Public Policies and the Demand for Vegetables

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Abstract

Increased consumption of vegetables may reduce obesity and the prevalence of cardiac diseases and cancer. Norwegians consume less vegetables than nutrition experts recommend and the per capita consumption is lower than in most European countries. To investigate the causes of low consumption, a two-step approach is used to estimate the demand segmented by nine different household types. In the first step, a probit model is estimated to investigate the decision whether to purchase traditional vegetables, salad vegetables, and industrially processed vegetables. Conditional on purchase, an almost ideal demand model is used to model how much to purchase.

The own-price elasticities and total expenditure elasticities are high for traditional and industrially processed vegetables for most household types. Especially households with children have elastic demand. Lower value added tax or lower import tariffs for traditional and industrially processed vegetables will increase the demand for these vegetables, while reducing the price of salad vegetables seem to have a limited effect. For households with children, increased incomes have large effects on the demand for traditional and industrially processed vegetables indicating that, for example, increased child support will result in increased vegetable consumption.

Keywords: vegetables, demand, segmentation, household types, policies

Introduction

Obesity and cardiac diseases are common in the Western world. Increased vegetable consumption can reduce these health problems. It is also well documented that a diet rich in vegetables has a cancer-preventive effect. Norwegians consume less vegetables than physicians and nutrition experts recommend. The primary objective of the nutrition policy in Norway, as in many European countries, is to increase the consumption of fruits and vegetables, and in a rapport the National Council of Nutrition (1998) recommends to double the consumption of fruits and vegetables. The consumption of vegetables is also lower in Norway than in most European countries. Table 1 shows the average vegetable consumption in selected European countries in 1990.

Table 1: Vegetables purchased in selected European countries (grams per capita and day).

	Norway	Ireland	UK	Luxembourg	Spain	Greece
Total vegetables	102	130	157	180	179	229
Fresh vegetables	80	99	103	129	155	203

Source: Andersen *et al.* (2000).

The low consumption of vegetables may be a consequence of high prices, low income, limited availability, low quality, socio-economic factors, eating habits, or other cultural factors. The Norwegian diet typically consists of one hot meal and three sandwich meals per day. A large share of the vegetables is eaten as a part of the hot meal and this may partly explain the low consumption compared with other countries. In most other countries, it is common to eat two hot meals per day. Another potential explanation is availability. There is limited availability of many types of fresh vegetables during parts of the year, especially in rural areas. Furthermore, according to Haga *et al.* (1997), about 40% of the grocery trade took place in discount stores with a limited selection of vegetables. Finally, there may be economic reasons for the low vegetable consumption. The agricultural policy causes high vegetable prices. In a purchasing power parity survey, Norway and the other Scandinavian countries have the highest prices on fruits and vegetables among the OECD-countries (OECD, 1992).

The purpose of this study is to analyze how prices and income can be used to increase the consumption of vegetables. Households are different and may react differently to price and income changes. The government influences the income of many types of households through various support schemes. Households with children receive support for each child, single parents receive extra support, retired people have their pension and so on. Moreover, the government influences relative prices through the agricultural policy, the import tariffs, and the value added tax. Given different reactions to changes in prices and income and an objective of targeting the policy against specific household types such as households with children, we divide the households in nine different types. This segmentation also prevents a loss of information increasing the efficiency of the model.

In the next section the econometric model is discussed. To take account of the two-stage decision process, we use a Heckman (1976) type of model. In the first step, a probit model approximates the purchase decision. In the seconds step, the almost ideal demand, AID, model (Deaton and Muellbauer, 1980) is used to find the demand for vegetables, conditional on the purchase decision. We proceed by discussing heterogeneity, the need for segmentation, and our data. Finally, the results in form of elasticity measures are presented. The estimates are discussed and we propose how the consumption of vegetables can be increased.

The econometric model

Not accounting for zero observations in limited dependent variable models may yield inconsistent parameter estimates (Amemiya, 1985). The models commonly used in dealing with the problem of zero consumption include the Tobit (Tobin, 1958), infrequency of purchase, and double hurdle models. A major difference among these models lies in the assumptions about the sources of the zero observations. The Tobit model assumes that the reasons for the zero observations are high relative prices or low income. This assumption may not be true for the cases when some zero observations are a result of nonparticipation decisions (Cragg, 1971). Furthermore, the Tobit model restricts the decisions about whether to consume and how much to consume to be determined by the same variables and in the same way. Second, zero observations may be due to infrequency of purchase and handled by an infrequency of purchase model (Deaton and Irish, 1984). The infrequency of purchase model is well suited for modeling demand for durable goods and may also be used to handle data based on a short observation period. Third, the zero purchase may be caused by non-preference for the good in question. In our case, it is hard to decide which model is most appropriate since zero purchases in our data set may be explained by several factors.

