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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) \[ W_i = \hat{\lambda} C_i + R_i, \]

where
- \( W_i \): total available floorspace of establishment \( i \);
- \( C_i \): selling area;
- \( R_i \): remaining space;
- \( \hat{\lambda} \) 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 expansion 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:

\[ Q_i = \beta (C_i - \gamma_1)^{\pi \epsilon} (R_i - \gamma_2)^{(1-\pi) \epsilon} \]

with \( \beta > 0, 0 \leq \gamma_1 \leq C_i, 0 \leq \gamma_2 \leq R_i, 0 < \pi < 1 \) and \( \epsilon > 0 \),

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 heterogeneities 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 activities 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:

— \( \beta \) 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)

\[
(3) \quad c_1 \cdot \gamma_1 + \pi (\gamma_1 - \gamma_2) = 0.
\]

Also, equations (1) and (3) give

\[
(4) \quad \gamma_1 \cdot \gamma_2 + \pi \cdot (\gamma_1 - \gamma_2).
\]

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)

\[
(5) \quad Q_1 = \beta (\gamma_1 - \gamma_2) \pi \cdot (\gamma_1 - \gamma_2) ^2 \cdot (1-\pi) ^ \epsilon,
\]

\[
(3) \quad C_1 = \gamma_1 + \pi (\gamma_1 - \gamma_2)
\]

and

\[
(4) \quad R_1 = \gamma_2 + (1-\pi) (\gamma_1 - \gamma_2).
\]

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 available floorspace \( W_i, \) The coefficients are \( \beta, \gamma_1, \gamma_2, \pi, \) and \( \epsilon, \)

The coefficients have the following restrictions: \( \beta > 0, 0 \leq \gamma_1 < C_1, 0 \leq \gamma_2 < R_1, 0 < \pi < 1 \) and \( \epsilon > 0. \)

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
\[
\frac{d \log Q}{d \log W} = \frac{\varepsilon}{W - \gamma_1 - \gamma_2} \triangleq E
\]
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 \(\varepsilon\) can be regarded as the asymptotic elasticity of the value of annual sales with respect to total floorspace. Coefficient \(\varepsilon\) has a more practical use, in that it determines the scale of an establishment above which diseconomies arise. Rearranging (6) we get
\[
W = (\gamma_1 + \gamma_2)E / (E - \varepsilon).
\]
We see that \(d \log Q / d \log W < 1\) for all \(W < W^*\), where \(W^*\) denotes the scale of an establishment where \(E = 1\).

We do not provide a theoretical value of \(\varepsilon\) 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 \(\tau\) 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): \(\tau\) set the
partitioning of total floorspace. The line defined by equation (3) shifts anti-clockwise, if \( \pi \) increases. The distribution coefficient also plays a role in reduced form equation (5). It can be derived that \( \frac{d\xi}{d\pi} = \xi \log_2 \frac{\pi}{1-\pi} \), so that \( \frac{d\xi}{d\pi} > 0 \) if \( \pi > 0 \) if \( \pi < < .5 \).

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, \( \xi \), is less than or equal to one.

If both \( Y_1 + Y_2 > 0 \) and \( 0 < \xi < 1 \), 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 \( \xi \) and the distribution coefficient \( \xi \). 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

Occupancy 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 large 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 \( \beta \) and \( \pi \) are replaced by \( \beta_i \) and \( \pi_i \). The use of equations (B1) and (B2) is justified in appendix B:

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

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

where \( W_i \): total available floorspace (in 10² m²) of establishment \( i \);
\( C_i \): selling area (in 10² m²);
\( Q_i \): value of annual sales (in 10² Dutch guilders);
\( HV_i \): occupancy costs per m² (in Dutch guilders);

\[
\bar{HV} = \frac{\sum_{i=1}^{1} W_i}{\sum_{i=1}^{1}}: \text{sample average occupancy costs per m}^2;
\]

\( M_i \): 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;

\( \bar{M}, \bar{SC} \) and \( \bar{TS} \): sample averages defined in the same manner as \( \bar{HV} \);

\( DX_i \): 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 50m² 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 multiplicative specification for \( \beta_i \), because
— such a specification accounts for interaction between variables;
— a convenient specification is obtained after logarithmisation.

Interpretation of coefficients of (8) and (9):
\( \beta_0 \): measure for the average efficiency of floorspace;
\( \beta_1 \): elasticity of \( \beta \) with respect to \( HV / \bar{HV} \);
\( \beta_2 \): influence of average percentage gross margin;
\( \beta_3 \): elasticity of \( \beta \) with respect to \( SC / \bar{SC} \).
$\beta_4$: elasticity of $\beta_i$ with respect to $TS_i/TS$;
$\beta_5$: various influences;
$\pi_0$: distribution coefficient if $DX_i = 0$ or if $DX_i$ is not available;
$\pi_{0+}$: distribution coefficient if $DX_i = 1$.

Preliminary tests pointed out that $Y_2$ 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: $Y_i > 0$ 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. Nootbooom (1980) found values of approximately 50m² for Dutch butcher's shops and small self-service grocery stores using a different model.

H2: $E < 1$ in all ten cases and significantly in eight: $E$ 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 $minW_i$, the minimum floorspace per sample (see Table A2 of Appendix A): no evidence is found that $E > 1$ for the shop types studied.

