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ANALYSIS OF THE USE OF RETAIL FLOORSPACE

by Roy Thurik and Johan Koerts

The relation between sales and floorspace per establishment is of importance for retail planning, shop design, efficiency diagnosis, etc. This relation varies with differences in marketing mix (assortment composition, service level) and differences in attractiveness of the location. The present study investigates the relation between total available floorspace, the value of total annual sales and the partitioning of total available floorspace for small retail establishments into selling area and remaining space. This partitioning is supposed to be an indicator for the level of own production and/or the share of self-service sales. Differences in attractiveness are described using occupancy costs (including rent costs) per square metre. The basic model presented consists of three equations with selling area, remaining space, and value of total annual sales as endogenous and total available floorspace as exogenous variable. This basic model is refined by studying the influence of specific establishment properties such as occupancy costs per square metre, size of the shopping centre, size of the township, level of own production, etc. Ten samples of Dutch retail establishments are investigated.

Assumptions

The following four assumptions are maintained throughout this article.

Firstly, total available floorspace of a retail establishment can be partitioned into selling area and remaining space. Selling area is the space to which customers have access: space used for receiving and serving customers, displaying goods and restocking displays. This space includes room for cash desks, service counters, etc. Remaining space consists of space used for storage, handling goods (packing, pricing, etc.), own production, administration, staff rooms, etc. Customers have no access to these parts of a retail establishment.

Shopkeepers have a certain flexibility in choosing the partitioning of total available floorspace. This partitioning is assumed to be flexible before as well as after the instalment of the shop.

(1) $W_i \triangleq C_i + R_i$,

where W_i: total available floorspace of establishment i;

C_i: selling area;

R_i: remaining space;

$\triangleq$ means equality by definition.

Secondly, total available floorspace is exogenous. The shopkeeper's present "plant size" is the result of a long term decision made in the past. In this study we will not try to describe the economic behaviour and technical restrictions involved in this decision. This assumption is made because

—expanion of an existing shop is often impracticable and always expensive;

— it is felt that, as soon as a shopkeeper is inclined to alter his total floorspace considerably, he is also willing to reorientate his market strategy, i.e. to change the shop type of his establishment or to change the shop location.

Thirdly, the value of annual sales per establishment belonging to a certain shop type depends on the size of its selling area and of its remaining space:

$$(2)\quad Q_i = \beta(C_i - \gamma_1)^{\pi\varepsilon} (R_i - \gamma_2)^{(1-\pi)\varepsilon} \text{ with } \beta > 0,\ 0 \leq \gamma_1 < C_i,\ \ 0 \leq \gamma_2 < R_i,\ 0 < \pi < 1 \text{ and } \varepsilon > 0,$$

where Q_i: value of annual sales in establishment i.

A shop type in the food trade is defined as a group of establishments which has a certain homogeneity regarding assortment composition, extent of own production and type of organisation (chain, co-operative, independent). Equation (2) must be considered as a basic relationship between the value of annual sales and floorspace. The influence of the remaining heterogeneities (with respect to the characteristics of the establishments) within a shop type will be dealt with in section 4. However, these deterogeneities are disregarded for the time being to illustrate the role of the coefficients of (2). Specification (2) reminds us of a Cobb-Douglas production function with two inputs: $C - Y_1$ and $R - Y_2$; a unique output Q corresponds to each combination of these inputs.

Specification (2) is chosen because it is assumed that in retailing both selling area and remaining space contribute to establish the value of annual sales and that these inputs can be substituted for one another. This substitution represents different marketing or operational strategies within a shop type.

The definition of a shop type given above is flexible enough to permit such strategies. A low ratio R/W is associated with

— a high share of self-service sales and a low share of counter service sales;
— a low share of own production: if this production is performed in the remaining space as is usual in retailing;
— a strategy in which only few goods are kept in stock and many are displayed;
— a strategy in which most handling of goods and most actvities of employees are performed in the selling area.

Of course, a high ratio R/W is associated with the opposite strategies. A multiplicative specification is chosen because it is felt that the effect of a change of one input factor on the value of annual sales depends on the level of the other. The Cobb-Douglas-type specification is chosen, because

— the above mentioned mechanisms justify such a specification;
— the use of Y_1 and Y_2 renders the Cobb-Douglas specification more flexible and they may be given a physical interpretation as will be explained below.

