Towards hierarchical linking of marketing resource allocation to market areas and product groups *

E. GIJSBRECHTS ** and Ph. NAERT ***

In this paper a marketing resource allocation model is developed that is intended as a decision support tool for management at a country level in a multinational multiproduct firm. At the same time overall company objectives and portfolio considerations are taken into account by imposing a set of constraints on the countries. Output of the models from the different countries can help corporate management in allocating resources to countries and in evaluating the short term opportunity cost of its strategic constraints. As such, the model is seen as a first step in working towards hierarchically linked allocation models.

1. Introduction

Much of marketing modeling has dealt with resource allocation decisions concerning single products or brands. Yet, a majority of companies operates a multiproduct business. As a result, marketing decisions for a single product should not be made in isolation but must be made within this multiproduct context. This calls for – as Little (1975) puts it – co-ordination of strategies for single products at higher company levels.

The multiproduct firm has in recent years received increasing attention in the strategic management and marketing literature. In marketing management, the label 'multiproduct' has often referred to diversification in different product groups or lines (e.g., a firm selling different brands of cereals), and even to product variation (e.g., marketing a brand of cereals in different sizes). The strategic management approaches have been primarily concerned with the problem of defining a portfolio of product groups (or business units), and have been mostly descriptive. A few exceptions are Corstjens and Weinstein (1982), Naert et al. (1983), Naert and Gijsbrechts (1984) and Larréché and Srinivasan (1981, 1982). The latter pay partial attention to resource allocation, but at a high level of aggregation (total marketing resources needed over a given planning horizon). Multiproduct marketing models, such as Bultez (1975) and Picconi and Olson (1978), have to a large extent looked at marketing resource allocation without much concern for strategic considerations. They can to a large extent be positioned at the operational level in the organization. While the above is an overly simplified comparison of strategic management and marketing approaches to multiproduct problems, [1] it is nevertheless fair to say that in most if not all models the link between decisions of a more strategic nature and the

* A preliminary version of this paper was presented at the Ninth International Seminar on Marketing, Aix-en-Provence, June 1982, under the title 'Towards a Product Group Marketing Resource Allocation Model'. We would like to thank Alain Bultez, Alfons Buts, Marcel Corstjens, John Little and Marcel Weverbergh for their suggestions and comments.

** E. Gijsbrechts is aspirant of the National Foundation for Scientific Research in Belgium.

*** Ph. Naert is professor at UFSIA, University of Antwerp and director of the European Institute for Advanced Studies in Management.

[1] For an extensive literature review see Gijsbrechts (1981). A more succinct review is given in Gijsbrechts (1982).

Intern. J. of Research in Marketing 1 (1984) 97–116
North-Holland

more tactical or operational ones have been particularly weak. [2]

This paper must be seen as a step in developing marketing models that eventually will provide a workable basis for linking decisions at different organizational levels. [3] It grew out of a concrete problem within a specific company. We will therefore in the first section describe the problem that led to this research effort. The basic model structure will be presented next, followed by a discussion on parameterization. Once the model parameters are obtained, attention is turned to resource allocation at different levels in the organization, and thus to decision linkage. A concluding section describes some limitations and indications for future work.

2. The problem

The company which served as testing ground for the model presented in this paper is a multinational multiproduct firm producing and selling industrial products. It exhibits a matrix structure. In each market area (a country in this case), where a local company is in operation, some or all of the product groups are marketed. Although local companies in different countries may sell the same product lines, marketing conditions may be very different, if only because the competitive environment varies greatly from country to country.

At corporate headquarters product group portfolio decisions are made, as well as decisions to expand or contract on the offering within each of the product lines. Decisions to allocate the total marketing budget to countries and product groups are also made centrally. As one of its inputs, corporate management each year asks each local manager to propose a marketing budget and a plan that will maximize profit for the coming year taking into account a set of centrally imposed constraints, such as, for example, achieving a minimum market share in each of the product lines. The various country proposals are then examined, and ultimately budgets are allocated to the countries. Corporate management has been rather unhappy with the local management budget proposals because in most cases they are lacking rationale. Corporate management feels that the budgets are not really linked to the allocation to the different product groups, to price behavior, competitive conditions and market response. Corporate management was therefore interested in developing a decision support tool that would help local managers to make budget proposals that are more rational and for which they could be held accountable. [4] These short term local marketing allocation models must, however, not only be useful for local management. They should also enable corporate management to evaluate the short term opportunity cost of imposing particular strategic constraints, or limiting the marketing budget available to a given country, and of limiting the total marketing budget. As such, a clear link is established between marketing decisions at the (lower) local and the (higher) corporate management level.

3. Model structure

The marketing resource allocation model must help local management to allocate a given marketing budget B over n product groups taking into account: (i) the response of

[2] STRATPORT is the only model where the basic ingredients are present to develop such linking.

[3] There is of course a vast literature on hierarchical linking. Examples are the decomposition algorithms developed in mathematical programming and organization theory, and the work on linking aggregate and detailed scheduling in production. For a review and a positioning of our approach within that literature, see Gijsbrechts (1983).

[4] For a similar experience in multi-store retailing, see Lodish (1982).

market share to marketing expenditure, to other marketing instruments and to competitive rivalry; (ii) the relation between market share, sales and profit; (iii) a set of strategic constraints imposed by corporate headquarters. We will first write the model in its most general form and then look at the particular specification we used.

3.1. The general model

$$\max_{b_j} \pi = \sum_{j=1}^{n} \left((p_j - c_j) q_j - b_j - FC_j \right) - FC,$$

subject to

$q_j = m_j M_j$ for all j,

$M_j = M_j(b_1, O_1, \ldots, b_n, O_n, b_{1c}, O_{1c}, \ldots, b_{nc}, O_{nc}, E)$ for all j,

$m_j = m_j(b_1, O_1, \ldots, b_n, O_n, b_{1c}, O_{1c}, \ldots, b_{nc}, O_{nc})$ for all j,

$l_j \leqslant m_j \leqslant u_j$ for all j,

$\sum_{j=1}^{n} b_j \leqslant B,$

$b_j \geqslant 0$ for all j,

where

π = global profit for the country,
= sum of profit across product groups,

n = number of product groups,

E = vector of socio-economic and demographic variables affecting market sales,

p_j = selling price per unit in product group j,

q_j = number of units sold in product group j,

c_j = variable cost per unit in group j, not including marketing effort,

b_j = marketing resources allocated to group j,

FC_j = fixed cost attributable to group j,

FC = general overhead for the local company,

m_j = local company's market share for group j,

M_j = local market sales for group j,

O_j = other marketing variables,

b_{jc} = marketing resources allocated to group j by competition,

O_{cj} = 'other marketing variables' as far as they relate to competition,

l_j = lower bound on market share for group j,

u_j = upper bound on market share for group j,

B = total marketing budget allocated to the country.

3.2. Discussion of the general model

The objective chosen as the basis for allocation is maximization of global profit in the country considered. It should be noted that the objective function covers only one period (one year), that is, short term profit is maximized. Longer term considerations will therefore have to be reflected in the constraints. We also observe that profit is maximized with respect to marketing resources only, and not, for example, with respect to price. This implies that price and other marketing variables are determined outside of the model. In other words, the local management has no control over these variables. It goes without saying that broadening the scope of the model to include maximization with respect to these variables as well would not essentially change the nature of the model.

Market sales may be a function of marketing activity of our company and of that of competitors. In other cases market sales may not be sensitive to marketing pressure (except for price of course). This will be a reasonable approximation if the market for the product group considered is mature (see, e.g., Lambin 1975), to the extent that a gain in sales is always realized at the expense of competitive sales.

The market share of a product group depends on the marketing resources and other marketing variables used by the company and by competitors to stimulate sales. Also the market share of a product group may not only depend on marketing pressure specific to it, but also on marketing pressure exercised with respect to other brands. If such is the case, product groups are interdependent on the demand side.

In the general specification, we have referred to marketing resources b_j in an aggregate way. It may be desirable to consider such resources in a disaggregate fashion by separating out advertising, promotion, personal selling and distribution expenses, in which case the model specification should be adapted accordingly. Or in other cases, the more detailed allocation is looked at separately outside of the context of the product group allocation model. Other factors influencing share will be such variables as, for example, price and quality.

Corporate management may impose upper and lower limits on the market share of the different groups. These constraints are the translation of strategic considerations. [5] This is clarified by looking at a few examples. Relatively new product groups may require large marketing investments now in order to yield high profits in future periods. In a short term model, however, they may not receive any of the available resources, unless some lower bounds on market share are imposed. Some product groups that are not very profitable now, may have to be given some of the resources in the light of research and development work that is expected to result in successful new product introductions in the near future. In other words, we keep investing in a product group that is perhaps less interesting now because we want to keep a foot in the market, in view of high potential in the future. Cash flow limits may put upper limits on share. Without them production capacity may be insufficient requiring new investments. Other constraints may account for economies of scale in production or joint production. For reasons of continuity and general image, market share constraints may be imposed to avoid overly drastic changes in marketing resource allocation.

