

Developments In Business Simulation & Experiential Exercises, Volume 20, 1993

A DYNAMIC MARKET SHARE ALLOCATION MODEL FOR COMPUTERIZED BUSINESS SIMULATORS

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ABSTRACT

Market demand models in simulators using old design technology do not model the purchase behavior of individual buyers, do not maintain independence between buyers and suppliers, and simulate zero-sum market share allocation processes. A new model is presented which realistically models the behavior of individual buyers, maintains independence of action between buyers and suppliers while allowing for reciprocal influence, and can be used to simulate either a zero-sum share allocation process or a shared-sum allocation process.

INTRODUCTION

The complete demand function in a typical computerized business simulator usually has two parts. One part models aggregate (market) demand and the other models demand experienced by each competitor (firm demand). The functional form used to model aggregate demand is also used to model the demand for each competitor's product. Parameters in each function may be the same or different, depending on the purposes of the designer.

It is interesting to note that the use of one functional form to model both aggregate demand and firm level demand began with early-computerized business simulators and continues today without challenge. This two-part demand function design is based on the implicit assumption that individual buyer behavior is properly modeled by using a functional form that is appropriate for modeling aggregate demand. While we owe a debt of gratitude to some of the pioneers in the field of computerized business simulator design, our debt should not keep us from challenging our inheritance.

A computerized business simulator could be based on many implicit assumptions and still possess objective learning validity (Carvalho, 1991 a). However, it is just as likely that implicit assumptions could be the source of dysfunctional dominant factors. To advance the state of the art in computerized business simulator theory and design, implicit assumptions need to be analyzed whenever found. Therefore, the purpose of this paper is to challenge the use of an aggregate demand function to model individual buyer behavior. An individual buyer behavior process will be modeled and discussed.

BACKGROUND

Many computerized business simulators model aggregate demand with a multiplicative function (Pray and Gold, 1982; Wolfe and Teach, 1987) of the form

$$Q = P^{\alpha} A^{\beta} R^{\gamma} \quad (1)$$

The demand determinants P, A, and R represent price, advertising and R&D respectively, and the exponents are constant elasticities. R&D expenditures are typically used as a surrogate for quality.

An interesting variation of the aggregate demand multiplicative function was developed by Thavikulwat (1989). Gold and Pray (1984) developed an aggregate demand function with variable elasticities. Carvalho (1991b, 1992) proved that under certain conditions the aggregate demand function is non-linear with an inflection point, and presented

two functions which satisfy the requirements of the proof.

Computerized business simulators that use the multiplicative function for aggregate demand usually use the same multiplicative functional form for the market share allocation function. Teach (1990) proposed a gravity flow model to replace the multiplicative function for market share allocation. With the gravity flow model a simulation designer can simulate overlapping markets by establishing centroids for the market segments either in terms of product attributes or demand determinants.

When Eq. 1 is used to allocate market share it has several attributes which can affect the realism of the simulator in which it is used. It is a deterministic function, meaning the buyer will respond to the stimulus of the demand determinants and buy regardless of their value. Buyers will not "not buy". The independence of buyers from suppliers is not maintained (Carvalho, 1992). Suppliers determine what the buyers will do. The buyers are passive responders to the actions of the suppliers.

Another attribute of Eq. 1 is the fact that it is a market demand function. Market demand functions do not model individuals purchase decision processes; they model a condition or state of affairs in the market. A market demand function indicates the quantity that will be purchased at each price by all people in the market. The process by which an individual buyer arrives at the decision to buy or not buy a particular product is not modeled by the market demand function.

Models of the type of Eq. 1 imply that what buyers do in period $n + 1$ is totally unaffected by what buyers did in period n . The behavior in each period occurs as though each period was the first period in which the market was operating. Any connection across periods is achieved only by the students using the simulator.

Finally, since Eq. 1 is a multiplicative function, all demand determinants interact with each other. The first derivative of the function with respect to any demand determinant is a function of all the other demand determinants. Therefore, this model implies that buyers optimize when making purchase decisions. However, optimization is not the only rational decision process possible, so use of this model is restrictive in terms of simulating alternative (and perhaps more frequently used) decision processes.