The coefficients have the following interpretation:

— ß is a coefficient which can be used to denote efficiency;
— obviously, specification (2) is not homogeneous in C and R. However, it is homogeneous of degree 3, if $C - Y_1$ and $R - Y_2$ are regarded as input factors. A value of $3 = 1$ indicates constant returns to scale, and increasing or decreasing returns are indicated by values greater or less than unity;
— indicates the degree to which establishments of a certain shop type are selling area intensive. It will be called distribution coefficient of the partitioning of total floorspace;
— coefficients Y_1 and Y_2 are associated with certain threshold spaces: space which must be present in every establishment of a shop type; a minimum space whose size is equal for all establishments and where activities are performed indispensable for retailing products. Nooteboom (1982) uses threshold labour in his analysis of labour productivity. He provides a theoretical justification of the value of threshold labour using queuing theory. He analyses floorspace productivity along the same line of thought. We do not provide a theoretical

justification for a selling area threshold and a remaining space threshold in our model of the use of floorspace. However, the idea of a threshold is attractive. Meanwhile, Y_1 and Y_2 will be called threshold coefficients. They are also used to study scale effects. See section 3.

Assumption (2) is a mere summary of constraints of a technical (operational) nature. Economic behaviour (the shopkeeper's decision) will decide what use will be made of total floorspace.

Fourthly, a shopkeeper tries to maximise the value of annual sales by manipulating the partitioning of total available floorspace, i.e. his marketing or operational strategy. The first order condition $dQ/dC = 0$ gives after substitution of (1) into (2)

$$(3)\quad C_i = \gamma_1 + \pi(W_i - \gamma_1 - \gamma_2).$$

Also, equations (1) and (3) give

$$(4)\quad R_i = \gamma_2 + (1-\pi)(W_i - \gamma_1 - \gamma_2).$$

It is easy to show that the stationary point defined by (3) and (4) refers to maximum.

Equations (3) and (4) can be viewed as the linear shop design expansion path. An obvious competitive type of behaviour is that a shopkeeper tries to maximise annual net profit, i.e. total revenue from annual sales minus total annual acquisition costs (= wholesale or invoice costs) minus total annual costs.

We choose to assume the maximisation of the value of annual sales, because

— it is realistic. A shopkeeper will concentrate on sales or market share rather than on profit, if he considers his market power towards customers and suppliers or if he considers his prestige. Furthermore, there are circumstances in which the continuity of a shop depends on the increase of sales rather than on that of profit;

— it is simple. Sales is an entity easy to observe continually, whereas profit is a result given, so to speak, by the auditor once a year. Furthermore, the problem of maximisation of the value of annual net profit is probably too complicated for shopkeepers who usually fail to have staff facilities. It involves not only the analysis of the explanation of sales (see above), but also that of percentage margin and costs (see below);

— maximisation of the value of annual net profit will not necessarily alter our model considerably. A detailed explanation goes beyond the scope of this article. See Thurik and Koerts (1984).

Model

The reduced form of our model is obtained after substitution of equations (3) and (4) into (2)

$$(5)\quad Q_i = \beta\left(\frac{\pi}{1-\pi}\right)^{\pi\varepsilon} (W_i - \gamma_1 - \gamma_2)^{\varepsilon} (1-\pi)^{\varepsilon},$$

$$(3)\quad C_i = \gamma_1 + \pi (W_i - \gamma_1 - \gamma_2)$$

and

$$(4)\quad R_i = \gamma_2 + (1-\pi) (W_i - \gamma_1 - \gamma_2).$$

The endogenous variables are value of annual sales of establishment i, Q_i, the size of its selling area C_i and of its remaining R_i; the exogenous variable is total availabe floorspace W_i. The coefficients are β, Y_1, Y_2, π and ε.

The coefficients have the following restrictions: $\beta > 0$, $0 \leq \gamma_1 < C_i$, $0 \leq \gamma_2 < R_i$, $0 < \pi < 1$ and $\varepsilon > 0$.

The second order condition of a maximum is fulfilled, if these restrictions are met.

We shall now further discuss the role of the coefficients in the model consisting of equations (3), (4) and (5) and the hypotheses we want to test. From equation (5) it is seen that

$$(6)\quad \frac{d\log Q}{d\log W} = \varepsilon\, W/(W - \gamma_1 - \gamma_2) \triangleq E$$

or expressed in words: the elasticity of the value of annual sales with respect to total floorspace, E, is scale dependent if $Y_1 + Y_2 = 0$. Scale is associated here with total available floorspace. The meaning of Y_1 and Y_2 is explained in section 2 by their interpretation as threshold coefficients. The elasticity of the value of annual sales with respect to total available floorspace decreases with scale, if indeed $Y_1 + Y_2 > 0$. The coefficient ε can be regarded as the asymptotic elasticity of the value of annual sales with respect to total floorspace. Coefficient 3 has a more practical use, in that it determines the scale of an establishment above which diseconomies arise. Rearranging (6) we get

$$(7)\quad W = (\gamma_1 + \gamma_2)E/(E-\varepsilon).$$

We see that $d\log Q/d\log W \gtrless 1$ for all $W \lessgtr W^*$, where W^* denotes the scale of an establishment where $E = 1$.

