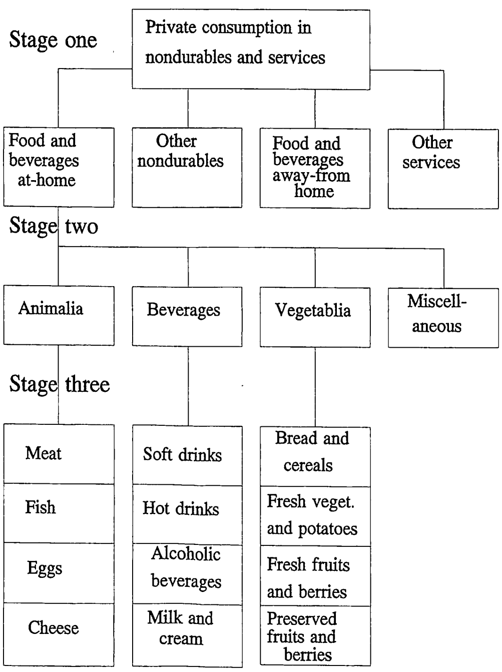

Fig. 1. Partitioning of goods in the three-stage model.

In a measurement-error context, the question is whether there can be constructed a set of 'small' errors, which can be added to or subtracted from some observations so that the animalia subsystem satisfies GARP. As is common practice, measurement errors in the quantities and not prices are focused on (e.g., Alston and Chalfant, 1992, p. 129).

The GARP violations are small. In the specification treating meat, fish, cheese, and eggs as four goods, the violations disappear when the quantity of fish is adjusted 1% downward for 1977 and 2% upward for 1989. When eggs, cheese, and milk is specified as one good, the two violations disappear when 1991's quantity of fish is adjusted 1% up. These small necessary adjustments show that the measurement-error interpretation is plausible. For the third specification, larger adjustments are required.

After adjusting the data for fish so that they satisfy GARP, the second step of the separability test is performed. However, as might be suspected from the findings of Barnett and Choi (1989), the Afriat inequalities are violated in several cases. They do not hold for any of the subsystems at stage three. Nevertheless, as noted above, the separability structures may be appropriate.

Since the nonparametric tests did not provide an answer regarding which commodity specification that is most appropriate for the animalia group, the most intuitively plausible one is used. Meat, fish, cheese, and eggs are, consequently, treated as four goods in the parametric analysis.

5. Estimation and testing of parametric model

The LSQ procedure in TSP was used for estimation. This seemingly unrelated regressions (SUR) procedure iterates over the covariance matrix of the residuals and converges to the maximum-likelihood estimator, given normality of the residuals. The expenditure shares in Eq. (1) sum to one for every observation. This implies that the covariance matrix of the residuals is singular and one equation is dropped from estimation.

Tests of homogeneity, symmetry, and no habit persistence are performed using a likelihood-ratio test. These tests have a considerable bias towards rejection in small samples (e.g., Bewley, 1986) and a commonly used correction factor is utilised to calculate a size corrected likelihood-ratio test

$$\mathrm{CLR} = \frac{2(T-k)}{T}(L_U - L_R) \tag{13}$$

where T is the number of observations, k is the average number of estimated parameters per equation in the unrestricted model, L_{U} is the value of the log-likelihood function for the unrestricted model, and L_{R} is the log-likelihood value for the restricted model.

Autocorrelation is frequently a serious problem in food demand studies using time–series data. It is tested for by a first-order Breusch–Godfrey test (Godfrey, 1978). This test is valid in the presence of lagged endogenous variables and is calculated using

$$\hat{u}_{it} = x_t'\pi + \rho\hat{u}_{i(t-1)} + v_{it} \tag{14}$$

where $\boldsymbol{x}_t$ is the vector of observed values of the regressors in period t, $\hat{u}_{it}$ the residuals associated with the estimation of $w_{it} = x_t'\pi + u_{it}$, π and ρ estimated parameters, and v_{it} is assumed to be white noise. The model was linearized in Eq. (14) as well as in the Reset test Eq. (15) by replacing the true price index by the estimated values of the index. The hypothesis of no first-order autocorrelation is rejected if ρ is significantly different from zero. The F statistic for the null hypothesis in Eq. (14) is asymptotically $F_{1,T-k-1}$.

