WHAT IS IT CONSUMERS REALLY WANT AND WHY? THE CASE OF FAT IN MILK

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Abstract

In this paper we investigate preferences for fat in milk through a structural characteristics model. The data includes information about daily purchases and social and demographic characteristics of approximately 2500 households. We find that consumers who prefer milk with a very high fat content can be reached both by information and prices, while consumers who prefer milk with a moderate to high fat share are not influenced by information, but are price sensitive. This is of great importance since these households drink a lot of milk and thereby get a considerable amount of fat through milk

Keywords: Fat in milk, Characteristics model, hedonic prices.

JEL: D12

Introduction

Health problems related to an excessive intake of saturated fat are among the major nutrition problems in most industrialised countries, as a high intake of saturated fat can lead to increased blood cholesterol levels and risk of various lifestyle-related illnesses. In Denmark, the consumption of saturated fat from milk has decreased during the last decade (Statistics Denmark, 2008), which in part might be a reaction upon massive campaigning from the Danish health authorities against an excessive intake of saturated fat, but also to a large extent due to the entrance of low fat varieties on the milk market (Smed and Jensen, 2004). These changes on the milk market give a good possibility to investigate preferences for saturated fat, how they can be expressed through demand and how they change over time and due to information.

In this paper we investigate preferences for fat in milk in depth through a structural characteristics model, i.e. a model where consumers derive utility from the characteristics inherent in milk, not from milk itself (Lancaster, 1966; Gorman, 1980). We introduce systematic changes in preferences initiated by a trend and exogenous health information. The data used for the estimations are based on an extensive panel dataset at household level. This means that it is possible to estimate the models household by household allowing for the maximum degree of individual heterogeneity.

There is a need to understand possible barriers for further reductions in the intake of saturated fat since this knowledge may be essential for the design of new actions aiming at reducing the intake of saturated fat. The derivation of a structural model for individual households brings us closer to separating preferences and changes in these due to e.g. information from reactions to prices and budget constraints.

The rest of this paper is organised as follows: Section 0 starts out with the basic theory of the characteristics model and then the data and the milk markets are described in section 0. Section 0 is about the construction of prices in the characteristics model and section 0 specifies the model using a quadratic utility function. Section 0 describes the results, i.e. valuation of fat, reactions to prices and information for different types of households and predictions of demand. Section 0 is devoted to a discussion and conclusion.

The characteristics model

The characteristics model was first developed by Gorman (1980) and Lancaster (1966) and further developed by Muellbauer (1974) and Rosen (1974). Generally, we assume that the world consists of H individual households. The number of goods available in each period is I and the number of characteristics is J. The connection between goods q and characteristics z is described through the technology matrix A.

$$
\begin{array}{cc}
 & \overbrace{\begin{array}{ccccc} 1 & \cdots & j & \cdots & J \end{array}}^{\text{Characteristics}} \\
\text{Goods} \left\{ \begin{array}{c} 1 \\ \vdots \\ i \\ \vdots \\ I \end{array} \right. &
\begin{bmatrix}
a_{11} & \cdots & a_{1j} & \cdots & a_{1J} \\
\vdots & \ddots & \vdots & \iddots & \vdots \\
a_{i1} & \cdots & a_{ij} & \cdots & a_{iJ} \\
\vdots & \iddots & \vdots & \ddots & \vdots \\
a_{I1} & \cdots & a_{Ij} & \cdots & a_{IJ}
\end{bmatrix} \equiv \mathrm{A}
\end{array}
\tag{1}
$$

It is assumed that the amount of characteristics can be aggregated over goods (the utility of a characteristic does not depend on its origin) and the relationship is assumed to be linear which means that the relationship between goods purchased and characteristics obtained can be written as:

$$z = \mathrm{A}'q \tag{2}$$

The technology matrix A is constant over households which implies that all households meet the same A matrix and we assume it to be constant over the time span used in our model (in principle the A matrix can change over time as products with new and previously unknown characteristics get into the market). For each household we observe the quantity purchased of each good: $q_t^h = \left(q_{1t}^h, \ldots, q_{it}^h, \ldots, q_{It}^h\right)'$ and we also observe a unit price for each good in each period: $p_t^h = \left(p_{1t}^h, \ldots, p_{it}^h, \ldots, p_{It}^h\right)'$. The total expenditure by household *h* in period *t* is therefore $x_t^h \equiv \left(p_t^h\right)' q_t^h$. Knowing the technology matrix A and the amount of goods purchased we can calculate the amount of characteristics purchased.

The optimisation problem

The households have preferences over characteristics, and the purchased quantities of goods that we observe are a result of households maximising their utility given the technology, the prices and the budget. In each period the household therefore faces the problem:

$$\begin{aligned} \underset{q_t^h}{Max} \quad & u^h\left(z_t^h \middle| \Omega^h\right) \\ s.t. \quad & z_t^h = \mathrm{A}_t' q_t^h \\ & x_t^h \geq \left(p_t^h\right)' q_t^h \\ & q_t^h \geq 0 \end{aligned} \tag{3}$$

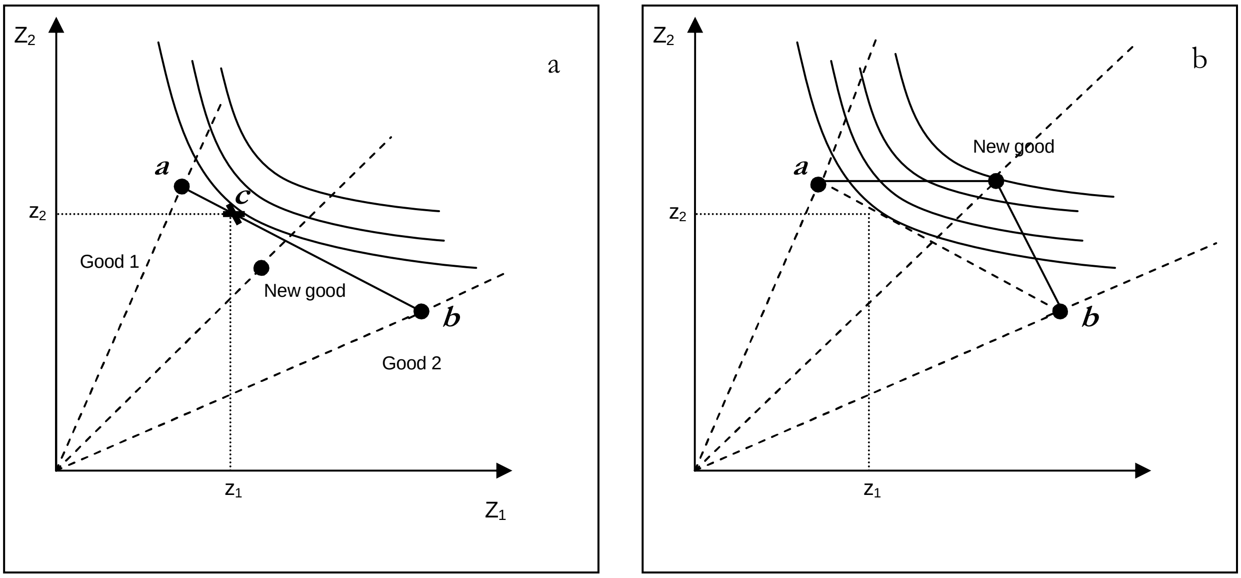
where Ω^h are socio-demographic characteristics and x_t^h is the total budget used by household *h* at time *t*. Note that the household optimises over goods *q*, but measures utility over characteristics *z*. This is because consumers purchase goods, but consume characteristics.

In the world of two characteristics the consumers' problem can be shown visually. Knowing the prices *p* and the total amount spent[1] *x*, we can calculate the amount of each characteristic $\left(z_1, z_2\right)$ that household *h* would obtain in period *t* spending all the money on good one (point *a* in Figure 1a below). If he spent all his money on good 2, he would obtain another amount of

[1] In theory we need to know the amount available for consumption. However, this amount cannot be observed, so we have to assume that the budget constraint is binding and use the observed amount actually spent.

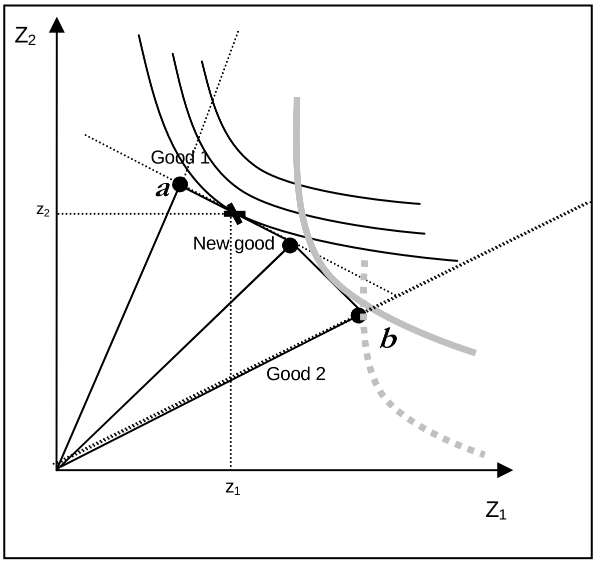
characteristics (point *b*). We assume that all goods can be purchased in continuous quantities. This means that any linear combination of goods 1 and 2 is possible, and the line between the highest obtainable level of characteristics (point *a* and point *b*) is therefore the budget restriction. When a new good, with known characteristics, but in new amounts, enters the market, the price of that good determines whether it will be purchased or not. In Figure 1a the price is too high (the consumer would get less of the characteristics z_1 and z_2 buying the new good) while in Figure 1b the price is so low that the budget constraint is pushed outwards and the consumers can obtain their preferred mix of characteristics in a cheaper way than by mixing good 1 and good 2.