A MODEL OF THE PURCHASE DECISION PROCESS

The problem addressed in this paper can be stated as follows: how does a buyer decide which of the competitive offerings to buy?

This problem is structured by the following assumptions. The product simulated is a small ticket consumer durable and is affordable to everyone in the target market. When an individual makes a purchase only one will be purchased. There are several competing products that have been on the market for some time.

The buyer will choose the perceived best value, where value is defined as quality/price. A buyer's perception of best value depends on the buyer's lifestyle, disposable income, and perhaps-other factors. Therefore, best value is relative and changes with time.

Buyers become aware of the perceived value of the alternatives through advertising and social interaction. Advertising is a process, which has a cumulative effect. The influence of social interaction is a

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function of market penetration achieved by the product by the end of the prior period.

Additional information about value may be obtained by personal research. The personal research effort is undertaken if advertising and/or social interaction has alerted the potential buyer to the possible value of the product but the buyer is not sufficiently convinced to make a decision.

The simple purchase decision process described, and diagrammed in Fig. 1, is a Markov process. The process consists of two stages, and two demand determinants are operating at each stage. Because of the carry-over effects assumed, purchase decisions made in any period are influenced by what has happened in prior periods. More complex models would have more than two stages and more than two demand determinants at one or more stages.

In a Markov process the outcome of an event B, at time t depends on the outcome of the event at some prior time. We will model the simplest Markov process in which the outcome of the event depends on the outcome of the event in the **immediately preceding** time period. More complex models could have the outcome probabilities be dependent on the outcome more than one period earlier, or some function of outcomes over several prior periods. Let B_t be the event that an individual will purchase product i. Because a purchase decision may be made at the end of stage one or stage two, the purchase probability distribution for the two stage purchase decision process is written as

$$p(B_t) = p(K)[p(B_{t-1})_{s1} + p(B_{t-1})_{s2}] \quad (2)$$

where p(K) is the purchase probability distribution in the prior period, and p(B_t)_{s1} and p(B_t)_{s2} are n x n matrices of transition probabilities at each stage of the decision process.

In each stage a buyer can make a decision based on either demand determinant alone, or both simultaneously. In other words a buyer can maximize or optimize or satisfice at each stage. Therefore

$$p(B_t)_{s1} = p(A_t)_{s1} + p(SI_t)_{s1} - p(A_t)_{s1}p(SI_t)_{s1} \quad (3)$$

$$p(B_t)_{s2} = p(P_t)_{s2} + p(R_t)_{s2} - p(P_t)_{s2}p(R_t)_{s2} \quad (4)$$

where the demand determinants are represented as follows: A = advertising; SI = social interaction; P = price; and R = quality.

The Markov process runs N times each decision period where N is the number of people in the market. Each person in the market will decide to buy product i or not buy any product. Then

$$F(B_i) = p(B_i)N \quad (5)$$

will be the proportion of the market that will buy product i. From the perspective of the supplier, F(B_i) will be the market share obtained by supplier i.

The procedure for calculating the transition probability matrices p(B_t)_j, where j is the stage of the purchase decision process, will now be explained. The procedure for each stage is identical, except for the variables used.

Step 1. Use Carvalho's (1992) model to calculate demand due to each demand determinant. The calculation must be performed ceteris paribus as required by the purchase decision process. Carvalho's model is based on the ceteris paribus assumption.

Values obtained by using Carvalho's model must be used as weights and the weights must be converted to a percentage weight by the usual process of dividing the weight for each product by the sum of the weights.

Mathematically the process is

$$x_{i,j} = x(Y)_j + x(Z)_j - x(Y)_j x(Z)_j \quad (6)$$

$$w_{i,j} = \frac{x_{i,j}}{\sum_{i=1}^n x_{i,j}} \quad (7)$$

where Y and Z represent the demand determinants operating in stage j.

Step 2. The w_i are the diagonal values in an n x n percentage weight matrix W. Since each value represents the probability of purchasing product i, the probability of purchasing some product other than i is 1 - w_i. In each row of the matrix the 1 - w_i weights must be distributed across all other alternatives in order to meet the requirement for a transition probability matrix. These distributed weights represent the process of those buyers who decide not to buy product i based on the perceived value of product i relative to the perceived value of product k where k ≠ i. Thus the 1 - w_i weight is distributed across the off-diagonal cells in row i.