Alston and Chalfant (1991a,b, 1993) discussed some effects of functional misspecification. They demonstrated the effects of using a wrong functional form for introducing autocorrelation, for finding spurious structural change, and for obtaining misleading results of tests for the demand restrictions. Functional misspecification is tested by a second-order Reset test including the square of the predicted expenditure share. It is calculated as

$$w_{it} = x_t'\pi + \rho\hat{w}_{it}^2 + u_{it} \tag{15}$$

The hypothesis of no functional misspecification is rejected if ρ is significantly different from zero.

Normality of the residuals is required to claim maximum-likelihood estimates. Since the expenditure shares are bounded between zero and one, we know that the residuals cannot be normally distributed. To test for the importance of deviations from normality, a small sample approximation to the Jarque–Bera test, which is proposed in Kendall and Stuart (1963, pp. 281–297), is used. It is calculated as

$$\lambda = \frac{(\delta-1)^2}{\delta-2}\left[\frac{\hat{a}_1^2}{6} + \frac{(\delta-1)(\delta+1)}{24\delta(\delta-3)} \times\left(\hat{a}_2 - 3\frac{\delta-1}{\delta+1}\right)^2\right] \tag{16}$$

with $\delta = T-k$. Here $a_1 = \mu_3/\mu_2^{1.5}$ is the measure of skewness, $a_2 = \mu_4/\mu_2^2$ is the measure of excess kurtosis, and the sample moments $\hat{\mu}_i$ are used to estimate a_i. λ is asymptotically distributed as $\chi^2_{(2)}$.

The explanatory power of the various models is evaluated by comparing the R^2 values adjusted for the degrees of freedom. $R^2(d)$ shows the relative improvement of the dynamic, R^2_{D}, compared with the static model, R^2_{S}, and adjusted for the degrees of freedom. It is calculated as

$$R^2(d) = \frac{R^2_{\mathrm{D}} - R^2_{\mathrm{S}}}{1 - R^2_{\mathrm{S}}} \tag{17}$$

6. Results

6.1. Tests for homogeneity, symmetry, and no dynamics

The probabilities of rejecting a null hypothesis given that it is true, the p values, are reported in Table 1. A hypothesis is rejected at the 5% level when the corresponding p value is below 0.05.

The hypothesis of no dynamics is rejected for each subsystem. These rejections suggest that the static model is not a valid parsimonious representation of the more general dynamic model. Further-

Table 1
Tests of restrictions; p values of size corrected likelihood-ratio tests

Stage	Homogeneity		Homogeneity and and symmetry		
	Static	Dynamic	Static	Dynamic	No dynamics
One	0.23	0.39	0.01	0.16	0.00
Two	0.00	0.00	0.00	0.00	0.02
Vegetablia	0.00	0.00	0.00	0.01	0.00
Animalia	0.57	0.38	0.00	0.09	0.00
Beverages	0.00	0.00	0.00	0.00	0.03

Table 2
Expenditure shares, goodness-of-fit statistics, and p values for misspecification tests

