Estimating the sales potential of a new heating system

An 'inverted' Lancaster approach

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The sales potential of a new consumer durable, district heating, is assessed in an established market. Given that very little information is available, Lancaster's model is 'inverted' to obtain an initial estimate of the future market share for the new product. This share is considered to depend on the cost of the new product versus the cost of the available ones, the comfort appeal of the new product compared to existing ones, and on the income distribution over the market population.

The model could be used by marketing managers as a tool for organizing their basic knowledge on particular markets when studying the introduction of a new durable.

1. Introduction

The model described in this article is part of a feasibility study of applying 'district heating' in existing family homes in Belgium. In particular, it aims at obtaining an initial estimate of the future market share of this new heating mode. District heating involves the distribution of centrally produced hot water through a double pipe network. The heat produced is used primarily for space heating, and a small fraction for heating water.

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In order to transfer the heat from the distribution network onto the hot water circuit of his house, the consumer needs a suitable installation, e.g., heat exchanger, calorimeter. The adaption from his house to district heating is comparable to the purchase of a durable product.

Given our interest in assessing the future demand for district heating, the existing marketing literature pertaining to new product models could provide some meaningful approaches.

(i) Since the publication of the Bass model in 1969, a variety of so-called 'diffusion models' have been developed which study the evolution in sales for a new durable product to 'innovative' and 'imitating' market segments, as a function of various marketing instruments (mainly price and advertising). [1]

The first drawback of these existing models for our analysis is the neglect of the aspect of competition from existing products. In the case of district heating the market is fairly established and sales will primarily be made at the detriment of existing heating systems.

Secondly, as was already recognized by Sahal in 1976, diffusion models shed very little light on the underlying reasons for adoption, i.e., on the properties and features of the new product (compared to existing ones).

A third problem concerning the use of a diffusion model for our purposes is the information required by such a model. Normally,

[1] An excellent overview of diffusion models is given in Lilien and Kotler (1983) and in Mahajan and Wind (1986).

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a diffusion model is estimated on the basis of sales figures from initial introduction periods. In the absence of such figures, data from 'analogous' product introductions from the past can be used for (ex ante) model parameterization.

Our problem with the use of 'analogous product info' [2] is not that no such comparable product has yet been introduced (in fact, existing gas central heating systems are very similar, from the consumer's point of view, to district heating), but that the circumstances in which this product was introduced have changed considerably (gas central heating competed with rather inferior alternatives such as stoves, whereas district heating now encounters a close substitute in the form of gas heating).

(ii) The class of perceptual models, which 'map' products in a multi-attribute space, and predict future market shares from the products' location vis-à-vis consumers' ideal points, do not suffer from these drawbacks. Models of this type are LINMAP (Shocker and Srinivasan (1974)), PERCEPTOR (Urban (1975)) and DEFENDER (Hauser and Shugan (1983)). Closely related to these models is the Lancaster characteristic model (Lancaster (1971)). This approach also characterizes goods as 'bundles' of attributes, through what is called the consumption technology, and then estimates the distribution of 'weights' attached to the various attributes by the population, in order to derive market shares for the different products.

In its normal use, the Lancaster model (and, for that matter, most of the perceptual models) requires the collection of information on the characteristics' content of various products, as well as preference data that are reliable and representative for the target population. The collection of such information is rather costly and time consuming (see, e.g., Wierenga (1984) and Hauser and Gaskin (1984)). Therefore, one should look for the most economical way of data gathering, leading us to the use of an 'inverted' Lancaster framework. As pointed out in the next sections, we rely on a priori information on the preference distribution to derive a perceived characteristic of the various products. This, in turn, will allow us to obtain an initial forecast of the success of the new heating mode.

The discussion is organized as follows. In section 2, the market for district heating is briefly characterized. Section 3 discusses the 'modified version' of the Lancaster model to be applied here. Section 4 elaborates on the use of the proposed approach for the district heating problem. Section 5 contains some concluding remarks.

2. The demand for district heating

The Belgian market of space heating systems in family homes is since long established. Major shifts occurred in the postwar period when central heating systems (most oil-based) penetrated fastly. Since 1973, energy markets became more dynamic, and in particular the home heating market has been changing. The analysis here is part of a feasibility study of applying district heating in existing cities.

Interest for district heating revived in Europe after 1973 (BMFT (1977), Beleidsadviesgroep Stadsverwarming (1977), and Muir (1973)). Inside the living space, district heating equals an oil or gas fired central heating system. However, for the market as a whole, large amounts of energy can be saved if the heat is generated in combined plants for electricity and low-temperature heat. Air pollution drops significantly (Muir (1973)). The heating infrastructure of the district will be unaffected by the scarcity of particular fuels because power plant steam generators can

[2] Which is also suggested by 'classical' microeconomic theory.

burn several fuels or can be rebuilt at relatively low cost. District heating is applied on a large scale in Sweden, Denmark and West Germany (Arbeitsgemeinschaft Fernwarme (1978)). In Belgium it is virtually unknown. Because of its apparent benefits with respect to energy conservation, supply security, and environmental protection, a project appraisal study of district heating in Belgium is undertaken (Verbruggen (1979)). In this paper, part of the demand study is reported.