We do not provide a theoretical value of ε against which we want to test our model. However, we shall assume that $\varepsilon \leq 1$. Nooteboom (1980) provides evidence in favour of $\varepsilon = 1$ for various shop types. The results of the empirical exercises of Tucker (1975) also imply $\varepsilon = 1$.

However, both authors use models which differ considerably from our model and in both studies unexplained variance after regression of floorspace on (a function of) total sales is considerable. Diseconomies may arise, because with increasing scale of the establishment shopkeepers are likely to increase

i) depth of the assortment composition (= number of different items per product group). This will result in diseconomies with respect to storage and display space and customers are likely to need more space;

ii) height of the assortment composition (= quality level of products). This will result in diseconomies with respect to storage and display and customers are likely to need more space;

iii) width of the assortment composition (= number of different product groups). The width of the assortment composition within a shop type is not likely to differ largely. The assortment composition can be widened with non-foods (tobacco products, magazines, household products, etc.). A certain minimum amount of space must be made available, to make shoppers aware that items of the product group are present in the shop. Furthermore, a shopkeeper does not usually choose his "best" space to display these articles;

iv) space per item. The more space is allocated to an item, the more likely it is to be seen by a shopper and, hence, the more likely to be purchased. We suppose, however, that there are diseconomies in this mechanism.

Two counterforces with respect to these diseconomies can be mentioned:

- with increasing depth and height of the assortment composition the average price level of goods increases. In our analysis Q is defined in terms of money (value of annual sales);
- the attractiveness of an establishment increases with increasing depth, height and width of the assortment composition, which may result in higher sales per unit of floorspace for the basic part of the assortment (goods which are present in every establishment of a shop type irrespective of its scale) than would have been the case without a deep, high or wide assortment composition.

It is not assumed that these counterforces are stronger than the arguments in favour of diseconomies. Pickering (1972) gives further reasons for diseconomies.

Coefficient π indicates the degree to which an establishment of a certain shop type is selling area intensive. This is best seen in equations (3) and (4): π set the partitioning of total floorspace. The line defined by equation (3) shifts anti-clockwise, if π increases. The distribution coefficient also plays a role in reduced form equation (5). It can be derived that $\frac{\partial Q}{\partial \pi} = \varepsilon Q \log \frac{\pi}{1-\pi}$, so that $\frac{\partial Q}{\partial \pi} \gtrless 0$ if $\pi \gtrless .5$.

The model consisting of equations (3), (4) and (5) is our maintained hypothesis.

The following hypotheses will be tested:

H1: the elasticity of the value of annual sales with respect to total available floorspace, E, decreases with size, i.e. $Y_1 + Y_2 > 0$;

H2: the asymptotic elasticity of the value of annual sales with respect to total floorspace, ε, is less than or equal to one.

If both $Y_1 + Y_2 > 0$ and $0 < \varepsilon < 1$, then E is a decreasing function of W and there is a total floorspace $W^* > 0$, below which $E > 1$ and above which $E > 1$. Furthermore, it will be interesting to see whether both selling area and remaining space show a threshold (i.e. both $Y_1 > 0$ and $Y_2 > 0$) and to interpret differences in the values of all coefficients for the different samples. Moreover, we want to see whether our model is able to describe the data satisfactorily.

Further hypotheses

In this section differences of the characteristics of establishments within a shop type will be discussed as well as consequences of these differences regarding the value of the efficiency coefficient β and the distribution coefficient π. The roles will be discussed of occupancy costs, gross margin, size of the shopping centre, size of the township, level of own production, etc. The choice of these variables depends on the availability of data.

Occupancy costs

Occpancy costs are defined as consisting of (estimated) rent and remaining occupancy costs (energy, insurance, maintenance of inventory, etc.). Firstly, it is assumed that rent price per unit of total floorspace is an indicator of the environmental attraction of the establishment. Secondly, it is assumed that the motivation to use available floorspace efficiently is induced by the height of occupancy costs per unit of floorspace. The use of rent price as an indicator for attraction makes the omission of environmental variables less serious. However, one can think of situations in which attraction and rent price are not necessarily correlated (e.g. cheap old city-centre building; almost entirely depreciated property).

H3: efficiency of total available floorspace increases if occupancy costs per unit of floorspace increase.

Shopping centre

The size of a shopping centre is defined as the number of retail establishments it consists of. If the size of a shopping centre increases, attractiveness increases and thereby the efficiency of total available floorspace of its establishments. The possible number of competitors also increases and then the efficiency of total available floorspace decreases. We have no hypothesis about the influence of the size of a shopping centre on the efficiency of total available floorspace. However, it is interesting to study its influence.