	w	R^2	R^2 (d)	BG (s)	BG (d)	RE (s)	RE (d)	JB (s)	JB (d)
Stage one									
Food-at-home	0.36	0.99	0.68	0.00	0.71	0.00	0.08	0.73	0.81
Food a.f.h.	0.05	0.79	0.33	0.03	0.33	0.00	0.42	0.36	0.16
Nondurables	0.21	0.98	0.74	0.00	0.62	0.00	0.06	0.81	0.98
Services	0.38	0.95	0.82	0.00	0.37	0.00	0.00	0.93	0.85
Stage two									
Animalia	0.32	0.87	0.39	0.00	0.64	0.13	0.96	0.85	0.99
Beverages	0.30	0.59	0.33	0.01	0.97	0.84	0.67	0.42	0.97
Vegetablia	0.24	0.95	−0.06	0.62	0.05	0.15	0.21	0.38	0.18
Miscellaneous	0.14	0.92	0.14	0.21	0.36	0.03	0.09	0.72	0.99
Stage vegetablia									
Cereals	0.36	0.94	0.18	0.39	0.72	0.96	0.70	0.56	0.51
Fresh vegetables	0.16	0.96	0.41	0.01	0.82	0.49	0.52	0.01	0.69
Fresh fruits, etc.	0.29	0.84	0.19	0.26	0.29	0.10	0.39	0.47	0.79
Preserves	0.19	0.91	0.33	0.00	0.05	0.15	0.89	0.98	0.21
Stage animalia									
Meat	0.63	0.95	0.85	0.01	0.59	0.33	0.56	0.42	0.66
Fish	0.19	0.92	0.77	0.02	0.99	0.36	0.40	0.40	0.23
Cheese	0.11	0.86	0.48	0.01	0.22	0.38	0.44	0.26	0.43
Eggs	0.07	0.98	0.38	0.01	0.36	0.00	0.20	0.82	0.93
Stage beverages									
Soft drinks	0.12	0.88	0.12	0.08	0.37	0.82	0.99	0.96	0.93
Hot drinks	0.16	0.96	0.16	0.71	0.78	0.89	0.38	0.01	0.01
Alcoholic beverages	0.45	0.94	−0.02	0.82	0.23	0.32	0.58	0.91	0.98
Milk and cream	0.27	0.96	0.31	0.26	0.39	0.00	0.02	0.77	0.99

more, neglecting dynamic effects seems to cause rejection of symmetry. The joint hypothesis of homogeneity and symmetry is rejected in each of the static systems, while it is not rejected for two of the dynamic ones. [3]

[3] The results reported in Table 1 raise another question, namely, should homogeneity and symmetry be imposed? These restrictions are frequently rejected when they are tested. Nevertheless, they are frequently imposed. Imposition of these restrictions eases the interpretation of the estimated elasticities and reduces the number of parameters that has to be estimated. On the other hand, the imposition of 'wrong' restrictions yields biased estimates of the parameters. In this paper, only nonrejected restrictions were imposed. If there are systematic or 'large' deviations, then the interpretation of the estimated elasticities becomes difficult. To check whether the statistical significant deviations were important, the numerical values of the homogeneity property, $\Sigma_j e_{ij} + E_i$, were calculated for each share equation. No individual divergence was larger than twice the estimated standard error of the corresponding expenditure elasticity.

6.2. Misspecification tests and goodness of fit

The p values of the tests for no autocorrelation, BG, no functional misspecification, RE, and normality of the residuals, JB, are presented in Table 2. The s and d denote the static and dynamic model, respectively. A p value below 0.05 implies that the corresponding hypothesis of no first-order autocorrelation, no functional misspecification, or normality of the residuals is rejected at the 5% level. Since these tests are strictly valid only within a single-equation framework, the results must be interpreted only as qualitative indicators on misspecification. The reported R^2 values are for the dynamic subsystems adjusted for the degrees of freedom. The $R^2(d)$ values show the relative improvement of the dynamic as compared with the static equations.

The test statistics indicate that misspecification is substantially reduced in the dynamic model. Absence

Table 3
Conditional uncompensated price, compensated price, and expenditure elasticities calculated at mean values (robust standard errors in parentheses)