In evaluating the demand for district heating capacity in a given district, several issues have to be kept in mind. Firstly, the extent of the market is limited because transportation of low-temperature heat is expensive. The maximum distance covered so far in Western Europe is about 20 miles. One can estimate the long-run heating capacity of a district within a fairly narrow range as the total demanded capacity of a well insulated and overall heated building stock. Secondly, the 'diffusion' of district heating will take place at the expense of other heating modes. Stoves and furnaces are, furthermore, durable goods, technically lasting for about 15 years (Dole (1975)). In other words, if no important shift in tastes or economic conditions occurs, only about 6.67% of the market population is free to choose a heating technique in any year. If, however, the fuel or exploitation costs of a particular technique change significantly, a consumer may profit by an immediate replacement of (or by) this technique. Ultimately, the penetration of district heating will result mainly from the interaction of three factors: (i) the construction of the hot water distribution network, representing the share of the district attained by the new system; (ii) the demand for replacement and additional capacity in the attained area of the district; and (iii) the share in the sales realised by district heating. This share depends on the cost and other characteristics of all available modes, as well as on the income level and preferences of consumers. The model presented here aims at estimating the sales share of district heating during one period. In this sense, it is a static model. The dynamics of introducing district heating can be analyzed by looking at a series of such static models.

The application discussed is deterministic, a one-year privately compiled series of the sales of heating systems in Belgium is used. As indicated earlier, the model developed here relies primarily on Lancaster's new approach to consumer demand (Lancaster (1971)) and on some extensions and commentaries made by Rosen (1974) and Ratchford (1975). Lancaster's procedure is 'inverted' in order to be useful here.

3. A 'modified' version of Lancaster's model

One of the major contributions of the new demand theory is that it can deal with 'new goods' in a natural way (Taylor (1975, p. 76)). A complete description of the theory may be found in Lancaster (1971). It is assumed that the reader is familiar with the theory, and the discussion will be limited to issues relevant for the application in this paper. To make the Lancaster framework suitable to model the penetration of district heating in Belgium, a few remarks are put forward.

First of all, the Lancaster model was originally intended for frequently purchased products. If the model is used for durables, Rosen (1974, p. 38) has pointed out that the linearity assumption of the consumption technology no longer applied (two six-foot cars are not equivalent to one twelve feet in length) and also the additivity property makes no sense (a twelve-foot car for half a year and a six-foot car for the other half is not the same as a nine feet all year round). In spite of these fundamental changes the structure of Lancaster's model remains useful as proven by Rosen's extensions of the theory. Because of the nonlinearity of the consumption technology the price of the product has to be incorporated as a separate characteristic. The efficiency frontier in the characteristics space no longer represents characteristics per money unit, but absolute quantities. Although Lancaster mentions the integration of the price as a characteristic he did not take in the importance of it (Lancaster (1971, p. 170)). If the additivity assumption does not hold it is impossible to draw edges and facets on the efficiency frontier, which consists only of vertex points. For his theoretical propositions, Rosen (1974) assumes therefore that there is a continuum of available durable goods such that the efficiency frontier is a continuous surface. It may be rather complicated to handle such sets when starting from the goods space in a particular application.

In this article, the vertex points of the efficiency frontier are derived by applying a linear transformation from the goods space with a consumption technology matrix containing the price of the products. The resulting vertices are connected to one another with edges and facets. Lancaster assumed that a consumer, whose equilibrium is located on an edge or on a facet, would buy the products projected in the adjacent vertices in a particular proportion. This proportion depends on the exact position of the consumer's equilibrium on the edge or facet. In the case of durable goods, the consumer can only buy one type or brand. A consumer in equilibrium on an edge or a facet is assumed to choose one of the adjacent vertices as the most appropriate. His choice will depend on the exact location of the equilibrium point on the edge or facet. In fig. 1 the point made is illustrated.

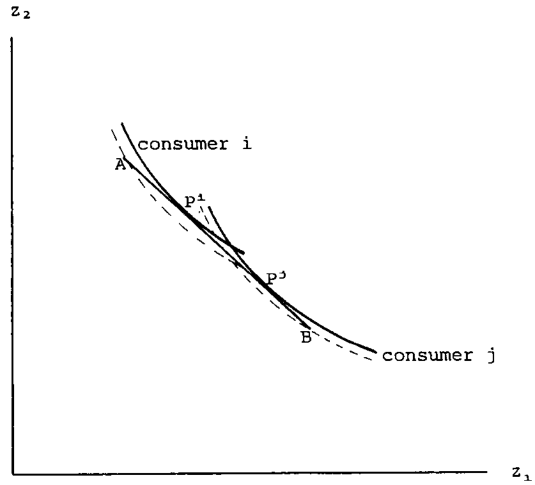

Fig. 1. Consumer choice in the characteristics space.

