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A NEW MARKET DEMAND MODEL FOR BUSINESS SIMULATORS

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ABSTRACT

A new market demand model for computerized business simulators is mathematically derived from theory, and correctly models both short-term and long-term consumer behavior. The inability of existing models to model long-term consumer behavior properly is explained. The new model offers far more design flexibility than possible with existing models, and reduces the possibility that the simulation will be perceived as unrealistic.

INTRODUCTION

It is well known that business simulators must be realistic in order to facilitate learning (Dittrich, 1977; Mehrez & Reichel, 1987; Norris, 1986; Wolfe & Jackson, 1986; Wolfe & Roberts, 1986). To improve realism, much effort has been devoted to improving the way market demand is modeled (Carvalho, 1991; Decker, LaBarre & Adler, 1987; Gold & Pray, 1983; Gold & Pray, 1984; Golden, 1987; Goosen, 1986; Teach, 1990; Thavikulwat, 1989). However, when these market demand models are used in simulators that run for multiple periods they have a major problem: *the long-term demand trend Ls not properly modeled.* Accordingly, the purpose of this paper is to present a solution to the problem of modeling long-term demand in business simulators. But first, the problem will be discussed in detail.

THE TYPICAL MARKET DEMAND MODEL

The typical market demand model used in business simulators is

$$Q = f(P^{\alpha}, M^{\beta}, R^{\gamma}, E^{\delta}, S^{\epsilon}) \qquad (1)$$

where P = price, M = marketing, R = product and service quality, E = economic index, and S = seasonal index. The exponents are elasticities and the variables are usually industry averages of decision values submitted by the students.

Most business simulators are designed to have constant elasticities, following the convention established by Alfred Marshall (1961). However, there are several exceptions to the general case. The model of Gold and Pray (1984) has variable elasticities to model a law of demand that has diminishing returns to the supplier. Decker, LaBarre and Adler's model (1987) incorporates diminishing returns and the concept of ordinal utility by using an optimal value as a divisor for the demand determinant. Carvalho (1991) models both increasing and decreasing returns, and the concept of ordinal utility.

The functional form used to model market demand is usually employed to model firm demand, where the values for the variables are the values of the demand determinants for each competitor. Elasticities at the firm level of demand, especially price, are usually not the same as for industry level demand. This paper is not concerned with firm level demand, that is market share.

There are two problems inherent in the typical market demand model. The first is related to the students' ability to forecast and plan (Teach, 1989), and the second is related to modeling long-term consumer behavior. Each of these problems can have a deleterious effect on the simulation's realism.

Forecasting Problem

When the elasticities are fixed values, the long-term trend in demand is the composite of the trends in the environmental variables, as determined by the administrator and the trends in the industry averages of the demand determinants. The student decisions create the trends in the demand determinants. Therefore, the long-term consumer demand trend is determined by the suppliers and/or the environment. This design creates the possibility of having many different trends.

Three cases that threaten simulation realism are worthy of consideration. In the first case, the environmental trends and the demand determinant trends exactly cancel each other. The trend experienced by the students would be a constant market demand. In the case opposite to the first, the trends exactly reinforce each other. Depending on the particular trends, market demand could increase exponentially. Although the probabilities of these cases occurring is unknown, they should not be discounted. Every effort needs to be made during the design of a simulator to achieve the highest possible degree of realism.

What probably occurs most frequently is something in between these extremes, with an oscillation between cancel and reinforce. Students do long-term planning, but they also adjust those plans based on past performance. This aspect of managerial behavior, which is very pragmatic, creates an effective market demand that places a premium on exponential smoothing for forecasting purposes.

Another worrisome case is the possibility that students' reactions to past performance in the simulation creates an interaction of trends that results in demand being distributed over time as a random error variable. If this happens, the students would not be able to forecast market demand, and would resort to guessing. The realism of the simulation would be seriously questioned. If the administrator could not plausibly explain the randomness in market demand, learning incentive might be destroyed.

When elasticities are variable rather than constant, the long-term demand trend problem could be compounded, as the elasticity trends become additional factors determining the long-term demand trend. Variable elasticities could be exacerbate or diminish the problem, but the threat to the simulation's realism remains.

Long-term Consumer Behavior Problem

$$\frac{\Delta Q}{\Delta D_l} \times \frac{D_l}{Q} \qquad (2)$$

is the definition of elasticity, where D_l is any demand determinant, the first term is the slope of the market demand function for that demand determinant, and the second term is the point at which the slope is evaluated. Therefore, when a value for elasticity is coded into the simulator, the shape of the law of demand is determined. Since the law of demand is a statement of consumer behavior, choosing values for the elasticities effectively models consumer behavior.