	e				$\hat{e}$				E
	1	2	3	4	1	2	3	4	
Food-at-home	−0.44 (0.10)	0.00 (0.03)	−0.29 (0.05)	−0.01 (0.07)	−0.18 (0.08)	0.04 (0.06)	−0.13 (0.20)	0.28 (0.10)	0.74 (0.04)
Food-away-from-home	−0.11 (0.24)	−0.57 (0.19)	−0.10 (0.20)	−0.32 (0.29)	0.28 (0.22)	−0.52 (0.51)	0.14 (0.22)	0.10 (0.52)	1.09 (0.20)
Nondurables	−0.67 (0.09)	−0.03 (0.05)	−0.63 (0.07)	0.02 (0.11)	−0.21 (0.39)	0.03 (0.07)	−0.35 (0.09)	0.53 (0.22)	1.32 (0.07)
Services	−0.12 (0.06)	−0.04 (0.03)	0.07 (0.04)	−0.97 (0.10)	0.25 (0.15)	0.01 (0.06)	0.30 (0.17)	−0.56 (0.25)	1.05 (0.06)
Animalia	−0.94 (0.15)	−0.11 (0.10)	−0.03 (0.13)	−0.16 (0.06)	−0.54 (0.16)	0.25 (0.09)	0.25 (0.11)	0.00 (0.05)	1.19 (0.17).
Beverages	−0.41 (0.14)	−0.85 (0.12)	0.13 (0.12)	−0.12 (0.06)	0.01 (0.15)	−0.48 (0.09)	0.42 (0.09)	0.05 (0.06)	1.24 (0.17)
Vegetablia	0.41 (0.09)	−0.03 (0.04)	−0.94 (0.08)	−0.04 (0.03)	0.61 (0.07)	0.15 (0.05)	−0.81 (0.07)	0.04 (0.03)	0.59 (0.10)
Miscellaneous	0.06 (0.14)	−0.00 (0.10)	−0.34 (0.12)	−0.28 (0.07)	0.29 (0.12)	0.21 (0.09)	−0.18 (0.11)	−0.19 (0.06)	0.69 (0.17)
Bread and cereals	−0.51 (0.18)	−0.17 (0.06)	−0.04 (0.10)	−0.05 (0.06)	−0.22 (0.14)	−0.04 (0.05)	0.18 (0.11)	0.09 (0.08)	0.79 (0.17)
Fresh vegetables and potatoes	0.38 (0.27)	−0.62 (0.10)	−0.19 (0.12)	−0.69 (0.14)	0.69 (0.21)	−0.49 (0.10)	0.04 (0.13)	−0.53 (0.16)	0.82 (0.20)
Fresh fruits and berries	−0.46 (0.19)	0.03 (0.08)	−0.95 (0.12)	0.12 (0.10)	0.02 (0.14)	0.23 (0.07)	−0.57 (0.11)	0.36 (0.12)	1.28 (0.20)
Preserves	−0.61 (0.34)	−0.03 (0.10)	0.16 (0.16)	−0.49 (0.14)	−0.18 (0.26)	0.15 (0.08)	0.48 (0.19)	−0.28 (0.17)	1.15 (0.30)
Meat	−0.90 (0.08)	−0.00 (0.03)	−0.02 (0.03)	−0.05 (0.03)	−0.28 (0.13)	0.18 (0.08)	0.09 (0.04)	0.01 (0.03)	0.98 (0.08)
Fish	−0.13 (0.16)	−0.93 (0.08)	−0.05 (0.08)	−0.05 (0.05)	0.61 (0.15)	−0.71 (0.11)	0.08 (0.10)	0.02 (0.11)	1.16 (0.21)
Cheese	0.09 (0.23)	−0.05 (0.13)	−0.85 (0.11)	0.03 (0.05)	0.52 (0.13)	0.13 (0.10)	−0.74 (0.07)	0.09 (0.08)	0.95 (0.27)
Eggs	−0.44 (0.34)	−0.09 (0.16)	0.08 (0.11)	−0.38 (0.19)	0.09 (0.43)	0.07 (0.19)	0.17 (0.06)	−0.33 (0.35)	0.83 (0.20)
Soft drinks	−0.78 (0.21)	−0.06 (0.07)	−0.24 (0.23)	−0.04 (0.16)	−0.61 (0.21)	0.11 (0.05)	0.32 (0.19)	0.29 (0.13)	1.23 (0.24)
Hot drinks	−0.21 (0.18)	−0.20 (0.07)	0.49 (0.19)	0.04 (0.15)	−0.22 (0.17)	−0.21 (0.04)	0.44 (0.19)	0.01 (0.11)	−0.10 (0.24)
Alcoholic beverages	0.06 (0.06)	−0.20 (0.03)	−1.06 (0.05)	−0.40 (0.05)	0.26 (0.06)	0.02 (0.02)	−0.37 (0.05)	0.01 (0.04)	1.51 (0.07)
Milk and cream	−0.10 (0.10)	−0.07 (0.04)	−0.03 (0.10)	−0.33 (0.07)	−0.02 (0.10)	0.02 (0.03)	0.24 (0.09)	−0.17 (0.06)	0.59 (0.11)

of autocorrelation is not rejected for any of the equations in the dynamic model, while no autocorrelation is rejected for twelve of the static equations. No functional misspecification is rejected in the equations for services and for milk and cream in the dynamic model, while it is rejected for seven of the static equations. Normality of the residuals is rejected for hot drinks in the dynamic model, and it is also rejected for fresh vegetables in the static specification.