Figure 1 Consumers' optimisation problem in a two characteristics world



More goods exist in the world than are purchased by the individual household. For another household it might be more efficient to purchase a mix of the new good and good 2 as shown in Figure 2. Due to the technology restriction, it is not possible to purchase characteristics outside the triangle $(a,b,0)$. This makes it difficult to point identify the parameters of the utility function for households who only purchase a good on the borderline, as e.g. the grey stipulated household in Figure 2. We will return to that later.

Figure 2 More consumers in a two goods, two characteristics world



Identification of implicit prices

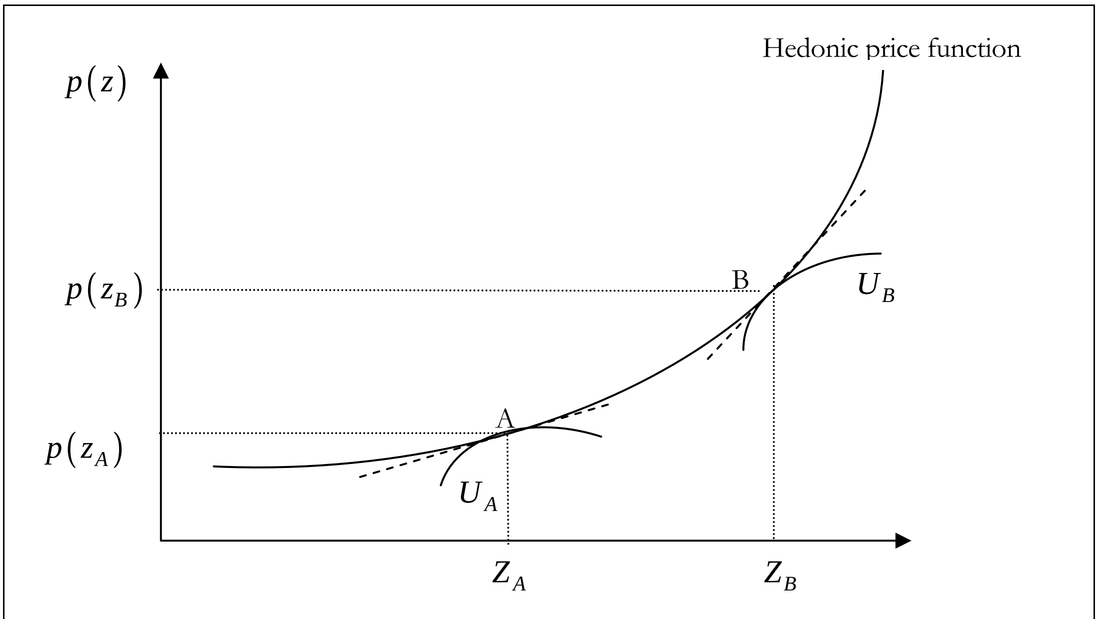
The implicit prices π measure how much money the household is willing to pay for an extra unit of characteristic *j*, $(\pi = \partial x / \partial z)$. If there are more goods than characteristics this implicit prices have to be estimated using a hedonic price function, see e.g. Rosen (1974), Ladd and Zober (1977) or Ladd and Suvannunt (1976). In a world with *J* characteristics optimised over *I* goods, the first-order conditions means that:

$$\frac{\partial u}{\partial q_i} - \frac{\partial u}{\partial x} p_i = \sum_{j=1}^{J} \frac{\partial u}{\partial z_j} \frac{\partial z_j}{\partial q_i} - \frac{\partial u}{\partial x} p_i = 0$$
$$\Updownarrow \tag{4}$$
$$p_i = \sum_{j=1}^{J} \frac{\partial u}{\partial z_j} \frac{\partial x}{\partial u} \frac{\partial z_j}{\partial q_i} = \sum_{j=1}^{J} \frac{\partial u}{\partial z_j} \frac{\partial x}{\partial u} a_{ij} = \sum_{j=1}^{J} \frac{\partial x}{\partial z_j} a_{ij}$$

The derivatives, $\partial z_j / \partial q_i$ are the elements in the technology matrix a_{ij}. The marginal utility of the budget $\partial u / \partial x$ is assumed to be constant. This implies that we have to assume homothecity of the utility function. This assumption is not realistic for luxury goods or goods with a large share of total consumption, but more realistic for a normal good with a smaller share of total expenditure (like milk). The homothecity and (4) implies that the price of a good is a weighted sum of the implicit prices of its characteristics $p_i = \sum_j \pi_j \alpha_{ij}$, which is one of the most important features of the characteristics model. If $p_i \geq \pi_j \alpha_{ij}$ then good *i* is not bought as illustrated in Figure 1a.

When implicit prices are used in a model estimating demand for characteristics there are several points to consider. Since one DKK spent on food will give you varying amounts of nutrients, dependent on which mixture of foods you choose to buy, the budget constraint in characteristics space is generally nonlinear. This leads to endogenous prices. However, under the assumption of constant return to scale, prices can be assumed to be exogenous in the optimal point (Deaton and Muellbauer, 1980). Another problem is that consumers choose quantity and price simultaneously as illustrated in Figure 3. This means that the model is unidentified (Ekeland et al., 2004), the implicit prices provide no more information than the preferences originally used to estimate the implicit prices. Brown and Rosen (1982), Kahn and Lang (1988), Eppel (1987) and Ekeland et al. (2004) suggest identification by allowing the price function to have higher powers of z (the characteristic) in the case of single market data or to use multi-market data to solve the identification problem. The main idea behind these identification strategies is that there must be additional parameters affecting the price functions that are not contained in the demand function. The multi-market identification approach, which is used here, builds on the assumption that the preference parameters and the distribution of tastes are identical across markets, but the price functions differ between markets, i.e. are affected by some additional variables not in the demand function. This implies different patterns of variance in different markets.

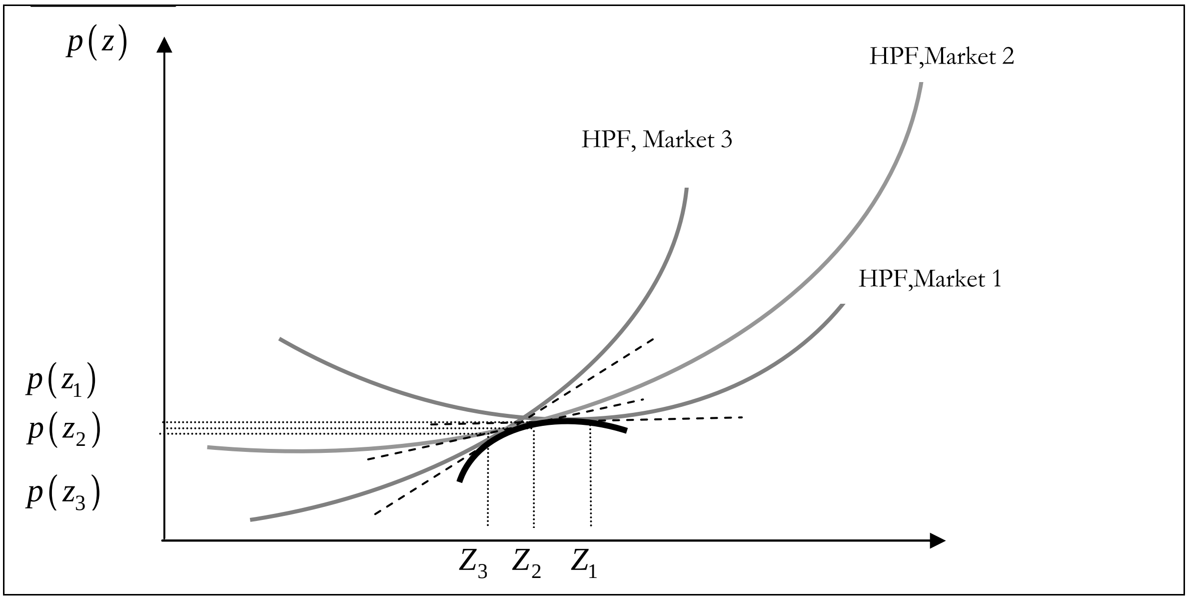
Figure 3 Simultaneous choice of price and quantity in the hedonic model*



*Adapted from Epple, 1987.

The identification of preferences from variation in the hedonic price functions are illustrated in Figure 4.

Figure 4 Illustration of identification in the multi-market case



HPF = hedonic price function.

Despite that the identification problems are solved in the multi-market case, a standard endogeneity problem persists, since the quantity and price of the characteristics are chosen simultaneously. This implies that the dependent variable (the chosen amount of the characteristic) and the implicit price are correlated through their dependence on the distribution of individual heterogeneity (Bartik, 1987; Kahn and Lang, 1988; Diamond and Smith, 1985).

Data and the milk market

Purchase data and background data

In the empirical estimations we use a comprehensive panel dataset from GfK-Denmark (a marketing institute with branches all over the world). The data cover the period from 1997 to 2004 and include information about daily purchases for individual households. Additionally, a wide range of social and demographic questions about the households (income, location, media habits, favourite store etc.) and information about each individual in the household (BMI, exercise habits, education, age etc.) are posed annually. These purchase data are combined with nutrition data such as the content of fat, protein, calcium etc. for each type of milk. This means that whenever a household purchases milk, we know the equivalent bundle of nutrients purchased.[2] On average 2,500 households report their purchases on a daily basis which sums up to 10,500 weekly observations on purchases of milk. The milk purchase data are aggregated up to monthly observations in order to minimise the amount of zeros in the dataset. This also makes the inter-temporally separable model, which we use, more appropriate since milk is a non-durable good.[3]

Information data

Consumers receive information about the connection between health and the intake of fat through various channels. Most studies incorporating the effect of health information on food demand use proxies to account for the amount of information that consumers receive. The most direct approach uses the number of relevant newspaper articles and/or the number of television transmissions (e.g. Piggott and Marsh, 2004; McGuirk et al., 1995; Schmidt and Kaiser, 2004; Verbeke and Ward, 2001; Smith et al., 1988). This approach is used here as the number of articles mentioning a link between the intake of fat and health are collected from Danish newspapers. The basic search words are fat/fat-rich/low fat in connection with health, slim, overweight, obesity resulting in 12 different combinations of searches. The articles are aggregated over newspapers independently of the size or location of the article. The number of articles is steadily increasing until 2001 and then it decreases.

