STRATPORT: A MODEL FOR THE EVALUATION AND FORMULATION OF BUSINESS PORTFOLIO STRATEGIES

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STRATPORT: A Model for the Evaluation and Formulation of Business Portfolio Strategies[#]

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ABSTRACT

A decision support system to evaluate and formulate business portfolio strategies is proposed. Strategies are expressed in terms of market share objectives to be achieved in each of the N business units in the portfolio. STRATPORT evaluates a strategy in terms of its long-term discounted profit as well as its short-term net cash flow implications. Risk considerations are incorporated as per the Capital Asset Pricing Model. The model explicitly considers marketing investment, capacity expenditures, working capital and the impact of "experience" on costs and revenues over a time horizon. The formulation of strategy is accomplished by maximizing long-term profit subject to a short-term net cash flow limit, with the maximization repeated over a range of values for the short-term net cash flow limit. The use of the Generalized Lagrange Multiplier Method permits the simultaneous optimization of N market shares to be accomplished more efficiently by N univariate maximizations. Although the function that is maximized in the univariate maximization is not unimodal, the newly proposed procedure guarantees that a global maximum will be found. The proposed approach can also be interpreted broadly as a decentralization mechanism for the multi-unit firm.

1. Introduction

The long-term profitability and survival of any multi-unit firm critically depends on the corporate strategy adopted by the firm in the allocation of resources to its current business units (BU) as well as to potential new business units. A key aspect of the firm's corporate strategy can be expressed in terms of market share objectives to be achieved for the different BU's in the portfolio. The purpose of this paper is to provide a framework and a method within which alternative portfolio strategies can be evaluated for their impact on long-term profitability vis-à-vis the short-term financial resources needed to achieve the strategic objectives. The paper also provides a method to formulate portfolio strategies which maximize long-term profits for different values of the short-term net cash flow limit.

A decision support system named STRATPORT (for STRATegic PORTfolio planning) has been developed to aid managers in the evaluation and formulation of business portfolio strategies. After interactively providing inputs based on data analysis and/or subjective judgment to various components of the model, the manager can evaluate proposed portfolio strategies and/or formulate improved strategies corresponding to different resource levels. The robustness of promising strategies may then be analyzed under specifications of alternative scenarios regarding the market place and the competition. The robust strategies so identified should then be investigated concerning other aspects not considered in the present framework. We hope this process will aid management in the development of a sound overall portfolio strategy articulated in terms of broad changes in the competitive position of the firm in the different BU's.

In Section 2, we provide a brief review of previous research on business portfolio strategies and relate it to the present approach. Section 3 provides an overview of the approach which is elaborated in Section 4 (Components of the Model), Section 5 (Evaluation of Portfolio Strategies) and Section 6 (Formulation of Portfolio Strategies). The limitations of the model and some potential extensions are discussed in Section 7. An illustrative use of the STRATPORT computer model is provided in [16].

2. Previous Research

The concept of a business portfolio has received substantial attention in the management literature in recent years. As this literature has been reviewed elsewhere [3, 4], the discussion below is admittedly brief. The notion that market share is a critical determinant of profitability has been empirically demonstrated in the PIMS Studies [5]. It also follows from the concept of "experience effects," empirically demonstrated by the Boston Consulting Group (BCG) [2] and others [28]. Market growth, on the other hand, has implications for profitability (through experience effects), cash flow and the likely nature of competition [2]. In the business portfolio approach pioneered by the BCG [13], each product is classified into one of the four quadrants of a (2 x 2) matrix based on market growth (high and low) and market share (high and low relative to leading competitor). Inferences made on the cash flow and profitability of the different quadrants are used to develop a balanced portfolio strategy. The market growth and market share variables are generalized in other approaches into more elaborate dimensions such as "industry attractiveness" and "company strength" [6], or "sector profitability" and "company's competitive capabilities" [24]. The position of a BU on these dimensions is qualitatively determined from a number of market, competitive, environmental and internal factors. Approaches to portfolio strategy formulation based on these concepts are being developed by corporate planning groups, e.g. [7] and are being advocated by the $100 million industry of corporate strategy consultants [14]. Critical appraisals of the business portfolio analysis approaches may be found in [6, 9, 32].

As in the previous research, the present approach incorporates the concepts of experience effects and the resulting relationship of market growth and market share to profitability. However, there are several major differences from previous research. Probably the most important difference is that while all the above approaches are qualitative in nature, the present model quantifies the long-term profit as well as short-term cash flow implications of a proposed portfolio strategy. The quantification allows one to employ computational methods to develop improved strategies. The quantification process also provides more flexibility to incorporate alternative concepts and assumptions. For instance, Day [9, p. 31] has observed that the BCG approach emphasizes relative profitability in comparison to competition while absolute profitability should be the more important consideration. The present approach avoids this problem by directly working with absolute profitability while still incorporating the competitive cost advantage obtained through experience effects on cost and price behavior. Furthermore, the previous approaches assume as truisms some propositions which have not been adequately empirically tested. For instance, there is an implicit assumption in the BCG framework that it is easier to gain market share in high growth markets. While this seems plausible from a competitive reaction point of view, an empirical study based on the PIMS data base [15] did not find the cash costs of gaining market share to vary substantially between moderate and rapid growth markets. Wensley [32] speculates that it may be the rate of change of technology (and not the correlated market growth rate, per se) that is important in this context since the firm can gain a competitive edge by investing in the latest technology. For such reasons, it seems highly desirable that management of the firm be given flexibility in stating as to how easy or difficult it is to gain market share in each of the business units rather than making the results predetermined solely by market growth rates; this is the approach followed in the proposed decision support system. In this sense, the present approach can be thought of as extending and operationalizing current portfolio approaches. In particular, the previous portfolio approaches force the manager to think about several factors which are relevant in assessing the market response function used in the present formulation (relating marketing investment to market share).

3. An Overview of the Model

Before describing the overall structure of STRATPORT, several general points need to be emphasized:

i) STRATPORT is a strategic decision support system which means that the concern here will be with strategic decision variables such as market share and overall marketing expenditures and not with tactical variables such as consumer and trade promotions, product line extensions, advertising campaigns or personal selling expenditures. While the tactical concern is on the allocation of resources <u>within</u> a BU, our strategic concern is on the allocation <u>across</u> BU's.

ii) The primary emphasis of STRATPORT is on portfolio strategy. It is not a comprehensive corporate strategy model in that basic R and D, personnel, manufacturing or financial policies (e.g., debt/equity, dividend) are not explicitly addressed. However, the implications of portfolio strategies for product development, capacity expenditures, production costs and revenues are taken into account.

iii) The firm is viewed as a portfolio of business units (BU's). The delineation of the BU's is a difficult managerial choice [9]. The BU's should, as far as possible, exhibit little cross-experience effects, i.e., "experience" in one BU should have little effect on the unit costs in some other BU. To provide a realistic assessment of the market response function (effect on market share of marketing expenditure in a BU), the definition of BU's should, as far as possible, be consistent with customer-based product-market definitions [10]. (Throughout, the term "product" is used more generally to include services as well.) The BU's should exhibit little cross-marketing effects. Consequently, a product-market should belong to only one BU. To minimize cross-experience effects, it may be necessary to group some product-markets (involving basically the same product) into one BU. Our approach assumes that, the synergistic aspects across BU's remain roughly the same, i.e., are not much affected by the portfolio strategy. (This assumption can be relaxed to an extent as explained in Section 7.) Finally, the definition of BU's should be, as far as possible, consistent with the organizational structure, e.g., the profit responsibility for a BU should not rest with two different divisions.

In practice, it is unlikely that all the above conditions will be met simultaneously. Consequently, after defining the BU's in such a way as to minimize the violation of these conditions, one needs to explicitly consider the implications of the violations when interpreting the results of the analysis. Furthermore, the impact of alternative delineations of the BU's may be examined through sensitivity analysis.

iv) The focus of STRATPORT is on the allocation of financial resources to the BU's, since a well thought out allocation of resources is believed to be key to the long-term profitability of the whole firm.

v) To take into account the long-term nature of strategic planning while minimizing the complexity of the model, STRATPORT considers a planning period and a post-planning period which are common to all the BU's.[1] Changes in the market share are assumed to be accomplished during the planning period. The post-planning period does not involve any strategy changes; it is included only from the point of view of capturing the long-term profitability implication of the strategy implemented during the planning period. Consequently, market shares are treated as if they remain constant during the post-planning period. The planning period should be long enough to implement the strategies but short enough so that the lack of detailed period to period modeling of marketing investment and capacity expenditures does not induce much error into the analysis. The post-planning period should be long enough to capture most of the impact of the strategy but short enough from the point of view of obtaining meaningful data. Typically, the planning period will be from 2 to 5 years and post-planning period from 10 to 15 years. The planning process is such that during the next planning cycle, some portion of the current post-planning period will, in turn, become the planning period.

vi) STRATPORT has been designed as a decision support system. It is easy to use, interactive and flexible enough to incorporate changes rapidly. This is an essential requirement since the data inputs to STRATPORT will necessarily involve uncertainties and it is essential to be able to do many analyses under alternate assumptions regarding the market place and the competition.

Figure 1 provides an overview of the components of the model for a single BU and introduces some of the key notation in the paper. Note that time t is at the end of period t (usually measured in years, semesters or quarters). For flow variables such as cost, revenue and production, we indicate the starting and ending points in time. To illustrate, ${}_{t1}C_{t2}$ denotes the cost from t1 to t2 with the convention that ${}_{0}C_{t2}$ is abbreviated as C_{t2}. The marketing expenditures E spent

FIGURE 1 ABOUT HERE

during the planning period change the market share from m_0 at the beginning of the planning period to m_T at the end of the planning period, with intermediate values $\{m_t\}$ specified in terms of m_T and m_0. (The market shares $\{m_t\}$ are defined on the basis of units sold and not on the basis of dollar sales.) As explained under (v) above, market share stays constant at m_T during the post-planning period. However, to maintain the market share at m_T, ${}_{T}H_{S}$ marketing dollars are spent during the post-planning period. The terms E and H incorporate marketing expenditures on items such as development and introduction of new products, advertising, promotion and personal selling. All costs other than marketing are included in the cost term C. As such, C includes items such as raw material, labor, overhead, depreciation, working capital financing, order/invoice processing and distribution. Since the market size is assumed to be exogenous, the knowledge of the market share m_T is enough to determine the sales of the firm during the planning and post-planning periods. The corresponding costs C_T and ${}_TC_S$ take into account experience effects and are expressed in constant dollars, as are all financial entities in STRATPORT. The evolution of industry average unit price is assumed to be exogenous and, in particular, driven by industry experience [2]. The average unit price, together with a factor to reflect the price-positioning of the firm relative to the industry enables us to determine the revenues R_T and ${}_TR_S$. The term Z measures the capacity expenditures over and above the depreciation expense in the planning period. Amount G is the additional working capital needed to finance the strategy over and above the working capital financing costs already included under C_T. The depreciation during the planning period of assets acquired prior to $t=0$ is denoted as A.