The goodness-of-fit statistics are high in the dynamic version of the model. The adjusted R^2 values are above 0.9 for fourteen of the equations. Furthermore, more than 30% of the unexplained variation in the static model is explained by the dynamic model for thirteen of the goods. On the other hand, the explanatory power decreases somewhat for vegetablia and alcoholic beverages.

The rejections of the hypothesis of no dynamics, more frequent rejections of symmetry, and substantially more misspecification suggest that the static model perform relatively poorly. For the remaining of the paper we will concentrate on results from the dynamic model.

6.3. Conditional elasticities

The parameter values and their robust standard errors, which are consistent even when the residuals are heteroscedastic (White, 1980), are given in Table A1 in Appendix and they are not discussed here.

As mentioned above, the conditional elasticities are related to the expenditures and prices within each subsystem. The numerical values of these elasticities and their standard errors are reported in Table 3. A necessary condition for concavity is that all the compensated own-price elasticities, $\hat{e}$, are negative and they are as expected negative. Furthermore, the uncompensated own-price elasticities, e, are negative and significantly different from zero. The absolute value is above one for alcoholic beverages. The expenditure elasticities, E, are positive and significantly different from zero except for hot drinks.

It is reasonable to expect that no pair of foods that have essentially the same role in the diet is a Hicksian complement. At stage three, there is one rather surprising complementary relationship that is statistically significant, namely, fresh vegetables and preserved vegetablia.

Table 4
Uncompensated own-price and expenditure elasticities

	Own-price			Expenditure		
	Conditional		Unconditional	Conditional		Unconditional
	Mean	1991	Mean	Mean	1991	Mean
Nondurables	−0.63	−0.65	−0.63	1.32	1.30	1.32
Services	−0.97	−0.97	−0.97	1.05	1.04	1.05
Food-away-from-home	−0.57	−0.52	−0.57	1.09	1.10	1.09
Food-at-home	−0.44	−0.36	−0.44	0.74	0.69	0.74
Animalia	−0.94	−0.94	−0.71	1.19	1.19	0.88
Meat	−0.90	−0.90	−0.72	0.98	0.98	0.86
Fish	−0.93	−0.95	−0.87	1.16	1.13	1.02
Eggs	−0.38	−0.22	−0.37	0.83	0.96	0.73
Cheese	−0.85	−0.88	−0.81	0.95	0.79	0.84
Beverages	−0.85	−0.85	−0.64	1.24	1.24	0.92
Soft drinks	−0.78	−0.83	−0.71	1.23	1.19	1.13
Hot drinks	−0.20	0.14	−0.20	−0.10	−0.81	−0.09
Alcoholic beverages	−1.06	−1.10	−0.81	1.51	1.51	1.39
Milk and cream	−0.33	−0.38	−0.27	0.59	0.62	0.54
Vegetablia	−0.94	−0.94	−0.87	0.59	0.57	0.44
Bread and cereals	−0.51	−0.55	−0.47	0.79	0.81	0.34
Fresh vegetables	−0.62	−0.51	−0.60	0.82	0.76	0.36
Fresh fruits, berries	−0.95	−0.92	−0.89	1.28	1.33	0.56
Preserved vegetablia	−0.49	−0.56	−0.47	1.15	1.13	0.50
Miscellaneous	−0.28	−0.33	−0.32	0.69	0.71	0.51

Appendix A. Table A1. Estimated parameters with robust standard errors in parentheses