Several of the indices introduced in the literature use a lag structure, as they find that press coverage has a cumulative effect. This includes simple cumulative indices as in McGuirk et al. (1995) and Schmidt and Kaiser (2004), declining shares to lagged index values as in Rickertsen et al. (1995) or more sophisticated structures as in Verbeke and Ward (2001). Based on the literature we choose to let the information last for a three-month period.[4]

The milk market

Until February 2001, there were four major types of milk on the Danish market: Whole milk, semi-skimmed milk, skimmed milk and buttermilk. Buttermilk is soured and therefore not

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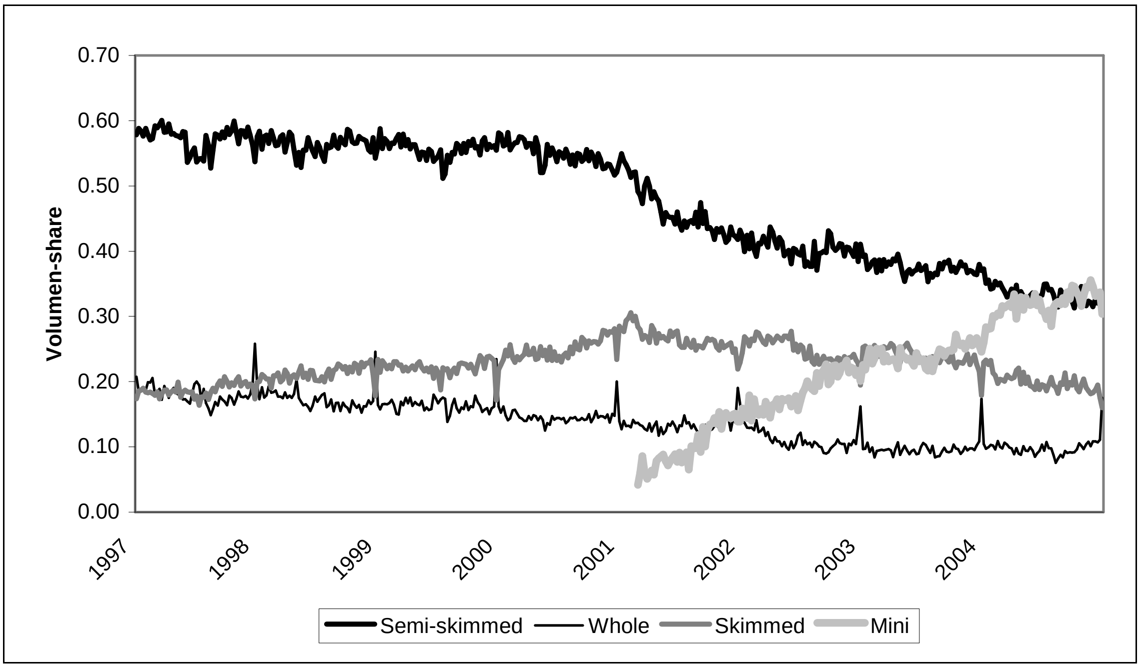
[2] For a throughout description of the data see Smed (2008).

[3] Milk will only keep fresh for a little longer than a week. The market for UHT milk is minimal in Denmark and almost all households buy and consume fresh milk.

[4] We have also tried a cumulative structure with no decay and a current index with no lags and the three-month structure shows the best result. More sophisticated analyses of the lag structure will be a route of further research.

included in the analysis. Whole milk has a fat content of 3.5 per cent, semi-skimmed milk of 1.5 per cent, skimmed milk has a fat content of 0.1 per cent. In February 2001, a new type of milk (mini milk) was introduced on the Danish market. Mini milk has a fat content of 0.5 per cent compared to the 1.5 per cent in semi-skimmed milk. This new type of milk took over part of the market for semi-skimmed milk and reversed the increasing trend for skimmed milk, while the trend for whole milk was almost unaffected as it is evident from Figure 5. The total volume of milk purchased has been more or less stable.

Figure 5 The Danish milk market, January 1997 to December 2004



In Smed (2005) and Smed and Jensen (2004) price elasticities for milk were estimated at an aggregate level both before and after the introduction of mini milk. These elasticities show that before the introduction of the new type of milk semi-skimmed and skimmed milk were substitutes. After the introduction of mini milk there is no longer any substitution between semi-skimmed milk and skimmed milk, while semi-skimmed is a substitute to mini milk. This is coherent with the characteristics model.

Prices

We take prices as given for the individual households, and thereby focus on the demand side, which seems reasonable in the market for foods since the individual consumer's decision cannot affect suppliers in the hedonic model for milk.. This is equivalent to the approach in

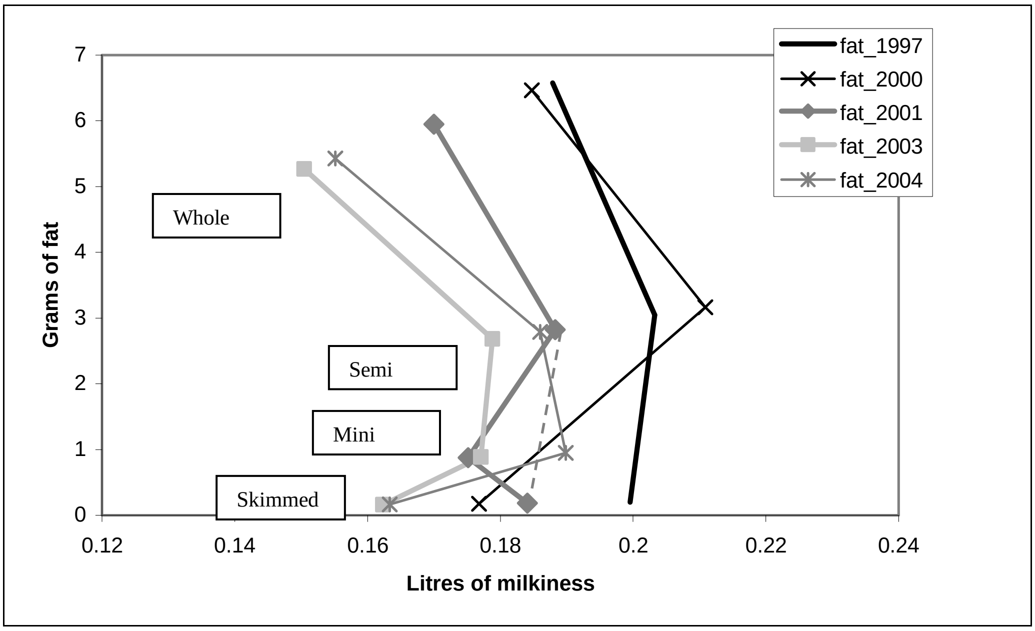
Muellbauer (1974) and Blow et al. (2005) and opposite Rosen (1974) who focuses on both the demand and supply side. The comprehensive dataset that we use allows us to follow individual households over a very long time (up to eight years) so we can deal with individual heterogeneity in the most extreme way by estimating the model individually for each household. All types of milk exist in both a conventional and an organic version. Milk is assumed to consist of two characteristics: milkiness and fat. Milkiness is best explained as the characteristic that distinguishes milk from a mixture of calcium and water, i.e. the fact that you can use it in your coffee, use it in pastry or on your cereals etc. One unit of milk contains one unit of milkiness independently of the type of milk, i.e. milkiness is measured in litres.

Identification and estimation of prices

We estimate hedonic price functions for several markets (different stores and different modes of produce) using observed purchases from all consumers. Demand functions are then estimated for the households assuming that they visit several markets i.e. go into different kinds of stores and buy both conventional and organic milk. This ensures identification, since parameters that do not influence the demand function for the individual consumer, namely other consumers' preferences, influence the hedonic price function. As our consumer only to a minor degree contributes to each particular hedonic price function, prices can be assumed to be exogenous. Furthermore, the usual problem of endogeneity does not apply since each consumer's demand function is estimated individually. It is assumed that there are three types of stores: discount stores, supermarkets and other stores. Furthermore, the country is divided into three regions: capital area, east and west since it is assumed that the price of milk depends on which part of the country it is bought in.

Figure 6 show how much of each of the characteristics fat and milkiness you get if you use one DKK on a particular type of milk, i.e. this is the empirical version of the theoretical Figure 1. From 1997 to 2000 the consumption set consists of only three points (skimmed, semi and whole milk), while the consumption sets in the other years have four points due to the entrance of mini milk on the market.