In this figure the axes represent the amount of characteristic 1 (z_1) and 2 (z_2) present in each product. Consumer i would like to purchase some device in between the offered products A and B, and so would consumer j. Since only A and B are offered, both consumers have to decide which one will be the best deal. In function of the preference structure and in function of the position of the virtual tangency point P the outcome will be either A or B. The division of the market share in equilibrium on edges or facets, over the adjacent vertices is carried out with the help of the transformed weight distribution (Lancaster (1971, pp. 79–81)).

A second difficulty in applying the Lancaster model to our problem relates to its 'direction' of use. Lancaster suggests using his model as follows: Firstly, the goods space is transformed into the characteristics space by means of the known consumption technology, whereafter the characteristics' weights distribution parameters are estimated through confrontation with observed market data. Knowledge of the 'consumption technology' is quite straightforward if only physical product characteristics enter the picture. If, however, one broadens the model to incorporate 'perceived' characteristics (see, e.g., Ratchford (1975)), one may encounter measurement problems in quantifying the amount of characteristics assigned by a population to a particular good, or at least the measurement effort will become quite extensive. Illustrations are provided in Ryans (1974), Wierenga (1984) and Hauser and Gaskin (1983). If it is possible to make plausible assumptions re-

Lancaster

1. modes → characteristics → efficiency frontier

   └── objectively known transformation

2. observed market equilibria⟩ ⟨computed market equilibria

   ↓

   estimation of the parameter(s) of the weights distribution

This paper

1. modes → only objectively measurable characteristics weights distribution

2. observed market equilibria⟩ ⟨computed market equilibria

   ↓

   estimation of the not directly measurable characteristics

3. measured characteristics → efficiency frontier estimated

Fig. 2. Schematic of Lancaster's procedure and of the procedure used in this paper.

garding the weight distribution a priori, it might be more 'efficient' to use Lancaster's model in an inverse way, as depicted in fig. 2.

Such an inverse procedure takes the weight distribution parameters as given, together with objectively measurable product characteristics. Levels of 'perceived' product attributes are then assessed to maximize the fit between estimated and observed market shares. Once the complete consumption technology is derived for existing modes, the efficiency frontier in the characteristic space can be determined.

In a recent contribution, Shugan (1987) estimates brand positioning maps using a procedure that shows resemblance to the inverted Lancaster approach applied in this article. In Shugan's analysis, a brand is characterized by its price, as well as by its position vis-à-vis two non-monetary product attributes. Taking the distribution of the preference parameter for these attributes, over consumers, as given, Shugan derives brand positions on the basis of time series information on price and market share for the different brands.

Shugan's approach differs from our analysis in several respects. Shugan analyses non-durable products that are positioned on the basis of two non-monetary characteristics in a per dollar map. In our study of (durable) heating systems, cost is included as a separate product attribute, and only one additional product characteristic is considered and estimated.

The utility functions in Shugan's analysis specify the consumers' relative preference for both non-monetary attributes. (Ultimately, a consumer buys the brand that offers him the highest per dollar utility.) In the absence of cross-sectional preference information, Shugan then assumes that preferences are uniformly distributed across consumers. In the present article, a consumer's utility function reflects his trade off between 'price' and other product characteristics. As such, it is quite logical that our distribution of the preference parameter will be related to the distribution of income across consumers, on which information is available (see section 4.2).

Generally speaking, the choice between the 'normal Lancaster' and the 'inverse order' procedure will depend on the kind of information available, as well as on cost-benefit considerations. In the case of district heating, it turns out that a priori knowledge of the 'consumption technology' is much more limited than insight into the distribution of preferences. In the spirit of 'evolutionary model building' (Lilien and Kotler (1983)), we suggest deriving a 'rough' market share estimate for district heating using the inverse procedure. Depending on the outcome of this effort, one will decide whether or not it is justifiable to engage in extensive data collection on preferences and perceptions of consumers to obtain a more refined parameter estimate.

4. An application of the model: The Belgian market of heating modes

4.1. Modes and characteristics

For the analysis of a particular market only the characteristics directly relevant to the choices of the consumers have to be considered (Lancaster (1971, pp. 140–156), and Ryans (1974)). Moreover, the model only has operational value if the products can be specified by a limited number of characteristics (Lancaster (1971, p. 140)) that can be quantified. In this application two characteristics of the heating modes are considered, i.e., economy (= negative cost or negative price) and comfort (Beleidsadviesgroep Stadsverwarming (1977)). Since a heating mode is an indivisible durable good, the general format of the consumer choice problem is

$$\max U(z_1, z_2 \mid \alpha)$$

subject to

$$\mathrm{E}(z_1, z_2) = 0 \text{ (efficiency frontier)},$$

where z_1 and z_2 are the characteristics' levels (z_1 = comfort, z_2 = economy), α = the preference parameter, and $U(z_1, z_2 \mid \alpha)$ specifies the utility a consumer attaches to the combination z_1 and z_2, given his α-level. For the market as a whole, the problem can be stated as

$$\max U(z_1, z_2, \alpha)$$

subject to

$$\mathrm{E}(z_1, z_2) = 0,$$

$$\int_0^1 \Psi(\alpha)\, \mathrm{d}(\alpha) = 1, \tag{1}$$

where utility is now specified as a function of the preference parameter, and $\Psi(\alpha)$ represents the distribution of this parameter over the population.