The cash flow need during the planning period and the long-term profit are given by the expressions on the bottom of Figure 1. The terms Z and G do not appear in the profit expression since they are expenditures and not expenses. (The expense part is already included in C_T and ${}_TC_S$.) Since depreciation A corresponds to an expenditure prior to $t=0$, the cost C_T overstates the expenditures during the planning period and this is compensated by the -A term in the expression for F. The profit expression incorporates capacity costs in the form of depreciation expenses rather than recognizing capacity expenditures as cash flows. The two approaches can be shown to be equivalent under realistic assumptions. Our approach of considering capacity expenses as depreciation facilitates the incorporation of experience effects on capacity costs and avoids the need to get into the detail of the exact timing of capacity expansions during the planning and post-planning periods. For similar reasons, the profit expression incorporates working capital costs in the form of financing expenses. For expositional convenience, the considerations of tax, discounting and risk have been postponed to §5.

As detailed in the next section, all the terms in Figure 1 can be expressed as explicit functions of m_T so that we can denote by $\pi_i(m_{Ti})$ and $F_i(m_{Ti})$ the long-term profit and the cash flow need during the planning period for achieving a market share m_{Ti} for business unit i $(i = 1,2,\ldots,N)$. ($F_i(m_{Ti}) < 0$ denotes that the i-th BU generates excess cash, while $F_i(m_{Ti}) > 0$ denotes that the i-th BU needs additional funds to finance the strategy.) Consequently,

$$\text{Total profit } \pi = \sum_{i=1}^{N} \pi_i(m_{Ti}), \quad \text{and} \tag{1}$$

$$\text{Net cash flow need during the planning period } F = \sum_{i=1}^{N} F_i(m_{Ti}). \tag{2}$$

As a result, the evaluation of a portfolio strategy $\underset{\sim}{m}_T = \{m_{T1}, m_{T2}, \ldots, m_{TN}\}$ is accomplished by determining its long-term profit implication π and short-term net cash flow implication F.

The formulation of a portfolio strategy is conceptualized as choosing $\underset{\sim}{m}_T^*$ so as to maximize π subject to a net cash flow limit Δ, i.e.,

$$\underset{\underset{\sim}{z}_1 \leq \underset{\sim}{m}_T \leq \underset{\sim}{z}_2}{\text{maximize}}\ \pi = \sum_{i=1}^{N} \pi_i(m_{Ti}) \tag{3}$$

$$\text{subject to } F = \sum_{i=1}^{N} F_i(m_{Ti}) \leq \Delta\ . \tag{4}$$

The limits z_{1i} and z_{2i} for $i=1,2,\ldots,N$ may be imposed by management on the basis of considerations such as the maximum risk the firm is willing to take in a BU, anti-trust, labor relations, customer reactions, social responsibility and prior contracts. These limits could also be utilized to place bounds, if so desired by management, on entities such as cash flows, capacity expansions and absolute sales levels for the BU's.

The constrained optimization (3)-(4) can be done using the Generalized Lagrange Multiplier Method [11]. Denoting the Lagrange Multiplier to be $\mu(\geq 0)$, the problem (3)-(4) for several values of Δ can be solved by solving (5) below for several values of μ:

$$\underset{\underset{\sim}{z}_1 \leq \underset{\sim}{m}_T \leq \underset{\sim}{z}_2}{\text{maximize}}\ \psi = \sum_{i=1}^{N} [\pi_i(m_{Ti}) - \mu F_i(m_{Ti})] . \tag{5}$$

The problem (5) decomposes into the N subproblems:

$$\underset{z_{1i} \leq m_{Ti} \leq z_{2i}}{\text{maximize}}\ [\pi_i(m_{Ti}) - \mu F_i(m_{Ti})],\ i = 1,2,\ldots,N \tag{6}$$

which is a considerably simpler problem since the optimization is done on a single variable m_{Ti}. The details of the optimization are discussed in Section 6.

STRATPORT can easily handle analysis of external BU's which are under consideration for acquisition. By comparing the results of the analysis with and without the external BU, the impact of the potential acquisition can be assessed. The analysis with the external BU should proceed by first lowering the cash flow limit Δ by the acquisition price. Likewise, the divestment of a BU can be assessed by doing the analysis with and without the BU. The analysis without the BU should proceed by first raising the cash flow limit Δ by the sale price for the BU.

4. Components of the Model for a Business Unit

Since much of the discussion in this paper relates to a single BU, we will, for the most part, omit the subscript i denoting the BU number and introduce the subscript only when needed. Thus, values for the parameters in the formulation below will, in general, be different across BU's. Only the time periods T and S are assumed to be the same across the BU's.

4.1 Market Response Function

The effect of marketing investment during the planning period, denoted as E, on the market share m_T at the end of the planning period is modeled by the response function:

$$m_T = L + (U - L)\left(\frac{E^{\alpha}}{B + E^{\alpha}}\right) \tag{7}$$

where L and U denote lower and upper limits on $m_T (0 \leqslant L < U \leqslant 1)$ and $B(> 0)$ and $\alpha(> 0)$ are parameters. As shown in Figure 2(a), the function is monotone increasing in E, S-shaped for $\alpha > 1$ and concave for $0 < \alpha \leqslant 1$.

FIGURE 2 ABOUT HERE

Usually, most companies do not have enough data to estimate this function. Consequently, the parameters of (7) may be determined using subjective judgments of the manager as per the procedure proposed by Little [19]. The following four inputs are used to estimate the parameters: the market share expected at T if no marketing investment is made; the marketing investment required to achieve a reference market share level at T; the expected market share at T for a 50% higher marketing investment;

and the maximum market share expected for an unlimited marketing investment. For an existing BU, the reference market share is taken to be the current market share m_0. For a new BU (i.e., $m_0 = 0$) the minimum expected market share is set equal to zero. If desired, the reliability of parameter estimates determined from managerial judgments may be improved by obtaining many additional judgments and using nonlinear estimation techniques [12].

To provide the market response judgments, the manager should be encouraged to think in terms of the best tactics (such as segmentation strategy, consumer and trade promotions, product line changes including new products, improvements in product quality, acquisitions of small competitors, advertising and personal selling) that can be used in the product-market(s) corresponding to the BU under consideration. Substantial attention needs to be paid to likely competitive reactions, the strengths and weaknesses of the firm and on the best ways to market to different segments constituting the product-market(s). The market response function is likely to be a critical component of the proposed approach and the quality of the results from the model will reflect the intensity of analysis done before providing the subjective judgments. From the input judgments, the parameters α and B can be determined satisfying the requirements $\alpha > 0$ and $B > 0$. The response function (7) has been successfully used in several decision calculus models [19, 20, 21].

Since the relationship between E and m_T is strictly monotone increasing, we can invert the relationship (7) to express E as a function of m_T:

$$E = [B(m_T - L)/(U - m_T)]^{1/\alpha} . \qquad (8)$$

4.2 Market Share Evolution

The evolution of market share from m_0 at time 0 to m_T at time T is modeled as:

$$m_t = m_0 + (m_T - m_0)f(t), \ t = 1,2,\dots,T \tag{9}$$

where $f(t)$ is an increasing function of t with $f(0) = 0$ and $f(T) = 1$. Eq. (9) may be rewritten as

$$m_t = m_T f(t) + m_0[1 - f(t)], \ t = 1,2,\dots,T \ . \tag{10}$$

Note that m_t is linear in m_T although it could be nonlinear with respect to t. (Note also that m_T can be greater than or less than m_0.) Although the proposed approach can be used with the general functional form (10), we consider the simpler case:

$$f(t) = (t/T)^{\beta}, \ \beta > 0 \ . \tag{11}$$

The evolution of m_t as per (10)-(11) is shown in Figure 2(b). Values of β close to zero would imply that, for all practical purposes, the market share change $(m_T - m_0)$ is accomplished in only a fraction of the total planning period $(0 - T)$ (see Fig. 2(b)). On the other hand, values of β close to 1 would indicate that the market share change $(m_T - m_0)$ is accomplished uniformly over the entire planning period. Consequently, by using different values of β for different BU's, we can utilize a planning period T common to all BU's, yet approximately take into account the fact that the planning period tends to vary across industries (e.g., steel vs. semiconductors). The parameter β can be determined from a managerial input on the proportion of the anticipated market share change that will be realized at the midpoint of the planning period. This input is to be provided consistent with the inputs for the market response function since the speed with which a strategy is to be implemented would, in general, affect the cost of accomplishing a strategy; conversely, the tactics used in expending E would affect the evolution of market share.

4.3 Total Production during the Planning Period: P_T

We assume throughout that production is equal to sales, i.e., we do not consider inventories and back orders. Let M_t denote the industry demand (in units) during period t (i.e., total sales for the product(s) corresponding to the BU for both the firm and its competitors). We assume that the $\{M_t\}$ are exogenous; i.e., the effect of E on M_t is assumed to be negligible. (This assumption can be relaxed to an extent as explained in Section 7.) The values $\{M_t\}$, possibly determined through sales forecasting procedures, are inputs to the STRATPORT model. Since the industry demand will depend on industry prices, the inputs $\{M_t\}$ should be provided consistent with the anticipated evolution of price (§4.6 and 4.7). The total production P_T for the firm is given by

$$P_T = \sum_{t=1}^{T} [(m_{t-1} + m_t)/2]M_t \tag{12}$$

where we have approximated the market share during the period by its average. It follows from (10)-(12) that

$$P_T = K_1 + K_2\, m_T \,, \tag{13}$$

where the K's, throughout this paper, are nonnegative constants which can be determined easily.

4.4 Total Cost (Other than Marketing) during Planning Period: C_T

A key concept, empirically tested and popularized by the BCG [2] is that of "experience effects," viz., the unit cost of the p^{th} unit sold goes down as the amount of experience (P) increases and may be approximated by the relationship:

$$c_P = cP^{-\lambda}, \; \lambda \geq 0, \; c > 0 \; . \tag{14}$$

The relationship (14) is shown in log-linear form in Figure 2(c).[2] In order to consider explicitly the marketing expenditures as a strategic investment, we, in contrast to the BCG, exclude marketing costs in the definition of c_P. Eq. (14) expresses the empirically found relationship that when experience (P) is doubled, the unit cost goes down by a constant proportion (k).

The experience effect is the net result of several factors such as "learning" and the consequent improvement in productivity, economies of scale, newer processes, product standardization, product redesign and material substitution. The value of λ can be estimated from past data by a log-linear regression of c_P against P or alternatively specified in terms of the proportion k as $\lambda = -\log k/\log 2$.

Let P_t denote the cumulative units sold by the firm up to time t. Consequently, the total cost of units sold from t1 to t2 is given by

$$_{t1}C_{t2} = \sum_{P=1+P_{t1}}^{P_{t2}} c_P = c \sum_{1+P_{t1}}^{P_{t2}} P^{-\lambda} \tag{15}$$

which may be approximated by

$$_{t1}C_{t2} \simeq c \int_{.5+P_{t1}}^{.5+P_{t2}} P^{-\lambda} dP \simeq c \int_{P_{t1}}^{P_{t2}} P^{-\lambda} dP = \frac{c}{(1-\lambda)} \left[(P_{t2})^{1-\lambda} - (P_{t1})^{1-\lambda} \right] . \tag{16}$$

The last part of Eq. (16) applies for $\lambda \neq 1$. A logarithmic expression is obtained for the case of $\lambda = 1$. The need to work with two different expressions is avoided by replacing $\lambda = 1$ by $\lambda = 0.999$, which provides an excellent approximation. Equation (16) provides a good approximation to (15) except for a new business unit for which $P_{t1} = 0$ when $t1 = 0$. In such a case a better approximation is provided by setting $P_{t1} = 0.5$ in the last term of Eq. (16).