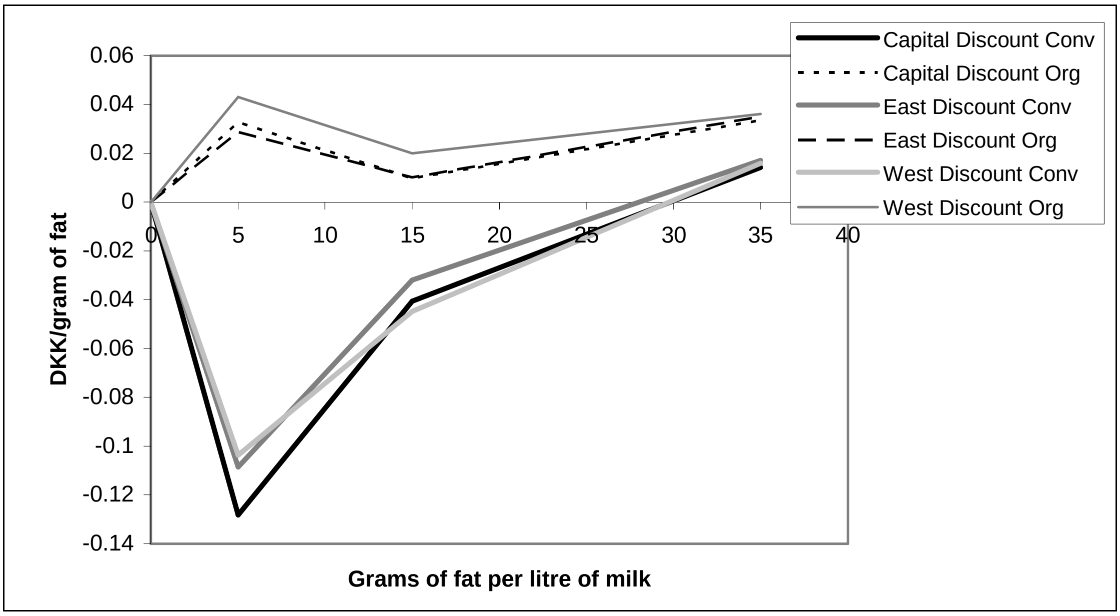
Figure 6 The empirical consumption set, capital, discount, conventional, standard dairy



In 2001 conventional mini milk is too expensive (the efficient consumption set is indicated by the stipulated grey line) and the consumers should not actually be buying it. That they do it anyway might be because the product is new on the market and has been marketed rather heavily. Similar consumption sets can be constructed for the other markets.

Figure 7 is a crude illustration of the hedonic price function for fat illustrated for selected markets. The figure illustrates the need for a quadratic form for the hedonic price function and separate markets for organic and conventional. The figure is crude in the sense that the average price of milk is used so the figure does not take into account the distribution of consumer preferences.

Figure 7 A crude empirical hedonic price function for fat, year 2003, standard dairy



Prices estimated from average prices of skimmed, mini, semi-skimmed and whole milk. Skimmed milk is the basis and the price of skimmed milk is assumed to reflect the price of milkiness (i.e. the amount of fat in skimmed milk is set to 0 in these figures, which also is a simplification). The price of fat is then calculated as the difference between the price of the milk in question and the price of skimmed milk since all milk is assumed to contain the same amount of milkiness.

In the demand model we treat preferences for milk as separable from all other food. Furthermore, we treat preferences for milkiness and fat as separable from the mode of produce (organic or conventional) and dairy (standard, discount or luxury dairy). As it appears from Figure 7 the hedonic price function for organic and conventional milk differs, but the hedonic price function for fat is unaffected by the dairy (not shown in the figure). This implies that mode of produce is treated as a separate market, while dairy appear as a dummy within the hedonic price equation. This means that 18 different versions of the hedonic price equation (5) are estimated, one for each market (3 types of stores, 3 regions and two modes of produce).

$$\begin{aligned} p_{i,t} &= \beta_{milkiness,t} + \beta_{luxury\_dairy,t} D_s + \beta_{discount\_dairy,t} D_d \\ &\quad + \beta_{fat,t} z_{fat,t} + \beta_{fat\_sq,t} \left(z_{fat,t} \right)^2 + \varepsilon_{it} \end{aligned} \tag{5}$$

The constant accounts for the price of one litre of "milkiness", D_s and D_d, are dummies accounting for a luxury and discount dairy, respectively,[5] z_{fat} accounts for the content of fat in grams. The polynomial of second order implies that the price of fat varies with the type of milk; as illustrated in Figure 7 it is more expensive to get your fat from whole milk than from

[5] The base is here a standard dairy. Discount dairies are mainly milk from foreign dairies, store brands etc. The luxury dairies are local or speciality dairies.

semi-skimmed milk. The parameters from this estimation result in a set of monthly implicit prices of characteristics, one for each market.

To construct individual prices for each household the estimated implicit prices at each market are weighted according to actual purchase patterns at either the organic or the conventional market and in the three different stores.[6]

Model specification

Demand under quadratic utility

We assume a quadratic utility function. The quadratic utility has a point with maximum utility (a bliss point) and the possibility of negative marginal as well as absolute utility of characteristics. This makes sense when estimating a model for characteristics. Free disposal is usually possible for goods, but not always for characteristics. It is not possible to dispose of fat without disposing of milkiness, and a positive utility of milkiness may outweigh a negative absolute utility of fat.

To keep the problem a little less complicated, the β matrix is assumed to be diagonal. In order to normalise the parameters, the alphas are assumed to sum to one. In a two characteristics world the utility function is:

$$u(z) = z'\alpha - 0.5z'\beta z = (1-\alpha_2)\,z_1 + \alpha_2 z_2 - 0.5\left(\beta_1 z_1^2 + \beta_2 z_2^2\right) \qquad (6)$$

which means that in optimum we have:

$$\frac{\partial u/\partial z_1}{\partial u/\partial z_2} = \frac{(1-\alpha_2)-\beta_1 z_1}{\alpha_2 - \beta_2 z_2} = \frac{\pi_1}{\pi_2} \qquad (7)$$

which for each household *h* is equivalent to

$$0 = \alpha_2^h \frac{\pi_{1t}^h}{\pi_{2t}^h} - \left(1-\alpha_2^h\right) + \beta_1^h z_{1t}^h - \beta_2^h \frac{\pi_{1t}^h}{\pi_{2t}^h} z_{2t}^h \qquad (8)$$

This is called *m*-demand (Browning, 1999), which implies that demand for one good is expressed as a function of demand for a reference good, here milkiness. As long as the reference good is normal this is a satisfactory measure of utility conditional on prices.

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[6] We assume that the consumer only buys milk in his own region.

We assume that we do not measure consumption perfectly, and a random term is therefore added to the z's.[7] The random terms on the z's are connected by the budget:

$$x = \pi_1 \left(z_1 + \xi_1 \right) + \pi_2 \left(z_2 + \xi_2 \right) \quad \Leftrightarrow \quad \xi_1 = \frac{x - \pi_1 z_1 - \pi_2 \left(z_2 + \xi_2 \right)}{\pi_1} \tag{9}$$

and we can therefore only identify one error term. We choose to assume that milkiness is observed perfectly, but fat is observed with uncertainty. Then the m-demand in (8) becomes:

$$0 = \alpha_2^h \frac{\pi_{1t}^h}{\pi_{2t}^h} - \left(1 - \alpha_2^h\right) + \beta_1^h z_{1t}^h - \beta_2^h \frac{\pi_{1t}^h}{\pi_{2t}^h} \left(z_{2t}^h + \xi_{2t}^h \right) \tag{10}$$

We know that z_1 is endogenous due to the correlation between milkiness and fat through the budget and we choose to instrument by the lagged value of milkiness and the total budget for milk. The instrumentation is done for each household individually:

$$z_{1t}^h = \eta_1^h z_{1t-1}^h + \eta_2^h \tilde{x}_t^h + \zeta_{1t}^h \quad \Rightarrow \quad \hat{z}_{1t}^h = \eta_1^h z_{1t-1}^h + \eta_2^h \tilde{x}_t^h \tag{11}$$

where z_{1t-1}^h is the lagged value of z_{1t}^h and $\tilde{x}_t^h$ is the budget for purchases of all types of milk. We include both the estimated value $\hat{z}_{1t}^h$ and the residual in the estimations; this is called the control function approach (Blundell and Powel, 2003). Equation (10) then changes to:

$$0 = \alpha_2^h \frac{\pi_{1t}^h}{\pi_{2t}^h} - \left(1 - \alpha_2^h\right) + \beta_1^h \hat{z}_{1t}^h + \delta^h \left(z_{1t}^h - \hat{z}_{1t}^h \right) - \beta_2^h \frac{\pi_{1t}^h}{\pi_{2t}^h} \left(z_{2t}^h + \xi_{2t}^h \right) \tag{12}$$

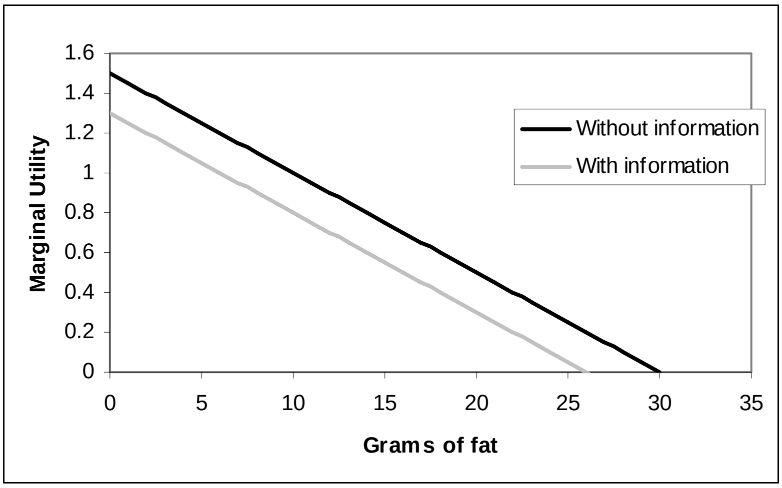
Including trend and information in the specification

A trend is introduced in the model in order to catch up with changes in preferences over time. The trend is made exponential (a matter of empirical evidence) and added to the alpha parameter. These decisions are based on empirical evidence through repeated reformulations of the model

We model the influence from information as additive on the alpha parameter, which implies that information decreases the marginal utility of fat with the same amount independently of how much fat is consumed. This is illustrated in Figure 8.

[7] We have also estimated a model where the random term is related to the preferences and therefore added to the alfas (Smed 2008). However, the conclusion was that measurement errors worked better.