The budget constraint indicates that the sum of the budgets allocated to the product groups may not exceed the total budget available to the country. The total budget itself reflects the financial possibilities (or limitations) of the company and priorities established at the corporate level, such as allocation between supporting existing products and product lines and investing in research and development, or providing more money to some countries with large potential, but where the company has not as yet made major inroads. [6]

Finally, we should observe that the model does not contain any cost functions. There are several reasons for this. First of all, production does not necessarily and in most cases will not take place in each country. As such, at the country level, production cost is exogenous. In addition, the variable cost per unit charged to the local company may not just include production cost, but it will be a transfer price which may include other types of costs as well. In any event the production cost functions (single or joint) will, at least as far as our problem is concerned, be a matter of concern to corporate but not to local management.

3.3. The specific model

The assignment of fixed costs to product groups is often rather arbitrary. Non-marketing fixed costs do not influence the marketing resource allocation decisions, and are therefore not retained in the specification. Market sales for each product class will be taken as an exogenous variable. This by no means

[5] For a discussion of the strategic impact of market share, see also the PIMS findings (e.g., Abell and Hammond 1979).

[6] The corporate constraints referred to above may themselves be the outcome of a model such as the one developed by Larréché and Srinivasan (1981).

implies that market sales is not influenced by marketing pressure, but the relation will be considered implicitly rather than explicitly.

Demand level interdependencies often exist but are difficult to estimate. Yet in 'product differentiation' or 'product variation' types of multiproduct firms demand interdependencies are important. Partially successful attempts at estimating such interdependencies are Bultez (1975) and Desmet (1981). They have empirically demonstrated that market share attraction models show reasonable promise in that respect. [7] For the analysis conducted here, we assume that product groups are not mutually dependent. This can be accomplished by appropriately constructing or defining the product groups. [8] In fact, the assumption is less restrictive than appears at first sight. Indeed, what we would like is demand independence in a marketing sense, but not necessarily in a portfolio sense. [9] Let us illustrate this by an example. Consider a company selling industrial drilling machines (product group 1) and small drills for personal use (product group 2). For a given level of marketing resources for product group 1, increasing the resources available to group 2 will have little effect on group 1 sales. Indeed, the two groups appeal to very different market segments. Yet, if we look at sales over time, product group 1 sales will be negatively correlated with product group 2 sales. As a matter of fact, in times of recession product group 1 sales decrease whereas product group 2 sales increase; and vice versa in times of an economic boom.

For the application at hand, the model thus reduces to:

$$\max_{b_j} \pi = \sum_{j=1}^{n} \pi_j = \sum_{j=1}^{n} \big((p_j - c_j) q_j - b_j \big),$$

subject to

$$q_j = m_j M_j \quad \text{for all } j,$$
$$m_j = m_j(b_j, O_j, b_{jc}, O_{jc}) \quad \text{for all } j,$$
$$l_j \leqslant m_j \leqslant u_j \quad \text{for all } j,$$
$$\sum_{j=1}^{n} b_j \leqslant B,$$
$$b_j \geqslant 0 \quad \text{for all } j.$$

which means that, looked at from a local management and optimization point of view, interdependencies are constraint interdependencies. [10]

To make the model operational, the market share function must be specified. Three variables will be considered: marketing resources allocated to group j (b_j), price per unit in group j (p_j), and value in group j (V_j). A few comments are in order. A product group consists of different products. The number of units, price and cost per unit are therefore hard to define. There are several ways to circumvent this difficulty. In case a product line has a leading or 'prime' product, q_j, c_j and p_j will be expressed in terms of this 'prime' product.

This is the approach taken here. [11] Value V_j is an index comprising both the breadth of the product group (implying that the broader our coverage of the product group, the larger our share will be), and the quality of the products. It should be clear that value only

[7] The merits of the market share attraction model are well recognized by now: from a theoretical point of view see, for example, Bell, Keeney and Little (1975), and on empirical grounds see, for example, Naert and Weverbergh (1981b).

[8] There are different approaches to define product groups and markets. See, for example, Chandon (1981) and Von Hippel (1978).

[9] Or, to use Kotler's terminology, the absence of product interaction (marketing independence in our terminology) does not exclude sales covariance (portfolio dependence).

[10] This is, of course, not the case at the corporate level, as should be clear from the foregoing discussion. In addition, there may be some hidden interdependencies even at the local level. Total fixed costs may be lower than if separate local companies were to market each of the product groups. Also the effectiveness of marketing pressure may be larger in the multiproduct case, because the different product groups use the same corporate label.

[11] In the case of very heterogeneous product groups price and quantity indices have to be constructed.

obtains an operational meaning when looked at in comparison to the competitive offering. (The 'value' variable employed here is the 'relative quality' variable defined in the PIMS data manual, weighted by the relative breadth of the product line.) As already indicated earlier, marketing resources cover personal selling, advertising and promotional effort (samples, information brochures and meetings, etc.). In our application personal selling is by far the most important marketing resource.

Since the market response is not just a function of the company's own marketing effort but also of competitive marketing, marketing variables are defined in relative terms, that is, $rp_j = p_j/p_{jc}$, $rb_j = b_j/b_{jc}$ and $rV_j = V_j/V_{jc}$. The following specification was obtained:

$$m_j = \alpha\left[\frac{\gamma_1 + rp_j^{\sigma}}{\gamma_2 + rp_j^{\sigma}}\right] \times \left[\frac{\mu_1 + rb_j^{\delta}}{\mu_2 + rb_j^{\delta}}\right]\left[\frac{\epsilon_1 + rV_j^{\beta}}{\epsilon_2 + rV_j^{\beta}}\right]. \quad (1)$$

This specification is arrived at by multiplying response indices corresponding to each of the marketing factors. The structure of each of the indices or modules is explained in that appendix.

It is well known that the specification chosen is very flexible. Depending on the value of the parameters each module can represent quite different response curves. It should be recognized, however, that if no restrictions are imposed on the parameters, the market share function may not be robust. Yet, if the range of variation in the variables is sufficiently large, market share range constraints are likely to be satisfied.

4. Parameterization

The model was tested with respect to one of the countries in which five product groups are marketed. The available historical data were insufficient to estimate equation (1) for each product group.

As a result we turn to subjective estimation, based on managerial judgment. In order to generate data, local managers are asked a number of questions concerning the 'expected' impact of relative price, value and marketing effort on market share, for each of the product groups. As such we try to estimate the expected value of the response curve.

Contrary to what seems to have become common practice in subjective estimation (see, e.g., Naert and Leeflang 1978, p. 258, and Naert and Weverbergh 1981a), we make sure that the number of subjectively generated data points exceeds the number of parameters. This allows for better preliminary input and specification validation. We can indeed judge whether managerial inputs are consistent with the specification. If they are not, either inputs can be adjusted or the specification is changed. [12] It is of course also possible that inputs and specification match closely but that after having seen the graphical representation of the estimated market share function, the manager still wants to adjust his inputs because he feels that the plotted outcomes do not really reflect his judgment.

The data generation procedure roughly works as follows. Local managers are asked the following type of question. Given the reference level of relative price, value and marketing effort (for example, last year's values), and given (or assuming) that relative value and marketing effort remain at these

[12] In case the number of subjectively generated data equals the number of parameters, a perfect fit between model and data is obtained, because no degrees of freedom are left for estimating deviations from the specified model. It is less likely that inputs, let alone the specification, will be questioned in such cases. For an extensive discussion, see Naert and Leeflang (1978, ch. 11) and Naert and Weverbergh (1981a). On the other hand it should be recognized that some managers will see as a disadvantage that with more data than parameters the estimated response function will not exactly pass through the managerial inputs.

levels during the next period, what market share do you expect for the next period if competitors do not change their price, and company price increases by: [13]
x_1%?
x_2%?
x_3%?
decreases by:
x'_1%?
x'_2%?
x'_3%?
Six data points are thus obtained for the group considered. For value and marketing resources, we proceed in a similar way. And therefore a total of eighteen data points is generated.

Having obtained the eighteen data points, a second order non-linear estimation procedure is applied to calculate the parameters of equation (1). In some cases new data had to be generated. When the range of variation is too small, problems of robustness may occur. Re-estimating with a broader range of values easily resolved the problem. In some other cases, the optimal marketing resource fell outside of the estimated range. It was felt that generating new subjective data to cover this extended range would improve optimization accuracy.

Management is then shown a graphical representation of the estimation outcomes. For each product group, the market share is plotted as an (estimated) function of each marketing variable, assuming the other variables remain at their reference level. The graphs also indicate the subjective data points.

Figure 1 shows the estimated market share relationships for group 3, and figure 2 for group 4. We see that in both cases there is a very close fit between the model and the data.

[13] We should observe that x_1, x_2, x_3, x'_1, x'_2, x'_3 are not fixed but will be determined as a function of the range in the past and will also take into account possible future values. For example, if management is planning a 50% price increase, the range covered by the subjective data generation should contain this 50% increase.

It should be noted that the same quality of fit was not obtained for each group and would not be in each of the countries. Take, for example, the estimated market share functions in figure 3. They relate to group 5. Whereas the estimated market share–relative marketing spending and market share–relative value still shows a reasonable fit, something is definitely wrong with respect to the market share–relative price relation (curve 1 in figure 3c). We should of course realize that the market share functions are estimated on the basis of the 18 data points, and that we do not estimate separate market share functions on the basis of the six data points relative to each of the variables. Nevertheless it seems likely that the data point A in figure 3c is the main cause of our trouble and that there is some inconsistency in the manager's responses. After submitting the graphical representations to management it became immediately clear that the relation they had in mind was concave rather than convex. Point A was then re-estimated (and became point B), resulting in a concave market share–relative price function (curve 2), and also a better fit for the relative marketing resource and value functions.