We started by estimating Cragg's (1971) double hurdle model, which allows for traditional corner solutions as well as other factors potentially explaining the zero purchases. The model assumes that the consumer makes two choices; whether to purchase and how much to purchase. The double hurdle model allows the two decisions to be determined by different sets of variables. However, consistent maximum likelihood estimation of this model is dependent upon the normality of the error term (Amemiya, 1985). After some experimentation with the double hurdle model without obtaining normally distributed errors, we decided to use the Heckman (1976) methodology for estimation. First, the probit model is used to approximate the decision to buy or not. The probit parameters are asymptotically normally distributed so maximum likelihood estimation of this model is consistent. In the second step, the demand conditional on positive purchase is modeled. Our model can be expressed by the participation equation $y_{ik}^* = x_{1k}'\alpha + \varepsilon_{1ik}$ and the consumption equation $w_{ik}^* = x_{2k}'\beta + \varepsilon_{2ik}$ where y_{ik}^* and w_{ik}^* are latent variables and x_{1k} and x_{2k} are vectors of explanatory variables accounting for participation and consumption. The subscripts i and k denote commodity i and household k, respectively. The observed budget shares, w_{ik}, is given as

$$\begin{aligned} w_{ik} &= x_{2k}'\beta + \varepsilon_{2ik} \quad \text{if} \quad x_{1k}'\alpha + \varepsilon_{1ik} > 0 \quad \text{and} \quad x_{2k}'\beta + \varepsilon_{2ik} > 0 \\ &= 0 \quad \text{otherwise.} \end{aligned} \tag{1}$$

We assume that the error terms are simultaneously normally distributed

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{pmatrix} \right) \tag{2}$$

where the commodity and household specific subscripts are neglected. The error term for the consumption equation may be written as

$$\varepsilon_2 = \frac{\sigma_{12}}{\sigma_1^2} \varepsilon_1 + v \tag{3}$$

where the stochastic error term v is assumed to be independent of ε_1. The expected purchase conditional on a positive purchase is given as

$$\begin{aligned} \mathrm{E}[w \mid y^* > 0] &= x_2'\beta + \mathrm{E}[\varepsilon_2 \mid \varepsilon_1 > -x_1'\alpha] \\ &= x_2'\beta + \frac{\sigma_{12}}{\sigma_1^2} \mathrm{E}\left(\frac{\varepsilon_1}{\sigma_1} \mid \frac{\varepsilon_1}{\sigma_1} > -\frac{x_1'\alpha}{\sigma_1} \right) \\ &= x_2'\beta + \frac{\sigma_{12}}{\sigma_1^2} \frac{\phi\left(\frac{x_1'\alpha}{\sigma_1} \right)}{\Phi\left(\frac{x_1'\alpha}{\sigma_1} \right)} \end{aligned} \tag{4}$$

where $\phi(.)$ is the density for a standard normal variable and $\Phi(.)$ is the corresponding cumulative distribution function. The unconditional budget share of commodity i is

$$\begin{aligned}\mathrm{E}(w) &= \mathrm{E}[w \mid y^* > 0] \cdot \mathrm{Prob}(y > 0) \\ &= \mathrm{E}[w \mid y^* > 0] \cdot \Phi\left(\frac{x_1^{'}\alpha}{\sigma_1}\right) \\ &= x_2^{'}\beta \cdot \Phi\left(\frac{x_1^{'}\alpha}{\sigma_1}\right) + \frac{\sigma_{12}}{\sigma_1^2}\phi\left(\frac{x_1^{'}\alpha}{\sigma_1}\right)\end{aligned} \tag{5}$$

Equation (5) can be consistently estimated in two steps (Amemiya, 1985: 387). In the first step, α/σ_1 is estimated with a probit model. Since we cannot estimate α/σ_1 separately, we follow the usual procedure and normalize σ_1 to 1 and calculate the inverse Mills ratio, $\phi(.)/\Phi(.)$. In the second step, the inverse Mills ratio is inserted into a linear approximate version of the AID model. For simplicity the model is estimated equation by equation using ordinary least squares and including the inverse Mills ratio from the first stage as an additional regressor.