Figure 8 The way information influences the marginal utility for fat



We do not include the trend and the information in the normalisation $(\alpha_1 + \alpha_2 = 1)$. This means that we get at utility function of the form:[8]

$$U(z_1, z_2) = (1-\alpha_2) z_1 + (\alpha_2 + \tau_2 \ln(t) + \gamma_2 I) z_2 - 0.5(\beta_1 z_1^2 + \beta_2 z_2^2) \quad (13)$$

The non-instrumented *m*-demand from (10) becomes:

$$0 = (\alpha_2 + \tau_2 \ln(t) + \gamma_2 I)\frac{\pi_1}{\pi_2} - (1-\alpha_2) + \beta_1 z_1 - \beta_2 \frac{\pi_1}{\pi_2}(z_2 + \xi_2) \qquad (14)$$

which can be rearranged to:

$$z_2 = \omega_1 + \omega_2 \ln(t) + \omega_3 I + \omega_4 \frac{\pi_2}{\pi_1} + \omega_5 \frac{\pi_2}{\pi_1} z_1 + \xi_2 \qquad (15)$$

where $\omega_1 = \alpha_2 \beta_2^{-1}$, $\omega_2 = \tau_2 \beta_2^{-1}$, $\omega_3 = \gamma_2 \beta_2^{-1}$, $\omega_4 = -(1-\alpha_2)\beta_2^{-1}$ and $\omega_5 = \beta_1 \beta_2^{-1}$. Note that $\omega_4 = -(1-\alpha_2)/\beta_2 = \omega_1 - \beta_2^{-1} \Leftrightarrow \beta_2^{-1} = \omega_1 - \omega_4$, which means that the relationships are:

$$\alpha_1 = \frac{\omega_4}{\omega_1 - \omega_4}, \quad \alpha_2 = \frac{\omega_1}{\omega_1 - \omega_4}, \quad \beta_1 = \frac{\omega_5}{\omega_1 - \omega_4}, \quad \beta_2 = \frac{1}{\omega_1 - \omega_4}$$
$$\tau_2 = \frac{\omega_2}{\omega_1 - \omega_4}, \quad \gamma_2 = \frac{\omega_3}{\omega_1 - \omega_4} \qquad (16)$$

The equation can of course also be estimated with z_1 as the dependent variable. The identification issues are equivalent.

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[8] Due to the stability of total consumption of milk and to save on degrees of freedom we choose here to formulate the model with only a trend on fat.

Tobit with censoring

It is not possible to buy a litre of milkiness without buying at least one gram of fat (skimmed milk), and it is not possible to purchase more than 35 grams of fat per litre of milkiness (wholemilk). These restrictions mean that the analytical *m*-demand in (15) cannot always be obtained. Households that have preferences for milk with less fat than skimmed milk and households that have preferences for milk with more fat than whole milk are censored. This problem is solved by estimating a Tobit model with two-sided censoring (Amemiya, 1984; Tobin, 1958). As the model is estimated for each household individually the actual equation to estimate with instruments (see (11)) becomes:

$$\begin{gathered} z_{2t}^h = \omega_1^h + \omega_2^h \ln(t) + \omega_3^h I_t + \omega_4^h \frac{\pi_{2t}^h}{\pi_{1t}^h} + \omega_5^h \frac{\pi_{2t}^h}{\pi_{1t}^h} \tilde{z}_{1t}^h + \omega_6^h \frac{\pi_{2t}^h}{\pi_{1t}^h} \left(z_{1t}^h - \tilde{z}_{1t}^h \right) + \xi_{2t}^h \\ z_{1t}^h \le z_{2t}^h \le 35 z_{1t}^h \end{gathered} \tag{17}$$

After estimating the parameters we then predict consumption of fat both in the estimation period and in the prediction period by ignoring the effect of the residual and using the true value of z_{1t}^h instead of the instrumented variable:

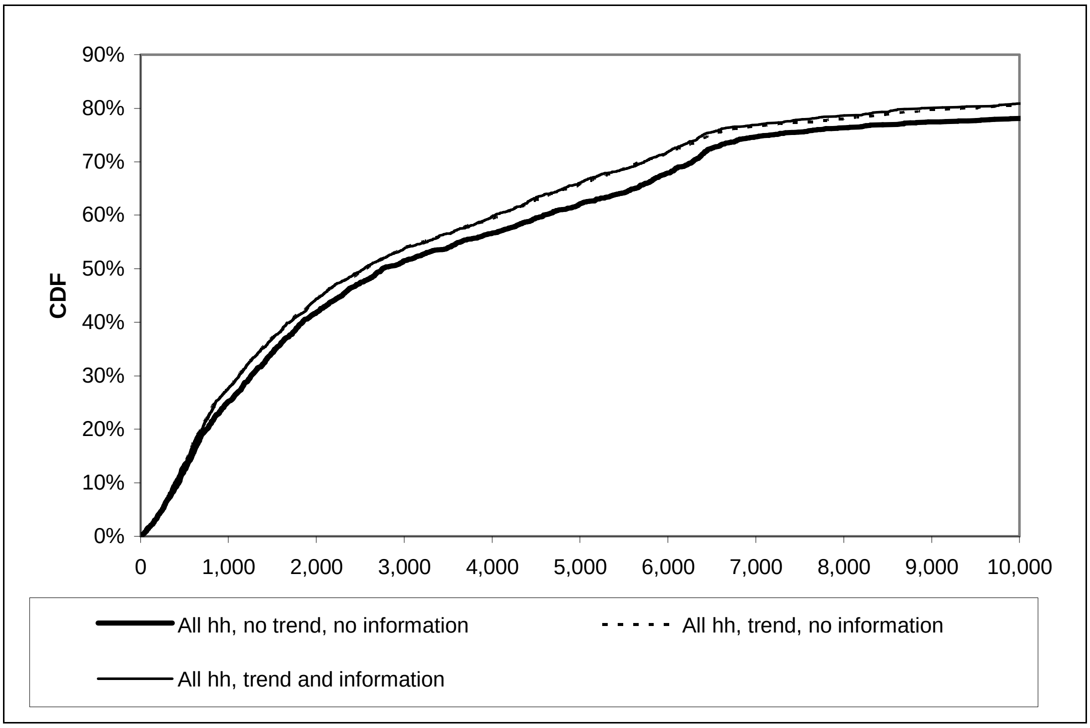
$$\hat{z}_{2t}^h = \omega_1^h + \omega_2^h \ln(t) + \omega_3^h I_t + \omega_4^h \frac{\pi_{2t}^h}{\pi_{1t}^h} + \omega_5^h \frac{\pi_{2t}^h}{\pi_{1t}^h} z_{1t}^h \tag{18}$$

We then calculate the predicted milkiness from this and the budget and prices:

$$\hat{z}_{1t}^h = \frac{x_t^h - \pi_{2t}^h \hat{z}_{2t}^h}{\pi_{1t}^h} \tag{19}$$

Figure 9 shows the Cumulative Density Function (CDF) of the mean squared percentage error on fat in the final estimation of the Tobit with two-sided censoring with instrumentation. The model is estimated over the whole period with and without trend and information. It is evident that the model which includes a trend to account for changing preferences for fat does better than a model without a trend. Including information along with the trend improves the model slightly.

Figure 9 Mean squared percentage error on fat, in an instrumented Tobit model with and without trend and information



Results

The estimated parameters give a range of possibilities to investigate household preferences for fat. One of the features of a quadratic utility function is that it is possible to calculate the preferred amount of fat and milkiness bought if there were no prices (i.e. the bliss point). If β is diagonal, the bliss points can be calculated from (13) as:

$$z_{1t}^{h*} = \frac{\alpha_1^h}{\beta_1^h} \quad \text{and} \quad z_{2t}^{h*} = \frac{\alpha_2^h + \tau_2^h \ln(t) + \gamma_2^h I_t}{\beta_2^h} \tag{20}$$

Where z_{1t}^h is milkiness and z_{2t}^h is fat. The optimal fat share can then be calculated from (20):

$$\frac{z_{2t}^{h*}}{z_{1t}^{h*}} = \frac{\left(\alpha_2^h + \tau_2^h \ln(t) + \gamma_2^h I_t\right)\beta_1^h}{\alpha_1^h \beta_2^h} \tag{21}$$

Both the optimal fat and the optimal fat share are changing over time due to the influence from the trend and information. Apart from the bliss point and the optimal fat share of fat in milk we also look at the own- and cross price elasticities. The derivation of the own price elasticities for milkiness and cross-price elasticities between milkiness and fat are shown in Smed 2008. To get more reliable results only households which buy more than one type of milk more than 30 per cent of the time are used in the figures below. The following section focuses on socio demographic differences in consumption, the next section focuses on price elasticities and reactions to information.

Valuation of fat over time and for various social and demographic groups

Especially in marketing strategies, but also in the design of public campaigns with the aim of decreasing the intake of saturated fat it is useful to know the socio-demographic characteristics of the target groups. This subsection shows differences in optimal fat share for different types of households and changes over time. Households with a negative optimal fat value and a negative optimal milkiness value ought not to be buying milk. There are only a few of these (between 2.4 and 3.7 per cent of the panel in different years). They are deleted from the figures below. A little more than four fifths of the panel have a positive optimal value of both fat and milkiness. A negative optimal fat share implies that the households would prefer milk with no fat and they think of the fat that comes along with the milkiness in a litre of milk as a nuisance. Those with a positive optimal fat share regard fat as a good to some extent.

Figure 10 shows the change over time for the density function over optimal fat shares for households that are in the panel the whole period from 1998 to 2003 (447 households). The distribution is calculated as a kernel regression with Gaussian kernel (see e.g. Blundell and Duncan, 1998). The figures show clearly how the optimal fat share declines over time. To the left and the right of the grey lines in the figure are the areas where it is not possible to reveal preferences i.e. households will have to buy milk with a smaller or larger fat content than actually preferred.