	α	γ				β	θ			
		1	2	3	4		1	2	3	4
Food-at-home	−0.119 (0.054)	0.193 (0.038)	−0.005 (0.011)	−0.143 (0.021)	−0.044 (0.025)	−0.092 (0.015)	0.401 (0.090)	−0.674 (0.166)	0.300 (0.086)	−0.027 (0.069)
Food-away-from -home	0.219 (0.042)	−0.005 (0.011)	0.021 (0.007)	−0.003 (0.013)	−0.013 (0.011)	0.004 (0.010)	−0.144 (0.056)	0.564 (0.120)	−0.157 (0.056)	−0.263 (0.047)
Nondurables	0.426 (0.049)	−0.143 (0.021)	−0.003 (0.013)	0.111 (0.025)	0.035 (0.024)	0.069 (0.017)	0.116 (0.105)	−0.268 (0.190)	0.416 (0.055)	−0.264 (0.099)
Services	0.474 (0.069)	−0.044 (0.025)	−0.013 (0.011)	0.035 (0.024)	0.022 (0.033)	0.019 (0.022)	−0.374 (0.153)	0.378 (0.266)	−0.558 (0.114)	0.554 (0.122)
Animalia	0.625 (0.249)	0.058 (0.067)	−0.001 (0.034)	−0.015 (0.049)	−0.056 (0.026)	0.063 (0.057)	0.493 (0.202)	−0.246 (0.141)	−0.499 (0.280)	0.252 (0.118)
Beverages	0.562 (0.224)	−0.079 (0.046)	0.086 (0.035)	0.033 (0.039)	−0.041 (0.022)	0.073 (0.052)	−0.275 (0.210)	0.374 (0.164)	0.054 (0.291)	−0.153 (0.128)
Vegetablia	−0.083 (0.101)	0.039 (0.029)	−0.061 (0.025)	0.023 (0.027)	−0.003 (0.015)	−0.095 (0.023)	−0.092 (0.057)	−0.070 (0.051)	0.126 (0.094)	0.035 (0.039)
Miscellaneous	−0.105 (0.098)	−0.017 (0.019)	−0.024 (0.016)	−0.041 (0.018)	0.099 (0.011)	−0.041 (0.023)	−0.126 (0.063)	−0.058 (0.049)	0.319 (0.099)	−0.135 (0.038)
Bread and cereals	−0.042 (0.215)	0.177 (0.077)	−0.076 (0.021)	−0.061 (0.056)	−0.037 (0.041)	−0.079 (0.064)	0.361 (0.144)	−0.281 (0.142)	0.134 (0.129)	−0.214 (0.188)
Fresh vegetables and potatoes	0.364 (0.107)	0.058 (0.040)	0.055 (0.016)	−0.046 (0.026)	−0.114 (0.027)	−0.029 (0.032)	−0.375 (0.108)	0.263 (0.081)	−0.040 (0.064)	0.152 (0.097)
Fresh fruits and berries	0.562 (0.209)	−0.124 (0.059)	0.022 (0.023)	0.062 (0.046)	0.051 (0.036)	0.081 (0.058)	−0.152 (0.125)	0.248 (0.136)	0.069 (0.128)	−0.165 (0.145)
Preserves	0.116 (0.177)	−0.111 (0.061)	−0.002 (0.015)	0.044 (0.043)	0.100 (0.036)	0.027 (0.055)	0.166 (0.141)	−0.229 (0.130)	−0.162 (0.108)	0.226 (0.160)
Meat	0.122 (0.273)	0.053 (0.038)	−0.007 (0.180)	−0.014 (0.017)	−0.033 (0.020)	−0.014 (0.054)	0.838 (0.129)	0.313 (0.225)	−1.316 (0.269)	0.165 (0.292)
Fish	0.574 (0.210)	−0.007 (0.018)	0.023 (0.016)	−0.007 (0.015)	−0.009 (0.010)	0.030 (0.040)	−0.527 (0.101)	−0.077 (0.190)	0.695 (0.228)	−0.091 (0.196)
Cheese	0.163 (0.141)	−0.013 (0.017)	−0.007 (0.015)	0.017 (0.010)	0.004 (0.006)	−0.006 (0.030)	−0.153 (0.049)	−0.096 (0.082)	0.588 (0.093)	−0.339 (0.112)
Eggs	0.141 (0.061)	−0.033 (0.020)	−0.009 (0.010)	0.004 (0.006)	0.038 (0.011)	−0.010 (0.012)	−0.158 (0.037)	−0.140 (0.063)	0.032 (0.068)	0.265 (0.122)
Soft drinks	0.237 (0.123)	0.037 (0.031)	−0.023 (0.025)	0.012 (0.039)	−0.012 (0.026)	0.031 (0.033)	0.355 (0.141)	−0.116 (0.068)	−0.158 (0.077)	−0.081 (0.077)
Hot drinks	−0.483 (0.133)	−0.064 (0.035)	0.183 (0.042)	−0.152 (0.060)	0.035 (0.032)	−0.155 (0.032)	−0.221 (0.075)	0.016 (0.039)	0.198 (0.050)	0.007 (0.052)
Alcoholic beverages	1.480 (0.138)	0.079 (0.038)	−0.192 (0.046)	0.303 (0.071)	−0.225 (0.047)	0.234 (0.033)	0.251 (0.099)	−0.091 (0.076)	−0.018 (0.076)	−0.142 (0.082)
Milk and cream	−0.234 (0.113)	−0.052 (0.030)	0.032 (0.027)	−0.163 (0.046)	0.202 (0.031)	−0.109 (0.030)	−0.385 (0.137)	0.191 (0.076)	0.022 (0.066)	0.216 (0.055)