Let $t = tF$ denote the point in time when the business unit (firm) started production (sales). Note that $tF \leqslant 0$. Consequently, ${}_{tF}P_0$ and ${}_{tF}P_T$ denote the cumulative production up to the start and end of the planning period. From (16),

$$C_T = \frac{c}{(1-\lambda)} \left[({}_{tF}P_T)^{1-\lambda} - ({}_{tF}P_0)^{1-\lambda} \right] . \tag{17}$$

Noting that ${}_{tF}P_T = {}_{tF}P_0 + P_T$ and substituting from (13), we get

$$C_T = (K_3 + K_4\, m_T)^{1-\lambda} - K_5 . \tag{18}$$

Eq. (18) assumes that $\lambda < 1$, i.e., unit cost drops by 0-49% when production (sales) is doubled. Higher values of λ do not occur in empirical studies [25, p. 16]. We have assumed that $\lambda < 1$ in the remainder of this paper for simplicity of presentation. The approach can, however, be easily extended to the unlikely case of $\lambda \geqslant 1$.

4.5 Total Cost (Other than Marketing) during Post-Planning Period: ${}_TC_S$

From Eq. (16)

$$_TC_S = \frac{c}{(1-\lambda)} \left[({}_{tF}P_S)^{1-\lambda} - ({}_{tF}P_T)^{1-\lambda} \right] \tag{19}$$

where ${}_{tF}P_S = {}_{tF}P_T + {}_TP_S$. Since market share stays at m_T for $t \geqslant T$, we have

$${}_{tF}P_S = {}_{tF}P_0 + P_T + m_T \sum_{t=T+1}^{S} M_t = {}_{tF}P_0 + K_1 + \left[K_2 + \sum_{t=T+1}^{S} M_t \right] m_T . \tag{20}$$

From (17)-(20), it can be verified that

$$_TC_S = (K_3 + K_6\, m_T)^{1-\lambda} - (K_3 + K_4\, m_T)^{1-\lambda} . \tag{21}$$

The cost expressions C_T and ${}_TC_S$ are based on experience effects and hence the unit costs are assumed to be driven by the cumulative production in the BU. If, however, the evolution of unit costs is believed to be more a function of time than of cumulative production, the model can be extended to handle such cases. This extension may be particularly appropriate when an important evolution of raw material costs is anticipated.

4.6 Revenue during the Planning Period: R_T

The empirical studies done by BCG [2] show that average (industry) unit price (in constant dollars) falls as the industry cumulative experience increases and can be approximated by a relationship similar to that for cost (Eq. (14)):

$$P_I = pI^{-\eta} \quad (\eta \geqslant 0) \tag{22}$$

where I is the cumulative number of units sold in the industry. However, unlike unit cost for which the exponent λ remains approximately constant over time, the exponent η may change over time as the competitive structure in the industry changes [25, pp. 21-24]. For instance, the average unit price may decline at a lower rate than unit cost for a new industry and decrease at a faster rate as the market matures and the competition intensifies. For simplicity, we assume that the exponent remains approximately equal to $\eta(\geqslant 0)$ during the planning period and equal to $\nu(\geqslant 0)$ during the post-planning period as shown in Figure 2(d). The approach can be easily extended to the case where the exponent takes on several different values corresponding to different time intervals from 0 to S. (As in the cost function, we assume that $\eta = 1$ and $\nu = 1$ are replaced by $\eta = 0.999$ and $\nu = 0.999$ respectively.)

By following the same type of reasoning as in Eq. (15)-(16), the industry revenue from t1 to t2 $(0 \leqslant t1 \leqslant t2 \leqslant T)$ is given by:

$$_{t1}Q_{t2} = \frac{p}{(1-\eta)} \left[(_{tI}I_{t2})^{1-\eta} - (_{tI}I_{t1})^{1-\eta} \right] \tag{23}$$

where $t = tI$ denotes the start time for the industry $(tI \leqslant 0)$ and $_{tI}I_t$ denotes the cumulative sales in the industry up to time t. Thus

$${}_{tI}I_t = {}_{tI}I_0 + \sum_{j=1}^{t} M_j \ . \tag{24}$$

The price set by the firm may actually be lower or higher than the average industry price according to the price positioning strategy adopted by the firm. Consequently, the firm's revenue during the time period t is

$${}_{t-1}R_t = \omega \ {}_{t-1}Q_t(m_t + m_{t-1})/2 \tag{25}$$

where the market share during the time period has been approximated by its average and ω is the ratio of the firm's price to average industry price. From (23)-(25)

$${}_{t-1}R_t = \frac{p\omega}{2(1-\eta)}\left[({}_{tI}I_t)^{1-\eta} - ({}_{tI}I_{t-1})^{1-\eta}\right](m_t + m_{t-1}) \ .$$

Substituting for m_t from (10)-(11) and simplifying we get

$${}_{t-1}R_t = m_T \ h_1(t) + h_2(t) \ , \tag{26}$$

where $h_1(t)$ and $h_2(t)$ are nonnegative constants. By summing (26) over $t = 1,2,\ldots,T$, we obtain

$$R_T = K_7 + K_8 \ m_T \ . \tag{27}$$

4.7 Revenue during the Post-Planning Period: ${}_TR_S$

The behavior of the industry average unit price during the post-planning period is modeled as

$$p_I = p'I^{-\nu} \ (\nu \geq 0) \ . \tag{28}$$

By a reasoning similar to that of (23)-(25) and noting that the market share stays constant at m_T during this period,

$${}_TR_S = \frac{p'\omega}{(1-\nu)}\left[({}_{tI}I_S)^{1-\nu} - ({}_{tI}I_T)^{1-\nu}\right]m_T$$

so that

$$ {}_T R_S = K_9 \, m_T \, . \tag{29} $$

As in the case of costs, the expressions R_T and ${}_T R_S$ can be modified to consider average unit price as a function of time as opposed to a function of industry cumulative sales.

4.8 Capacity Expenditures Over and Above the Expenses Included in Cost: Z

A market share of m_T at the end of the planning period requires a production capacity of

$$ X = m_T \, M_T \, . \tag{30} $$

Denoting the current plant capacity as X_0, capacity expansion expenditures will be incurred during the planning period if $X > X_0$. On the other hand, if $X < X_0$, then the liquidation of the capacity $(X_0 - X)$ can generate a cash inflow for the firm. Let Y, the capacity expenditures corresponding to X be modeled by

$$ Y = \left(\frac{bX^{\gamma}}{a + X^{\delta}} \right) - q \tag{31} $$

where $q(> 0)$ denotes the cash value of divesting the entire current capacity (as can be seen by substituting $X = 0$ in (31)), b, γ, a and δ are strictly positive with $0 < (\gamma - \delta) < 1$. The function Y can be shown to be monotone increasing in X and is S-shaped if $\gamma > 1$ and concave if $0 < \gamma \leqslant 1$ as shown in Figure 2(e).

The parameters of the function (31) can be determined from the following data: cash value q of divesting entire current capacity X_0, a "realistic" plant size $X_R(> X_0)$ and the corresponding capacity expenditure Y_R, a "large" plant size $X_L(> X_R)$ and the corresponding Y_L and the marginal expenditure rate of expanding capacity beyond X_L. An iterative procedure has been designed to determine b, a, γ and δ satisfying the constraints on these parameters and passing through the points $(0,-q)$, $(X_0,0)$ and (X_R,Y_R).

In the case of a new BU for which the firm considers building capacity, the value $X_0 = 0$, so that formulation (31) may be modified to

$$Y = bX^{\sigma} \quad (0 < \sigma < 1) \ . \tag{32}$$

The function Y is a concave increasing function of X. The parameters b and σ can be determined from the inputs (X_R,Y_R) and (X_L,Y_L). Since Eq. (32) can be treated as a special case of (31) by defining $a = q = 0$, $\gamma = 1 + (\sigma/2)$ and $\delta = 1 - (\sigma/2)$, we restrict our further discussion to Eq. (31). (Other nonnegative γ and δ such that $\gamma - \delta = \sigma$, could also have been used without affecting the results).

The amount Y is an expenditure and <u>not</u> an expense. The expense part of capacity expenditures has been already included in C_T and ${}_TC_S$ in the form of depreciation. To avoid double counting, we define Z as the amount of expenditures over and above what is "expensed" during the planning period. Denoting by θ_1 the proportion of Y that is not expensed during the planning period, we have

$$Z = \theta_1 Y, \ (0 \leqslant \theta_1 < 1) \ . \tag{33}$$

As a special case, if the firm follows straight-line depreciation with zero salvage value, then θ_1 can be determined as equal to 1 - (T/useful life of a new plant). From (30)-(31) and (33)

$$Z = \left(\frac{K_{10} \ m_T^{\gamma}}{K_{11} + m_T^{\delta}} \right) - K_{12} \ . \tag{34}$$

4.9 Depreciation of Previous Assets During Planning Period: A

Let A denote the depreciation over the time period 0 to T of assets acquired prior to $t=0$. The amount A can be easily determined by comparing book values of the previous assets at $t=0$ and $t=T$. Since depreciation is only an expense and not an expenditure, the amount C_T overstates expenditure by the amount A. Thus the actual expenditure is $C_T - A$ and this is the reason the term $-A$ appears in the expression for cash flow need F in Figure 1.

4.10 Additional Working Capital: G

A change in market share would, in general, call for a change in the working capital (cash + inventory + equipment on lease + accounts receivable - accounts payable). The working capital g_t required during time period t is modeled as a function of the revenue ${}_{t-1}R_t$ during time period t as

$$g_t = \chi({}_{t-1}R_t)^{\zeta}, \quad (\chi>0, \zeta>0) \tag{35}$$

and is displayed in Figure 2(f). The parameter ζ may be expected to be less than 1 since cash and inventory tend to grow less than proportionately to revenue. On the other hand, it is possible that $\zeta>1$ since accounts receivable may grow more than proportinately to revenue as the last set of customers may have to be attracted with more favorable credit terms.

The two parameters in Eq. (35) may be estimated from past data by a log-linear regression of working capital as a function of revenue. If, however, data are not available, managerial inputs are obtained on the appropriate working capital expressed as a proportion of revenue for two revenue levels such as: (i) past period's revenue and (ii) 50% above past period's revenue. For a new BU, past period's revenue is replaced by the reference market share times the industry revenue for the past time period or the T-th time period depending on whether the BU is in an existing or new industry. The parameters χ and ζ can be easily determined from the above two managerial inputs.