H3: $\beta_i > 0$ 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 $\beta_i$ with respect to relative occupancy costs per m² $HV_i/HV$, $\beta_i$, varies between .29 for women's underwear shops and .81 for confectioner's shops. Ignoring the results for greengrocers ($\beta_1 = .43$) and for women's underwear shops ($\beta_1 = .29$), the remaining eight $\beta_i$ do not differ significantly from .65. Before discussing further results, we first examine the values found for the distribution coefficient $\pi_0 < \pi_0 < 1$ and significantly, which is in accordance with the theoretical requirements. Its value varies largely among the shop types: $\pi_0 = .14$ for baker's shops and $\pi_0 = .72$ for independent clothes shops. Nootbooom (1980) found values of approximately .3 for Dutch butcher's shops and small self-service grocery stores using a different model.

H4: $\beta_5 < 0$ 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: $\pi_{10} > 0$ 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: $\pi_{10} v0$ 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: $\beta_5 v0$, 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: $\pi_{10} > 0$ 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).

<table>
<thead>
<tr>
<th>Shop Type</th>
<th>GSt78</th>
<th>BAK77</th>
<th>CON79</th>
<th>CL179</th>
<th>CLC79</th>
<th>WUN77</th>
<th>SHO76</th>
<th>PHO80</th>
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<td>(.08)</td>
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<td>(.12)</td>
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Note Table 1: see next page.

Note: Estimated standard errors (,) are printed beneath the estimated coefficients. Coefficient $\hat{\gamma}$ is called significantly different from zero at a 10% level of significants, if $|\hat{\gamma}| > 1.64$.

The square of the correlation coefficient between the vectors of the dependent variable and its estimation is taken as a measure of goodness of fit. 1 refers to the analog 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 $\Omega$ is meaningful. See Appendix B.
share of a photographer’s shop is high.

H9: \( \beta_3 < 0 \) in eight of our ten cases and significantly in five: \( \beta_3 > 0 \) 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 \( \beta_3 \) 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 \( \beta_2 \) 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; \( \beta_3 \) 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. \( \beta_3 \);

ii) floorspace efficiency appears to increase with increasing population of the township: \( \beta_4 > 0 \) 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 50m²) tend to have a lower selling area intensity than larger ones; \( \beta_1 < 0 \) and significantly in column SH076. 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:

- \( Y_1 < \min C \), for eight out of ten cases: \( Y_1 > \min C \), but not significantly for greengrocers and photographer’s shops. See Tables 1 and A2:
- \( Y_1 > 0 \) in all ten cases and significantly in six;
- average value for \( Y_1 \) 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

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

**APPENDIX A: Data**

**Table A1.** Description of the samples used.

<table>
<thead>
<tr>
<th>code</th>
<th>number of observations</th>
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<td>greengrocer</td>
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<td>89</td>
<td>1977</td>
<td>baker's shop</td>
</tr>
<tr>
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<td>77</td>
<td>1977</td>
<td>confectioner's shop</td>
</tr>
<tr>
<td>CL179</td>
<td>98</td>
<td>1979</td>
<td>clothes shop (independent)</td>
</tr>
<tr>
<td>CLC79</td>
<td>75</td>
<td>1979</td>
<td>clothes shop (small chain)</td>
</tr>
<tr>
<td>WUN77</td>
<td>54</td>
<td>1977</td>
<td>women's underwear shop</td>
</tr>
<tr>
<td>SHO76</td>
<td>118</td>
<td>1976</td>
<td>shoe shop</td>
</tr>
<tr>
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<td>83</td>
<td>1980</td>
<td>photographer's shop</td>
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<tr>
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<td>68</td>
<td>1980</td>
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<tr>
<td>ELE80</td>
<td>102</td>
<td>1980</td>
<td>electro-technical retailer</td>
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</table>
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: \( W \) is total available floorspace, \( C \) selling area, \( R \), remaining space, \( Q \), total annual sales, \( H \), occupancy costs per \( m^2 \) and \( M \), 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.

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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 $\theta$, with $\theta' = (\beta Y_1 Y_2' \varepsilon)$, depends on the assumptions we make with respect to the stochastic specification of our model. We simply choose to add disturbance terms $\nu_{11}$, $\nu_{21}$ and $\nu_{31}$ 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:

\[ \log Q_1 = \log K + \pi \log \frac{\pi}{1-\pi} + \varepsilon \log (W_1 - Y_1 - Y_2) (1-\pi) + \nu_{11}; \]

\[ C_1 = \gamma_1 + \pi (W_1 - Y_1 - Y_2) + \nu_{21}; \]

\[ R_1 = \gamma_2 + (1-\pi) (W_1 - Y_1 - Y_2) + \nu_{31}. \]

It should be noted that $\nu_{21} + \nu_{31} = 0$ 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 distribution. The same result is valid for a subset of a system of equations. See Kooiman (1982). We now define $V_i$ with

\[ V_i = \begin{pmatrix} \nu_{11} \\ \nu_{21} \end{pmatrix} \sim N(0, \Omega) \]

for $i = 1, \ldots, l$: 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. $\mathbb{E}(V_i V_i') = 0$ 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 $\theta$ after concentrating this function with respect to $\Omega$. 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).