In checking the quality of the subjectively estimated response functions we could for given past values of rp, rV and rb compare observed and predicted market shares.

For group 5, for example, the subjectively estimated market share response function is

$$m_{5t} = 0.565\left(\frac{3.068 + rp^{0.795}}{-0.402 + rp^{0.795}}\right) \times \left(\frac{-0.200 + rb^{0.382}}{2.134 + rb^{0.382}}\right) \times \left(\frac{-0.859 + rV^{0.255}}{-0.759 + rV^{0.255}}\right). \tag{2}$$

Table 1 shows real and predicted market shares. We notice substantial differences except for the most recent period. This is to be

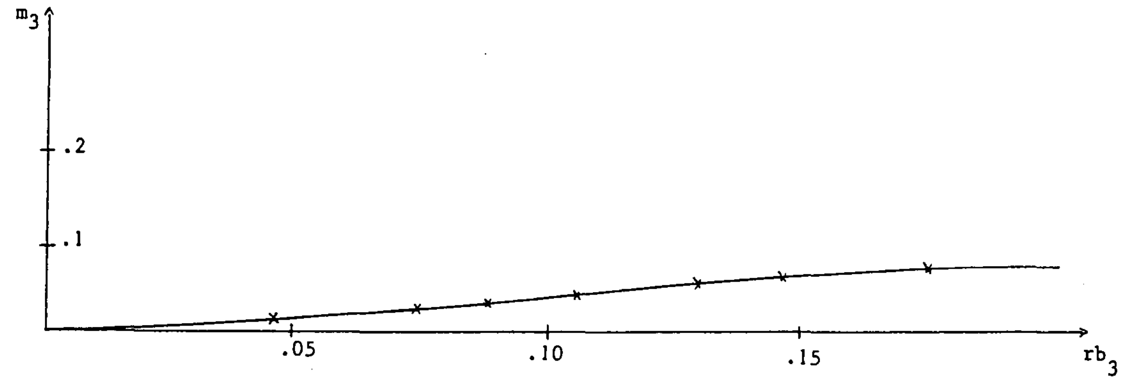

Figure 1a. Market share as a function of relative marketing spending (group 3).

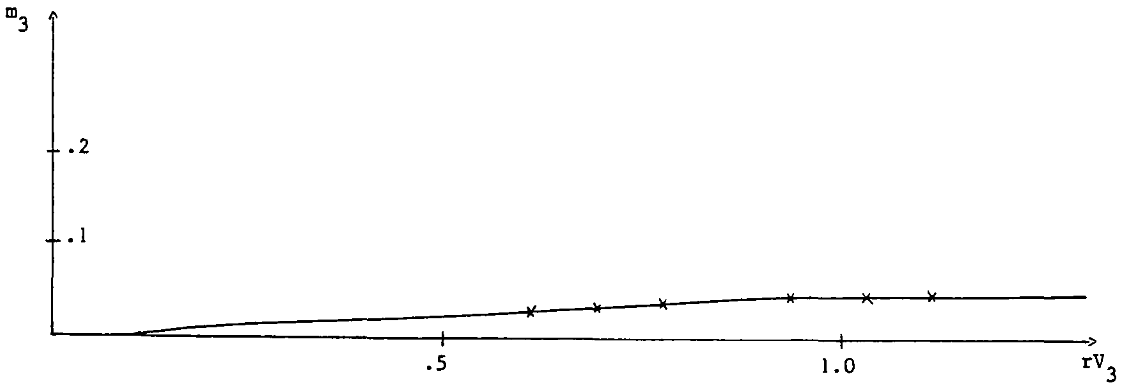

Figure 1b. Market share as a function of relative value (group 3).

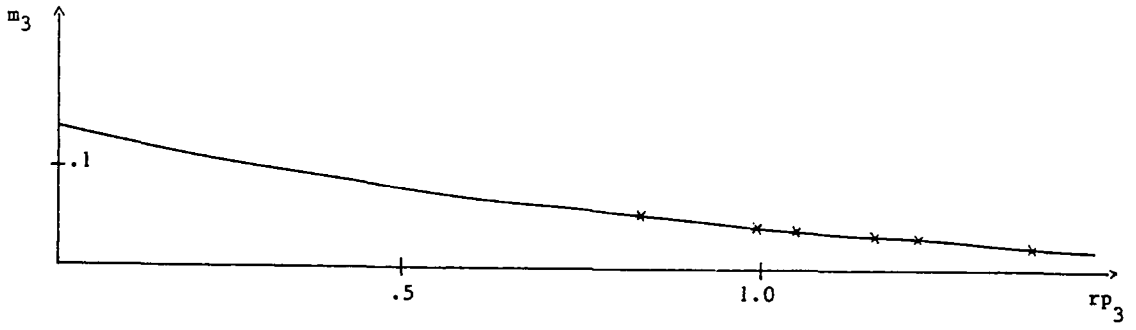

Figure 1c. Market share as a function of relative price (group 3).

expected, since the subjective estimates relate to the current and not to the past situation. We also notice that market share has grown over time. Given that the subjective model operates within the current capital of good-will, it is then natural that it overpredicts market shares in past periods when goodwill was substantially lower. The observed differences may in addition be partly due to the unreliability of the objective data – which is indeed considered by managers to be very large. For more recent periods, however, data have grown to be more reliable, and therefore the difference should be smaller. In any event, the differences are large and close future monitoring will be necessary to continuously confront objective values and subjective estimates.

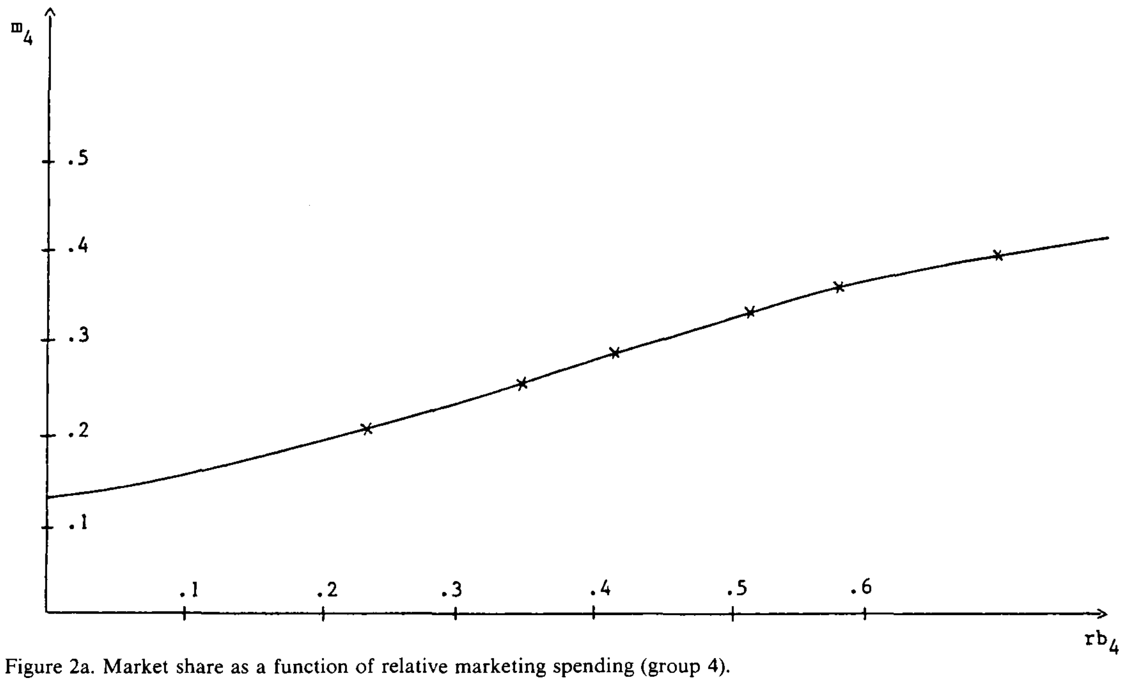

Figure 2a. Market share as a function of relative marketing spending (group 4).