The change in working capital corresponding to the change in market share is given by $g_T - g_0$, where g_0 is the current working capital which may be obtained from accounting records. As in the case of capacity expenditures (§4.8), a correction needs to be made to avoid double counting the working capital financing costs which are already included under C_T. Denoting by θ_2 the proportion of $(g_T - g_0)$ that is not expensed during the planning period, the additional working capital over and above the expenses already included in C_T is given by

$$G = \theta_2 \; (g_T - g_0) \; . \tag{36}$$

For instance, if financing cost is taken to be a simple interest of r% per period then $\theta_2 = [1 - (Tr/100)]$. Substituting for g_T from (35) and (26) and simplifying, we obtain

$$G = [K_{13} + K_{14} \; m_T]^{\zeta} - K_{15} \; . \tag{37}$$

4.11 Cost of Maintaining Market Share at m_T during Post-Planning Period: ${}_T H_S$

Let V denote the proportion of the firm's revenue that is spent on marketing expenditures to maintain the market share at m_T. We model V as

$$V = d - e(m_T - L), \; (d > 0) \tag{38}$$

which is displayed graphically in Figure 2(g). The parameters d and e can be determined from the subjective estimates of V provided by the manager for two values of m_T between L and U. Since we would expect economies of scale to exist in marketing expenditures [5], the parameter e will usually be positive except when intense competitive reaction may be expected for a large market share buildup. The cost of maintaining market share from t to t+1 $(t \geq T)$ is given by:

$$ {}_tH_{t+1} = V \; {}_tR_{t+1} \tag{39}$$

From (38)-(39),

$$ {}_tH_{t+1} = d \; {}_tR_{t+1} - e \; {}_tR_{t+1} \, (m_T - L). \tag{40}$$

Summing (40) over the post-planning period

$$ {}_TH_S = d \; {}_TR_S - e \; {}_TR_S \, (m_T - L). \tag{41}$$

From (29) and (41)

$$ {}_TH_S = K_{16} \, m_T - K_{17} \, m_T \, (m_T - L). \tag{42}$$

5. Evaluation of a Portfolio Strategy

We may now assemble the components of the model developed in Section 4 in order to evaluate a portfolio strategy.

5.1 Profit from Business Unit: π

From Figure 1, the profit π from the BU is

$$ \pi = (R_T + {}_TR_S) - (C_T + {}_TC_S) - (E + {}_TH_S) \; . \tag{43}$$

Substituting from (27), (29), (18), (21), (8) and (42) in (43), we get

$$ \begin{aligned} \pi = {} & K_7 + K_8 \, m_T + K_9 \, m_T - (K_3 + K_4 \, m_T)^{1-\lambda} + K_5 \\ & - (K_3 + K_6 \, m_T)^{1-\lambda} + (K_3 + K_4 \, m_T)^{1-\lambda} \\ & - \left[\frac{B(m_T - L)}{(U - m_T)} \right]^{1/\alpha} - K_{16} \, m_T + K_{17} \, m_T (m_T - L) \; . \end{aligned} $$

Upon simplifying we obtain

$$\pi = K_{18} + K_{19}\, m_T - (K_3 + K_6\, m_T)^{1-\lambda} + K_{17}\, m_T(m_T - L) - \left[\frac{B(m_T - L)}{(U - m_T)}\right]^{1/\alpha} . \quad (44)$$

The constant $K_{19} = K_8 + K_9 - K_{16}$ is nonnegative since $d(= K_{16}/K_9)$, the proportion of the firm's revenue spent on maintaining market share at $m_T = L$ is realistically less than unity.

5.2 Cash Flow Need during the Planning Period for the Business Unit: F

From Figure 1, the cash flow need for the BU during the planning period is given by

$$F = E + C_T - R_T + Z + G - A . \quad (45)$$

$F < 0$ denotes that the BU generates a cash outflow during the planning period while $F > 0$ means that the BU has a net cash need to be met. Substituting from (8), (18), (27), (34) and (37) in (45), we get

$$F = \left[\frac{B(m_T - L)}{(U - m_T)}\right]^{1/\alpha} + (K_3 + K_4\, m_T)^{1-\lambda} - K_5 - K_7 - K_8\, m_T + \left(\frac{K_{10}\, m_T^{\gamma}}{K_{11} + m_T^{\delta}}\right) - K_{12}$$

$$+ (K_{13} + K_{14}\, m_T)^{\zeta} - K_{15} - A$$

which upon simplifying yields

$$F = \left[\frac{B(m_T - L)}{(U - m_T)}\right]^{1/\alpha} + (K_3 + K_4\, m_T)^{1-\lambda} + \left(\frac{K_{10} m_T^{\gamma}}{K_{11} + m_T^{\delta}}\right)$$

$$+ (K_{13} + K_{14}\, m_T)^{\zeta} - K_8\, m_T - K_{20} . \quad (46)$$

5.3 The Evaluation of a Portfolio Strategy

If the portfolio strategy is defined in terms of the market share m_{Ti} to be achieved for the i-th BU for $i = 1,2,\ldots,N$, we can evaluate the profit π_i and net cash flow F_i using Eq. (44) and (46) respectively. The overall profit π and overall net cash flow F are given by Eq. (1) and (2) respectively. Alternatively, the marketing strategy may be formulated in terms of the marketing investments $\{E_i\}$ to spend on each of the BU's. In this case the m_{Ti} corresponding to the E_i has to be first calculated from Eq. (7) for each business unit before adopting the above procedure for determining the overall π and F.

For simplicity of exposition, we have so far ignored tax effects, discounted cash flows and considerations of risk. We now consider these issues in turn.

5.4 Tax Effects

Let τ denote the tax rate for the firm. We assume that the reported earnings of the firm, summed over the BU's, will be positive and hence the taxes will be positive over the planning and post-planning periods. Since losses can usually be carried a few years backwards and/or forwards, this assumption appears to be a reasonable one. The profit expression given in Eq. (43) gets modified to

$$\pi = (1 - \tau)\ (R_T + {}_TR_S - C_T - {}_TC_S - E - {}_TH_S)\ . \tag{47}$$

However, in the cash flow expression given in Eq. (45), only E, C_T and R_T are affected by taxes. The terms Z, G and A are neither revenues nor expenses, a fact also acknowledged by their absence in the profit expression. Thus cash flow need during the planning period gets revised to

$$F = (Z + G - A) + (1 - \tau)\ (E + C_T - R_T)\ . \tag{48}$$

5.5 Discounted Cash Flows

The profit and cash flow expressions in Eq. (47)-(48) need to be discounted to $t=0$ in order to take into account the time pattern of cash flows and, as will be seen in §5.6, to incorporate risk considerations. It should also be noted that discounting reduces the sensitivity of the results to the length of the post-planning period and to end of horizon effects. Let r denote the discounting rate. (The determination of r is taken up in §5.6). To discount a cash flow during time period t back to $t=0$, it needs to be multiplied by the factor $1/(1+r)^{t-.5}$. Let the symbol D in front of a financial entity denote the fact that it is expressed in discounted terms. Consequently, Eqs. (47)-(48) get modified to

$$D\pi = (1 - \tau)\ (DR_T + {}_TDR_S - DC_T - {}_TDC_S - E - {}_TDH_S), \quad \text{and} \tag{49}$$

$$DF = (Z + G - A) + (1 - \tau)\ (E + DC_T - DR_T)\ . \tag{50}$$

No discounting of Z, G, A and E are done since they are already expressed in dollars at $t=0$.[3]

The equations in §4 expressing the financial entities as a function of m_T get correspondingly modified when expressed in discounted terms. Eq. (27), (29) and (42) still apply to DR_T, ${}_TDR_S$ and ${}_TDH_S$, respectively. However, the computation of the K constants in these equations get appropriately modified. The main change in the discounted formulation is in the expressions for DC_T and DC_S $(= DC_T + {}_TDC_S)$ which can be shown to be

$$DC_T = \left[\sum_{t=1}^{T} (K_{21,t} + K_{22,t}\ m_T)^{1-\lambda}\right] - K_{23}, \quad \text{and} \tag{51}$$

$$DC_S = \left[\sum_{t=1}^{S} (K_{24,t} + K_{25,t}\ m_T)^{1-\lambda}\right] - K_{23}\ . \tag{52}$$

5.6 Considerations of Risk

One of the most important developments in modern finance (e.g., [30, Chapters 7-8]) is the capital-asset pricing model, originally developed to incorporate risk considerations in the valuation of securities [27] and subsequently adopted to the evaluation of risky investments by the firm (e.g., [29]). The basis of the capital-asset pricing model is that different discount rates have to be applied to alternative capital-budgeting projects (such as the BU's considered in this paper) to reflect the different risks associated with each project. Furthermore, the risk element to be considered is the "systematic" or unavoidable risk of the project which results from the covariance of the returns of the project with the returns of a fully diversified portfolio of investments. The "unsystematic" or residual risk of the project is less relevant as it can be avoided through diversification, by the firm investing in multiple BU's and by stockholders investing in multiple firms.

To simplify exposition, we first consider the case of the firm with N BU's with an all-equity capital structure. The implication of debt in the capital structure is considered later. For the all-equity case, it follows from the capital-asset pricing model [30, Eq. (8-2)] that

$$r_{ei} = r_f + [\mathrm{Beta}_i \, (r_m - r_f)] \tag{53}$$

where

r_{ei} = required rate of return for the ith BU (the subscript e denotes equity)

r_f = risk-free rate of return (e.g., for short-term treasury bills)

r_m = expected rate of return on a well diversified investment portfolio (e.g., Standard and Poor's 500)

$Beta_i$ = regression coefficient relating the excess rate of return (i.e., rate in excess of the risk-free rate) of the ith BU to the excess rate of return of a well diversified investment portfolio.

Since r_f and r_m are known from financial markets, r_{ei} can be determined once $Beta_i$ is known.

One suggested method (see [31] for an actual application) for determining $Beta_i$ for a specific BU is to identify one or more firms with publicly traded stocks which have approximately the same systematic risk characteristics as the BU under consideration. Denoting such a similar firm as j, we first compute $Beta_j'$, the leverage adjusted Beta for firm j, as per Eq. (54) below. By averaging $Beta_j'$ over firms similar to i, $Beta_i$ is obtained. The leverage adjustment is given by [30, Eq. (8A-4)].

$$Beta_j' = Beta_j \; [1 + DE\,(1 - \tau)]/[1 + DE_j\,(1 - \tau)] \tag{54}$$

where DE is the debt-equity ratio (in market value terms) for the firm with the N BU's, DE_j is the debt-equity ratio for firm j and τ is the tax rate. The Beta for actively traded stocks are available from a number of organizations such as Merrill, Lynch, Pierce, Fenner and Smith; Wells-Fargo Bank; and the Value-Line Investment Survey. An alternative, and probably cruder, approach to determining $Beta_j$ is to regress the rate of return on the assets (market value) of the jth firm to an economy-wide index of returns such as the average return on assets of nonfinancial corporations [1]. If the ith BU is an existing BU, this latter approach can also be used with the rate of return on assets for the ith BU to yield $Beta_i$ directly.

Having determined $Beta_i$, the required rate of return r_{ei} for the firm with all-equity capital structure is calculated from Eq. (53). Since the firm under consideration is likely to have debt in the capital structure, the required rate of return r_i for the ith BU is modified to [30, pp. 232-3]:

6. The Formulation of a Business Portfolio Strategy

6.1 The Overall Approach

The design of a portfolio strategy for the various BU's may be conceptualized as that of determining the optimal market shares $\underset{\sim}{m}_T^*$ so as to maximize the overall profit π subject to a net cash flow limit of Δ (Eq. (3)-(4)). If $\Delta > 0$, this means that the net cash flow need for the whole firm during the planning period is not to exceed Δ. The same formulation with a negative value for Δ, say, $\Delta = -\Gamma$ where $\Gamma > 0$, can be used to maximize profit subject to the requirement that the system generate at least Γ dollars of excess cash during the planning period. ($F \leqslant \Delta$ (Eq. (4)) is equivalent to $-F \geqslant \Gamma$.) As remarked in Section 3, the overall optimization (Eq. (3)-(4)) can be accomplished by solving the simpler univariate maximization given by Eq. (6) for each of the BU's, for a specific value of the Lagrange Multiplier μ. The maximization of Eq. (6) is discussed later in Section 6.2.