The economy of a heating mode is computed on the basis of its expected average yearly heating costs. Naturally, difficulties arise if the perception of the true costs by the consumers is biased (Auld (1972) and Monroe (1973)). With respect to the fuel costs most consumers lack knowledge on the average energy conversion efficiencies of the devices, the heat content of the fuels, and on the prices of the various fuels. Electric space heating is extraordinarily expensive in Belgium because of a high Kilowatt-hour (kwh) price, and will only be installed in houses characterized by an excellent thermal integrity. In this study, insulation is not considered, although this can easily be done if need be. The insertion of heat insulation qualities into the analysis will augment the number of modes considered. A heating mode implying a higher degree of thermal integrity will trade off higher investment expenditures versus lower fuel costs. Another extension one can make is the distinction between heating systems installed in buildings under construction and new systems installed in existing buildings.

It is obvious that the capital costs of systems fueled with secondary energy forms (electricity, district heating) must be adjusted to enable the elimination of chimneys. This refinement is not included either. In this paper central heating, respectively stoves fired with gas or with oil are treated as one mode because the respective systems are very similar as to yearly heating costs and other characteristics, and because the accessibility to the systems is complementary. Natural gas is not supplied to inhabitants in rural areas; on the other hand, the use of oil as heating fuel in urban areas is impeded by legal prescriptions as to the storage of this fuel.

The modes studied in this example, their yearly costs and their market share in the sales of new systems in 1975 are shown in table 1. The number of modes considered and their actual costs for the consumers can be measured more accurately by studying a real life district heating project. It will be necessary to resort to inquiries in the district in order to derive reliable estimates.

The other characteristic of the heating modes is an amalgamation of various features

Table 1
Heating modes: Annual cost and market share for Belgium, 1975

Mode	Annual heat consumption (MWh)	Annual cost capital, fuel, maintenance (BF)	Share in the sales (%)
Stove, coal	14	15278	12.501
Stove, gas/oil	14	16030	41.856
Electricity accumulation	14	22572	3.693
Central heating, gas/oil	28	31074	34.328
Electricity resistance eparate appliances	14	37567	5.378
Electricity floor integral heating	28	74147	2.144

and is called 'comfort'. It is difficult to enumerate all elements affecting the 'comfort level' of a particular mode, and even more troublesome to obtain 'metric' measurements that are representative of the population. Because of the lack of data with respect to the comfort characteristic, Lancaster's model is applied in the inverse way as discussed in section 3.

4.2. Assessing the weights distribution

Following Lancaster's advice (Lancaster (1971, pp. 72–73)), the indifference structure of the individual consumer is represented by a Cobb–Douglas function

$$U(z_1, z_2 \mid \alpha) = z_1^{\alpha} z_2^{1-\alpha} = \text{constant},\quad 0 \le \alpha \le 1, \tag{2}$$

with

z_1 = comfort characteristic,
z_2 = economy characteristic,
α = preference parameter.

The Cobb–Douglas preference function has unitary income elasticity and unit elasticity of substitution. These properties imply such highly special results for demand theory in the traditional setting that the form is inappropriate for traditional representative consumer analysis. In the new consumption theory there is no unique indifference structure but a spectrum of structures containing as many elements as there are values of the preference parameter considered. Every particular consumer or group of consumers is assigned a particular α-value in function of their subjective value judgements and in function of their income.

The weights distribution, i.e., the distribution over the preference parameter, can be written as $\Psi(\alpha) = \Phi(\alpha) \cdot f(\alpha)$. In this expression, $\Phi(\alpha)$ is a distribution derived from the income distribution, and $f(\alpha)$ is a prior distribution over the preference parameter, representing the value judgements independent of the income.

It is assumed that the income is lognormally distributed over the population. Various sources point out that this is a fair approximation (Aitchison and Brown (1973, pp. 107–120) and Koninkrijk België (1976)). Formally, the lognormal income distribution is given by

$$\Lambda(y; \mu, \sigma^2) = \frac{1}{y\sigma\sqrt{2\pi}} \exp\left(-\frac{1}{2\sigma^2} (\log y - \mu) \right)^2, \tag{3}$$

where y = income, and μ and σ are the parameters of the distribution.

Estimation of the parameters of this density function is based on published financial statistics (Koninkrijk België (1976)), communicating mean and median income per tax-payer for all administrative entities in Belgium. The estimated parameters are (based on total Belgian values)

$\sigma = 0.747757$,
$\mu = 5.099866$.