Township

The size of a township is defined by its population number. If the size of a township increases, its purchasing power increases and then the efficiency of total available floorspace of its establishments is likely to increase. The possible number of competitors also increases and then the efficiency of total available floorspace decreases. We have no hypothesis about the influence of the size of a township on the efficiency of total available floorspace. Important variables in conjunction with the size of a township seem to be: number of competitors, population density, purchasing power per inhabitant or the regional function of the township. These variables are lacking in the present samples. However, it is interesting to study the influence of the size of a township.

Own production

The own production sales share plays a role in differences of efficiency of total available floorspace and in the partitioning of floorspace. The concept of own production has largely differing meanings for the shop types studied in this chapter. If a florist's shop selling area consists for a large part of a greenhouse, it is assumed that selling area intensity increases and that efficiency of total available floorspace decreases (a shopkeeper cannot afford to build a greenhouse on a favourable, expansive site).

H4: efficiency of total available floorspace decreases if selling area of a florist consists for a large part of a greenhouse.

H5: selling area intensity increases if selling area of a florist's shop consists for a large part of a greenhouse.

If an electro-technical retailer also deals in electronic installations and repairs, selling area intensity is assumed to decrease, because the preparations for these installations will take remaining space. The influence of efficiency of total available floorspace is assumed two-fold: if an electro-technical retailer is also involved in installations and repairs, it could be said that sales are generated outside the establishment so that efficiency will increase. However, such a retailer is not likely to allocate space for the preparations of installations and repairs if he occupies a favourable expensive site. We have no hypothesis about the influence on efficiency of total available floorspace.

H6: selling area intensity decreases if an electro-technical retailer is also involved in installations and repairs.

Total sales of photographer's shops consists of retail sales (including developing and printing, which is usually contracted out to a laboratory) and own production sales, for which a studio and/or dark room is used. Regarding the influence of the retail sales share of photographer's shops the following hypotheses are made:

H7: efficiency of total available floorspace increases if the retail sales share of photographer's shops increases.

H8: selling area intensity increases if the retail sales share of photographer's shops increases.

Gross margin

Unfortunately, no precise description is available of differences in the assortment composition, service level or level of own production per establishment per sample. Therefore, average percentage gross margin will be used as a makeshift. Average percentage gross margin is the difference between the value of total annual sales and the value of total annual wholesale costs expressed as a percentage of the former. It is unorthodox to experiment with this variable, which can also be conceived of as a resultant of retail activities. It is assumed, however, that a high average percentage gross margin stems from

—a high average selling price, which might indicate that the assortment composition is particularly deep or that a high service level is offered. Probably, the labour involved in a high service level takes space, so that efficiency of floorspace drops if the service level increases, or more generally, a high service level requires spacious surroundings;

—a low average purchasing price, which might indicate that considerable labour (own production) has to be performed before the goods can be displayed to customers. The performance of this labour takes space. A low purchasing price might also indicate a large bulk per purchase, which implies a low ordering frequency, leading to higher stock levels.

The influence of competition on the buying and selling market is neglected in the above assumptions. The influence of productivity on price-setting is also ignored.
H9: efficiency of total available floorspace decreases if average percentage gross margin increases.

Tests

Hypotheses H1 through H9 are tested using a model consisting of equations (B1) and (B2) with $Y_2 = 0$ and where ß and π are replaced by $ß_i$ and π_i. The use of equations (B1) and (B2) is justified in appendix B:

$$(8)\quad \beta_i = \beta_0 \left(\frac{HV_i}{\overline{HV}}\right)^{\beta_1} [\exp \beta_2 (M_i - \bar{M})] \left(\frac{SC_i}{\overline{SC}}\right)^{\beta_3} \left(\frac{TS_i}{\overline{TS}}\right)^{\beta_4} \exp(\beta_5 DX_i);$$

$$(9)\quad \pi_i = \pi_0 + \pi_1 DX_i,$$

where W_i: total available floorspace (in 10^2 m^2) of establishment i;
C_i: selling area (in 10^2 m^2);
Q_i: value of annual sales (in 10^3 Dutch guilders);
HV_i: occupancy costs per m^2 (in Dutch guilders);
$\overline{HV} = (\sum_{i=1}^{I} HV_i)/I$: sample average occupancy costs per m^2;
M_i: average percentage gross margin divided by 100;
SC_i: indicator of size of shopping centre: SC_i increases if the size of the shopping centre (expressed in number of establishments) increases;
TS_i: indicator of size of township: TS_i increases if the size of the township (expressed in population number) increases;
$\bar{M}$, $\overline{SC}$ and $\overline{TS}$: sample averages defined in the same manner as $\overline{HV}$;
DX_i: dummy variable which has different interpretations according to the sample where it is used:
—column SHO76 (shoe shops)
$DX_i = 1$ if selling area is smaller than $50m^2$ and 0 otherwise;
—column PHO80 (photographer's shops)
$DX_i = 1$ if the retail sales share exceeds 85% and 0 otherwise;
—column FLO80 (florist's shops)
$DX_i = 1$ if selling area consists for a large part of a greenhouse and 0 otherwise;
—column ELE80 (electro-technical retailers)
$DX_i = 1$ if also electric installations are also made and 0 otherwise.