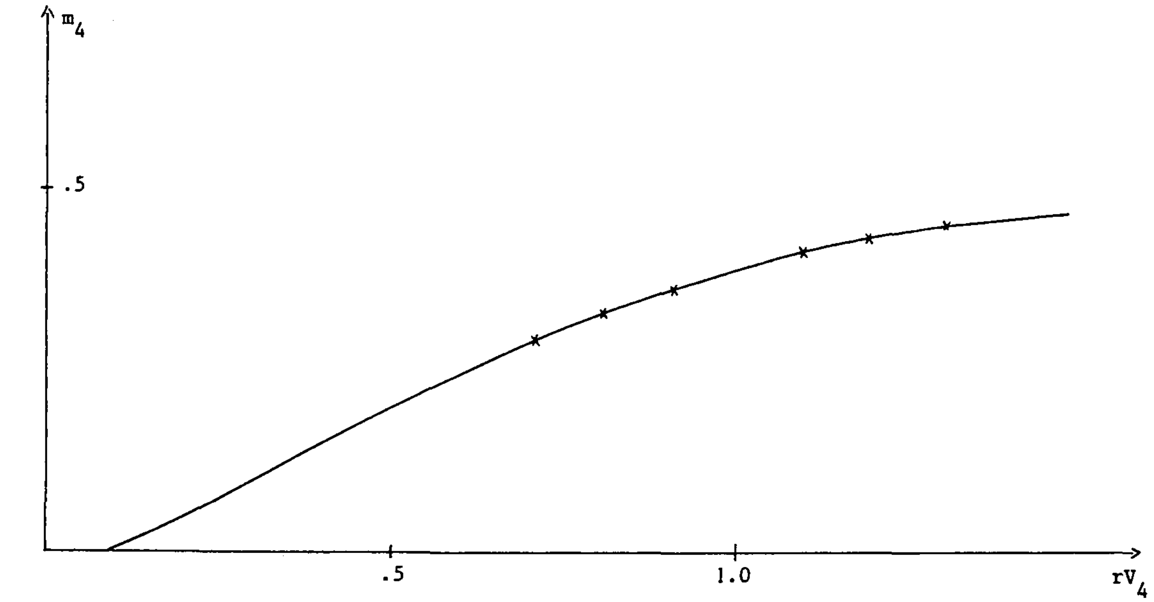

Figure 2b. Market share as a function of relative value (group 4).

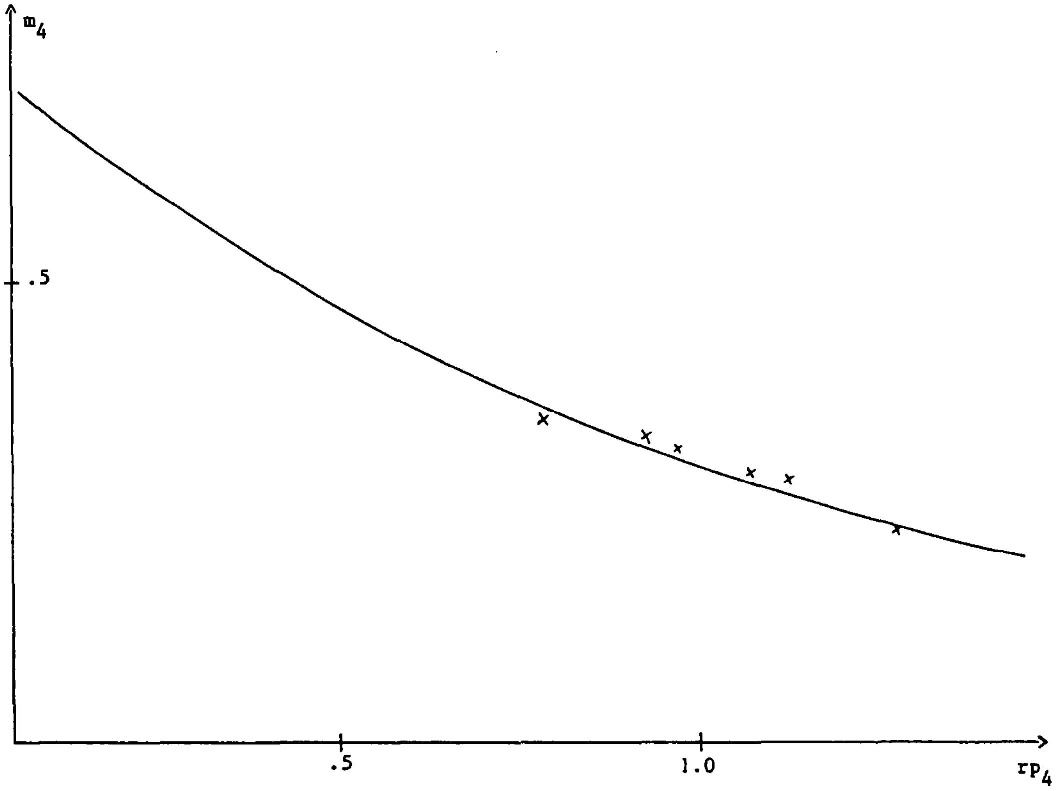

Figure 2c. Market share as a function of relative price (group 4).

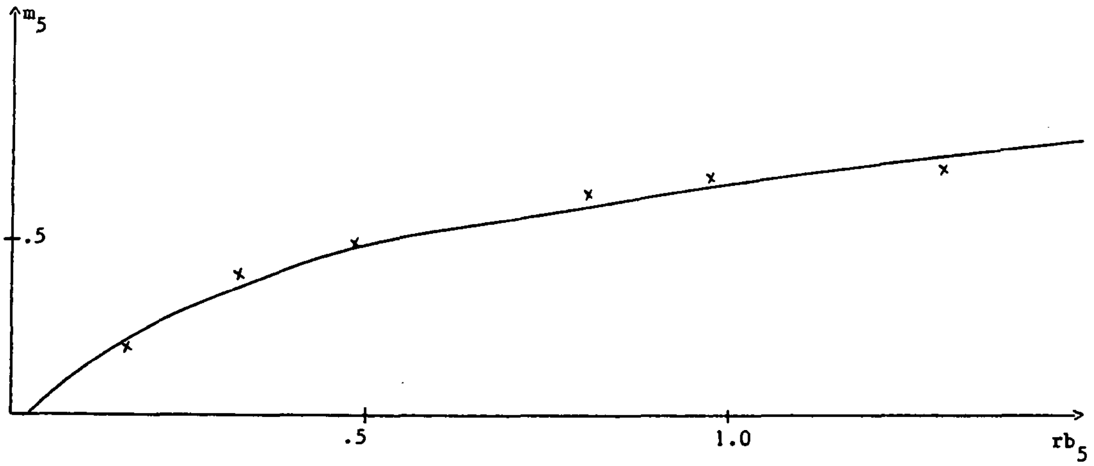

Figure 3a. Market share as a function of relative marketing spending (group 5).

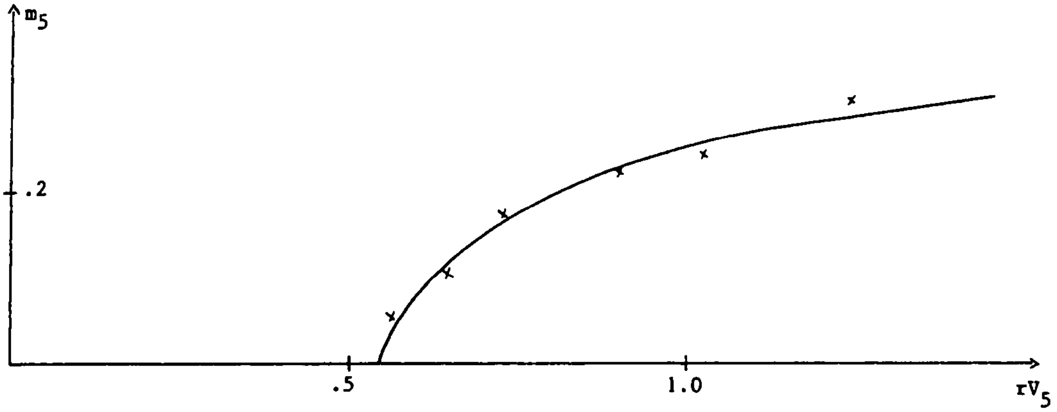

Figure 3b. Market share as a function of relative value (group 5).