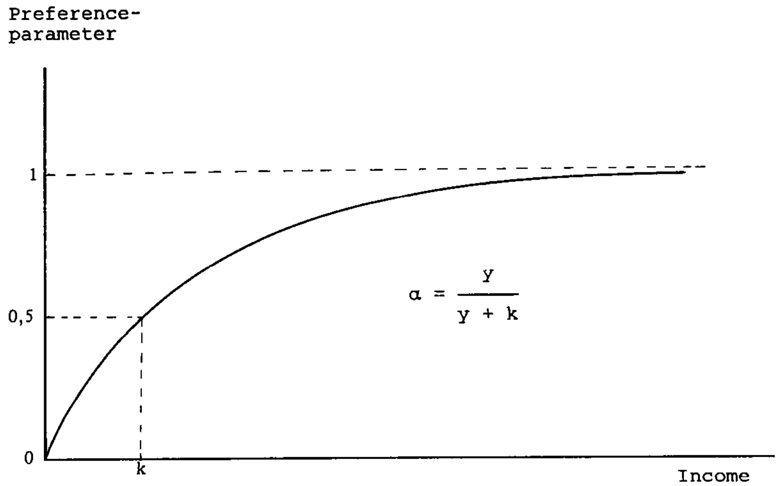

Fig. 3. Relationship between individual income and preference parameter.

The relationship between the preference parameter and the income is expressed by a function

$$\alpha = \frac{y}{y+k},$$

shown in fig. 3. This function indicates that if income is small, attention will be concentrated on the economy of a mode, and if income is high, comfort will be emphasized. The parameter k equals the income level for which consumers put equal emphasis on both characteristics.

If the characteristics of the goods were objectively known, one could estimate the income level k on the basis of the observed market behavior of the population. In this article Lancaster's model is inverted and the comfort characteristic will be estimated from the observations, while a value equal to the average income is assigned to k.

The distribution $\Phi(\alpha)$ then results from the transformation of eq. (3) as a function of α, which leads to the following expression:

$$\Phi(\alpha) = \frac{1}{\alpha(1-\alpha)\sigma\sqrt{2\pi}} \times \exp\left(-\frac{1}{2\sigma^2}\left(\log\frac{k\alpha}{1-\alpha} - \mu\right)^2\right). \quad (4)$$

It is further assumed that $f(\alpha)$ is a uniform density function over the interval (0, 1). This non-informative function implies that consumer behavior is 'captured' in $\Phi(\alpha)$, or that preference is largely income-driven. Given the nature of the product considered (high involvement durable), this assumption seems quite plausible. It follows that

$$\Psi(\alpha) = \Phi(\alpha).$$

4.3. Equilibrium conditions

The equilibrium conditions for the individual consumer are developed in detail by

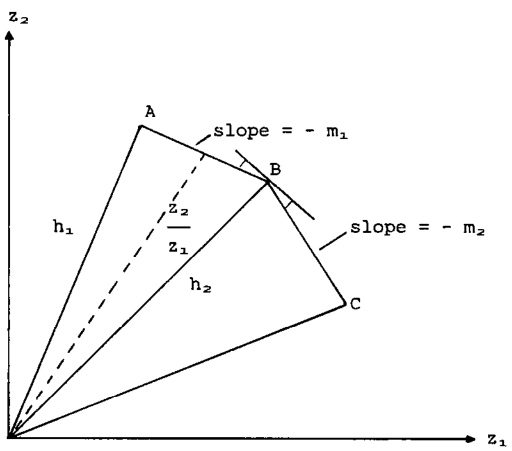

Fig. 4. Efficiency frontier in the characteristics space.

Lancaster (1971, pp. 75–82). A consumer is in equilibrium on an edge of the efficiency frontier ABC if his subjective rate of characteristics substitution

$$\frac{\mathrm{d}z_2}{\mathrm{d}z_1}$$

is equal to the objective rate $-m_i$, $i = 1, 2$, as expressed by the efficiency frontier (fig. 4). A consumer will choose a point on the edge AB with slope $-m_1$ when his preference parameter obeys

$$\frac{m_1}{m_1 + h_1} \le \alpha \le \frac{m_1}{m_1 + h_2}.$$

To calculate the share of the market population that will select a point on the line segment AB, one evaluates

$$\int_{m_1/(m_1+h_1)}^{m_1/(m_1+h_2)} \Psi(\alpha)\,\mathrm{d}\alpha.$$

Analogously, the share of the population selecting point B as the optimal characteristics combination is given by

$$\int_{m_1/(m_1+h_2)}^{m_2/(m_2+h_2)} \Psi(\alpha)\,\mathrm{d}\alpha.$$

The market share coinciding with an edge has to be divided over the adjacent vertices. In order to perform this division, the density function $\Psi(\alpha)$ is transformed into a density $W(\lambda)$, where λ is the parameter of the convex linear combination of the vertices ($0 \le \lambda \le 1$) (see fig. 5). The density function $W(\lambda)$ over the edge AB in function of λ is derived as a transformation of $\Psi(\alpha)$. The part of the market population finding the optimal characteristics combination on edge AB, assigned to vertex B is given by