Figure 10 The density function for the optimal fat share over time

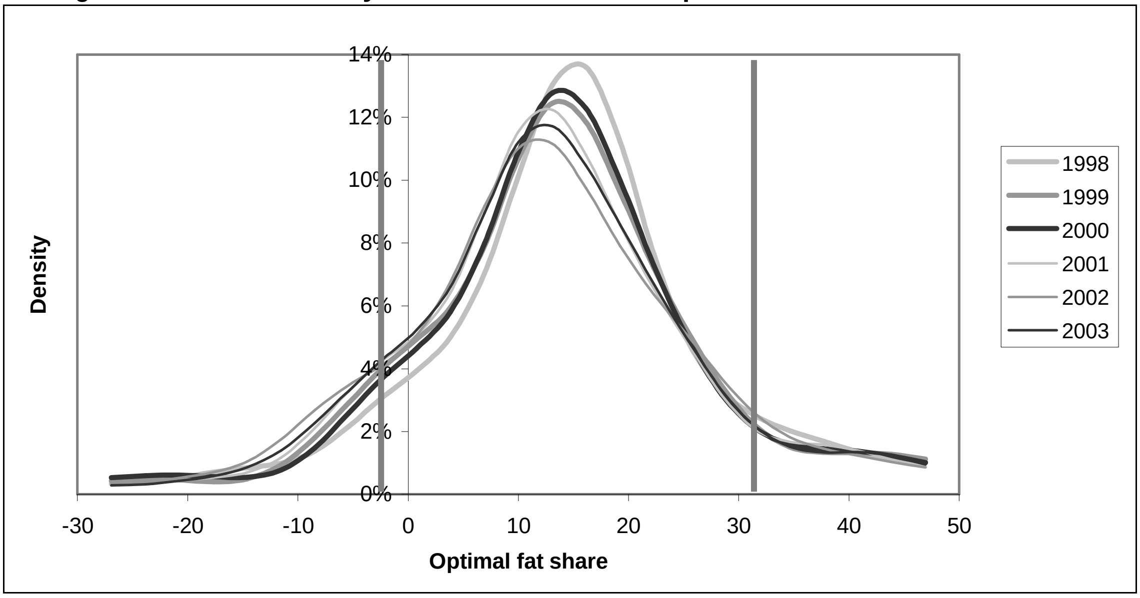


Figure 11 and Figure 12 show the optimal milkiness consumption together with optimal fat share. The milkiness haters are left out. All columns in the figure sum to one. Many households, 40 per cent of the panel in 2004, have a moderate optimal milkiness consumption and a moderate to high optimal fat share (optimal fat between 5 to 35 grams of fat per litre). The fat-haters (optimal fat share less than 1) are represented in each group of milkiness attitudes while the fat-lovers (optimal fat share 35 or above) are concentrated among those who prefer a low milkiness consumption. There are no fat-lovers who prefer a high weekly consumption of milkiness. The change in preferences towards milk with lower fat share is clear when comparing the combinations of optimal milkiness consumption and optimal fat share in 1997 (Figure 11) with 2004 (Figure 12).

Figure 11 Distribution of the panel over optimal fat shares and milkiness in 1997

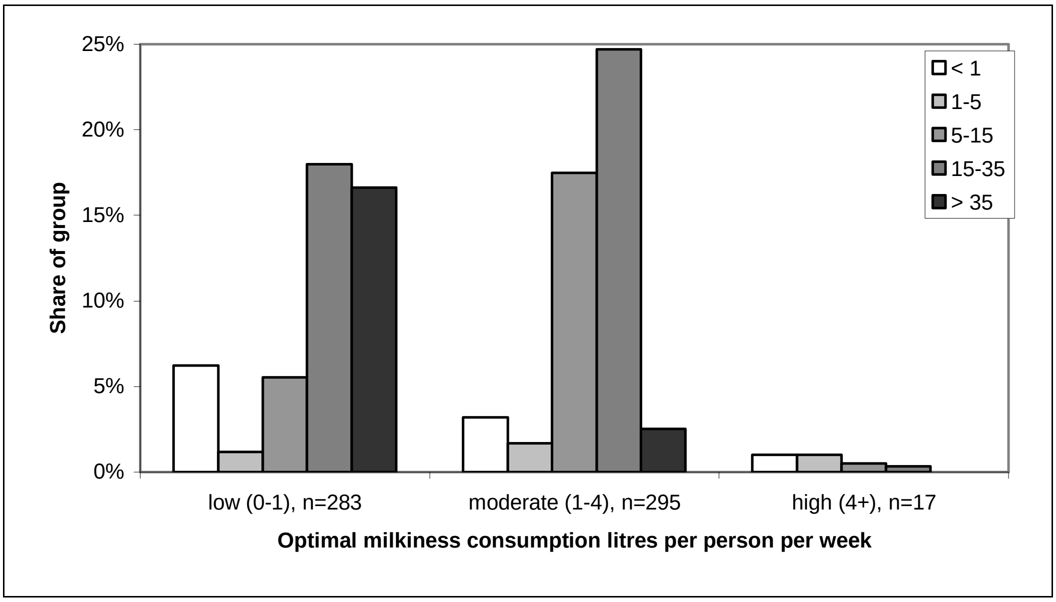


Figure 12 Distribution of the panel over optimal fat shares and milkiness in 2004

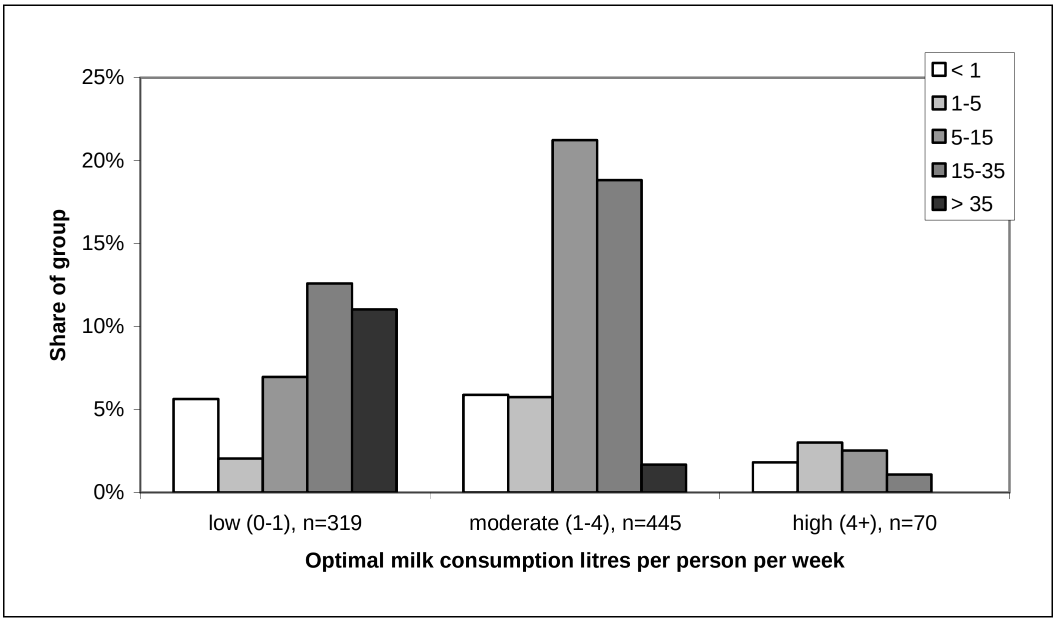


Figure 13 shows the optimal fat share for households with different level of education. There is not much difference between households with no or vocational education, while households with a longer or medium further education[9] prefer a lower fat content. Households with a short education show a distribution with two bulks, one around 12 and another around 32 grams of fat per litre of milk.

[9] For a detailed description of the educational groups see chapter 2 in Smed (2008).

Figure 13 Distribution of optimal fat share for households in different educational groups, 1997