$$\begin{aligned} y_{ik} &= \alpha_{i0} + \alpha_{i1}\ln p_1 + \alpha_{i2}\ln p_2 + \alpha_{i3}\ln p_3 + \alpha_{i4}\ln p_4 + \alpha_{i5}\ln m_k + \alpha_{i6}D_k + \varepsilon_{1ik} \\ w_{ik} &= \beta_{i0} + \beta_{i1}\ln p_1 + \beta_{i2}\ln p_2 + \beta_{i3}\ln p_3 + \beta_{i4}\ln p_4 + \beta_{i5}\ln\frac{m_k}{P} + \beta_{i6}D_k + \beta_{i7}\frac{\phi(.)}{\Phi(.)} + \varepsilon_{2ik}. \end{aligned} \tag{6}$$

Here will y take the value of 1 given a positive purchase and zero otherwise. The p's are prices of the three vegetables and other food. We assume that identical prices face all households in each observation period. The total food expenditure is denoted m and P is a Laspeyres food price index constructed by Statistics Norway. A vector of socio-economic and demographic variables, D, which mostly are dummy variables is also included. Let $\mathrm{d}w_i/w_i = \mathrm{dln}w_i = \mathrm{dln}q_i + \mathrm{dln}p_i - \mathrm{dln}m$ and the price elasticities may be derived as

$$\begin{aligned}\frac{\partial \ln q_i}{\partial \ln p_j} &= \delta_{ij} + \frac{1}{w_i}\left(\beta_{ij}\cdot\Phi(x_1^{'}\alpha) + \frac{\partial}{\partial \ln p_j}\left(\int_{-\infty}^{x_1^{'}\alpha}\phi(t)dt\right)\cdot(x_2^{'}\beta) + \frac{\sigma_{12}}{\sigma_1^2}\frac{\partial\phi(x_1^{'}\alpha)}{\partial \ln p_j}\right) \\ &= \delta_{ij} + \frac{1}{w_i}\left(\beta_{ij}\cdot\Phi(x_1^{'}\alpha) + \alpha_j\phi(x_1^{'}\alpha)(x_2^{'}\beta) + \frac{\sigma_{12}}{\sigma_1^2}\alpha_j\phi(x_1^{'}\alpha)\right)\end{aligned} \tag{7}$$

where the Kronecker delta δ_{ij} = -1 if $i = j$, and δ_{ij} = 0 otherwise. The expenditure elasticity is calculated as

$$\frac{\partial \ln q_i}{\partial \ln m} = 1 + \frac{1}{w_i}\left(\beta_{i5}\cdot\Phi(x_1^{'}\alpha) + \alpha_5\phi(x_1^{'}\alpha)(x_2^{'}\beta) + \frac{\sigma_{12}}{\sigma_1^2}\alpha_5\phi(x_1^{'}\alpha)\right) \tag{8}$$

Heterogeneity and segmentation

Households are different and react differently to changes in prices and income. The advantage of using micro data is the possibility to account for this heterogeneity. If, for example, young urban singles without children increase their consumption of vegetables when the prices of vegetables decrease while old couples in rural areas do not change their consumption, the econometric model should account for this heterogeneity. If this heterogeneity is neglected, the model is not estimated efficiently. One way to take differences in household structure into account is to modify the constant term by translating, see for example Pollak and Wales (1981). But translating taking account of the possible reactions to changes in prices and expenditure introduces a high degree of non-linearity in our model. An alternative solution is to segment the sample according to various household types and estimate the model for each household type separately as, for example, in Ben-Akiva and Lerman (1983).

Another reason for segmentation is the usefulness for policy purposes. The government influences households' consumption of vegetables through various taxes and subsidies. If the government wants to target their initiatives to certain household types, it is important to know their price and income elasticities. Let us look at some examples. First families with children receive support for every child and single parents receive income support. To calculate the effect on vegetable consumption of an increase in single parents' support, we need to know this household type's income elasticity for vegetables and how much the support changes total income.

Second, the government influences the prices on food commodities by import tariffs and agricultural policy. If the government plans to increase import tariffs of vegetables, it is of interest to know how the increased prices will affect welfare levels in different household types. Assuming the government wants to maintain the welfare of households with children, the elasticities may be used to calculate how much extra support this household type needs to be equally well off after the increase in import tariffs.