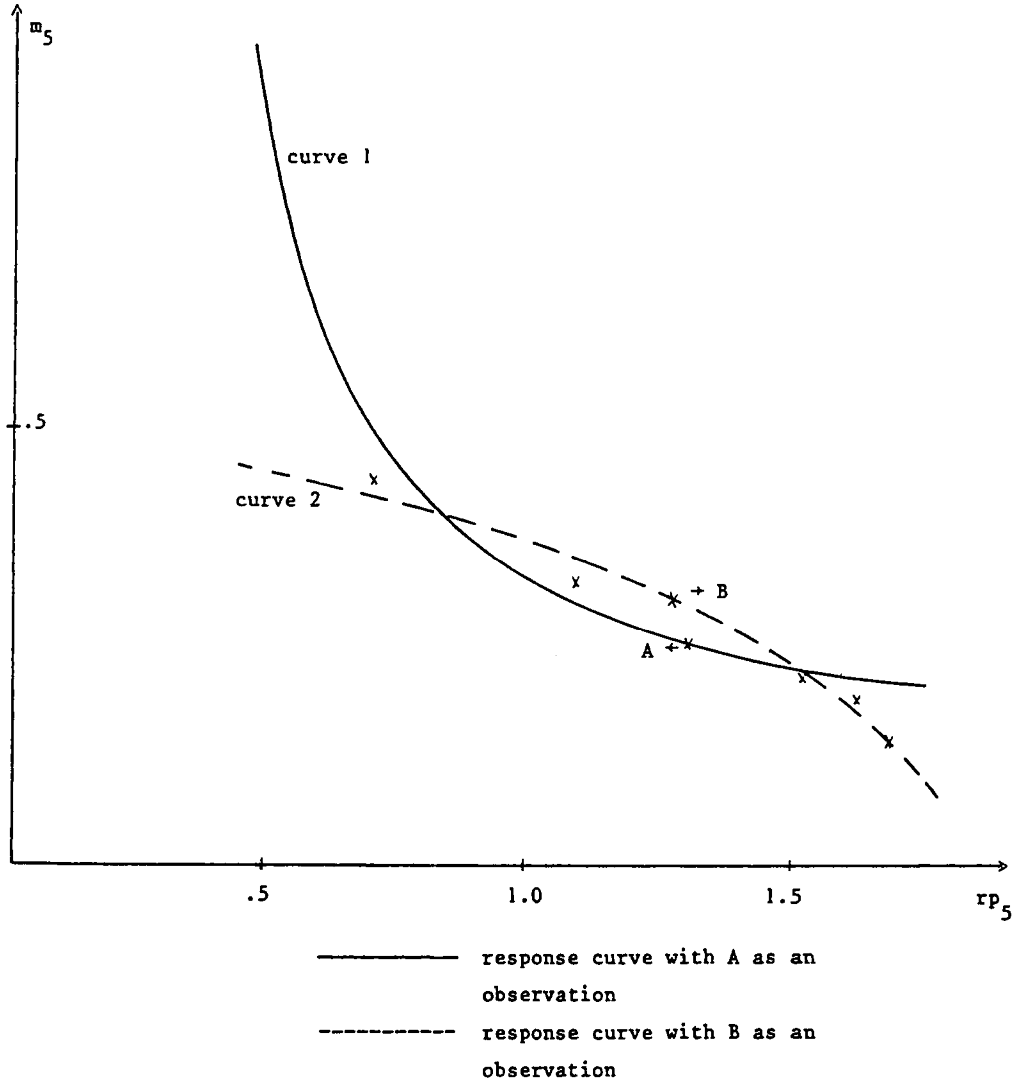

Figure 3c. Market share as a function of relative price (group 5).

Table 1
Group 5 observed and predicted market shares.

Year	Observed share	Predicted share
1975	0.240	0.414
1976	0.280	0.375
1977	0.285	0.393
1978	0.310	0.376
1979	0.320	0.359
1980	0.300	0.308

5. Resource allocation and benefits to local management

Given the estimated market share functions, as well as predictions for relative price, relative value, and competitive marketing effort, the market share–marketing spending relations for each group applicable in the multiproduct marketing resource allocation model can be established. One can also write each product group's profit π_j as a function of its marketing spending b_j. Figure 4 shows the profit function for group 3. We observe that profit is zero with $b_3 = 0$, corresponding to the fact that market share is then expected to be zero (see figure 2a) and that profit is increasingly negative as b_3 increases. This points to the fact that in this product category no sales can materialize without having a sales force. Figure 4 also shows the lower limit b_{31} that is needed to satisfy the constraint that market share m_3 must be at least 3.5 percent (i.e., $l_3 = 0.035$). That is, the local company is forced to invest in product group 3 although this contributes negatively to country profit. We should also realize that the influence on total country profit will be larger than what is shown in figure 4, because the amount b_{31} could have been profitably invested in another

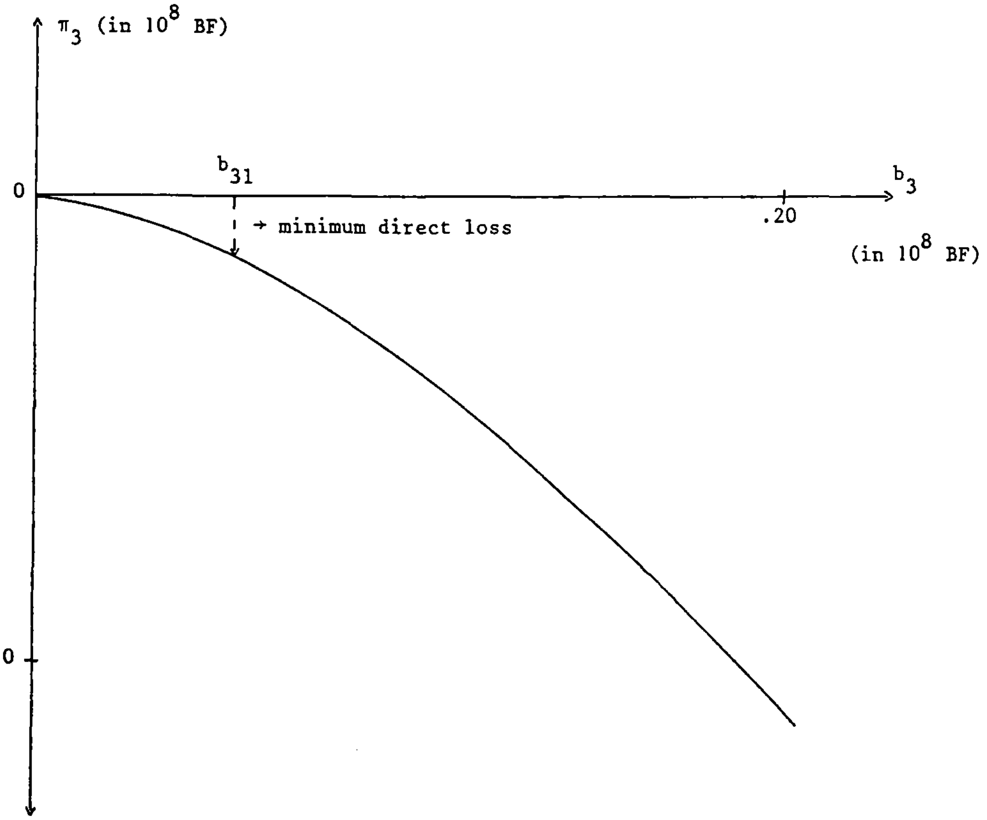

Figure 4. Product group profit as a function of marketing effort (group 3).

product group. In other words, we should also take opportunity costs into account. That is, in fact, what a global optimization model does, as we will see below in discussing the benefits of the model.

Figure 5 shows the profit function for group 4. With lower and upper market share bounds l_4 and u_4, minimum and maximum marketing effort would be b_{4l} and b_{4u}. The curve shows that taken separately, product group 4 profit would be maximized with $b_4 = b_4^*$, but that cannot be reached because of the maximum share constraint. Again, given a binding total budget constraint, b_4^* may not be the optimum in an overall maximization.

Given a total budget available to the management of a particular country (either a first indication from the corporate headquarters of what will be available, or a level proposed by the local management), and given production or transfer price costs, and upper and lower market share constraints, a non-linear optimization routine is applied to yield values for b_1 to b_5 that yield a maximum profit for the next budget period.

Of course, one should be careful in blindly accepting this analytical optimum as the best possible company policy. As is the case for all models, the validity of the obtained results depends, among other things, on the quality of the model inputs, which may be uncertain. In addition, some strategic constraints may be hard to quantify.

The ultimate budget proposal will therefore

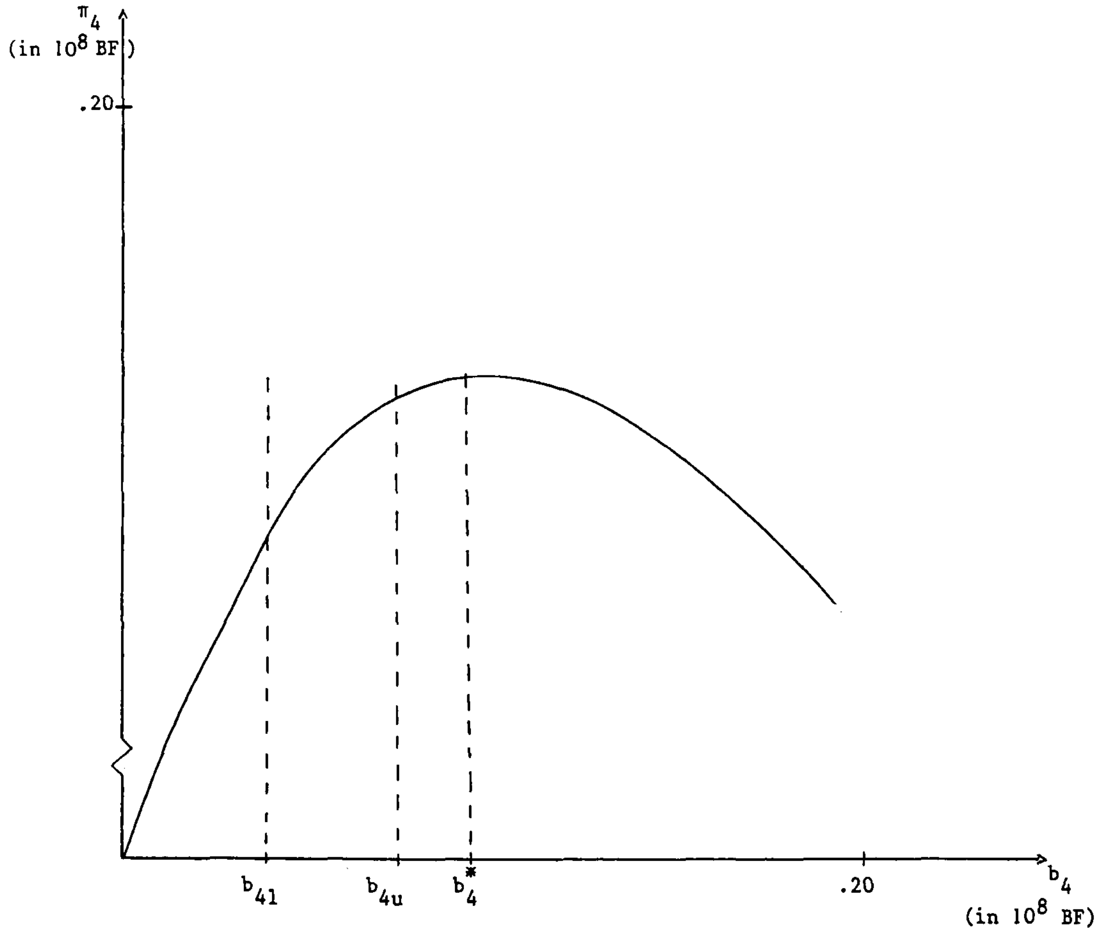

Figure 5. Product group profit as a function of marketing effort (group 4).

be a blend of results provided by the model and qualitative insights and constraints not represented in the mathematical structure.