$$\int_0^1 \lambda W(\lambda)\,\mathrm{d}\lambda,$$

and the part assigned to vertex A is given by

$$\int_0^1 (1-\lambda) W(\lambda)\,\mathrm{d}\lambda.$$

If the analysis would deal with non-durable,

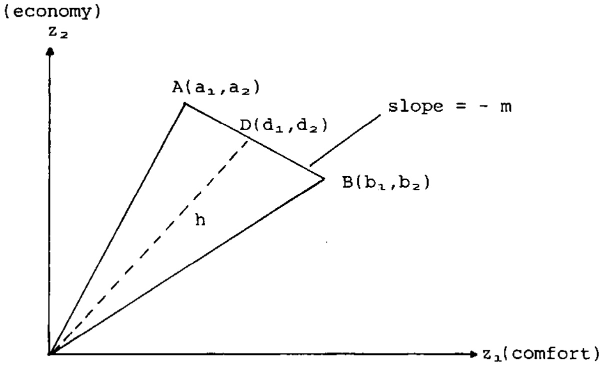

Fig. 5. Division of the market share of an edge.

frequently purchased products, a consumer choosing point D would spend a fraction λ of his expenditures on the product group, on product B, and a fraction $(1-\lambda)$ on product A. In other words the additivity assumption holds. In this application with durable goods, an individual consumer preferring point D is viewed as hesitating between A and B. Of all consumers with the optimal characteristics combination on the edge AB, a number

$$\int_0^1 \lambda W(\lambda)\,\mathrm{d}\lambda$$

will decide to purchase B, and the others

$$\int_0^1 (1-\lambda) W(\lambda)\,\mathrm{d}\lambda$$

will look for product A.

4.4. Estimation of the comfort characteristic

Given our estimate for the weight distribution, as well as information on the 'economy' characteristic of various modes, it is possible to derive 'comfort' values on the basis of observed market behavior of the consumers, i.e., the market share captured by the existing heating modes in 1975.

Because of the complex analytical form of the weights density function and the transformation thereof, and because of the iterative nature of the estimation procedure, a computer program of Lancaster's model is written. It enables one to estimate any two-di-

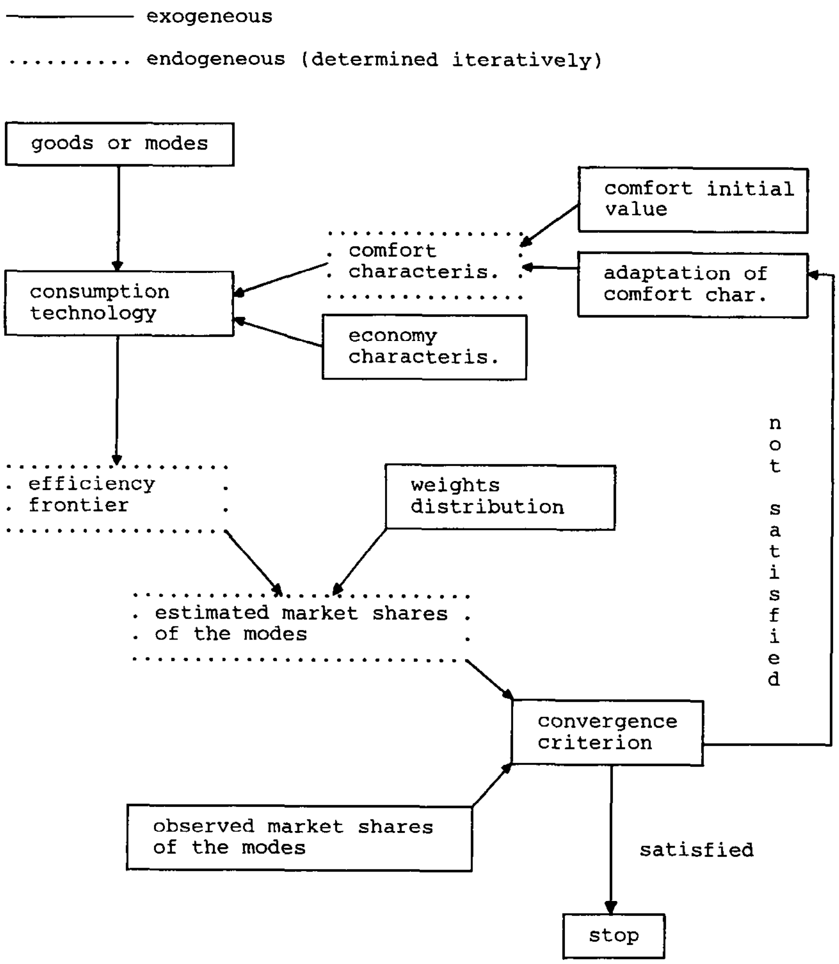

Fig. 6. Schematic flowchart of the program.

mensional characteristics frontier from an arbitrary n-dimensional goods space and the accompanying consumption technology matrix. The method is iterative, the particular characteristic vector is changed by small amounts up to the point where observed and

Table 2
Characteristics, estimated and observed market shares of the heating modes (1975)

Heating mode	Characteristics		Market shares	
	Economy (1)	Comfort (2)	Observed (3)	Estimated (4)
Stove, coal	−15278	126.01	12.501	12.590
Stove, gas/oil	−16030	129.56	41.856	41.954
Electricity accumulation	−22572	142.97	3.693	3.790
Central heating gas/oil	−31074	163.04	34.328	34.317
Electricity resistance separate appliances	−37567	170.40	5.378	5.284
Electricity floor integrated heating	−74147	212.00	2.144	2.065

estimated market shares converge. A schematic flowchart of the program is shown in fig. 6.