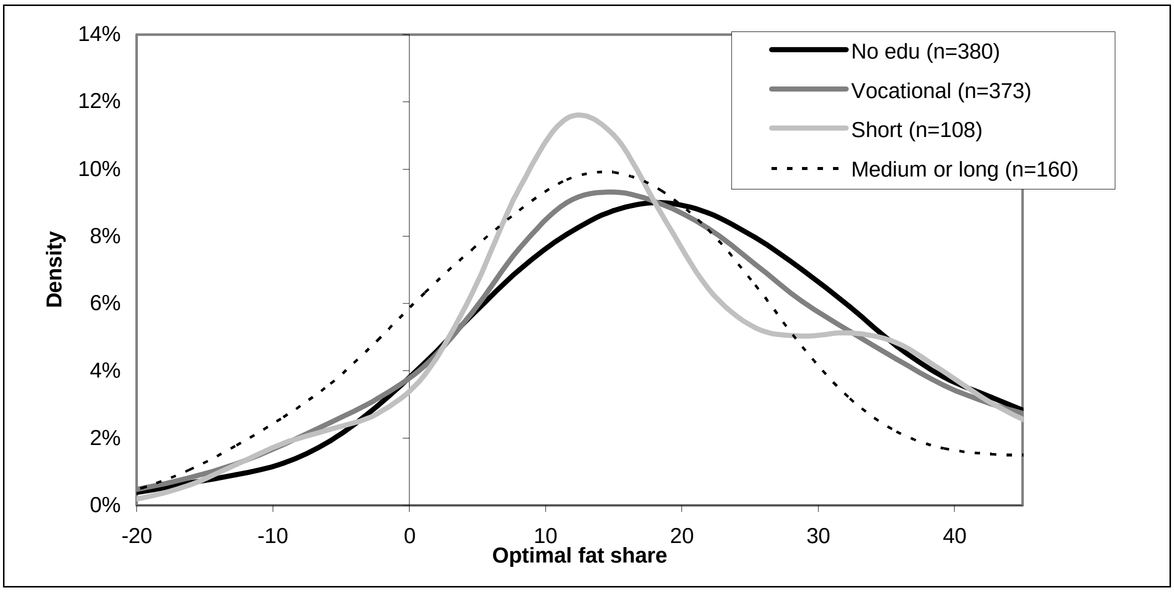
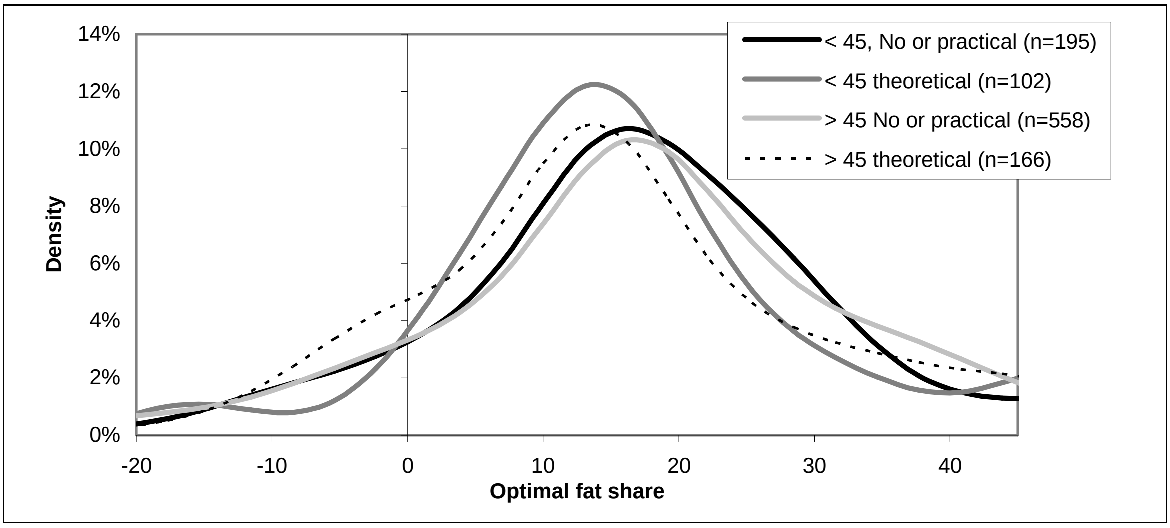


Figure 14 shows the distribution over fat share for a combination of education and age, note that the educational definitions here are slightly different, namely divided into either practical or no education versus theoretical education. For each of the age groups the theoretically educated prefer milk with lower fat content.

Figure 14 Distribution of fat share for a combination of education and age, 1997

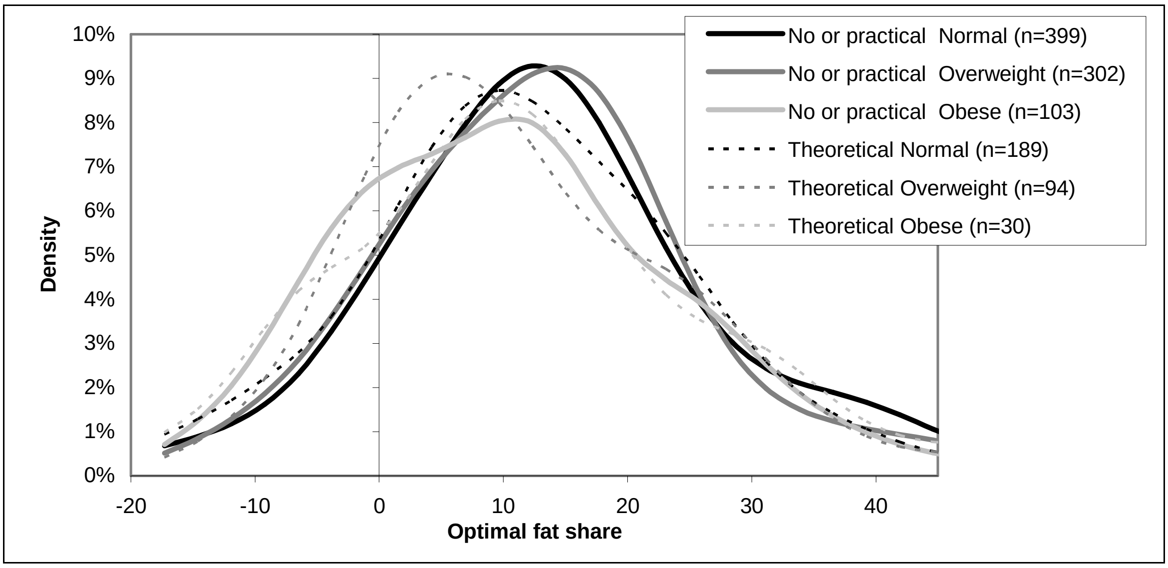


Finally, Figure 15 shows the distribution over optimal fat share in 2004 for combinations of BMI[10] and education. The theoretically educated households have a lower optimal fat share than households with no or practical education, but it seems like obese individuals prefer a

[10] Questions of height and weight for each individual in the household are only posed in 2004. BMI is calculated as: $BMI = weight(kg) / (height(m))^2$. Overweight is then defined as a BMI above 25, but below 30, while obesity is defined as having a BMI above 30.

lower optimal fat share than those with normal weight. This might indicate that the consumption of milk is an area where it is rather convenient to save calories.

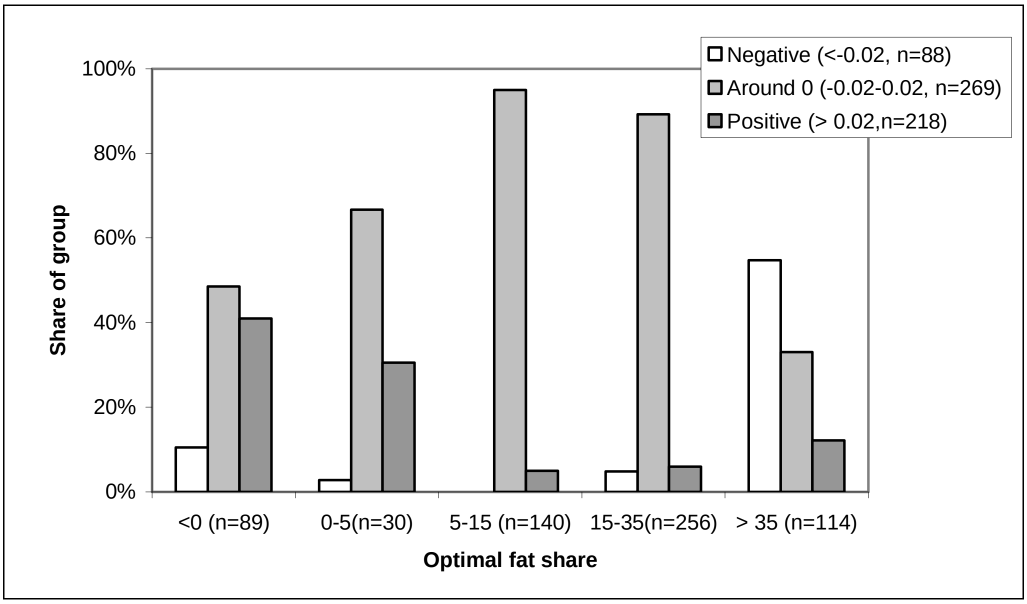
Figure 15 Distribution of optimal fat share for combinations of BMI and education



Political implications – who can be affected by prices and information

It is of great interest to investigate the size and sign of the price elasticity, the trend and the information parameter for households with different optimal fat share. In the following figures the panel is divided into groups according to their optimal fat share and their trend and information parameters are compared together with own price elasticities for fat. A negative trend parameter indicates that the optimal amount of fat in grams per week per person decline over time, while a negative information parameter indicates that households decrease their optimal fat share according to information about the relation between fat consumption and health. On average, 57 per cent of the households have a negative trend parameter. Figure 16 shows the share of households with negative and positive trends, respectively, separated by optimal fat share (the columns within each group sum to 1). In general, households that like fat (the fat lovers who prefer an optimal fat share > 35) have a larger tendency to have a negative trend for fat, while households that do not like fat (optimal fat share < 5) have a larger tendency to have a positive trend than the average. Most households with a moderate fat share do not change consumption (the trend parameter is around zero).

Figure 16 Optimal fat share and the trend parameter in 1997



Most households have an information parameter just around zero. A positive and significant reaction to information gives no meaning in the current model. Of great interest is the 11 per cent of the panel having a large reaction to information (having an information parameter below -0.001). One fourth of these are fat-haters (optimal fat share < 0 grams per litre) while one third are high fat consumers (optimal fat share =15-35 grams per litre) and another fourth are fat-lovers (> 35 grams of fat per litre). Figure 17 shows the sign of the information parameter separated by optimal fat share (each optimal fat share group sum to 1). The figure shows clearly that those who react even moderately to information (having an information parameter below -0.0005) are either the fat-lovers or fat-haters. Those who reacts the least are moderate to high fat consumers.