Third, the food industry can use elasticities to target marketing campaigns. For example, campaigns leading to price reductions can be targeted towards household types with the most price elastic demand. Furthermore, the own-price elasticities in combination with the number of households of various types can be used to calculate the expected profit from alternative ways of directing the campaign.

A final reason for segmentation is that estimation of aggregate demand functions is more appropriate when the household types in question are relatively homogenous regarding price and expenditure responses. If the responses to changes in prices are quite heterogeneous, it is preferable to estimate the demand for each household type separately. To investigate the need for segmentation, we have to test for identical demand coefficients for different household types. We follow the methodology outlined in Ben-Akiva and Lerman (1983). First, we divide the data sample into $g = 1, ..., G$, segments, where the sum of the number of observations in the different segments is equal to total number of observation in the data sample. The null hypothesis for homogeneous market segments is $H_0 : \beta^0 = \beta^1 = ... = \beta^G$, where β^g denotes a vector of coefficients in market segment g. The statistic for the likelihood ratio test is given by

$$L = -2\left(L_N(\hat{\beta}) - \sum_{g=1}^{G} L_{N_g}(\hat{\beta}^g) \right) \tag{9}$$

where $L_N(\hat{\beta})$ is the value of the log-likelihood function for the restricted model, i.e. the model using the complete sample. $L_{N_g}(\hat{\beta}^g)$ is the value of the likelihood function when the model is estimated using the observations of the g^{th} sub sample. The test statistic, L, is χ^2

distributed with degrees of freedom equal to the number of restrictions, $\sum_{g=1}^{G} K_g - K$, where K_g is the number of coefficients in the model using the g^{th} sub sample and K is the number of coefficients in the model using the complete sample. Furthermore, $K_g = K$.

If we assume a normal distribution, the log-likelihood function for this model is the sum of the probit log likelihood (purchase/not purchase) and the log likelihood of the regression of w on x_2 and the inverse Mills ratio, conditional on a positive purchase.

The data

We use Statistic Norway's yearly consumer surveys for the 1986 to 1998 period consisting of about 17,000 observations. During each year about 1,400 households keep accounts of their purchases over a two-week period. The households are representative for the population and the observations are equally distributed throughout the year. The consumer surveys are going on continuously and every year new households are chosen so we do not have a panel. For food products, both expenditures and quantities are recorded while only expenditures are recorded for other products. We can construct unit prices for vegetables by dividing expenditures by quantities. However, unit prices reflect quality variation as well as price variation. Furthermore, it is not obvious which unit price to use for households not purchasing the commodity in question. We solved these problems by using the Consumer Price Index (CPI) for each commodity. The CPI is a monthly Laspeyres index with fixed weights. One main objective of the consumer surveys is to produce material for calculating the weights of the CPI, and the weights change once a year according to the observed changes in budget shares.

One problem with combining the survey data with the monthly price indices is that the survey period may be in two months. We solved this problem in the following way. For the households keeping accounts within one month we used the CPIs for that month. For, the households keeping accounts in a period overlapping two months we used a weighted average of the CPIs for the two months, with the number of days in each month as weights.

We study the demand for three different vegetable groups. We aggregated the vegetables as in the consumer surveys and the CPI. The traditional vegetable group consists of fresh cabbage, cauliflower, and carrots; the salad vegetable group consists of tomatoes, onion, cucumber, lettuce, Swedish turnips, paprika, and other fresh vegetables; and the industrially processed vegetable group consists of frozen vegetables, dried vegetables, canned vegetables, pickled vegetables, and pre-prepared meals of vegetables. The traditional vegetables and the industrially processed vegetables are mainly cooked and used at dinner. The salad vegetables are mainly used for salads and are consumed at any of the meals.

We estimate the demand for the three vegetable groups using the prices of each vegetable group, a price index for other food products, the total food expenditures deflated by the CPI food price index, socio-economic and regional dummy variables, population density, a trend, and quarterly dummy variables.

The elasticity estimates

The two-step model is estimated for each household type. First, we estimated the probit model using maximum likelihood and a stepwise procedure including all the variables. When the *t* statistics of some coefficients had a numerical value below 1.5, we dropped the variable with the numerically lowest *t* value and estimated the model again. We repeated this procedure until the *t* values of all coefficients was numerically higher than 1.5. The limit is set as low as 1.5, because we do not want to drop a relevant variable making the parameter estimates inconsistent, On the other hand, the inclusion of an irrelevant variable only makes the model inefficient.