We end this section by discussing some of the benefits of this kind of short term resource allocation model to local management.

First of all, it forces more systematic thinking before submitting a budget proposal. This should lead to a better understanding of the relation between market results and the various marketing factors affecting these results.

Secondly, it provides information processing support in preparing budget allocation proposals.

Thirdly, through the constraints it guarantees that the local allocation decisions are compatible with higher level objectives and programs.

Another potential use of the model by local (and by corporate) management is the examination of the sensitivity of total profit to the market share constraints. Figure 6 shows total profit for four levels of l_3, the lower bound on group 3 market share. As expected from what we saw in figure 4, profit goes up as l_3 goes down. Note that the difference in profit between $l_3 = 0.035$ ($\pi = 26.65$ million BF) and $l_3 = 0$ ($\pi = 35.2$ million BF) is larger

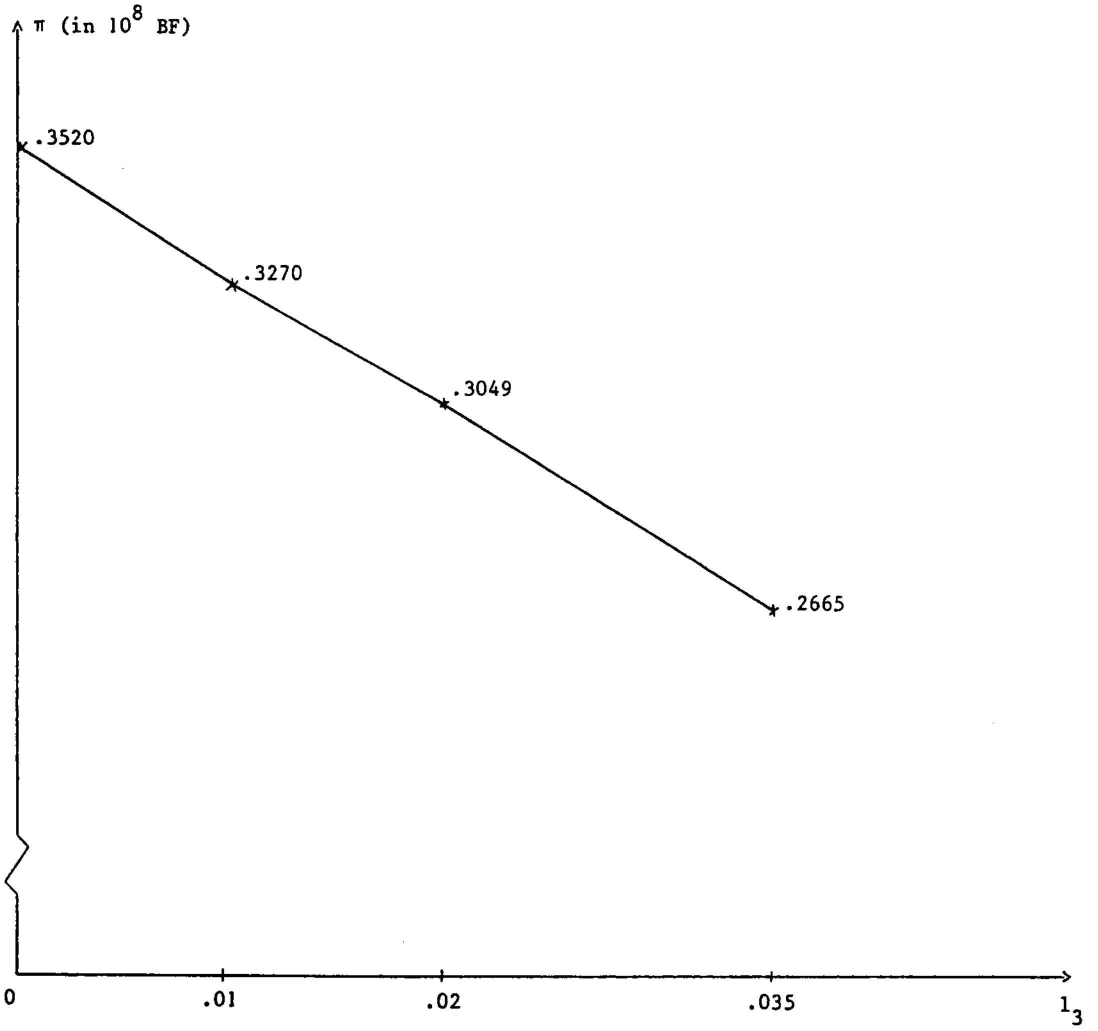

Figure 6. Total profit as a function of the lower bound on group 3 market share (l_3).

than what appears from looking at figure 4. As already pointed out when discussing figure 4, this is explained by the fact that reallocating marketing resources from group 3 to profitable groups not only reduces the losses of group 3, but increases the profit in (some of) the other groups. Local management can use this information for demonstrating to corporate management how local short term profit is affected by the market share constraint. In other words they can show their short term opportunity cost.

The above considerations may also have portfolio implications with respect to a country or with respect to the company as a whole. We will come back to this point when discussing benefits to top management in the next section.

The decision linkage described thus far takes the following form: top management sends down information (constraints) with respect to budget availability and market share requirement. Local management, using the model, responds by communicating (rational) budget proposals to the top level. Given this process of information exchange, however, top management is still confronted with the problem of allocating overall company marketing resources to different countries, and of formulating market share requirements. In the next section, we show how the top level can extract valuable information for its own decision problems from the local level model. [14]

6. Decision linkage – benefits to corporate management

The first obvious advantage is that local budget proposals become more meaningful because they now have some rationale behind them.

[14] Top down and bottom up approaches are discussed by Day (1981), who explicitly considers the problem of market definition in this context.

But there is clearly much more. If corporate management is to allocate overall company resources to different countries each year, it should at least have an idea of the marginal profit contribution of each local company. In other words, it is the aggregate effect that is of interest, not the details of how it is arrived at. The local company model can be used to produce such aggregate profit function.

For each of a number of marketing resource levels B, the model can generate the corresponding total local company profit, assuming optimal resource allocation. Figure 7 shows the result of this procedure for 5 levels of B under the assumption that $l_3 = 0$. The currently available budget is 20 million BF, and 12.5 million is the minimum budget necessary to satisfy the lower market share bounds (for groups other than 3).

Beyond 36 million BF, B is no longer binding and total profit remains constant at a level of 41.6 million BF. For the current budget of 20 million BF profit is 35.2 million BF. Increasing the budget by 10 million BF results in a profit of 40.2 million BF, or at the margin, a million BF invested in that country brings in an additional net profit of 0.5 million BF. The profit function picture – and therefore the marginal profit contribution – is only approximate in the sense that five points are connected by straight lines. We can of course get as fine an approximation as we want by considering a large number of levels for B.

The points obtained can also be looked upon as 'data points', generated by the local model, through which a continuous function $\pi = f^*(B)$ can be fitted. A specification is suggested by the data points and also based on managerial judgment. For the country considered, an S-type curve was estimated, giving: [15]

[15] π and B are expressed in 10^8 BF.