Implicit in the definition of the law of demand is the assumption that consumer needs, preferences and income do not change in the time period for which market demand is calculated. *Therefore, elasticity is a model of short-term consumer behavior.* However, it is known that elasticities change with time (Tellis, 1988) because life styles, preferences and discretionary incomes change with time. *Given that the typical market demand model does not use elasticities that change with time, long-term consumer demand behavior is' not modeled*

The design of the typical market demand model implies that the market will adopt whatever product is offered. The trend resulting from the interaction of the environmental trend and the student created trend determines the rate at which the product will be adopted by the market. Furthermore, the typical market demand model implies that consumers' life styles and preferences never change. It also implies that consumers' purchase decisions in one period are perfectly independent from decisions made in any prior period, or to be made in any subsequent period. However, it is generally recognized that consumer purchase decisions at any point in time are function of the consumer's disposable income, present life style, and expectations concerning future income and life style.

The typical market demand model poses a threat to simulation realism when students try to analyze the product life cycle as a part of their strategic planning process. Since simulators are designed so that all competitors produce and sell the same product(s), the product life cycle is the same as the market demand trend. Given the discussion above about the possibilities for demand trends, the risk that students will complain about a lack of realism is obvious.

MODELING LONG-TERM DEMAND

Assuming that current consumer behavior is dependent on past experience as well future expectations, short-term demand must be treated as part of a longer-term trend. In other words, *to model consumer behavior properly in a business simulator, the model used must model short-term demand as an increment of long-term demand.*

The Product Life Cycle (PLC) concept has wide and growing recognition as a model of the long-term demand trend for a product (Curry & Riesz, 1988). From the supplier's perspective the PLC represents the rate of diffusion of a product through the market. From the consumer's perspective the PLC represents the rate of adoption of a product.

Thavikulwat's (1989) model incorporates a discontinuous function to represent the PLC, uses constant elasticities, and models short-term demand as a variation from the long-term demand trend due to the effect of pricing. Carvalho (1991) suggested a model in which the PLC models an "indifference point" level of demand and is multiplied by the variation of short-term demand from the indifference level due to the effect of all demand determinants. Furthermore, the variance from long-term demand in Carvalho's model is probabilistic, whereas in Thavikulwat's model it is deterministic.

NEW MARKET DEMAND MODEL

A fundamental assumption in the economic theory of consumer behavior states that all consumers will maximize utility. Utility maximization is achieved when

$$\frac{MU_1}{P_1} = \frac{MU_2}{P_2} = \frac{MU_i}{P_i} = \pi_i \ . \ . \ . \qquad (3)$$

where MU is marginal utility, P is price of the product, i = 1_3n and n is the number of products that will be purchased in the period. The ratio ¥i can be considered a benefit/cost ratio, and is the point of indifference.

The benefits obtained from any product depend on the consumer's life style and expectations. Since consumers in any market have different life styles and expectations, there will be a probability distribution of these variables over the market. Likewise, there is a probability distribution of disposable income over the market. Therefore, rr is distributed over the market segment according to some probability distribution, f(rr).

According to the proof of Carvalho (1991), any unimodal probability distribution will have the mathematical properties necessary to model the law of demand properly. Let f(w) be the two parameter gamma distribution (Mood & Graybill, 1963)

$$f(\pi;\alpha,\beta) = \frac{1}{\alpha!\beta^{\alpha+1}}\pi^{\alpha}e^{-\frac{\pi}{\beta}} \qquad (4)$$

where 0 < rr _ Œ, When a > I and B > 0, f(rr) is unimodal.

A particular product offered for sale will have a benefit/cost ratio rr(P), where the benefit the consumer enjoys is directly related to the perceived quality of the product, and the cost to the consumer is the price set by the supplier. The suppliers, by virtue of the product and customer service performance specifications offered, and the degree of conformance to those specifications, determine the quality offered (Buzzell and Gale, 1987). In a simulation quality offered is usually a function of marketing and R&D variables. Now let

$$\pi_p = \pi_s + \frac{IP_s - IP}{\sigma_1 IP_s} + \sum_{2}^{n} \frac{ID_i - ID_s}{\sigma_i ID_s} \qquad (5)$$

where rrs is the standard benefit/cost ratio that the market will accept, IP = harmonic average of all competitor's prices, **ID** = average of all competitors' values for a particular non-price demand determinant, the subscript s refers to an industry standard value, and oi is a parameter set to provide the elasticity desired. In the design of the simulation, the values of 0 would have to be chosen in conjunction with the two parameters for the gamma distribution.