In table 2 the results of the iterative procedure are summarized. Columns (1) and (3) of this table are provided exogeneously. The comfort index (column (2)) is the desired result, together with the economy characteristic it determines the efficiency frontier in the characteristic space. Moreover, the levels of the comfort characteristic turn out to be consistent with expectations for the various heating modes. Comparison of the estimated market share (column (4) in table 3) with the observed ones, allows one to conclude that the derived efficiency frontier is the one confronted by the market population. Therefore, the resulting comfort index serve as 'objective measure' of the non-monetary characteristics assigned to the heating modes by the households.

4.5. *Introduction of a new heating mode: District heating*

On the basis of the market description derived in the previous section and summarized in table 2, it is possible to estimate the market share of a new heating mode offered to consumers. One only has to decide upon the characteristics of the new mode and to run the Lancaster model once, after incorporation of the new vertex in the efficiency frontier. The estimated market shares of all available modes result immediately.

Given uncertainty about the exact values of the characteristics of the new mode, sensitivity analysis is recommended. Once the height of the comfort is fixed, the model can generate a demand curve for the product, i.e., a relationship between market share and price, all other things remaining constant. Three levels of comfort of district heating are considered: 180, 165 and 150. To grasp the significance of these numbers one should refer to table 2. A value between 165 and 180 is very plausible, implying district heating to be from slightly to substantially more comfortable than gas/oil fired central heating systems. The value of 150 is unrealistically low, but may be the situation faced by the new mode if it is unknown by the population and if no successful information campaign is carried out.

Table 3
Market shares of the heating modes after introduction of district heating (comfort index 180)

Price of district heating BF/ MWh	% Market share of						
	Stove coal oil	Stove gas/ mul.	Electr. accu	Central gas/oil	Electr. separate	District heating	Electr. floor
1200	12.4	42.1	3.9	34.4	0.4	5.7	1.2
1160	12.4	42.1	3.9	32.3	–	8.2	1.1
1120	12.4	42.1	3.9	29.6	–	11.0	1.0
1075	12.4	42.1	3.9	25.8	–	14.8	0.9
1030	12.4	42.1	3.9	20.8	–	19.9	0.9
990	12.4	42.1	3.9	14.1	–	26.7	0.8
950	12.4	42.1	3.9	5.0	–	35.8	0.8
900	12.4	42.1	1.0	–	–	43.8	0.7
860	12.4	38.9	–	–	–	48.0	0.7
820	12.4	34.8	–	–	–	52.1	0.7
770	12.4	30.5	–	–	–	56.4	0.6
730	12.4	26.0	–	–	–	61.0	0.6
690	12.4	21.3	–	–	–	65.7	0.6
645	12.4	16.4	–	–	–	70.6	0.5
600	12.4	11.5	–	–	–	75.6	0.5

For the three levels of comfort, a demand relationship is estimated by simulating the market shares of the various modes for a set of heat prices of district heating. The economy characteristic, or in other words the yearly total heating cost of district heating is computed by multiplying the heat price with the gross annual consumption of 29.38 MWh, and adding the annuitized installation costs. Results for the district heating comfort level 180 are summarized in table 3.

Because of its particular comfort attributes, district heating is able to drive out two electric heating modes at extremely high MWh prices (1200 BF/MWh and higher). One mode of electric heating called 'electric floor' will keep a small fraction of the market because it