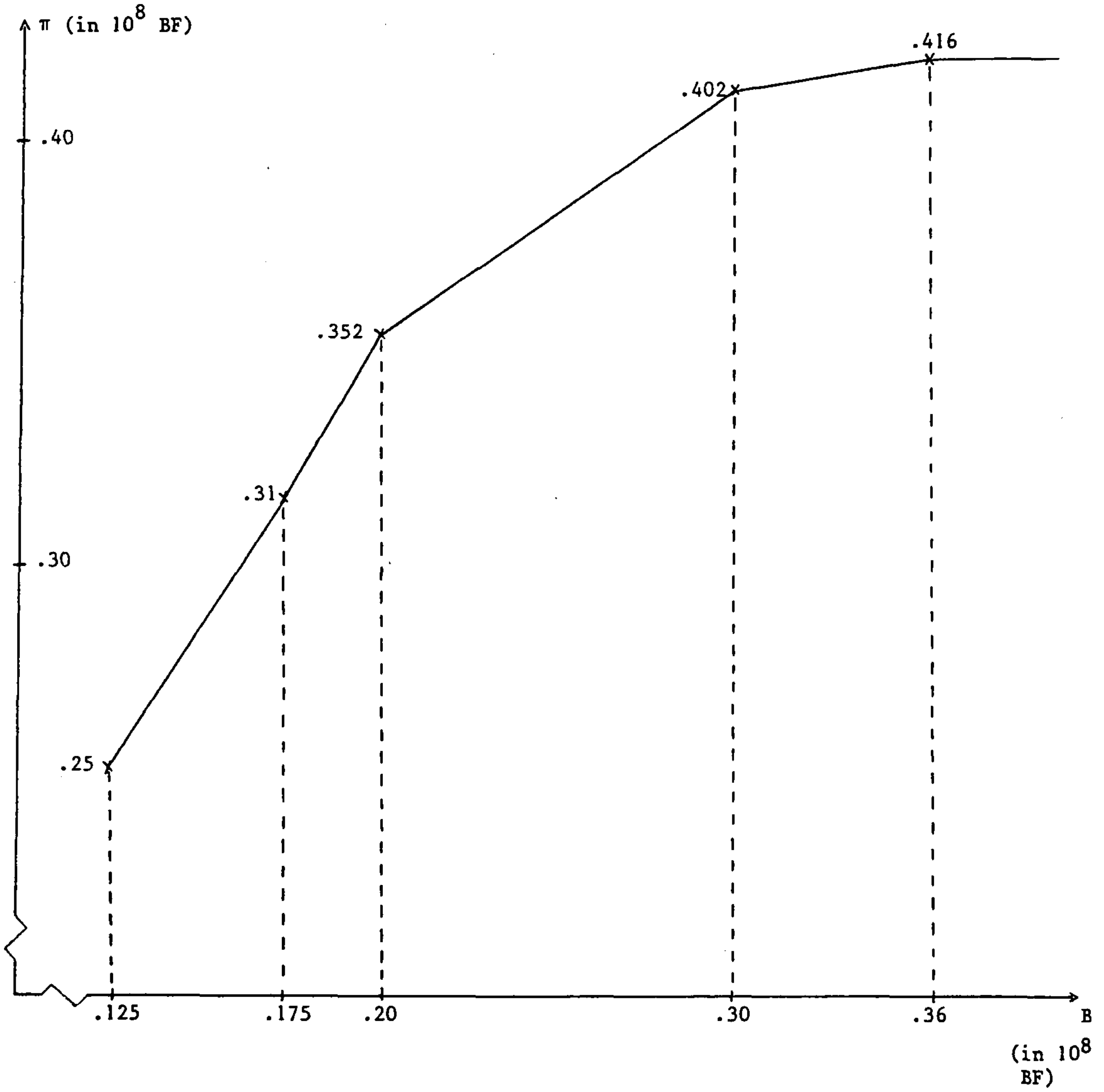

Figure 7. Total profit as a function of the total budget allocated to a country.

$$\pi = \hat{\alpha}\frac{\hat{\beta} + B^{\hat{\delta}}}{\hat{\gamma} + B^{\hat{\delta}}}, \tag{3}$$

with[16] $\hat{\alpha} = 0.416$, $\hat{\beta} = 0.0000076$, $\hat{\gamma} = 0.0000126$ and $\hat{\delta} = 6.723$.

For our analysis, data are obtained in only one of the local companies, for which the estimated aggregate profit function is shown in figure 8 (curve 1)

[16] The upper limit was not estimated but fixed at 0.416.

When fully implementing the model in practice, similar total profit/total budget functions can be obtained for other local companies. This type of relationships constitutes important bottom-up information. Indeed, in the company considered, the top level allocation problem can now be formulated as

$$\max_{B^c} \sum_c^C \pi^c = \sum_c^C f^{*c}(B^c),$$

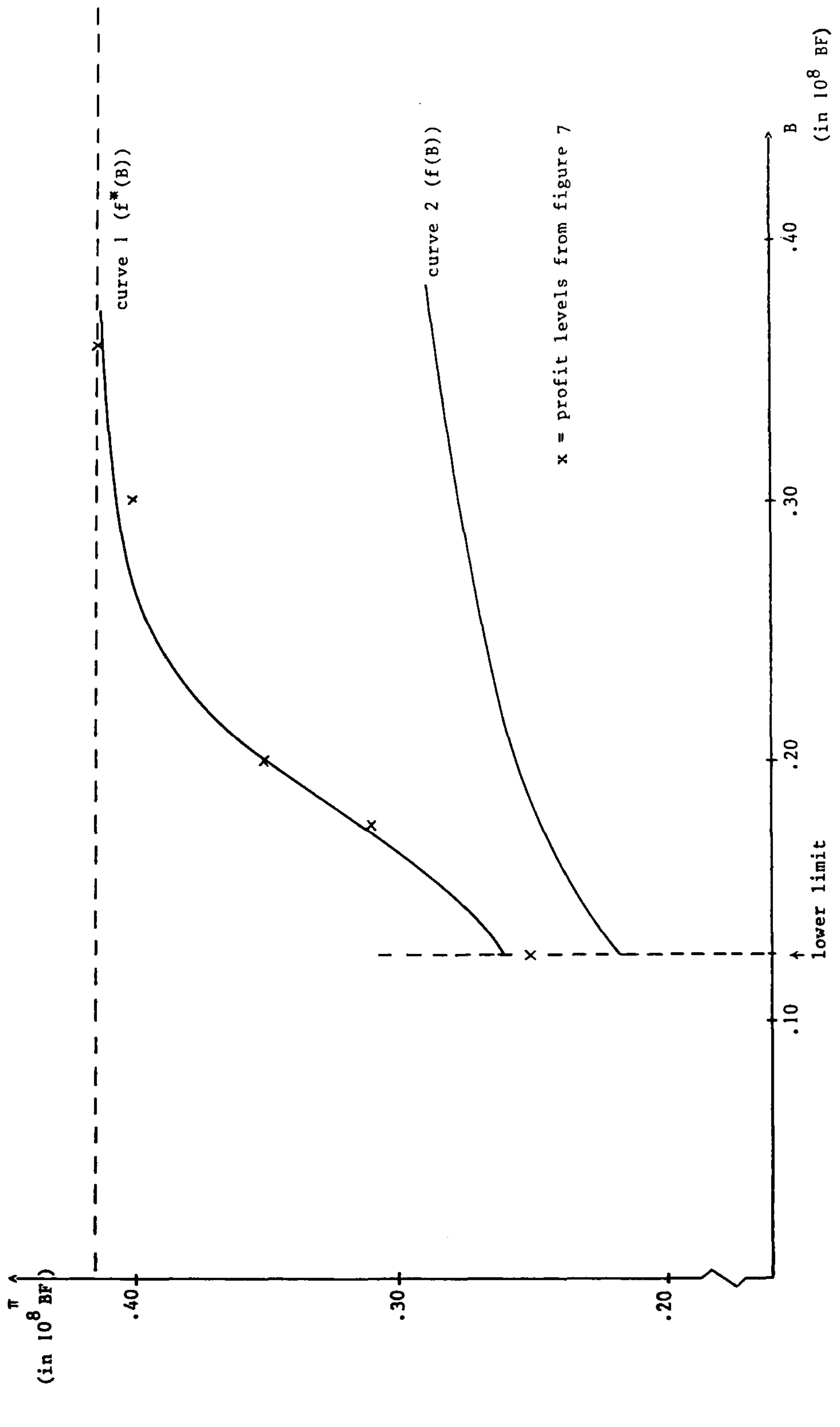

Figure 8. Estimated total profit function (curve 1) and proportional allocation profit function.

subject to

$$\sum_c^C B^c \leqslant TB,$$

$$(B^c)_1 \leqslant B^c \leqslant (B^c)_u, \quad \forall c\text{: 1 to } C,$$

where

$\pi^c =$ $f^{*c}(B^c)$ = the total profit/total budget function found for local company (= country) c,

$C =$ number of local companies,

$TB =$ company marketing resources to be allocated in the planning year,

$(B^c)_1, (B^c)_u =$ lower and upper bound on B^c, budget allocated to country c.

These bounds are necessary to guarantee feasibility of the resulting lower level problems, given their market share constraints. For example, as indicated before, for the local company whose profit function is shown in figure 7, $(B^c)_1 = 12.5$ million BF, that is, the minimum amount necessary to satisfy all minimum level market share constraints. It should be clear that $(B^c)_1$ and $(B^c)_u$ can also reflect other strategic considerations such as wanting to spend a minimum amount in a country that has only recently been entered. In addition the corporate budget allocation model could also contain other types of long term constraints and objectives, which have not been focused upon here.

Given the total profit/total budget functions for each country and given the various constraints, the problem can now be solved to yield optimal budgets B^{c*}. These can then represent the 'final' top-down budget constraints communicated to the local companies.

We will illustrate the process for the case of two local companies. For the first one we had

$$\pi^1 = 0.416\frac{0.0000076 + (B^1)^{6.723}}{0.0000126 + (B^1)^{6.723}},$$

with constraints $(B^1)_1 = 0.125$ and $(B^1)_u = 0.36$.