In the second step, we used the same strategy but included the prices in the model regardless of the value of their associated *t* statistics since we strongly believe that the prices have an effect on the quantity purchased. Furthermore, OLS does not give unbiased standard errors for the Heckman model, since they are heteroscedastic. However the LIMDEP program, which was used corrects for this inefficiency by the method described in Heckman (1979).

In Tables 2, 3, and 4, the elasticities are presented for the total sample (Total) and the nine household types:

S45- :	Single persons younger than 45 years.
S45-65:	Single persons between 45 and 65 years.
S65+:	Single persons older than 65 years.
CNC45-:	Couples without children, the primary household member (the person that keep the accounts) is younger than 45 years.
CNC45-65:	Couples without children, the primary household member is between 45 and 65 years.
CNC65+:	Couples without children, the primary household member is older than 65 years.
CWC:	Couples with children living in the household.
SWC:	Singles with children living in the household.
Others:	Other households with or without children.

The group traditional vegetables is denoted 1, the group salad vegetables is denoted 2, the group industrially processed vegetables is denoted 3, the group other foods is denoted 4, and the price and expenditure elasticities (measured at the average value of the variables) are denoted as follows:

e_{i1}:	The price elasticity between the quantity of group *i* and the price of traditional vegetables.
e_{i2}:	The price elasticity between the quantity of group *i* and the price of salad vegetables.
e_{i3}:	The price elasticity between the quantity of group *i* and the price of industrially processed vegetables.
e_{i4}:	The price elasticity between the quantity of group *i* and the price of all other foods.
E_i:	The total food expenditure elasticity of vegetable group *i*.

The tables also contain the following descriptive statistics:

N+:	The share of the households with a positive purchase of the commodity.

N:	The number of households.
%W+:	Average purchase for households with a positive purchase.
R^2_{adj} :	The coefficient of determination adjusted for degrees of freedom.
IMR:	The inverse Mills ratio. If IMR is marked as + in the tables, the variable is included in the second step estimation If IMR is marked as zero in the tables, the *t* value of this coefficient is less than 1.5 and the variable is excluded from the second step estimation.

We used the likelihood ratio test, described above, to find out if the household types react equally in relation to changes in prices and expenditure. We performed the test for each of the vegetable groups, and in all three cases the null hypothesis of equal coefficients were rejected at the 5% level. It means that estimating the model on the data segmented by household types is more efficient than on the whole sample.

Table 2 shows the elasticities and other measures for the group traditional vegetables. The own-price elasticity, e_{11}, for couples with children and single parents is more elastic than for the other household types taking the values –1.52 and –1.21, respectively. These values suggest that when the prices of traditional vegetables decrease couples with children and single parents are expected to increase their consumption more than other household types. The cross-price elasticities between traditional vegetables and the two other vegetable groups are mostly relatively small (and also insignificant). The cross-price elasticities between traditional vegetables and other foods is, however, negative for all the groups and relatively large in absolute values. They are also significantly different from zero for six of the household types. This complementary relationship reflects that the group other foods consists mostly of dinner products such as meat and fish. Since traditional vegetables mostly are eaten at dinner with meat and fish they are likely to be complements in consumption. So when meat or fish prices increase, the demands for traditional vegetables decrease. Price increases for meat and fish may also result in that households drop dinner or consume more of dinner products eaten without vegetables. It is worth noting that couples with children have the most negative cross-price elasticity between traditional vegetables and other foods.

The expenditure elasticity for traditional vegetables is also highest for couples with children, indicating that when food expenditures increase, couples with children increase their consumption of traditional vegetables more than other household types. Middle-aged couples without children have the lowest expenditure elasticity for traditional vegetables.

Relatively few of the youngest singles purchase traditional vegetables. Just 32% of the singles below 45 years purchased one or more of the vegetables included in the group traditional vegetables. Couples with children use less of their food expenditure on one of the traditional vegetables than the other household types, while couples between 45 and 65 years is the household type that used most. As is common in econometric estimation using pooled cross-section data, the R^2 values are low. The inverse Mills ratio has positive and significant effect for six of the ten household types.