The definition of the dummy variables DX_i depends primarily on limitations of our data sources. We restrict ourselves to a muliplicative specification for $ß_i$, because
—such a specification accounts for interaction between variables;
—a convenient specification is obtained after logarithmisation.

Interpretation of coefficients of (8) and (9):
$ß_0$: measure for the average efficiency of floorspace;
$ß_1$: elasticity of $ß_i$ with respect to $HV_i/\overline{HV}$;
$ß_2$: influence of average percentage gross margin;
$ß_3$: elasticity of $ß_i$ with respect to $SC_i/\overline{SC}$;

β_4: elasticity of β_i with respect to $TS_i/\overline{TS}$;
β_5: various influences;
π_0: distribution coefficient if $DX_i = 0$ or if DX_i is not available;
$\pi_0 + \pi_1$: distribution coefficient if $DX_i = 1$.

Preliminary tests pointed out that $\hat{Y}_2$ does not differ significantly from zero and that standard errors of most coefficients are lower if $Y_2 = 0$ than if $Y_2 \neq 0$. See Thurik and Koerts (1983).

Estimations are computed for ten samples of small Dutch retail establishments. A concise description of these samples is given in Appendix A. The estimation model and procedure are dealt with briefly in Appendix B. Estimation results are given in Table 1. The following conclusions can be drawn regarding the hypotheses formulated above:

H1: $\hat{Y}_1 > 0$ in all ten cases and significantly in six. We conclude that a positive value for the selling area threshold is generally found: its value ranges from 12 to 30m². Support is found for the hypothesis that the elasticity of the value of annual sales with respect to total available floorspace, E, decreases with scale for all shop types. Nooteboom (1980) found values of approximately 50m² for Dutch butcher's shops and small self-service grocery stores using a different model.

H2: $\hat{\varepsilon} < 1$ in all ten cases and significantly in eight: $\hat{\varepsilon}$ is not significantly different from one for confectioner's shops and electro-technical retailers. The hypothesis is supported that the asymptotic elasticity of the value of annual sales with respect to total available floorspace is not greater than one: a value of less than one is inferred from the estimations. The shop size below which $E > 1$, W^* can be computed with (7). Their values generally do not differ much from $\min W_i$, the minimum floorspace per sample (see Table A2 of Appendix A): no evidence is found that $E > 1$ for the shop types studied.

H3: $\hat{\beta}_1 > 0$ and significantly for all ten cases. Strong support is found for the hypothesis that efficiency of total available floorspace increases if occupancy costs per unit of floorspace increase. The elasticity of β_i with respect to relative occupancy costs per m² $HV_i/\overline{HV}$, β_1, varies between .29 for women's underwear shops and .81 for confectioner's shops. Ignoring the results for greengrocers ($\hat{\beta}_1 = .43$) and for women's underwear shops ($\hat{\beta}_1 = .29$), the remaining eight $\hat{\beta}_1$ do not differ significantly from .65. Before discussing further results, we first examine the values found for the distribution coefficient π_0 $< \hat{\pi}_0 < 1$ and significantly, which is in accordance with the theoretical requirements. Its value varies largely among the shop types: $\hat{\pi}_0 = .14$ for baker's shops and $\hat{\pi}_0 = .72$ for independent clothes shops. Nooteboom (1980) found values of approximately .3 for Dutch butcher's shops and small self-service grocery stores using a different model.

H4: $\hat{\beta}_5 < 0$ and significantly for florists. See column FLO80. The hypothesis is supported that floorspace efficiency decreases if selling area of a florist consists for a large part of a greenhouse.

H5: $\hat{\pi}_1 > 0$ and significantly for florist's shops. See column FLO80. The hypothesis is supported that selling area intensity increases if selling area of a florist consists for a large part of a greenhouse.

H6: $\hat{\pi}_1$ v0 and significantly for electro-technical retailers. See column ELE80. The hypothesis is supported that selling are intensity decreases if an electro-technical retailer is also involved in electric installations.

H7: $\hat{\beta}_5$ v0, but not significantly for photographer's shops. See column PHO80. The hypothesis is not rejected that floorspace efficiency increases if the retail sales share of a photographer's shop is high.