6.4. Unconditional elasticities

The more policy relevant unconditional own-price and expenditure elasticities are shown in Table 4. The unconditional expenditure elasticities approximate income elasticities. The expenditure elasticities show that nondurables, services, food-away-from-home, fish, soft drinks and alcoholic beverages are luxury goods, while the demand for hot drinks is very inelastic with respect to income.

The demands are not elastic with respect to own price for any good. The demands for hot drinks and for milk and cream are highly inelastic with respect to own price.

The conditional own-price and expenditure elasticities calculated at the mean and 1991 values of the input variables are also presented in Table 4. If the expenditure shares change over time, the values of the demand elasticities will change. However, the elasticities are quite stable over time for most goods. One notable exception is hot drinks. The demand for food and beverages at-home has become less price elastic over time and the own-price elasticity was -0.36 in 1991.

Finally, the unconditional expenditure elasticities differ substantially from the conditional elasticities for the goods in the vegetablia group. The conditional expenditure elasticities are more than twice as high as the unconditional elasticities. The unconditional own-price elasticities deviate more than 0.2 from the conditional elasticities for the groups animalia and beverages at stage two and for alcoholic beverages at stage three. These differences demonstrate the importance of adjusting conditional elasticities before they are used for policy purposes.

7. Conclusions

The demand for disaggregate food commodities were estimated in a three-stage model. The separability structure in the model was checked by nonparametric tests. Some GARP violations were detected in the animalia subsystem. However, they were removed by small adjustments in the quantities of fish. Consequently, the violations are interpreted as the results of measurement errors.

The almost ideal system was used for the parametric analysis. The static version was a less satisfactory representation of demand than a dynamic counterpart. Rejections of demand restrictions, serious misspecification, and rejections of the hypothesis of no dynamics were interpreted as evidences of the need to incorporate dynamic elements into the model.

The estimated conditional elasticities found by the dynamic model are intuitively plausible. The values are also stable over time for most food and beverages. The values of the unconditional elasticities differ from the values of conditional elasticities for several goods. These differences demonstrate the need to correct conditional elasticities before their use for most policy purposes.

The demands are not elastic with respect to own price for any of the goods. The elasticities for nondurables, services, food-away-from-home, fish, soft drinks, and alcoholic beverages are elastic with respect to income while the demand for hot drinks is very inelastic.

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References

Alessie, R., Kapteyn, A., 1991. Habit formation, interdependent preferences and demographic effects in the almost ideal demand system. The Economic J. 101, 404–419.

Alston, J.M., Chalfant, J.A., 1991a. Unstable models from incorrect forms. Am. J. Agricultural Economics 73, 1171–1181.

Alston, J.M., Chalfant, J.A., 1991b. Can we take the con out of meat demand studies?. Western J. Agricultural Economics 16 (1), 36–48.

Alston, J.M., Chalfant, J.A., 1992. Consumer demand analysis according to GARP. Northeastern J. Agricultural Resource Econ. 21 (2), 125–139.