Table 2: Price and expenditure elasticities and descriptive statistics for traditional vegetables (Elasticities significant at the 5% level are marked with bold type)

	Total	S45-	S45-65	S65+	CNC 45-	CNC 45-65	CNC 65+	CWC	SWC	Others
e_{11}	**-1.13**	**-0.89**	**-1.03**	**-0.83**	**-1.03**	**-0.61**	**-1.15**	**-1.52**	**-1.21**	**-0.79**
e_{12}	0.31	0.42	0.03	-0.10	**0.47**	0.21	**0.61**	0.56	0.22	0.33
e_{13}	0.11	-0.31	0.19	0.43	0.43	-0.13	0.01	0.25	0.32	0.43
e_{14}	-0.32	-0.88	-0.14	**-0.58**	**-0.95**	**-0.96**	-0.47	**-1.61**	**-1.02**	**-1.38**
E_1	**2.12**	**1.09**	**0.93**	**0.97**	**1.52**	**0.66**	**1.15**	**2.01**	**1.21**	**0.84**
N+	0.67	0.32	0.52	0.57	0.55	0.75	0.74	0.73	0.57	0.72
N	17032	1023	596	985	1012	1452	1455	7794	748	1967
%W+	1.87	2.53	3.08	2.81	1.83	2.18	2.15	1.54	1.82	1.94
R^2_{adj}	0.17	0.19	0.19	0.14	0.03	0.13	0.09	0.12	0.24	0.13
IMR	+	0	0	0	+	0	+	+	+	+

In Table 3, the elasticities and other measures for the group salad vegetables are shown. These vegetables are not mainly consumed as parts of a hot meal as many of the vegetables in the other groups. Most of the own-price elasticises indicate inelastic demand. Except for the group S45-65 all own-price elasticities are below 1 in absolute value and many are close to zero. The two household types consisting of singles younger than 65 years and the household type Others have the numerically highest own-price elasticities, indicating that these groups will increase their consumption of salad vegetables more than other groups if prices of these vegetables decrease. Most of the cross-price elasticities are small and also the cross-price elasticities with respect to other foods are small indicating that salad vegetables are relatively independent of the prices of meat and fish products. Expenditure elasticities are mostly above unity, and the youngest single households have the most elastic demand with an expenditure elasticity of 1.72. Again, among the group of young singles there are relatively few households that purchased one or more of the salad vegetables. But the household type S45- used a larger share of their food expenditure on salad vegetables than any other household type.

Table 3: Price and expenditure elasticities and descriptive statistics salad vegetables (Elasticities significant at the 5% level are marked with bold type)

	Total	S45-	S45-65	S65+	CNC 45-	CNC 45-65	CNC 65+	CWC	SWC	Others
e_{21}	-0.06	0.06	-0.17	-0.15	-0.15	-0.28	-0.01	-0.13	-0.01	-0.08
e_{22}	**-0.38**	**-0.93**	**-1.71**	-0.16	-0.65	-0.09	0.06	**-0.36**	-0.06	**-0.99**
e_{23}	0.01	0.43	**1.21**	0.16	-0.08	-0.21	-0.43	-0.09	-0.29	-0.40
e_{24}	0.01	-0.40	0.56	0.02	-0.15	-0.01	-0.13	-0.41	-0.20	0.15
E_2	**1.68**	**1.72**	**0.95**	**1.33**	**1.05**	**1.31**	**0.95**	**1.24**	**1.06**	**0.82**
N+	0.81	0.56	0.67	0.63	0.82	0.85	0.78	0.88	0.75	0.82
N	17124	1023	600	994	1022	1458	1458	7836	752	1981
%W+	3.07	4.44	4.04	3.42	3.50	3.44	2.94	2.76	3.15	3.07
R^2_{adj}	0.13	0.14	0.15	0.13	0.09	0.14	0.07	0.09	0.08	0.11
IMR	+	+	0	+	0	+	0	+	0	0

In Table 4, the elasticities and other measures for the group industrially processed vegetables are presented. All household types have relatively large own-price elasticities. Couples with children have the most price elastic demand, with a value of –1.44. But the own-price elasticity for the aggregate of all households is even larger indicating that estimating an aggregate demand function for all household types gives a biased estimate of the own-price elasticity. The cross-price elasticities between the vegetable groups are low. The cross-price elasticities between industrially processed vegetables and other foods are small and negative in most cases. The expenditure elasticities are higher than unity for most of the household types indicating that when expenditures on food increase the share of industrially processed vegetables will increase.