H8: $\hat{\pi}_1 > 0$ and significantly for photographer's shops. See column PHO80. The hypothesis is supported that selling area intensity increases if the retail sales

TABLE 1

ESTIMATES OF COEFFICIENTS OF THE MODEL CONSISTING OF EQUATIONS (B1) AND (B2) WITH (8) AND (9).

shop type		GRE78	BAK77	CON77	CLI79	CLC79	WUN77	SHO76	PHO80	FLO80	ELE80
average efficiency	$\log\hat{\beta}_0$	6.35	5.98	6.11	6.56	6.54	6.22	6.26	6.65	6.14	6.75
		(.05)	(.04)	(.04)	(.10)	(.09)	(.07)	(.04)	(.07)	(.08)	(.09)
occupancy costs	$\hat{\beta}_1$	.45	.56	.81	.51	.68	.29	.62	.54	.73	.64
		(.07)	(.09)	(.12)	(.11)	(.09)	(.10)	(.08)	(.10)	(.12)	(.09)
% gross margin	$\hat{\beta}_2$	-1.17	-.69	-1.35	-.53	-1.56	2.40	.18	-1.84	-1.07	-.53
		(.49)	(.68)*	(.53)	(.68)*	(.77)	(1.02)	(.63)*	(.70)	(.59)	(.85)*
shopping centre	$\hat{\beta}_3$	.04	.20	.18	.02	-.70	.41	.00	-.15	-.13	-.22
		(.07)*	(.09)	(.18)*	(.13)*	(.23)	(.27)*	(.11)*	(.15)*	(.10)*	(.09)
township	$\hat{\beta}_4$	.10	.02	.33	.13	-.04	.26	.11	.15	.14	.19
		(.05)	(.05)	(.09)	(.07)	(.11)*	(.12)	(.06)	(.09)	(.12)*	(.06)
other influences on efficiency	$\hat{\beta}_5$							.03	.08	-.28	.01
								(.09)*	(.08)*	(.10)	(.11)*
threshold	$\hat{\gamma}_1$	.24	.12	.14	.25	.21	.30	.14	.25	.12	.15
		(.03)	(.05)	(.04)	(.17)*	(.18)*	(.11)	(.08)	(.06)	(.11)*	(.14)*
distribution	$\hat{\pi}_0$	.24	.14	.18	.67	.72	.57	.50	.31	.57	.53
		(.02)	.02)	(.02)	(.02)	(.01)	(.05)	(.02)	(.03)	(.04)	(.02)
other influences on distribution	$\hat{\pi}_1$							-.22	.05	.21	-.06
								(.09)	(.03)	(.04)	(.03)
sales elasticity	$\hat{\epsilon}$	.49	.73	.97	.72	.73	.40	.72	.52	.62	.91
		(.06)	(.10)	(.10)	(.09)	(.06)	(.11)	(.08)	(.09)	(.10)	(.08)
number of observations	I	133	89	77	98	75	54	118	83	68	102
neg. concentr. loglikelihood	L	208.4	95.7	80.1	267.5	153.1	60.9	229.2	118.5	89.1	263.5
goodness of fit	1 r^2	.40	.55	.73	.63	.80	.56	.77	.57	.93	.76
goodness of fit	2 r^2	.49	.27	.47	.86	.97	.57	.82	.58	.92	.81
goodness of fit	3 r^2	.90	.93	.95	.70	.84	.57	.82	.86	.67	.83
correlation of residuals	r	.01	.15	.01	.07	-.40	-.12	-.01	.14	-.17	-.19

Note Table 1: see next page.

Note: Estimated standard errors ($\hat{\sigma}$) are printed beneath the estimated coefficients. Coefficient $\hat{n}$ is called significantly different from zero at a 10% level of significants, if $|\hat{n}|$ V1.64 $\hat{\sigma}(\hat{n})$.

The square of the correlation coefficient between the vectors of the dependent variable and its estimation is taken as measure of goodness of fit: 1 refers to the antilog form of equation (B1), 2 to equation (B2) and 3 to equation (B3). The correlation coefficient between the vectors of residuals of equations (B1) and (B2) is computed. Its value is relevant to conclude whether our assumption of a non-diagonal covariance matrix Ω is meaningful. See Appendix B.

share of a photographer's shop is high.

H9: $\hat{\beta}_2 < 0$ in eight of our ten cases and significantly in five: $\hat{\beta}_2 > 0$ for women's underwear shops and shoe shops and significantly only for women's underwear shops. We have no clear explanation for this last result. A hypothesis is that a women's underwear shop can only be run successfully (i.e. high floorspace efficiency), if the assortment composition is deep (high margins), whereas less successful shops remain to exist. Ignoring the result for women's underwear shops, we conclude that support is found for the hypothesis that efficiency of total available floorspace decreases if average percentage gross margin increases. There is considerable variation in the values found for β_2 among the shop types. This variation and the high errors are assumed to result from the fact that average percentage gross margin is a far from ideal indicator for assortment composition or labour intensity. From the results concerning $\hat{B}_2$ we conclude that the explanation of equation (2) is likely to increase, if gross margin is taken instead of annual sales as the left-hand variable: $\hat{\beta}_2$ does not differ significantly from -1 in nine out of ten cases:

From Table 1 it can also be seen that

i) floorspace efficiency does not appear to be systematically influenced by size of the shopping centre. Cf. $\hat{\beta}_3$;
ii) floorspace efficiency appears to increase with increasing population of the township: $\hat{\beta}_4 > 0$ in nine out of ten cases and significantly in seven. This is a very interesting result which requires further research. For instance, it might partly be due to the fact that in small townships and villages there are many shopkeepers who do not abandon business in spite of a low sales level;
iii) floorspace efficiency does not differ significantly between independent and chain clothes shops. Selling area intensity is lower for independent than for chain clothes shops. This is easy to understand, since chain shops have the possibility to have tasks performed outside the establishment (in a central administrative or warehouse establishment);
iv) extremely small shoe shops (with a selling area smaller than $50m^2$) tend to have a lower selling area intensity than larger ones; $\hat{\pi}_1 < 0$ and significantly in column SHO76. On account of the "boutique" character of extremely small shoe shops, no stock whatsoever is present (or displayed) in the selling area. It is therefore probable that relatively more remaining space is needed.

The final remarks of this section involve the threshold coefficient of selling area, Y_1. Support for the threshold interpretation of Y_1 is provided by the fact that

— $\hat{Y}_1 < \min C_i$ for eight out of ten cases: $\hat{Y}_1 > \min C_i$ but not significantly for greengrocers and photographer's shops. See Tables 1 and A2:
— $\hat{Y}_1 > 0$ in all ten cases and significantly in six;
— average value for $\hat{Y}_1$ among all shop types is approximately .2. Twenty square metres seem a very reasonable area for the following interpretations of a threshold: area for a counter with a cash stand, area for a shopkeeper and one or two customers and area for some essential products.

Conclusions

The model consisting of equations (3), (4) and (5) serves its purpose very well in explaining the relation between sales, total floorspace and its partitioning into selling area and remaining space, because

i) explanation is high for cross-section samples. See goodness of fit in Table 1;
ii) estimated standard errors are systematically low;
iii) most hypotheses to be tested are supported.

Furthermore, it is interesting to see that occupancy costs per square metre contribute considerably to the explanation of differences in efficiency of total available floorspace, that this efficiency appears to increase with increasing town size, and that the idea of a threshold in selling area is supported. The results reported in this article are obtained with samples of small Dutch establishments. Nooteboom (1980) obtains comparable results for Dutch butcher's shops and small self-service grocery stores using a different model. Thurik and Koerts (1984) obtain comparable results for large French and smaller Dutch supermarket(-like) establishments using the same model.

References

Barten, A. P., 1969, Maximum likelihood estimation of complete systems of demand equations, *European economic review*, 1, pp7-73.

Hoek, G. Van der, 1980, *Reduction methods in nonlinear programming* (Mathematisch Centrum, Amsterdam).

Kooiman, P., 1982, Using business survey data in empirical disequilibrium models, Paper 82/41 (International Centre for Economics and Related Disciplines, London School of Economics).

Nooteboom, B., 1980, *Retailing: applied analysis in the theory of the firm* (J. C. Gieben, Uithoorn).

Nooteboom, B., 1982, A new theory of retailing costs, *European economic review*, 17, pp163-186.

Pickering, J. F., 1972, Economic implications of hypermarkets in Britain, *European Journal of Marketing*, 6, pp257-269.

Rachman, D. J., 1969, *Retail strategy and structure: a management approach*, (Prentice Hall, Englewood Cliffs).

Thurik, A. R. and J. Koerts, 1983, Further study on the use of retail floorspace and its efficiency, Report 8303/S (Econometric Institute, Erasmus University, Rotterdam).

Thurik, A. R. and J. Koerts, 1984, On the use of supermarket floorspace and its efficiency, in: The economics of distribution (France Angeli Editore, Milano), pp387-445.

APPENDIX A: Data

Table A1. Description of the samples used.

code	number of observations	year of collection	shop type
GRE78	133	1978	greengrocer
BAK77	89	1977	baker's shop
CON77	77	1977	confectioner's shop
CLI79	98	1979	clothes shop (independent)
CLC79	75	1979	clothes shop (small chain)
WUN77	54	1977	women's underwear shop
SHO76	118	1976	shoe shop
PHO80	83	1980	photographer's shop
FLO80	68	1980	florist's shop
ELE80	102	1980	electro-technical retailer

These Dutch data were gathered by the field force of the Research Institute for Small and Medium-Sized Business in the Hague. The shop types consist primarily of independent establishments. An establishment is called independent if the enterprise to which the establishment belongs consists of one establishment. There are enterprises which consist of a few establishments. Only for clothes shops the sample is divided in two subsamples: one consisting of independent establishments and one consisting of small chain establishments.