Step 3. To distribute the not-purchase product i weights calculate distribution weights, dw_i, according to the equations

Step 4. Multiply dw_k(1 - w_i). This is the percentage weight that goes in

$$dw_k = \frac{w_k}{\sum_{k=1}^{n-1} w_k} \quad \text{where } k \neq i \quad (8)$$

column k of row i. The matrix W is now complete.

Step 5. After the weight matrix W for each stage has been calculated, the transition probability matrices need to be calculated. This is achieved by the calculation

$$p(B_t)_j = K \sum_{j=1}^m \pi_j (W_j) \quad (9)$$

$$\text{where } \sum_{j=1}^m \pi_j \leq 1.0 \quad (10)$$

where m is the number of stages in the process. π_j is the probability that a buyer will buy at the end of stage j.

DISCUSSION

The market share allocation model presented in this paper has several interesting features not available in other models.

Market share allocation depends on the outcome of the purchase decision process and not on the nature of the process used. Accordingly the maximization, optimization and satisfying decision strategies are simulated by the model presented.

Product awareness must occur before a purchase decision is made or before a decision is made to investigate the product further. The model presented simulates this truth quite realistically because the purchase decision process has two stages.

The outcomes of the decision process are buy or not buy. In any demand period there are no other possible outcomes. These

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outcomes are accurately simulated by the model presented.

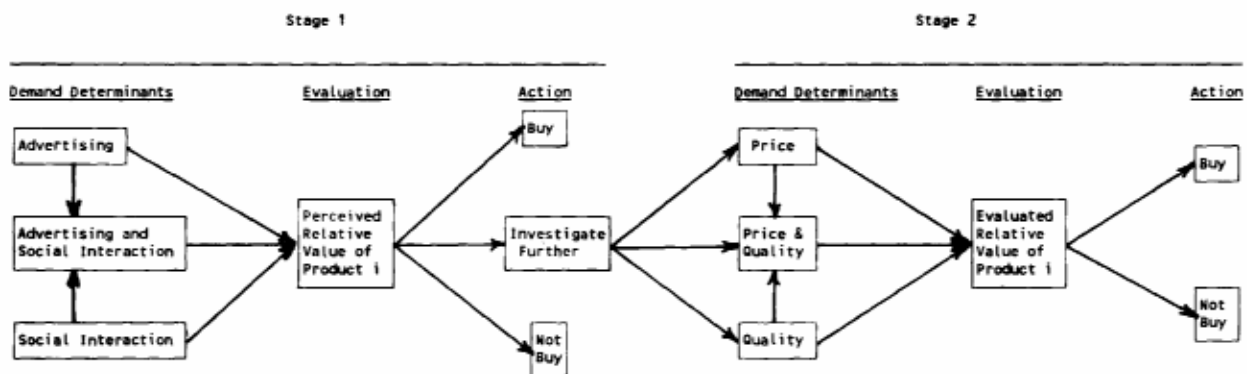
As long as the inequality *specified* in (10) is maintained the potential market will be greater than the actual market, and the independence of buyers from suppliers will be maintained. Suppliers influence buyers but buyers are not passive respondents to the actions of suppliers as in typical models.

Use of Carvalho's demand function permits the simulation of a specific type of product. Among the specific products that are simulated are small kitchen appliances, electronic devices such as stereos, and gardening tools. Thus a simulator using this model could be product specific rather than generic.

The typical simulator is zero-sum because the total of the aggregate demand is allocated to the competitors. What one competitor gets another loses. Competitors will obtain their allocated share as long as they have sufficient product available either from current production or inventory or both.

A simulator using the model presented herein could be designed either as a zero-sum simulator or a shared-sum simulator. When used as a zero-sum simulator market share allocation is obtained by multiplying aggregate demand by Eq. 5. When used as a shared sum simulator, Eq. 5 is multiplied by some quantity Q to obtain the quantity demanded of each competitor's product. Thus, with the availability of the model presented herein, the implications of zero-sum and shared-sum simulators on student learning can now be examined.

Figure 1. Flow Diagram of Purchase Decision Process for Product i.



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