For industrially processed vegetables, young singles is the household type with less frequent purchase. Also in the other two household types consisting of singles there are relatively few households that purchase these products compared to couples either with or without children. Of those who buy some industrially processed vegetables, the three household types consisting of singles, use a larger part of their expenditures on this group than any other household type.

Table 4: Price and expenditure elasticities and descriptive statistics for industrially processed vegetables (Elasticities significant at the 5% level are marked with bold type)

	Total	S45-	S45-65	S65+	CNC 45-	CNC 45-65	CNC 65+	CWC	SWC	Others
e_{31}	0.01	-0.05	-0.21	-0.18	-0.14	**0.26**	0.06	0.14	0.14	-0.18
e_{32}	-0.15	-0.23	0.15	0.12	0.09	-0.34	-0.10	-0.14	-0.08	-0.45
e_{33}	**-1.62**	**-0.80**	**-1.02**	**-0.85**	**-1.37**	**-1.04**	**-1.09**	**-1.44**	**-0.92**	**-1.22**
e_{34}	-0.55	-0.30	-0.42	-0.14	0.12	-0.23	**-0.57**	0.25	**-1.13**	0.85
E_3	**1.26**	**1.11**	**0.95**	**1.02**	**1.51**	**0.93**	**1.01**	**1.42**	**0.89**	**1.69**
N+	0.57	0.34	0.39	0.36	0.61	0.61	0.52	0.65	0.50	0.57
N	17168	1027	601	1002	1022	1461	1466	7849	754	1986
%W+	2.13	3.49	3.55	3.27	2.69	2.35	2.15	1.75	2.35	2.16
R^2_{adj}	0.16	0.13	0.22	0.13	0.11	0.09	0.12	0.09	0.20	0.16
IMR	+	0	0	0	+	0	0	+	0	+

Discussion and conclusions

The estimation results show that the own-price elasticities for traditional vegetables and industrially processed vegetables are high and the own-price elasticities for salad vegetables are much lower. These differences indicate that estimation of disaggregate demand functions reveal facts that product aggregation may obscure. The same is true for the cross-price effects between the vegetable groups and the group other foods. While the cross-price effects indicate that traditional vegetables and other foods as well as industrially processed vegetables and other foods are gross complements, the cross-price effects between salad vegetables and other foods are close to zero suggesting independence. This is as expected since the group Other foods consists mostly of meat and fish products, and the traditional vegetables and the industrially processed vegetables are usually eaten with hot meals. The tests for segmentation suggest that demand functions segmented by household types use the information more efficiently than an aggregate demand function for all household types. In contrast to the demand for traditional and salad vegetables, many people, particularly among the youngest households, eat salad vegetables without any hot meal.

For all three vegetable groups, the expenditure elasticities are high and they are among the highest for households with children. Consequently, these households are expected to increase their consumption of vegetables more than other household types when expenditure on food increases. To find out what happens with consumption of vegetables when income increases we have to take account of the income effects on the food consumption. Carpentier and Guyomard (2001) show how to calculate unconditional elasticities from conditional elasticities when a weakly separable two-stage demand system is used. Following their approach the unconditional total expenditure elasticities of the vegetable group in question may be calculated as $E_i = E_{(G)i}E_G$ where $E_{(G)i}$ is the estimated conditional expenditure elasticity (the expenditure elasticities reported in Tables 2, 3, and 4) and E_G is the total expenditure elasticity for group G (food). If total expenditure is equal to income, the total expenditure elasticity will be equal to the income elasticity. As an approximation, we use Vale's (1996: 243) average income (total expenditure) elasticity for Norwegian food-at-home consumption. It was calculated to be 0.79 and we calculate the income elasticities for the traditional vegetable group for couples with children (household type CWC) using the conditional expenditure elasticity reported in Table 2. The total expenditure elasticity $E_1 = 2.01*0.79 = 1.59$, suggesting that couples with children regard traditional vegetables as a luxury good. This is in line with Vale (1996), who found that the expenditure elasticity for this commodity was higher than 1 for all types of households with children.

Lower value added taxes or lower import tariffs for traditional and industrially processed vegetables will increase the demand for these vegetables, while reducing the price of salad vegetables seem to have a limited effect. Increased incomes have large effects on the demand for traditional and industrially processed vegetables for households with children indicating that, for example, increased child support will result in increased vegetable consumption. To increase the consumption of vegetables one should rather subsidize than tax meat and fish products. These are complementary products to most vegetables, so lower prices may increase the demand for the complementary vegetables.

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