Table A2. Further description of the samples: W_i is total available floorspace, C_i selling area, R_i remaining space, Q_i total annual sales, HV_i occupancy costs per m^2 and M_i gross profits divided by total annual sales. Floorspace is expressed in 10^2 m^2. Sales are expressed in 10^3 Dutch guilders of the year of collection and occupancy costs in Dutch guilders of the year of collection.

code	$\min W_i$ $\bar{W}$ $\max W_i$	$\min C_i$ $\bar{C}$ $\max C_i$	$\min R_i$ $\bar{R}$ $\max R_i$	$\min Q_i$ $\bar{Q}$ $\max Q_i$	$\min HV_i$ $\overline{HV}$ $\max HV_i$	$\min M_i$ $\bar{M}$ $\max M_i$
GRE78	.42	.20	.12	134	47	.194
	1.16	.46	.69	398	158	.300
	3.60	1.25	2.35	685	397	.451
BAK77	.61	.15	.45	161	59	.427
	1.64	.33	1.30	393	189	.596
	2.90	.85	2.60	1190	429	.707
CON77	.65	.18	.35	105	77	.421
	1.56	.40	1.16	403	189	.600
	3.00	1.00	2.50	1019	391	.750
CLI79	.65	.55	.07	331	59	.210
	3.67	2.59	1.08	1029	204	.372
	11.50	6.07	5.50	2884	609	.526
CLC79	.70	.50	.10	324	99	.311
	3.72	2.76	.96	1066	234	.374
	20.40	13.60	7.00	4952	588	.465
WUN77	.45	.40	.05	152	60	.286
	1.29	.88	.41	376	197	.399
	2.54	1.90	1.35	766	424	.477
SHO76	.50	.30	.15	154	72	.279
	1.75	.92	.82	434	214	.359
	4.80	2.85	2.60	1195	514	.493
PHO80	.43	.20	.18	254	92	.196
	1.50	.66	.84	638	260	.363
	3.07	1.43	2.20	1492	891	.493
FLO80	.52	.36	.10	134	69	.318
	1.58	1.07	.51	350	171	.477
	3.90	3.40	1.70	793	311	.653
ELE80	.80	.40	.10	289	61	.169
	3.14	1.68	1.46	1205	157	.277
	9.51	5.43	5.21	3782	331	.434

Note: for shoe shops occupancy costs per m^2 are not available: non-labour costs per m^2 are taken instead.

APPENDIX B: Estimation procedure

The estimation of the vector of basic coefficients θ, with $\theta' = (\beta \gamma_1 \gamma_2 \pi \varepsilon)$, depends on the assumptions we make with respect to the stochastic specification of our model. We simply choose to add disturbance terms v_{1i}, v_{2i} and v_{3i} to the reduced form of our model consisting of equations (3), (4) and (5) after taking logarithms in (5). we obtain the following stochastic reduced form:

(B1) $\log Q_i = \log\beta + \pi\varepsilon\log\frac{\pi}{1-\pi} + \varepsilon\log(W_i - \gamma_1 - \gamma_2)(1-\pi) + v_{1i};$

(B2) $C_i = \gamma_1 + \pi(W_i - \gamma_1 - \gamma_2) + v_{2i};$

(B3) $R_i = \gamma_2 + (1-\pi)(W_i - \gamma_1 - \gamma_2) + v_{3i}.$

It should be noted that $v_{2i} + v_{3i} = 0$ in equations (B2) and (B3). Therefore, one of these equations can be deleted in our estimation procedure. We choose to leave out equation (B3). Barten (1969) proves that for obtaining maximum likelihood estimates, it does not matter which one is left out, if the singularity occurs in a complete system of equations with a disturbance vector having a multivariate normal distrubution. The same result is valid for a subset of a system of equations. See Kooiman (1982). We now define V_i with

$$V_i = \binom{v_{1i}}{v_{2i}} \sim N(0, \Omega)$$

for $i = 1, \ldots, I$: bivariate normal distribution with zero means and constant, positive definite and symmetric covariance matrix

$$\Omega = \begin{pmatrix} \omega_{11} & \omega_{12} \\ \omega_{21} & \omega_{22} \end{pmatrix}.$$

In addition, we assume the disturbance vectors V_i to be independent over the individuals, i.e. $E(V_i \, V'_{i'}) = 0$ for $i \neq i'$.

Full information maximum likelihood estimates may now be found by locating a maximum of the likelihood function with respect to the coefficient vector θ after concentrating this function with respect to Ω. See Thurik and Koerts (1984). Numerical minimisation of L is performed by the variable metric algorithm of Broyden, Fletcher, Goldfarb and Shanno. See for instance Van der Hoek (1980).