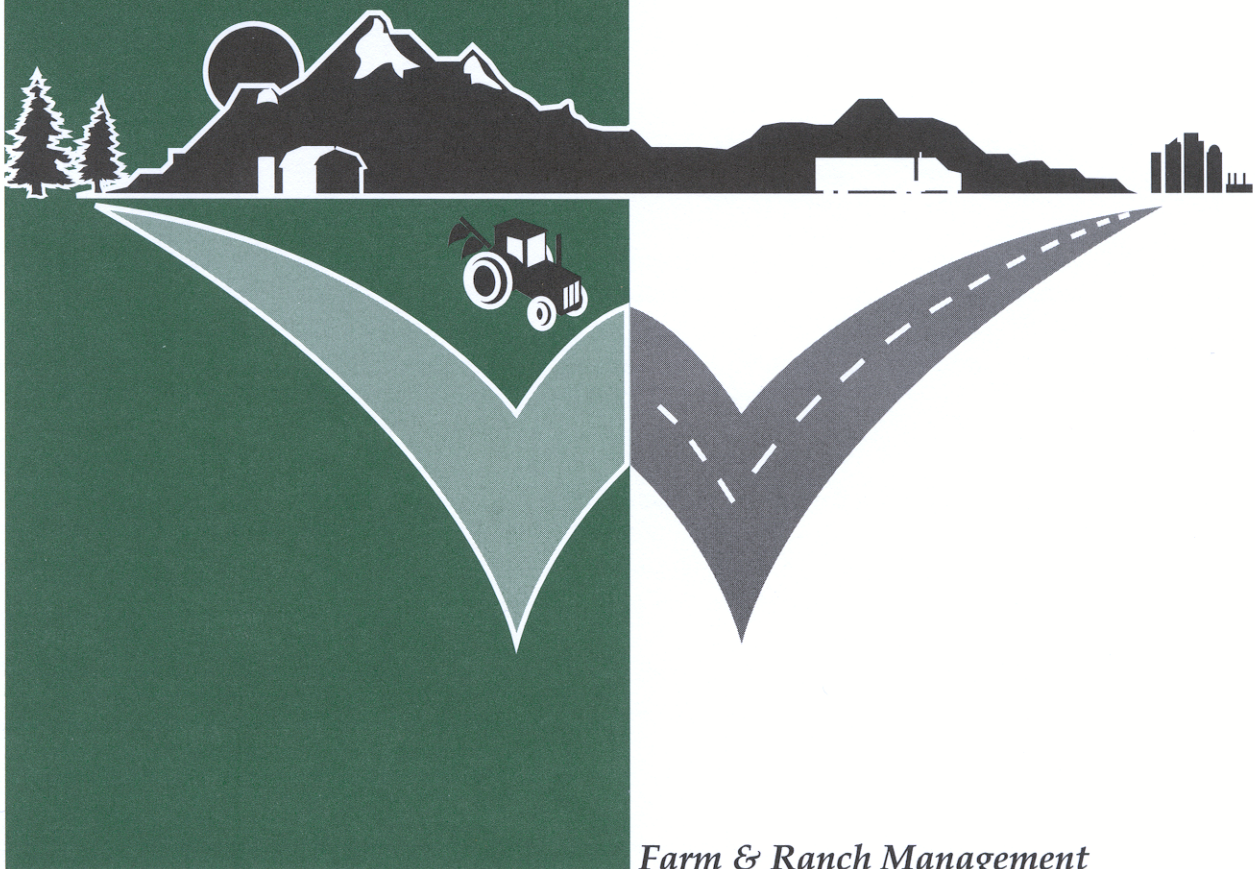


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Dynamic Strategic Interaction: A Synthesis of Modeling Methods

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Agribusiness in the western U.S. no longer consists only of atomistic producers selling into homogeneous commodity markets. Rather, marketing concepts such as value-added, differentiation, branding and supply-chain management are now as familiar to growers, grower cooperatives and marketing boards as they are to food processors and retailers downstream. From Pink Lady apples in Washington State to Shamrock foods in Arizona and Sunkist in California, “commodity” marketers are developing a level of sophistication on par with the most aggressive consumer good manufacturers. With this increased level of marketing sophistication, however, comes a new definition of “competition.” Competition no longer implies passive acceptance of a market price, but rather active design of a marketing program intended to develop and exploit strategic pricing opportunities.