Suppose we solve Eq. (6) for specific value of $\mu = \mu'$ (say) and obtain the optimum values $\underset{\sim}{m}_T^*$. Let $\Delta' = \sum_{i=1}^{N} F_i(m_{Ti}^*)$. Theorem 1 in [11] guarantees that $\underset{\sim}{m}_T^*$ maximizes profit (Eq. (3)) when the net cash flow limit is Δ' (i.e., the right hand side of Eq. (4) is replaced by Δ'). However, note that the particular constrained problem (i.e., the value of Δ') that is solved is not known in advance but arises in the course of the solution of Eq. (6). In general, different values for μ will lead to different values of Δ so that we get an entire range of optimal strategies corresponding to different values for the cash flow limit Δ. It is important to note that in the context of formulating a portfolio strategy one is interested not so much in finding the optimum $\underset{\sim}{m}_T^*$ for a single value of Δ, but rather in exploring the entire range of what can be obtained for various values of Δ. Consequently, our approach appears to be naturally suited to the formulation of a portfolio strategy.

The functional forms used in our approach (see Figure 2) are such that the functions π and F (Eq. (3)-(4)) do not have desirable properties such as π being concave in $\underset{\sim}{m}_T$ and F being convex in $\underset{\sim}{m}_T$. Consequently, a caveat of the proposed procedure is that it does not guarantee that an optimum can be found for <u>every</u> value of Δ. In other words, there may exist "gaps," i.e., ranges of values for Δ for which there exists no corresponding value for μ. The problem is less likely to be an important one for firms with a larger number of business units. To identify optimal solutions corresponding to gaps, the STRATPORT computer package employs dynamic programming [23] of the system (3)-(4). Our recommendation is to first employ the Generalized Lagrange Multiplier (GLM) approach and conduct sensitivity analyses on uncertain parameters as well as different scenarios of the market and the competition through the GLM approach before turning to dynamic programming (DP). Our experience has been that GLM is computationally more efficient (by an order of magnitude) and computationally more accurate in comparison to DP. Furthermore, we believe that ignoring the gaps initially would facilitate managerial learning since the strategies identified by GLM tend to be "continuous" as a function of Δ, i.e., the optimum strategy for $\Delta'' > \Delta'$ tends to be a minor variation of the strategy for Δ' augmented possibly by a major investment in one or more BU's. The strategies corresponding to gaps, on the other hand, tend to be discontinuous. A minor increase in Δ may change the solution dramatically. For instance, a resource level Δ' may involve an investment in $BU_{\cdot}$. However, with a slightly larger resource level Δ'', the firm may be able to make more profit by investing in BU_j and BU_k and abandoning BU_i.

6.2 The Univariate Maximization of m_T^*

The maximization of Eq. (6) for a single BU may rewritten as:

$$\underset{z_1 \leqslant m_T \leqslant z_2}{\text{maximize}}\ y(m_T) = \pi(m_T) - \mu F(m_T) \tag{56}$$

where the subscript i corresponding to the BU has been dropped for notational convenience. Since L and U are, by definition the lower and upper bounds on m_T, we assume that $L \leqslant z_1 \leqslant z_2 \leqslant U$. For expositional convenience, we consider the formulation with neither taxes nor discounting. Substituting from (44) and (46) into (56) we obtain

$$\begin{aligned} y(m_T) = {} & J_1 + J_2\, m_T - (K_3 + K_6\, m_T)^{1-\lambda} + K_{17}\, m_T(m_T - L) \\ & - J_3\left(\frac{m_T - L}{U - m_T}\right)^{1/\alpha} - (J_4 + J_5\, m_T)^{1-\lambda} \\ & - \left(\frac{J_6\, m_T^{\gamma}}{K_{11} + m_T^{\delta}}\right) - (J_7 + J_8\, m_T)^{\zeta}\ , \end{aligned} \tag{57}$$

where the J's are easily determinable nonnegative constants which depend on the value of μ.

The (global) maximum of $y(m_T)$ has to occur either at the boundaries z_1 or z_2 or at an interior point $(z_1 < m_T < z_2)$ at which $dy/dm_T = 0$. Consequently, by comparing the values of y at $m_T = z_1$, $m_T = z_2$ as well as at interior points at which the function is stationary (i.e., $dy/dm_T = 0$), we can determine m_T^*. The function $y(m_T)$ is not unimodal so that the usual global maximization procedures such as the Fibonacci or golden-section search [34, p. 121] can not guarantee global maxima.

The identification of stationary points of $y(m_T)$ is not a simple task, because the function (57) is complicated. However, by making a transformation of variables from m_T to n_T as specified below, the function $y(n_T)$ becomes considerably simpler from the point of view of identifying all stationary points. The transformation for $m_T > L$ is

$$m_T = n_T^{1/\varepsilon} + L, \quad 0 < \varepsilon < 1 . \tag{58}$$

The determination of ε is discussed subsequently. The derivative dm_T/dn_T is strictly positive as long as $m_T > L$ which is satisfied for the interior region $z_1 < m_T < z_2$ since $z_1 \geqslant L$. Consequently, the stationary points $dy/dm_T = 0$ and $dy/dn_T = 0$ have a one-to-one correspondence. Thus the global maximum of $y(m_T)$ can be obtained by evaluating $y(m_T)$ at the corner points z_1 and z_2 as well as the interior values $\{m_T\}$ corresponding to the stationary points of $y(n_T)$.

Substituting (58) into (57), we obtain

$$\begin{aligned} y(n_T) = {} & J_1 + J_2(n_T^{1/\varepsilon} + L) - (K_3 + K_6 L + K_6\, n_T^{1/\varepsilon})^{1-\lambda} \\ & + K_{17}(n_T^{1/\varepsilon} + L)n_T^{1/\varepsilon} - \left[\frac{J_3\, n_T^{1/\varepsilon\alpha}}{(U - L - n_T^{1/\varepsilon})^{1/\alpha}}\right] - (J_4 + J_5 L + J_5\, n_T^{1/\varepsilon})^{1-\lambda} \\ & - \left[\frac{J_6(n_T^{1/\varepsilon} + L)^{\gamma}}{K_{11} + (n_T^{1/\varepsilon} + L)^{\delta}}\right] - (J_7 + J_8 L + J_8\, n_T^{1/\varepsilon})^{\zeta} . \end{aligned} \tag{59}$$

It can be shown that the function $y(n_T)$ satisfies the property that we can write down the closed-form expressions for <u>monotone increasing functions</u> $w_1(n_T)$ and $w_2(n_T)$ satisfying

$$dy/dn_T = w_1(n_T) - w_2(n_T) \tag{60}$$

provided $\varepsilon < \min(1 - \lambda,\ 1/\alpha,\ \gamma - \delta,\ \zeta)$. (Such a property is not shared by $y(m_T)$ and hence the need for the transformation.) Consequently by choosing such an ε and identifying the set of all $\{n_T\}$ which satisfy

$$w_1(n_T) = w_2(n_T) \ , \tag{61}$$

we can identify the stationary points of $y(n_T)$ and hence solve the problem of finding the value m_T^* which solves (56) for a specific value of μ.

6.3 Identifying the Stationary Points of $y(n_T)$

The stationary points of $y(n_T)$ are, from (61), the intersection points of the monotone increasing functions $w_1(n_T)$ and $w_2(n_T)$. Figure 3 illustrates an efficient procedure developed by the authors [17] for identifying the intersection points. Let n_1 denote the value of n_T corresponding to the lower limit z_1 for m_T. At n_1, we find $\phi_1 = w_1 - w_2$. Since

FIGURE 3 ABOUT HERE

both functions are monotone increasing in n_T the intersection of the two curves can not occur until w_2 goes up by a magnitude of ϕ_1, corresponding to the point n_2. At n_2, determine $\phi_2 = w_1 - w_2$. Again, the intersection can not occur until w_2 goes up by another ϕ_2, leading to the point n_3. The determination of n_2, n_3, etc. can be done by interval bisection [34, p. 122] or by other methods. Eventually, the values of ϕ become so small that an intersection point has been identified. Moving n_T past the intersection point, say n_4, w_2 is above w_1 by a magnitude ϕ_3. Now w_1 has to go up by ϕ_3 at least before the next intersection point, leading to n_5. At n_5, $(w_2 - w_1) = \phi_4$ leading to the point n_6. This sequence identifies the second intersection point. Eventually all intersection points are identified by this procedure by increasing n_T up to n_7 which corresponds to the upper limit z_2 for m_T.

Although the actual computational procedure used [17] is more sophisticated, the basic idea is as described above. The procedure is computationally efficient [17]. The STRATPORT computer package using the Generalized Lagrange Multiplier approach determines the $\underset{\sim}{m}^*_T$ for $N = 10$ and for 11 different values of μ in less than 20 seconds of CPU time on a DEC 2050 system. The computer time goes up only linearly with respect to the number of BU's. This efficiency is very valuable in conducting sensitivity analyses of large problems in an interactive mode.

6.4 Determining the Range for the Lagrange Multiplier

As described in Section 6.1, STRATPORT determines the values of $\underset{\sim}{m}^*_T$ for several values of μ to obtain a range of strategies corresponding to different values of Δ. Suppose the user wants to determine the strategies for values of Δ in the range (Δ_1, Δ_2) with $\Delta_1 \leq \Delta_2$. The value of Δ_1 (and/or Δ_2) could be negative to denote the requirement that the system generate excess cash. We describe below the determination of the Lagrange Multipliers μ_1 and μ_2 corresponding to Δ_1 and Δ_2 respectively.

Let $F(\mu)$ be the net cash flow corresponding to the optimal strategy associated with the Lagrange Multiplier μ. Since μ is the "cost" of the financial resource F in the objective function (see Eq. (5)), $F(\mu)$ will be monotone nonincreasing in μ. Consequently, $\mu_1 \geq \mu_2$ leads to $\Delta_1 \leq \Delta_2$. The determination of $F(\mu)$ involves computing $\underset{\sim}{m}^*_{Ti}$ corresponding to each BU using (6), evaluating F_i through (46) and summing it over the BU's. We first solve the unconstrained problem, i.e., the problem for $\mu = 0$ (cf. Eq. (3) and (5)). Depending on the value of $F(0)$, three cases arise:

Case (i) $F(0) \leqslant \Delta_1$. Since the net cash flow needed for the unconstrained problem is less than Δ_1, the solution for $\mu = 0$ continues to be the optimum for all values of Δ (recall that Δ_1 is the lower bound for Δ). Thus $\mu_1 = \mu_2 = 0$.

Case (ii) $\Delta_1 < F(0) \leqslant \Delta_2$. The unconstrained optimum (i.e., $\mu = 0$) is also optimum for the requirement level Δ_2 so that $\mu_2 = 0$. μ_1 (corresponding to Δ_1) needs to be determined.

Case (iii) $F(0) > \Delta_2$. Both μ_1 and μ_2 need to be determined.

Since $F(\mu)$ is monotone nonincreasing in μ, the values of μ_1 (corresponding to Δ_1 -- Cases (ii) and (iii)) and μ_2 (corresponding to Δ_2 -- Case (iii)) can be determined by the interval bisection procedure [34, p. 122].