Since no data are available to us on other local companies, we introduce some hypothesized relationships and constraints to represent the second country,

$$\pi^2 = 0.4\frac{0.00067 + (B^2)^3}{0.01 + (B^2)^3},$$

with constraints $(B^2)_1 = 0.10$ and $(B^2)_u = 0.55$.

Assuming an overall budget TB equal to 0.7 (also expressed in 10^8 BF), the following optimal local company budgets are obtained:

$$B^{1*} = 0.293 \quad \text{and} \quad B^{2*} = 0.407,$$

giving an overall profit of 0.7823 or 78.23 million BF.

Since, in this case, only the total budget constraint is binding at the optimum, the solution – $B^{1*} = 0.293$ and $B^{2*} = 0.407$ – implies equal short term marginal profit contributions for each of the countries.

The process of 'generating' the functions $\pi^c = f^{*c}(B^c)$ through local level sensitivity analysis has the important advantage of dealing with the problem of suboptimality, which would otherwise occur in the hierarchical resource allocation structure. The reason for this advantage is that the $\pi^c = f^{*c}(B^c)$ relationships not only implicitly summarize the 'detailed' (product group-related) local problem characteristics (i.e., relative price, relative value, competitive marketing effort, market size and gross margin for each product group in the country) and constraints, but also imply an 'optimal' allocation of the local budget, given these characteristics in the planning year. [17]

To show the benefits of the model building effort even more clearly, we have represented in figure 8 [$f(B)$ curve 2] the relation between local company profit and budget, given the same subjectively generated response func-

[17] This property is indeed sufficient to overcome suboptimality in budget allocation for the given problem. See, for example, Geoffrion (1970) or Silverman (1972).

tions that have been used in determining curve 1 $[f^*(B)]$, but assuming that the budget is allocated to product groups proportional to the allocation used in the reference period and without worrying about market share constraints. It can be seen that $\pi = f(B)$ exhibits a meaningfully lower profit value for a given budget than its counterpart $\pi = f^*(B)$. This indicates that, given the current local problem characteristics, applying past budgeting allocation practice results in very substantial suboptimization and leads to a serious underestimation of the real profit potential of the country in the planning period, even if this potential is squeezed by more severe market share constraints. For example, from figure 8 we can see that for the present local budget $B = 20$ million BF, optimal profit is about 35 per cent higher than the profit resulting from applying the reference allocation scheme.

Since the degree of underestimation of profit potential will vary among countries, these relationships will lead top management to suboptimal allocation to local companies. Use of the 'constructed' functions $f^{*c}(B^c)$ avoids this problem.

To end this section we indicate a few additional uses of the model at the corporate level. We already indicated, when discussing benefits to the local management, the possibility of calculating opportunity cost of the various market share constraints. This should obviously be valuable information at the corporate level as well. Such information can, as indicated, have portfolio implications. For example, the company has recently decided to discontinue product group 3 in the country for which the results were presented in this paper, and is presently considering divesting the product group worldwide.

As a final example of corporate level use of the model, one may consider the upper bounds on market share. In case such bounds are based on scarcity in production capacity, profit implications of relaxing upper bound constraints may be an element in making capacity expansion decisions.

7. Conclusions

This paper has described a short term marketing resource allocation model and its relation to decisions to be made at a higher level in the organization. As such it has provided a link between decisions at different levels in the organization. Limitations of the model and the approach have been presented throughout the text and need not be repeated. Two points, however, deserve our special attention.

We should be aware that the results are based on estimated response functions. Sensitivity of the solution to variations in the uncertain parameters is therefore advisable. In addition continuous confrontation of estimated results with real observations is a must. Such confrontation will over time lead to more confidence in the results and to adaptation of parameters and model structure as necessary.

We should also recall that the linkage between organization levels takes the form of a feedback process, where local managers provide information as to what the best performance would be under various conditions, characterized by corporate constraints, and top management uses this information to decide upon these constraints, given a set of strategic objectives.

In developing hierarchically linked models for more complex problem situations, involving many decisions and covering several periods, we will have to face, in a more challenging way than was the case here, the trade-off problem of model completeness and tractability.

Appendix

Each module in specification (1) is based on the following expression:

$$\left[\eta_{1i}+(\eta_{2i}-\eta_{1i})\frac{X_{ji}^{\eta_{4i}}}{\eta_{3i}+X_{ji}^{\eta_{4i}}}\right], \qquad (A.1)$$

which can be rewritten as

$$\eta_{2i}\frac{((\eta_{1i}\eta_{3i})/\eta_{2i})+X_{ji}^{\eta_{4i}}}{\eta_{3i}+X_{ji}^{\eta_{4i}}}. \qquad (A.2)$$

Equations (1) and (A.1) [or (A.2)] are then related as follows:
$rp_j = X_{j1}$, $rb_j = X_{j2}$, $rV_j = X_{j3}$, $\gamma_2 = \eta_{31}$, $\mu_2 = \eta_{32}$, $\epsilon_2 = \eta_{33}$, $\alpha = \prod_{i=1}^{3}\eta_{2i}$, and γ_1, μ_1 and ϵ_1 is $(\eta_{1i}\eta_{3i}/\eta_{2i})$ for $i = 1$, 2 and 3 respectively.

We notice that (1) contains only 10 parameters, whereas multiplying three indices such as (A.1) or (A.2) contains twelve parameters. This is simply because after multiplication, only ten of the twelve parameters remain identifiable. Only the product of η_{21}, η_{22} and η_{23} can be identified and not the three parameters separately.

References

Abell, D., J. Hammond (1979), *Strategic market planning.* Englewood Cliffs, NJ: Prentice Hall.

Bell, D.E., R.L. Keeney, John D.C. Little (1975), A market share theorem. *Journal of Marketing Research* 12, May, 136–141.

Bultez, Alain (1975), *La firme en concurrence sur des marchés interdépendants.* Unpublished doctoral dissertation, Université Catholique de Louvain.

Chandon, Jean-Louis (1981), *Identification of product market opportunities.* Paper presented at Intensive Advanced Course in Marketing: Corporate Diversification and Management of the Industrial Innovation Process, European Institute for Advanced Studies in Management, Nov. 16–9.

Corstjens, Marcel, David Weinstein (1982), Optimal product–market portfolio analysis. *Management Science.*

Day, G. (1981), Strategic marketing analysis and definition; An integrated approach. *Strategic Management Journal* 2, 281–299.

Desmet, Pierre (1981), *Optimisation des politiques promotionnelles de l'entreprise pluri-productrice.* Unpublished doctoral dissertation, Université de Lille.

Geoffrion, A.M. (1970), Primal resource directive approaches for optimizing nonlinear decomposable systems. *Operations Research* 18, May/June, 375–403.

Gijsbrechts, Els (1981), *Multiproduct marketing models: The state of the art.* Working paper no 81-45, European Institute for Advanced Studies in Management, Nov.

Gijsbrechts, Els (1982), *Problems and potential of multiproduct marketing model building.* Ninth International Research Seminar in Marketing, Aix-en-Provence.

Gijsbrechts, Els (1983), *Hierarchical approaches to large scale organizational problems: An overview.* Working paper 83-89, UFSIA, CBB, Antwerp.

Kotler (1971), *Marketing decision making: A model building approach.* New York: Holt, Rinehart and Winston.

Lambin (1975), *Advertising competition and market conduct in oligopoly over time.* Amsterdam: North-Holland.

Larréché, Jean-Claude, S. Srinivasan (1981), STRATPORT: A decision support system for strategic planning. *Journal of Marketing* 45, Fall, 39–52.

Larréché, Jean-Claude, S. Srinivasan (1982), STRATPORT: A model for the evaluation and formulation of business portfolio strategies. *Management Science* 28, Sept., 979–1001.

Little, John D.C. (1975), BRANDAID: A marketing mix model. *Operations Research* 23, July–Aug., 628–673.

Lodish, Leonard M. (1982), A marketing decision support system for retailers. *Marketing Science* 1, no 1, Winter, 31–56.

Naert, Ph., E. Gijsbrechts (1984), *A decision support system for allocating marketing resources to products and product groups.* Working paper 84-97, UFSIA, CBB, Antwerp.

Naert, Ph., Peter Leeflang (1978), *Building implementable marketing models.* Leiden/Boston: Martinus Nijhoff.

Naert, Ph., Marcel Weverbergh (1981a), Subjective versus empirical decision models. In: Randall Schultz and Andris Zoltners, *Marketing decision models*, ch. 5, 99–123. Amsterdam: North-Holland.

Naert, Ph., Marcel Weverbergh (1981b), On the prediction power of market share attraction models. *Journal of Marketing Research* 18, May, 146–153.

Naert, Ph., E. Gijsbrechts, M. Weverbergh (1983), Een beslissingsondersteuningssysteem voor het alloceren van marketing middelen in een multiproduktonderneming. *Bedrijfskunde*, Sept.

Picconi, M.J., Ch.L. Olson (1978), Advertising decision rules in a multibrand environment: Optimal control theory and evidence. *Journal of Marketing Research* 15, Feb., 82–92.

Silverman, G. (1972), Primal decomposition of mathematical programs by resource allocation, Part I and II. *Operations Research* 20, 58–93.

Von Hippel, Eric (1978), Successful industrial products from customer ideas. *Journal of Marketing* 42, Jan., 39–49.