Economic analysis can help managers better understand the opportunities they may face. Indeed, much of the recent empirical research in both marketing and industrial organization focuses on the nature of strategic interaction among rival firms (Feichtinger, Hartl, and Sethi, 1994; Slade, 1995). However, economists tend to take a positive approach in testing whether market power or strategic behavior exists, while marketing researchers build normative models that make optimal use of limited marketing budgets. For both purposes, however, each must estimate parameters that describe strategic conduct. In theory, these two disparate approaches should yield identical results, but in practice their fundamentally different modeling techniques often leave this similarity in some doubt. While most researchers agree that marketing strategies based on advertising, promotion, pricing, product attributes or product line must be cast in a dynamic framework, that is where the agreement ends. Indeed, the heart of the discrepancy between the two modeling approaches lies in competing assumptions regarding how to treat the dynamic impacts of marketing investments. Essentially, there are two broad model types that appear in the industrial organization and strategic marketing literatures, respectively: (1) Nerlove-Arrow, or “goodwill” models, and (2) Lanchester, or “market share” models.

Among the first studies to incorporate advertising dynamics, Nerlove and Arrow (1962) maintain that advertising expenditures are in fact investments in a long-lived capital asset they termed “goodwill.” Because goodwill is both slow to develop and depreciates (in an economic, rather than accounting sense) slowly over time once established, the impact of an investment made in one period can be felt for many periods into the future. As a result, economic models that describe the effect of advertising on sales must be inherently dynamic. With this approach, goodwill becomes the single state variable. Examples include Roberts and Samuelson’s (1988) dynamic conjectural variations model of strategic advertising interaction in the cigarette industry, Gasmi, Laffont and Vuong’s (1992) treatment of marketing activities in the soft drink industry, or Slade’s (1995) analysis of price and advertising rivalry among biscuit makers. On the other hand, authors in the strategic marketing field regard market share as the relevant state variable. Specifically, Vidale and Wolfe (1957) and Kimball (1957) develop a model of dynamic market share rivalry based on Lanchester’s (1921) study of battlefield strategy. By assuming marketing activities by duopolists act directly on the rate of change of their respective market shares, Lanchester-type models reduce a potentially complex problem to one consisting of a single state variable. Examples of this approach include Deal (1979), Sorger (1989), Erickson (1992, 1997), and Chintagunta and Vilcassim (1992, 1994). While both require the estimation of strategic response parameters, it is perhaps surprising that neither has sought insight from the other on how to accomplish this.

Nonetheless, such a synthesis is possible and potentially desirable. Despite the compelling logic of either approach, each has its conceptual and empirical strengths and weaknesses. Whereas the notion of advertising contributing to a capital asset that has a lasting effect on sales is intuitively plausible, Nerlove

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- Arrow models are difficult to apply because goodwill is inherently latent or unobservable. Moreover, it is a depreciating asset, yet the rate of depreciation is typically underidentified in most empirical applications. Perhaps due to the fact that the objective in applying this type of model is usually only the estimation of response parameters and not the complete parameterization of an optimal control problem, they also tend to be very complex with many state and more control variables.

Although market-share state variables in Lanchester-type models are readily observable and result in very simple, elegant solutions, there are a number of reasons why this approach is perhaps overly restrictive. First, in order to retain the mathematical tractability of dealing with only one state variable, researchers tend to apply the Lanchester framework only to duopolies (Sorger, 1989; Chintagunta and Jain, 1995; and many others). Erickson (1997) recognizes this weakness by extending the model to include dynamic conjectural variation terms wherein several competitors respond to changes in market share with contingent advertising strategies, but he uses synthetic parameters to solve for the optimal path of advertising and does not estimate response parameters. In contrast, structural game theoretic models do not face the same restrictions on the number of potential rivals because they do not purport to solve for equilibrium control paths. For example, Slade (1995) employs a differential game approach similar to Karp and Perloff (1993) in analyzing both price and advertising competition among several rival brands of crackers in a local oligopolistic market. Roberts and Samuelson (1988), Gasmı and Vuong (1991) and Gasmı, Laffont, and Vuong (1992) adopt similar structural approaches, but restrict their analyses to duopolistic rivalry in order to focus on the problem of competing with multiple-tools. Their econometric models could, however, easily be extended to include more general oligopolistic rivalry at little cost.