Alston, J.M., Chalfant, J.A., 1993. The silence of the lambdas: a test of the almost ideal and Rotterdam models. Am. J. Agricultural Econ. 75, 304–313.

Anderson, G., Blundell, R., 1983. Testing restrictions in a flexible dynamic demand system: an application to consumers' expenditure in Canada. Rev. Economic Studies 50, 397–410.

Assarsson, B., 1991. Alcohol pricing policy and the demand for alcohol in Sweden 1978–1988. Working Paper, Department of Economics, Uppsala University, Sweden.

Barnett, W.A., Choi, S., 1989. A Monte Carlo study of tests of blockwise weak separability. J. Business & Economic Statistics 7 (3), 363–377.

Bewley, R., 1986. Allocation Models: Specification, Estimation and Applications. Ballinger, Cambridge, MA.

Central Bureau of Statistics, 1979. National Accounts 1962–1978, Oslo.

Central Bureau of Statistics, 1981. National Accounts 1949–1962, Oslo.

Central Bureau of Statistics, 1989. National Accounts 1976–1986, Oslo-Kongsvinger.

Central Bureau of Statistics, 1993. National Accounts 1991, Oslo-Kongsvinger.

Chalfant, J.A., Zhang, B., 1995. Variations on Invariance or Some Unpleasant Nonparametric Arithmetic. Working Paper, Department of Agricultural Economics, University of California, Davis.

Chen, P.Y., Veeman, M.M., 1991. An almost ideal demand system analysis for meats with habit formation and structural change. Can. J. Agricultural Econ. 39, 223–235.

Deaton, A., Muellbauer, J., 1980a. An almost ideal demand system. The Am. Economic Rev. 70 (3), 312–326.

Deaton, A., Muellbauer, J., 1980b. Economics and Consumer Behavior. Cambridge Univ. Press, Cambridge.

Edgerton, D.L., 1992. Estimating Elasticities in Multi-Stage Demand Systems. Paper presented at the American Agricultural Economics Association's Annual Meeting in Baltimore.

Edgerton, D.L., 1997. Weak separability and the estimation of elasticities in multi-stage demand systems. Am. J. Agricultural Econ. 79, 62–79.

Edgerton, D.L, Assarsson, B., Hummelmose, A., Laurila, I.P., Rickertsen, K., Vale, P.H., 1996. The Econometrics of Demand Systems: With Applications to Food Demand in the Nordic Countries. Kluwer Academic Publishers, Dordrecht.

Godfrey, L.G., 1978. Testing against general autoregressive and moving average error models when the regressors include lagged dependent variables. Econometrica 46 (6), 1293–1302.

Kendall, M.G., Stuart, A., 1963. The Advanced Theory of Statistics, Vol. 1, 2nd edn. Charles Griffin, London.

Manser, M.E., 1976. Elasticities of demand for food: An analysis using non additive utility functions allowing for habit formation. Southern Economic J. 43, 879–891.

Moschini, G., Meilke, K.D., 1989. Modeling the Pattern of Structural Change in U.S. Meat Demand. Am. J. Agricultural Econ. 71, 253–261.

Pollak, R.A., Wales, T.J., 1992. Demand System Specification and Estimation. Oxford Univ. Press, New York.

Rickertsen, K., 1994. The Demand for Food and Beverages in Norway. Report No. 13 Department of Economics and Social Sciences, Agricultural University of Norway, Ås.

Rickertsen, K., Chalfant, J.A., Steen, M., 1995. The effects of advertising on the demand for vegetables. Eur. Rev. Agricultural Econ. 22, 481–494.

Rickertsen, K., 1996. Structural Change and the Demand for Meat and Fish in Norway. Eur. Rev. Agricultural Econ. 23, 316–330.

Vale, P.H., 1989. Etterspørsel etter matvarer. Analyser på grunnlag av forbruksundersøkelsene i Norge (in Norwegian). Melding nr. 59, Department of Agricultural Economics, Agricultural University of Norway, Ås.

Varian, H., 1983. Non-parametric Tests of Consumer Behavior. Rev. Economic Studies 50, 99–110.

White, H., 1980. A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. Econometrica 48, 817–838.