6.5 The Profit-Financial Resource Envelope

The results of the STRATPORT optimization with tax and discounting for various values of μ may be displayed as shown by the curve ABCDEG in Figure 4. As we would expect, the net present value π is monotone increasing in Δ, exhibits diminishing returns, eventually reaches a maximum value, and stays there for larger values of Δ. (Constraint (4) is not binding for such large values of Δ so that $F < \Delta$.) Considering, for instance, the points C and D, let μ_C and μ_D denote the corresponding values for the Lagrange Multiplier. Theorem 2 in [11] shows that

$$\mu_C \geqslant (\pi_D - \pi_C)/(F_D - F_C) \geqslant \mu_D \ . \tag{62}$$

Thus μ_D and μ_C bracket the marginal effect on π from external financing in the range C-D. Consequently, μ can be interpreted roughly as the rate of increase in net present value from additional cash investment.

6.6 Average and Marginal Yields $\bar{\rho}$ and ρ

For managerial interpretation, a measure such as rate of return or yield is more suitable than net present value. We define the investment F made for S periods to have an average yield $\bar{\rho}$, if it generates the same net present value as a cash flow stream of $\bar{\rho}F$ \$/period for $t = 1,2,\ldots,S$. (If $F = -\Gamma < 0$, this may be interpreted to mean that the amount Γ "borrowed" for S periods requires an "interest payment" of $\bar{\rho}\Gamma$ \$/period for $t = 1,2,\ldots,S$). We use current dollars since managers usually think of rates of return in nominal terms. Let r' be the present nominal discount rate for the overall firm, determined using the current Beta coefficient for the firm and applying Eqs. (53) and (55), after omitting subscript i. To determine the $\bar{\rho}$ corresponding to investing F dollars for S periods and obtaining a net present value of π, we set

$$\pi = \bar{\rho}F\left[\sum_{t=1}^{S}\frac{1}{(1+r')^{t}}\right] - F\left[1-\frac{1}{(1+r')^{S}}\right] .$$

Simplifying, we obtain

$$\bar{\rho} = r'\left[1+\frac{(\pi/F)}{\left\{1-\left(\frac{1}{1+r'}\right)^{S}\right\}}\right] . \qquad (63)$$

Eq. (63) is consistent with the fact that if the average yield equals the discount rate $(\bar{\rho} = r')$, the net present value is zero. The yield measure is similar to internal rate of return. However, in contrast to internal rate of return, which assumes that intermediate cash flows can be reinvested at the internal rate of return, the yield measure assumes more realistically that intermediate cash flows are reinvested at the present discount rate. If S is large, Eq. (63) can be approximated by

$$\bar{\rho} \simeq r'[1 + (\pi/F)]. \tag{64}$$

To obtain the marginal yield ρ, we replace π/F by $d\pi/dF$. From Eq. (62)

$$\mu \simeq d\pi/dF \tag{65}$$

so that Eq. (63)-(64) gets replaced by

$$\rho \simeq r' \left[1 + \frac{\mu}{\left\{ 1 - \frac{1}{(1 + r')^S} \right\}} \right]. \tag{66}$$

For large values of S, Eq. (66) may be approximated by

$$\rho \simeq r'(1 + \mu). \tag{67}$$

Using the concept of marginal yield, the firm may examine portfolio strategies for a range of values for ρ on the basis of what it regards as an acceptable range of values for the marginal yield (Eq. (66)). The marginal yield also provides a rough guideline for the extent of external financing since the marginal yield from financing should exceed the marginal cost of capital. Since the marginal cost of borrowing and/or raising additional equity increases as Δ increases the marginal cost of capital ξ will increase with Δ. The marginal cost of capital is given by a slight modification of Eq. (55):

$$\xi = W_e \hat{r}_e + W_d \hat{r}_d \tag{68}$$

where $\hat{r}_e$ and $\hat{r}_d$ denote the equity and debt cost of capital at the margin and are to be subjectively, estimated. (Eq. (68) assumes that the debt/equity ratio is not altered.) Referring to Figure 4, we can determine the marginal yields corresponding to points A, B, C, D and E from their corresponding μ's (Eq. (66)). The approximate optimum amount Δ^* corresponds to the last of these points for which the marginal yield exceeds the marginal cost of capital. We define ρ^* to be the marginal yield corresponding to Δ^*.

6.7 The Marginal Yield ρ^* as a Decentralization Mechanism

The theoretical significance of ρ^* is that it could act as a decentralization mechanism for the entire firm once it has been centrally determined. Business units can operate independent of each other, but with ρ^* acting as the coordinating mechanism. Business units which can generate yields in excess of ρ^* can borrow from the corporate financial pool (internally generated funds as well as external funds) up to that point which makes diminishing returns lower the BU's yield down to ρ^*. Conversely, BU's which generate yields lower than ρ^*, can loan funds to the corporate financial pool until that point when the BU's yield increases to ρ^*. However, this interpretation should be regarded as only approximate. The process may not exactly converge i.e., corporate pool's lending may not exactly equal borrowing, since the functions used in our approach do not satisfy suitable convexity/concavity properties needed for convergence.

6. Concluding Remarks

An important feature of the STRATPORT formulation is its modular construction in terms of the various components that determine the profit and cash flow need (see Figures 1 and 2). It is not difficult to add, remove or modify these modules while keeping the overall model structure the same. The key requirement on the modules, however, is that the financial entities should be capable of being expressed as explicit functions of m_T. To illustrate, it would be worthwhile to replace the market response module (Section 4.1) by a more elaborate module which would integrate market response information on the different product-markets that comprise a BU so as to provide the overall market response function. Alternatively, one may replace the same module by one which links marketing expenditure on the one hand and market share on the other through strategic variables of the kind used by PIMS [26] and ADVISOR [18]. Similarly, the cost modules (Sections 4.4 and 4.5) could potentially be modified by modeling separately the different components which lead to experience effects (e.g., scale effects separated from "learning" effects).

Recognizing the inherent uncertainties in strategic planning, it is extremely important to analyze the sensitivity of the results to assumptions regarding the parameters of the models as well as regarding competitive reactions. In fact, such sensitivity analysis may distinguish inputs where more accurate information is needed from inputs which have relatively little impact on the results. The sensitivity analysis may also identify decision areas for greater managerial attention. For instance, a relatively large impact of a change in an experience coefficient λ may suggest that greater attention needs to be paid to manufacturing strategy and productivity improvements.

The main restrictions in the structure of the model concern the specific forms selected for each function, the absence of cost and market interactions between the BU's and the treatment of price behavior and market size as exogenous. The functional forms specified in the model are relatively general and will not usually represent a serious limitation. The other restrictions were made because of the difficulty to obtain reliable data either empirically or through managerial judgment as well as the mathematical and computational difficulty to represent these more complex phenomena. Consequently, these restrictions should be borne in mind in interpreting the results of the model. The extension of the model to relax such restrictions is a subject for future research.

The assumption of exogenous market sizes can be relaxed to an extent by an iterative application of STRATPORT. One may first apply STRATPORT using data on $\{M_t\}$ obtained by standard forecasting techniques. One can then utilize the optimal marketing expenditure E obtained from STRATPORT to update $\{M_t\}$. STRATPORT could then be reapplied with the modified $\{M_t\}$ and the process repeated until the market demands $\{M_t\}$ are roughly consistent with the optimal expenditure E. The iterative application of STRATPORT could also be useful in incorporating changes in synergy as a result of portfolio strategy, i.e., parameter inputs to one BU may be affected by the strategies chosen for some other BU's. The feasibility of such iterative analysis is facilitated by the computational efficiency of the STRATPORT model.

STRATPORT, as presently designed, is mainly a decision support system for evaluating and formulating business portfolio strategies, answering "what if" questions and assessing the long-term impact of strategic decisions. It may also be integrated with a broader management information system keeping historical data on plans as well as actual results. This would be useful in at least partially making managers accountable to the inputs they provide, thereby reducing any tendency to "game" the system. In broader context, it can serve as a feedback, control and managerial incentive system so that strategic plans can be compared in terms of predicted vs. actual results and corrective actions taken to improve the implementation of strategy [7].

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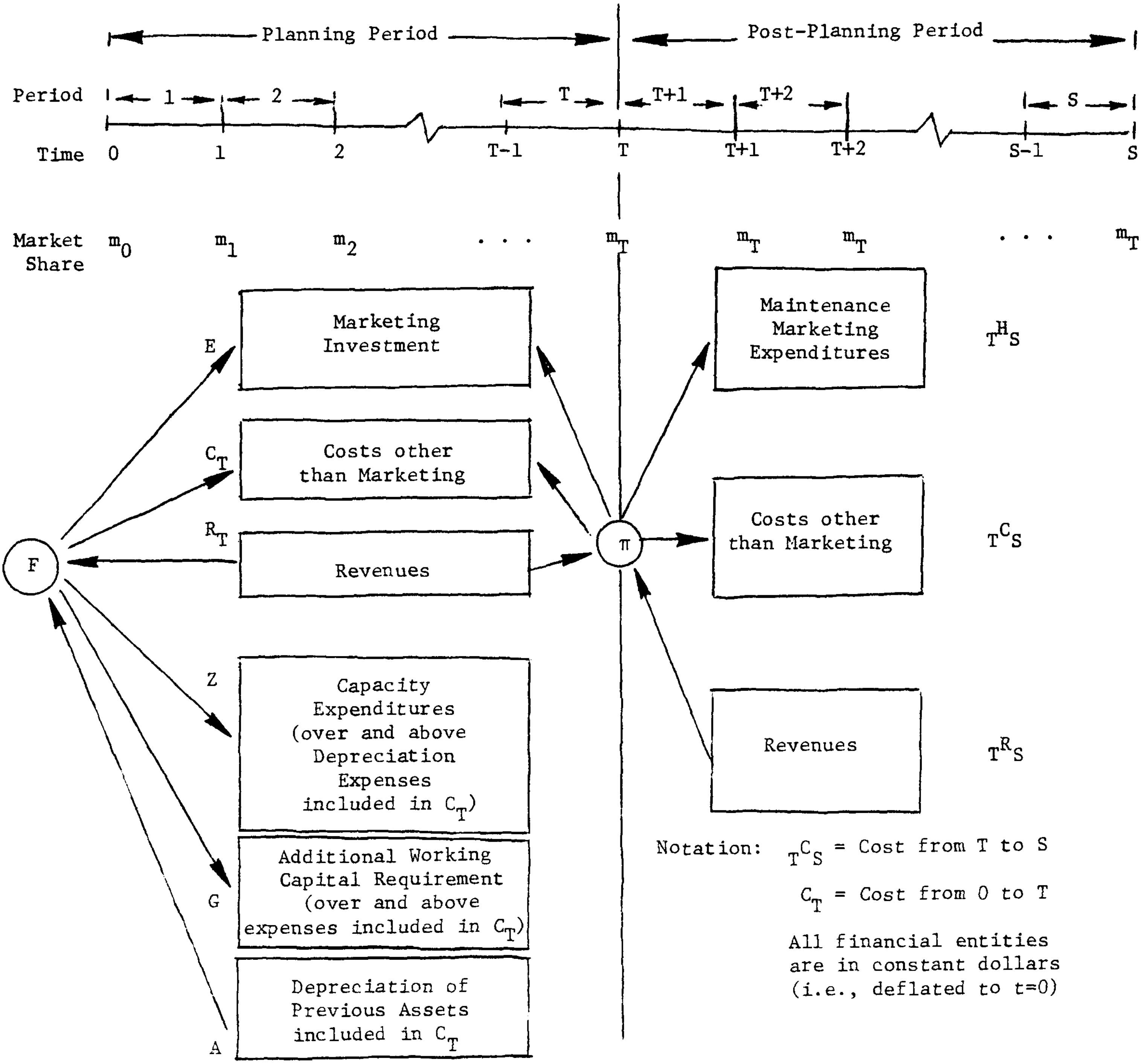