Second, in considering only market-share rivalry, Lanchester models do not allow for aggregate market growth as a result of competitive advertising. Although this limitation also applies to conditional demand models, it is possible to incorporate aggregate market impacts through two-level demand systems (Richards, van Ispelen, and Kagan). Third, although notable exceptions exist, such as Chintagunta and Vilcassim's (1994) model of advertising and "detailing" by pharmaceutical marketers, studies in the Lanchester tradition typically include only one strategic variable. Clearly, this approach is not entirely realistic because most marketing managers now recognize the potential for complementarity among the tools at their disposal, such as promotion and advertising or merchandising and new product development. Fourth, while the differential equations describing the evolution of duopoly market share are mathematically plausible, they are *ad hoc* as they are not grounded in any theoretical model of consumer choice. Rather, because market share evolves as consumers respond to marketing variables in an optimal way, changes in market share should be fully consistent with constrained consumer optimization. Liang (1986), Chintagunta and Jain (1995), Chingtanunta and Rao (1996) and Cotterill and Putsis (2000) each present alternative ways to incorporate consumer demand into models of strategic rivalry, but none of these studies represents a fully dynamic approach to the problem at hand. By grounding a dynamic, strategic-marketing model in consumer theory, we may be able to estimate a system of equations that provides a more realistic description of the likely outcome of market share rivalry.

We propose a model that addresses each of these weaknesses by integrating features from both industrial organization and marketing research models of strategic rivalry. First, by treating each firm within an oligopoly as being in an "us versus them" battle for market share, we are able to condense a potentially intractable oligopoly problem into one that is mathematically manageable. This is a realistic approach in that oligopolistic firms rarely single-out particular rivals for a targeted price cut or advertising campaign. Second, we explicitly account for the fact that marketing strategies can, and do, include choices over several marketing variables and that these choices are endogenous to market performance and rival strategies. Consequently, we specify a fully simultaneous model of product demand and strategic-response. This is again realistic as firms allocate marketing budgets among different functions according to their effectiveness in countering rival strategies and in working with other marketing activities. Third, we base the dynamics governing market share in a model of consumer optimization, so strategic interaction impacts firm performance not directly, but through demand for their product. This is a more realistic and plausible motivation for the evolution of market share as it goes to the *cause* of

changes in share rather than the *symptoms* of rivals' actions. By incorporating these three features into a model of strategic rivalry, we hope to create a synthesis that performs better than existing models.

An Empirical Comparison

To facilitate comparison, we first present a brief description of a typical Lanchester-type model and then offer an alternative. With a Lanchester approach, firms maximize the present value of future profits subject to the dynamic evolution of their market share, which is in turn determined by the nature of the strategic response of their rivals. In a duopoly, the single state variable is defined in terms of firm l 's market share (M_l) so that rival market share is the simple complement of this: $M_j = 1 - M_l$. Market share growth is assumed to rise with the effectiveness of a firm's own marketing activities and the extent of the market not currently being served. Moreover, each marketing activity has a diminishing marginal impact on a firm's own market share as initial gains are, quite plausibly, easier than later ones. With these assumptions, the equation of motion for the market share of firm l is written as:

$$\dot{M}_l = M_{l,t} - f_l M_{l,t-1} = (b_l A_l^{a_l})(1 - M_l) - (b_{-l} A_{-l}^{a_{-l}})M_l + e_l,$$

where \dot{M}_l is the change in market share of the l^{th} firm, A_l, A_{-l} are a set of j marketing tools available to firm l and its rival, respectively, and e_l is a random error. For example, this set of tools may consist of advertising, product development expenditure, number of distinct brands (product line length) or price. In this general form for firm l 's market share dynamics, b_l measures the effectiveness of the particular strategic tool, whereas a_l provides an estimate of its curvature. Further, we include the parameter N ($0 < N < 1$) to account for the possibility that market share adjustment from one period to the next is costly, so it is not instantaneous if firms behave optimally. Equation (1) forms the basis of the Lanchester model of market share rivalry. Despite its simplicity, intuitive appeal, and considerable empirical support, it nonetheless rests on an *ad hoc* specification for the evolution of market share.

On the other hand, if the equations of motion for market share represent a system of consumer demand functions, such as the Almost Ideal Demand System (AIDS) model of Deaton and Muellbauer (1980), then they can be consistent with optimal consumer behavior. More specifically, if prices are indeed endogenous (Liang, 1986; Cotterill and Putsis, 2000), then the demand system itself should be written in inverse, or *price-dependent* form with firm-level quantities as explanatory variables. This is the Inverse Almost Ideal Demand System (IAIDS) of Moschini and Vissa (1992) and Eales and Unnevehr (1993). Allowing for the fact that consumer learning, habits, costly search, and the formation of a stock of marketing goodwill all imply that demand is inherently dynamic, we write the IAIDS equations of motion as the system of inverse demand equations:

$$\dot{M}_{it} = q_i M_{i,t-1} + \sum_j d_{ij} \ln A_{ij} + \sum_j d_{-ij} \ln A_{-ij} + g_i \ln q_i + g_{-i} \ln q_{-i} + h_i \ln Q + v_i,$$

for all l firms using j marketing tools, where z_i is the rate of market-share adjustment, q_i is the unit volume sold by firm i , Q is the total quantity index, v_i is a random error term and the other variables are as defined above. With this specification, average price levels for each rival firm are implicitly endogenous, so they are strategic variables in the IAIDS model, but not the Lanchester model. Note also that this model can generalize to multiple strategic variables and many firms. Next, with the competing market-share adjustment equations defined in (1) and (2), we derive equations for each model that define the optimal strategic response in each marketing mix variable from the first order conditions of the firm's dynamic optimization problem.

The details of this derivation for the IAIDS model are in Richards and Patterson, but we summarize the logic here. If we assume the firms play a non-cooperative game in each marketing tool in every time period, a closed-loop solution to the dynamic problem constitutes a Nash equilibrium where each decision variable is a function not only of time, but of the current state of the game. In this respect, we model a sub-game perfect solution. Clearly, solving this problem in more than two market shares i.e. in an oligopoly, or with multiple tools is analytically intractable. Therefore, we adopt a new approach by considering the oligopoly solution as simply a series of "us versus them" duopoly games. This approach, while unique, is valuable in two respects. First, it reduces the number of state variables, thus making what would otherwise be an intractable economic problem easily solvable with analytical methods. Second, it is intuitively preferable because firms do not single-out rivals for targeted advertising or pricing strategies as a complete, multi-firm strategic response model would imply. Rather, they set policies conditional on the strategic environment they face, which may consist of any number of rivals. By optimizing their marketing decisions given the optimal reactions of the collection of other firms, the industry equilibrium is still Nash. Consequently, we estimate a demand system wherein the arguments are the own firm's marketing activities, all other firms' activities, the own firm's quantity, all other firms' quantities, and an aggregate sales index. Estimating this system in a fully simultaneous model that also includes supply, or conduct, equations for each quantity and marketing activity provides a consistent set of response-parameter estimates. Deriving an econometric model, however, does not guarantee that it provides a better fit to the data compared to the existing approach.

To examine whether it does, we estimate a similar simultaneous system of equations consisting of the equations of motion from a Lanchester model of market share rivalry along with the implied first order conditions for the optimal choice of each marketing activity. Because the IAIDS and Lanchester models are not nested in one another, we compare their empirical performance using a battery of non-nested tests consisting of: (1) the J-test of Davidson and MacKinnon (1981), (2) the Likelihood Dominance criterion of Pollak and Wales (1991), and (3) two measures of predictive accuracy B the root mean square error and Theil's U (Theil 1961). The data for our comparison consist of 65 four-weekly observations of ready to eat cereal sales, prices and brand introduction data taken from the IRI Infoscan data base for the Baltimore / Washington, D.C. market. We combine these data with smoothed quarterly observations on advertising and product development expenditure for the top four cereal companies.

In this example, we find that all three methods of comparison favor the IAIDS over the Lanchester model. Perhaps more importantly, we also find that several important implications that arise from the IAIDS results are either absent in the Lanchester results, or the Lanchester model suggests an entirely different strategy. For example, the IAIDS results show that advertising expenditures and new product introductions are complementary, whereas the Lanchester model does not. Given that firms rarely introduce new products without advertising, and never without some prior commitment to significant investment in product development, the Lanchester results appear to be of little value. Beyond these, and similar, insights into the conduct of marketing rivalry, the approach illustrated here may be valuable to marketing researchers or managers in general in a wide variety of similar contexts.

In particular, recognizing that strategic variables affect firm performance only indirectly through consumer demand is more consistent with marketing practice than is a simple, mechanistic assessment of the tactical benefits of putting capital toward each marketing tool. Indeed, well-planned marketing decisions are taken with customer-oriented goals in mind so gains on rivals are achieved by reaching the same set of customers in a more effective way. Further, this analysis shows that these strategic goals need not be couched in terms of a series of one-on-one interactions with rivals as in traditional oligopoly analysis, but rather as if each firm exists in a duopoly -- a duopoly consisting of itself and all other rivals. This perspective not only serves to make dynamic empirical analysis of oligopolistic rivalry mathematically solvable, but also provides more general recommendations as to the optimal policy of any one industry member. In light of these results, the path of future research in this area is clear. Namely, broadening the scope for integrating methods from marketing research into econometric orthodoxy.

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