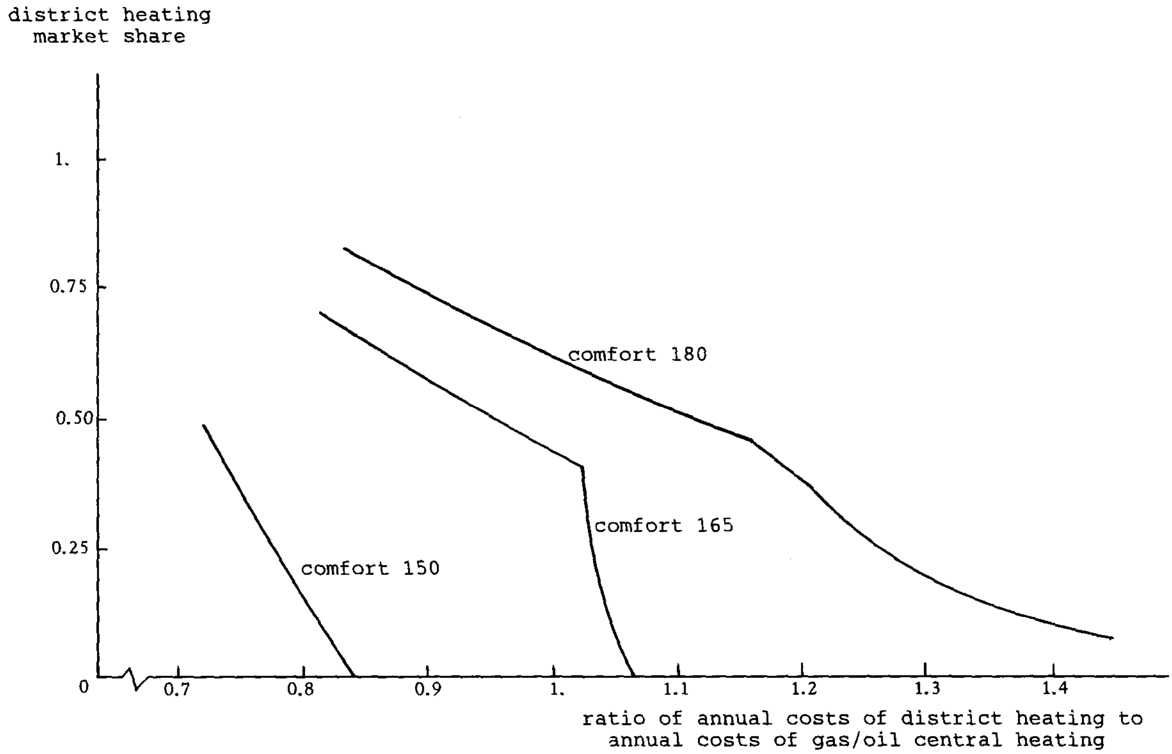

Fig. 7. Market share of district heating as a function of its costs and the comfort-value assigned.

is superior in comfort to all other available modes. The new mode expands primarily to the other side of the spectrum when its total yearly cost decreases. The crumbling of the competing modes occurs one after the other. The successive process is described by Lancaster as 'circles of substitution' (Lancaster (1971, pp. 64–67)). For a small decrease in price only 'close' goods are affected, but as the price continues to fall, goods further and further away will become ousted from the market.

After the take-over of the 'electric resistance separate' heating share, the new mode competes in first place with gas/oil fired central heating systems. At a MWh price of about 900 to 950 BF, gas/oil central heating is dominated. From there on district heating enters into competition with the stoves. Electricity accumulation is not a match for the new mode. The market share of the gas/oil fueled stoves decreases smoothly, as the cost of the challenging system decreases further.

The demand curves for district heating for three comfort levels are shown in fig. 7. It is obvious from table 3 that similar curves are derived simultaneously for all available modes. The format of representation is not conform to the usual quantity-abscis and price-ordinate pictures. The horizontal axis represents the ratio of the average yearly cost of district heating to the average yearly cost of a gas/oil fired central heating system. On the vertical axis the estimated market share of the new mode in the sales of heating systems is represented. The kinks in the curves shown point out where the circles of substitution are widened. Because the various modes possess the characteristics in different proportions, the process of substitution of the existing systems by the new mode occurs unequally, resulting in different slopes of the demand curve segments. The price elasticities of demand also vary along the curve and in a kink node there are two elasticities. The shape of the demand curves for comfort indices inbetween the represented ones will be very similar.

5. Conclusion

With very limited statistical data, using a set of plausible assumptions and a consistent theoretical framework borrowed from Lancaster (1971), a procedure is set up that provides basic information for the introduction decision of a district heating company.

Demand curves for district heating are estimated, integrating as independent variables

- a monetary characteristic of all heating modes, i.e., total annual heating costs of the various modes;
- a non-monetary characteristic, summarizing all attributes of the modes with the exception of the monetary elements;
- a density function of the income of the households;
- available prior knowledge about the preferences of the population with respect to monetary and non-monetary characteristics.

With the estimated demand curves one can derive the share of district heating in the sales of heating systems during a particular period as a function of the price of district heating and its comfort appeal. This share is a crucial variable in the estimation of the penetration pattern of the new mode, in turn one of the key factors determining the economic feasibility of district heating (Verbruggen (1979)). The model is static and deterministic. It has to be seen as a 'preliminary' step in the process of evaluating the potential of the new heating mode.

From the results of using this preliminary model, decision makers may decide that the new product looks promising enough to warrant further investigation. Based on refined (and costly) information on how the existing modes as well as the new mode are judged by consumers in terms of comfort, one is able to check model assumptions more thoroughly (e.g., homogeneity in perceptions), and specify a more precise location for the new product in the characteristics space from which market shares can be predicted.

Immediate model refinements could be the use of more market share observations in order to improve the comfort characteristic estimates, and the use of survey information from the district to 'estimate' the level of income where consumers are indifferent between economy and comfort.

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