F = Cash Flow need during Planning Period = $E + C_T - R_T + Z + G - A$

π = Long-Term Profit = $(R_T + {}_TR_S) - (C_T + {}_TC_S) - (E + {}_TH_S)$

FIGURE 1. Components of Long-Term Profit and Short-Term Cash Flow Need for a Single Business Unit

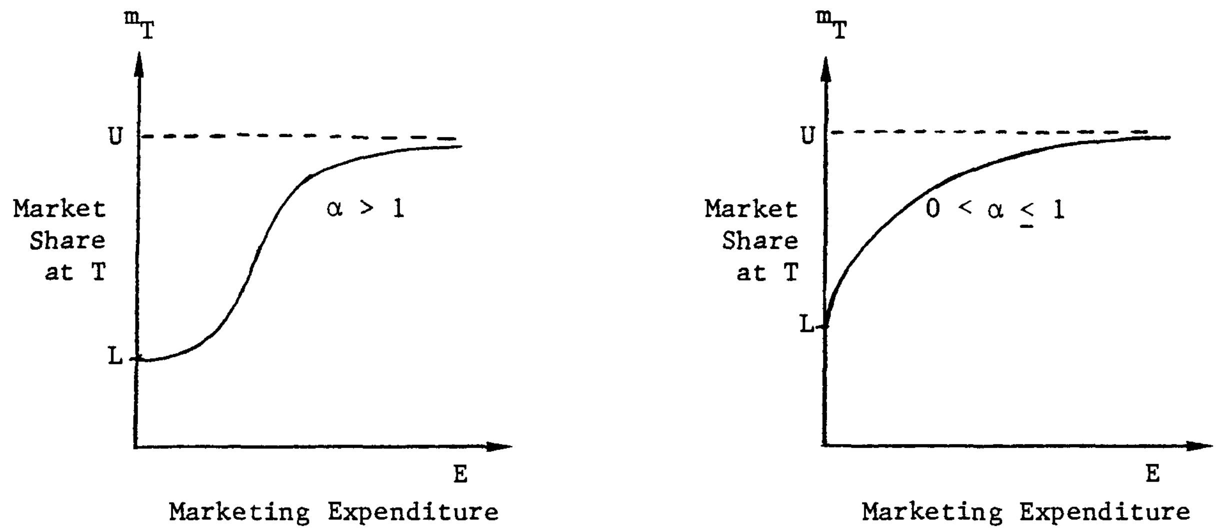


FIGURE 2(a). Market Response Function

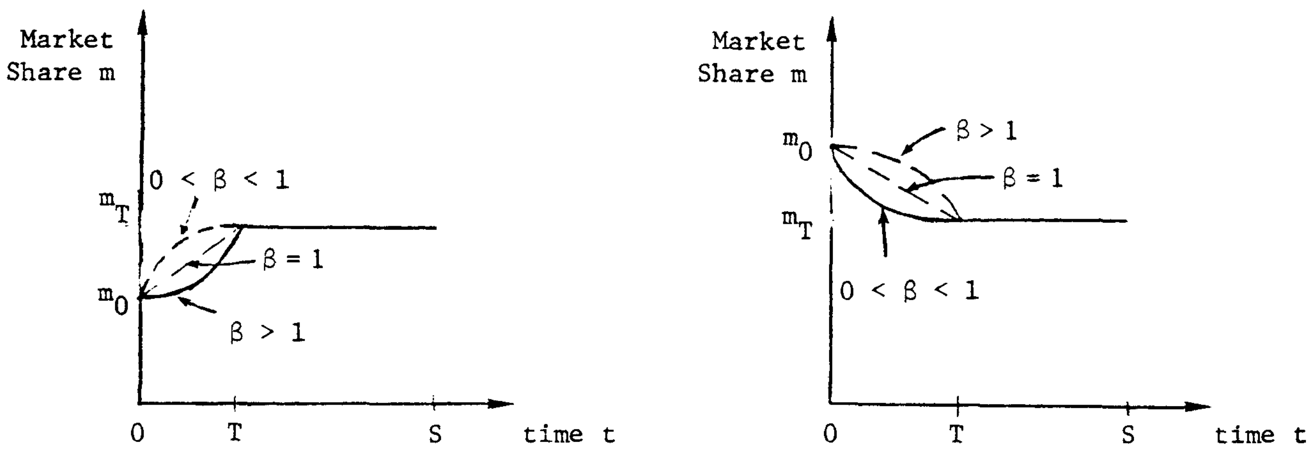


FIGURE 2(b). Market Share Evolution

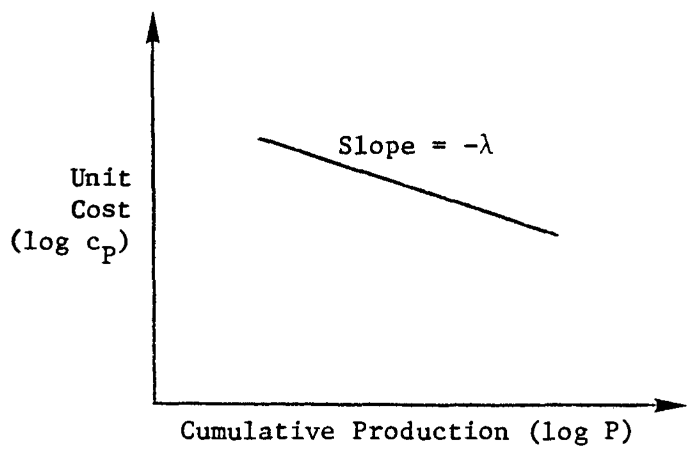


FIGURE 2(c). Evolution of Unit Cost

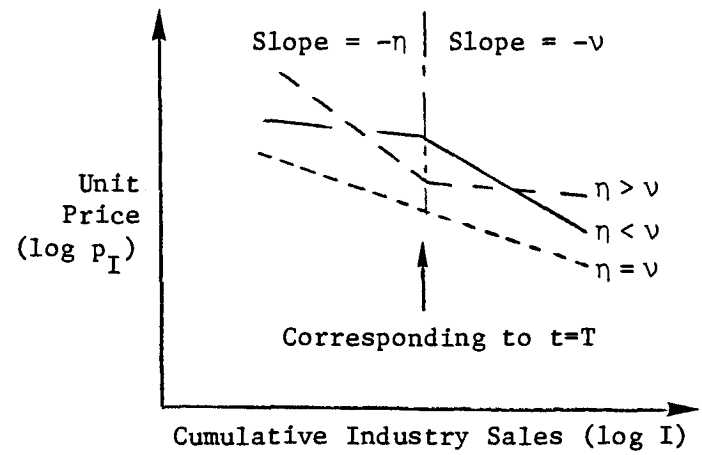


FIGURE 2(d). Evolution of Unit Price

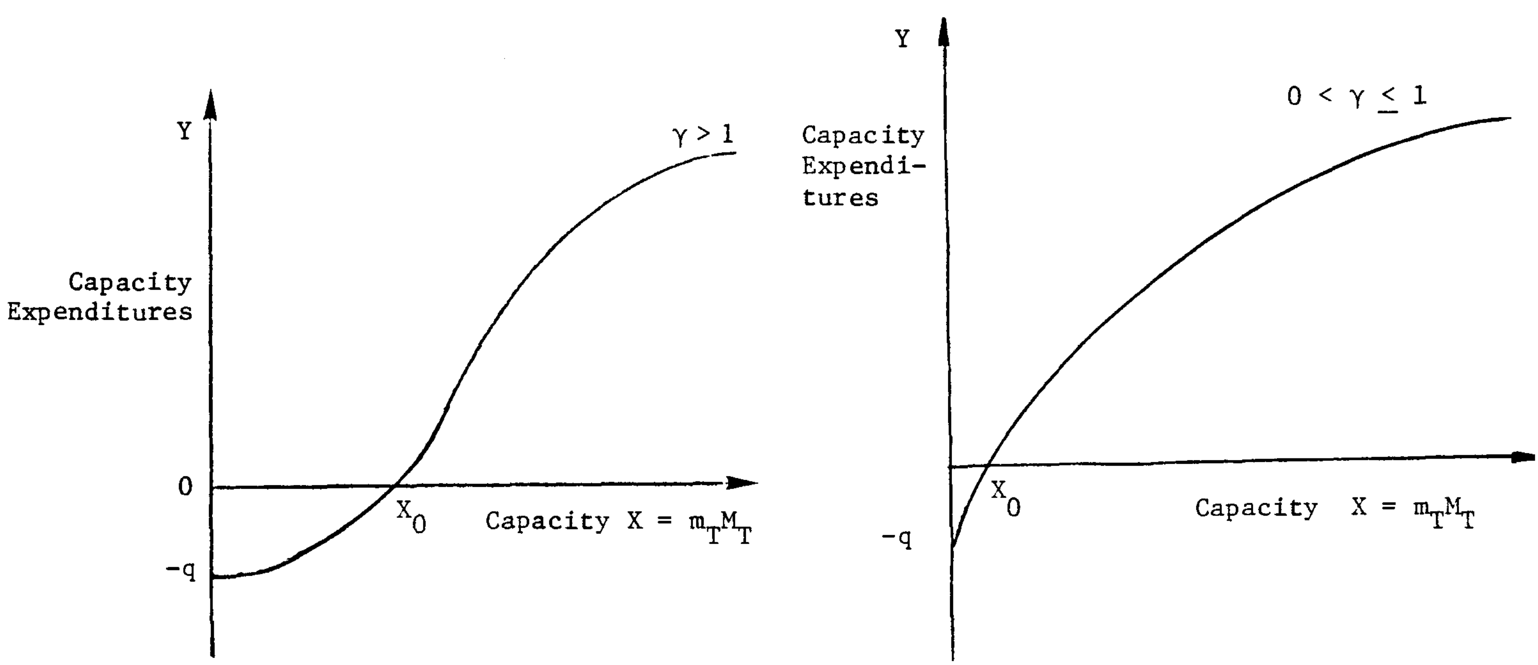


FIGURE 2(e). Capacity Expenditure Function

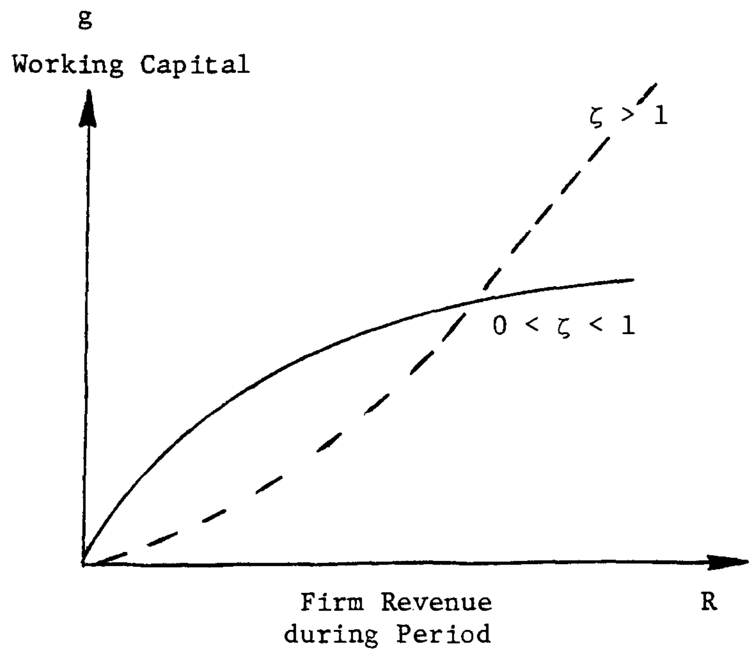


FIGURE 2(f). Working Capital Function

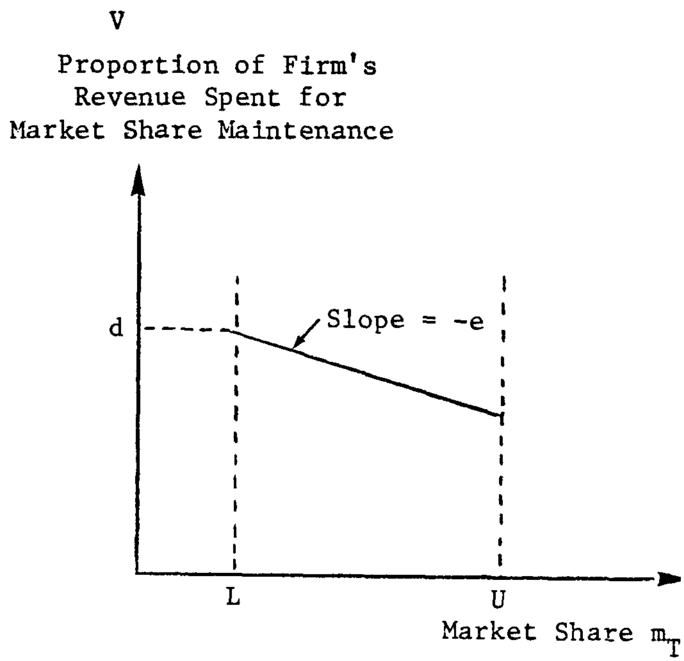


FIGURE 2(g). Market Share Maintenance Function

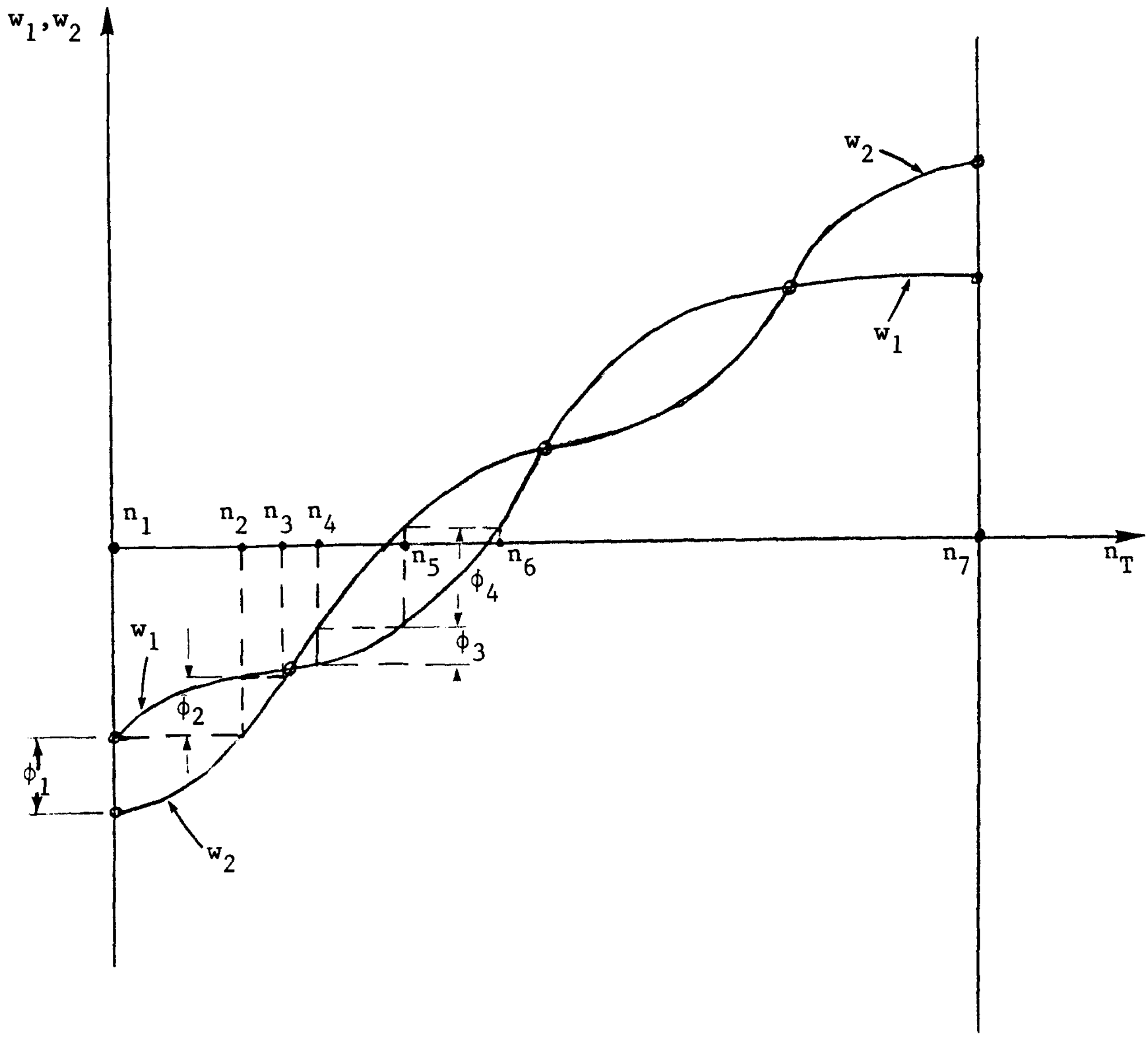
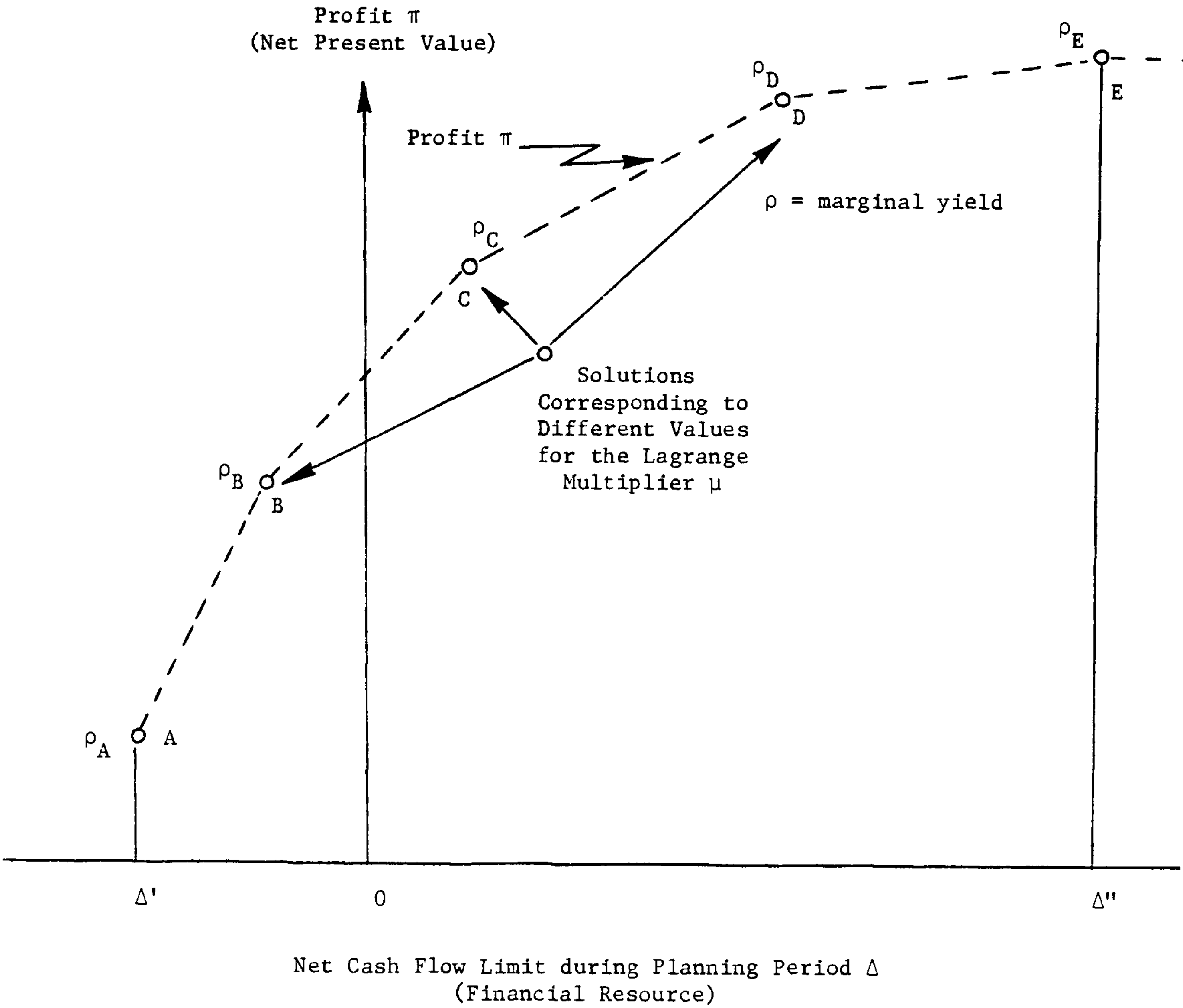


FIGURE 3. Finding the Intersection Points of Two Monotone Increasing Curves



Note: For values of Δ such that $\Delta' \leqslant \Delta \leqslant \Delta''$, net cash flow need F = net cash flow limit Δ.
For values of $\Delta > \Delta''$, net cash flow need F $(=\Delta'')$ < net cash flow limit Δ

FIGURE 4. Profit-Financial Resource Envelope

FOOTNOTES