Figure 17 Optimal fat share and the sign of the information parameter in 1997

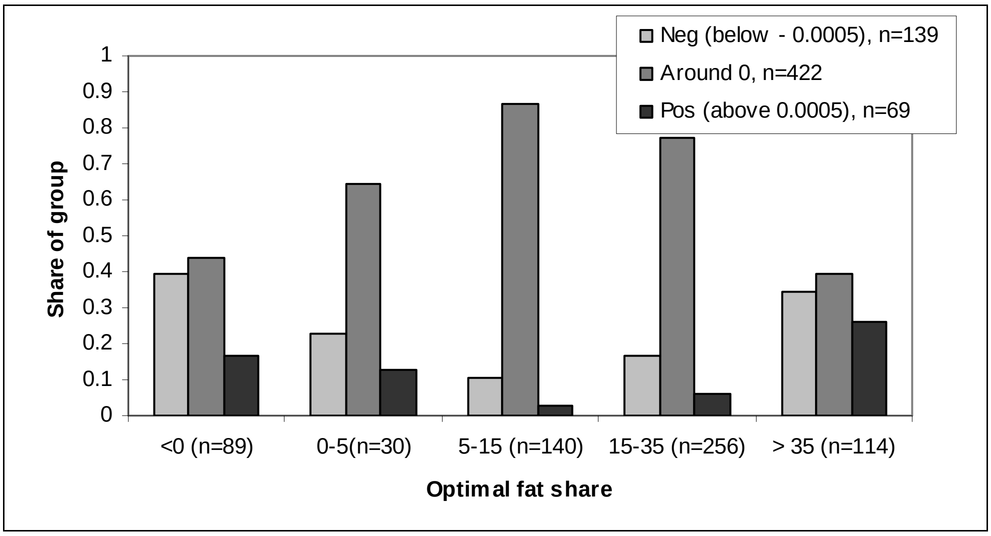
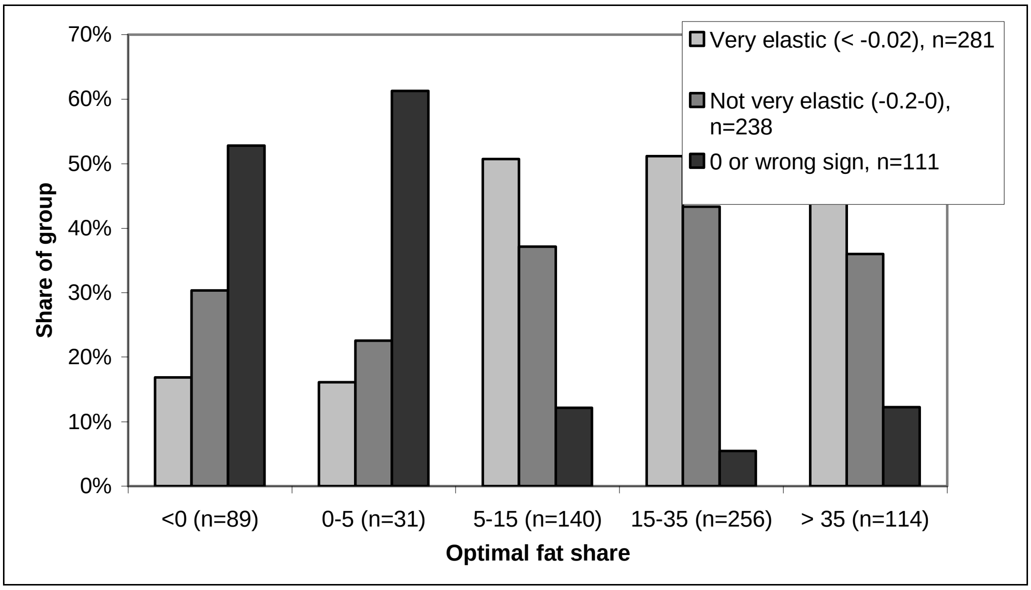


Figure 18 shows the price elasticity separated by optimal fat share (columns in each group sum to one). Most households have a negative own price elasticity for fat (17 per cent have an own price elasticity of 0 or with wrong sign). As much as 45 per cent are rather price elastic with an own price elasticity below -0.2. This figure clearly shows that fat-haters (optimal fat share below 0) and low fat consumers (optimal fat share between 0 and 5) are not very price elastic, while the fat-lovers (optimal fat share at 35 or above) and the moderate to high fat consumers (optimal fat share at 5-35 grams per litre) are rather price elastic. That the fat-haters are price inelastic comes naturally from these households being on the edge and the closest they are to having their preferences fulfilled are by consuming skimmed milk. The prices of the other types of milk would have to change radically to make these types of milk attractive to the fat-haters. More interestingly is it that the fat-lovers, who are also on the edge, but in the other end of the possible consumption set, are rather influenced by prices.

Figure 18 Optimal fat share and mean own price elasticity in 1997



Conclusion and discussion

The market for milk is suitable for economic analysis since almost all Danish households purchase milk and the characteristics inherent in milk are well defined. During our data period there has been a significant decrease in the consumption of fat from milk without any particular decrease in the total consumption of milk. This decrease has been due to both changing preferences for fat and the entrance of a new low-fat variety of milk. In this paper, the demand for fat in milk has been analysed in a structural characteristics model for milk. Estimating a structural model makes it possible to separate preference for milk from the influence of prices, trends and information.

Over time consumers seem to prefer milk with less fat. This change seems to be due to both a general trend and for some consumers also the influence of information. Interestingly, there are no large differences between weight groups and preferences for milk. It even seems like obese and overweight have preferences for milk with a lower fat content than normal weight individuals. The majority of the fat-lovers (optimal fat share above 35) have a large negative trend for fat. This indicates that households that prefer milk with a high fat content decrease their consumption of fat more than other types of households. Most households that prefer milk with a high fat content are moderate milk consumers (i.e. prefer less than 1 litre a week). It is therefore important to take the amount of milk consumed into account when predicting the changes in total amount of fat consumed, not only the share of fat.

In order to plan, design and implement political interventions with the aim of changing consumers' preferences for fat it is of major importance to know how to reach the target groups. Most households do not react to information, but among those who do, there is an over-representation of fat-lovers and the fat-haters. Information might therefore be one way to reach households that prefer milk with a high fat content. However, using information to change consumption might also influence the fat-haters. It is therefore important to consider what happens if the fat-haters get lower preferences for fat. Price policy might be a more effective way to reach high fat consumers since most households have a negative own price elasticity for fat. Households that prefer milk with a fat content lower than 5 grams per litre are mostly price inelastic so the price instrument will not influence the fat-haters to the same extent as will information. The price instrument will reach a broader group of households since also moderate fat consumers are rather price sensitive.

References:

Amemiya T. (1984). Tobit models: A survey. Journal of Econometrics, 24 (1-2), 3-61.

Bartik T. (1987). The estimation of demand parameters in hedonic price models. Journal of Political Economy, 95 (1), 81-88.

Blow, L., M. Browning and I. Crawford (2005). Revealed preference analysis of characteristics models. CAM working paper no 4, CAM, University of Copenhagen.

Blundell R.W. and A. Duncan (1998). Kernel regression in empirical microeconomics. Journal of Human Resources, 33 (1), 62-87.

Brown J.N. and H.S. Rosen (1982). On the estimation of structural hedonic price model. Econometrica, 50 (3), 765-768.

Browning M. (1999). Modelling commodity demands and labour supply with m-demands. Discussion Papers 99-08, Department of Economics, University of Copenhagen, Denmark.

Deaton A. and J. Muellbauer (1980). Economics and consumer behaviour. Cambridge University Press, Cambridge, UK.

Diamond D.B. and B.A. Smith (1985), Simultaneity in the market for housing characteristics. Journal of Urban Economics, 17: 280-292.

Ekeland I., J. J. Heckman and L. Nesheim (2004). Identification and Estimation of hedonic models. Journal of Political Economy, 112 (1), 60-109.

Epple D. (1987). Hedonic prices and implicit markets: Estimating demand and supply functions for differentiated products. Journal of Political Economy, 95 (1), 59-80.

Gorman, W. M. (1980). A Possible Procedure for Analysing Quality Differentials in the Egg Market. Review of Economic Studies, 47 (5), 843-856.

Kahn S. and K. Lang (1988). Efficient Estimation of Structural Hedonic Systems. International Economic Review, 29 (1), 157-166.

Ladd G.W. and M. Zober (1977). Model of consumer reaction to product characteristics. The Journal of Consumer Research, 4 (2), 89-101.

Ladd G.W. and V. Suvannunt (1976). A model of consumer reaction to produced characteristics. American Journal of Agricultural Economics, 58: 504-510.

Lancaster K. (1966). A new approach to consumer theory. Journal of Political Economy, 4 (2), 132-157.

McGuirk A., P. Driscoll, J. Alwang and L. Huang (1995). System misspecification testing and structural change in the demand for meat. Journal of Agricultural and Resource Economics, 20 (1), 1-21.

Muellbauer J. (1974). Household production theory, quality and the hedonic technique. American Economic Review, 64 (6), 977-994.

Piggot N.E. and T. Marsh (2004). Does food safety information impact U.S. food demand? American Journal of Agricultural Economics, 86 (1), 154-174.

Rickertsen K., J.A. Chalfant and M. Steen (1995). The Effects of Advertising on the Demand for Vegetables. European Review of Agricultural Economics, 22 (4), 481-494.

Rosen S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. Journal of Political Economy, 82 (1), 34-55.

Schmidt T.M. and H.M. Kaiser (2004). Decomposing the variation in generic advertising response over time. American Journal of Agricultural Economic, 86 (1), 139-153.

Smed S. (2005). Demand structure and willingness to pay for organic dairy products. Cahiers Options Méditerraneées, 64: 33-44.

Smed S. and J.D. Jensen (2004). Demand for low fat dairy product – demand for healthiness or taste? In: Russel C.S. and S. Krarup (Eds.), Environment, Information and Consumer Behaviour. AKF Forlaget, Copenhagen.

Smed, S. (2008). Empirical studies on "Health, Information and Consumer Behaviour". PhD thesis, University of Copenhagen.

Smith M.E., E.O. van Ravenswaay and S.R. Thompson (1988). Sales loss determination in food contamination incidents: An application to milk bans in Hawaii. American Journal of Agricultural Economics, 70: 513-520.

Statistics Denmark (2008). http://www.statistikbanken.dk/statbank5a/default.asp?w=1024

Tobin J. (1958). Estimation of relationships with limited dependent variables. Econometrica, 26 (1), 24-36.

Verbeke W. and R.W. Ward (2001). A fresh meat almost ideal demand system incorporating negative TV press and advertising impact. Agricultural Economics, 25 (2-3), 359-374.