1. Differences in planning periods $\{T_i\}$ across the BU's can be accommodated in our framework by defining the common planning period T to be the maximum value of T_i over the N BU's and choosing the shapes of the market share evolution curve (§4.2) differently for the different BU's. For expositional convenience, the post-planning period is assumed to be common across the BU's, although this assumption can be easily relaxed.
2. The formulation in Eq. (14) can be easily generalized to the case where the right hand side of Eq. (14) is modified to $cP^{-\lambda} + c_0$ with $c_0 > 0$. The only change involved is that the total cost C_T as computed in this section has to be augmented by an additional term $c_0(P_T)$ where P_T is given by Eq. (13).
3. For reasons explained in §3, our approach incorporates capacity costs in the form of depreciation expenses rather than considering capacity expenditures directly as cash flows. The latter approach is theoretically more appropriate. The two approaches are equivalent under realistic assumptions had all cash flows been expressed in current dollars. By making a modification (details too cumbersome to provide here) in the way depreciation is included into the computation of total cost C, the two approaches, under realistic assumptions, become equivalent even if the cash flows are expressed in constant dollars and/or discounted.

LIST OF INSEAD RESEARCH WORKING PAPERS

80/01 "Identifying cognitive style determinants of retail patronage, by Christian PINSON, Arun K. JAIN & Naresh K. MALHOTRA, Jan. 1980.

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