From Eq. 3, a consumer will buy the product when rri = rrp

Therefore,

$$F(p) = \int_{0}^{\pi_p} f(\pi)\, d\pi \qquad (6)$$

is the proportion of consumers in the market that will buy the product as offered. It is important to note that this proportion is determined by suppliers and buyers interacting in the market place. But since consumers behave as the law of demand predicts, and the law of demand is modeled by a probability distribution, *the behavior of the market is probabilistic.* This is in sharp contrast to the traditional model in which the behavior of the market is deterministic.

Assume that the product being simulated is a durable good with a life longer than the planned duration of the simulation. Further assume that in the market being simulated each consumer will buy only one unit of the product when a purchase is made. The new demand model can now be stated verbally, as follows: *The proportion of the market that will buy the simulated product in the time interval **t,*** **t+At** *is a proportion of those who have not purchased the product by time* t *multiplied by a proportion of those who have previously purchased the product.* Mathematically, the new model is

$$\frac{dp}{dt} = \eta\, p_t F(p)(1 - p_t) \qquad (7)$$

where Pt is the proportion of the market that owns the product at time **t,** and F(p) from Eq. 6 is not a function of time. Note that F(p)(1-pt) is the proportion of the market that has not made a purchase prior to the time t that will make a purchase in the time interval t, H- At. This would he a purchase made rationally, as assumed in economic theory. Also note that Npt, the proportion of those who already own the product, acts as a social influence on those who have not made a purchase (Rogers, 1983).

The solution to Eq. 7 is

The cumulative demand up to time t is

$$Q_t = S_m p_t E^t \qquad (9)$$

Eq. 8 is the well-known S-shaped logistic function. If F(p) remains fixed for all runs of the simulation, Pt will have an inflection point at t = 0, at which point Pt = *0.5.* The starting value of Pt can be made easily changeable by using the equation t = **DP** - x, where DP = decision period, and x is the number of offset periods desired. If F(p) varies, the S-shaped trend remains, but pt will vary around a trend.

where **Sm** is the size of the market in terms of number of consumers or buying units, and E is the economic index. Accordingly, the demand in any period is

$$Q = (Q_t - Q_{t-1})S^t \qquad (10)$$

where S is the seasonal index.

In real industries, backlog is a common problem. Backlog occurs when the number of orders for a period is greater than the capacity of the industry. Backlog can be easily incorporated into this model by defining backlog as Qt - **SVt,** where SV is the industry supply available. Assuming none of the backlog is canceled, the demand in any period will be

$$Q = (Q^t - (Q_{t-1} - SV_{t-1}))S^t \qquad (11)$$

when Qt-1 - **SVt-1** > 0. Otherwise, period demand is calculated according to Eq. 9.

DISCUSSION

The gamma function is skewed to the right. This causes the rate of change of f(rr) to be greater when *rr* < *rrs* than when rr > **rrs** provided that rrs is the modal value of f(rr). This means that customers are slower to adopt a product than they are to switch from a product already adopted if the product's benefit/cost ratio falls. Such asymmetric behavior may be more appropriate for some product/market simulations than the symmetric behavior modeled by Carvalho's (1991) function. By careful choice of a value for the parameter a, the gamma distribution can approximate a symmetric distribution. The parameter B only changes the scales of the axes.

A product/market is simulated when the parameters a, B, rrs, 1Ps, $(Idi)_s$, N, and x are chosen. By using published industry ratios to get values for Ips, and market research to get a value for IPs, actual product/market situations can be simulated. Thus the new model offers considerably more modeling flexibility than prior models with a reduced threat to simulation realism.

In the model presented above, short-term consumer behavior (the law of demand) is modeled in Eq. 6, and long-term consumer behavior (the PLC) is modeled in Eq. 8. Short-term buying behavior is probabilistic, and the nature of that behavior will depend on the particular unimodal probability distribution chosen for e. Because Eq. 6 enters into Eq. 8, long-term behavior is also probabilistic.

The model presented models the ***interaction*** between the independent decisions of buyers and suppliers that takes place in real markets. Actions taken by students to influence demand enter into the model in Eq. 6 only in terms of affecting the proportion of consumers that will buy the simulated product each period. If ei = long term demand will proceed according to the trend established by Eq. 8. Otherwise, in each period ***the rate of adoption of the product by the consumers*** will be either increased or decreased. This means that the suppliers affect the second derivative of the demand function. Stated otherwise, supplier actions can accelerate or decelerate sales.

Suppliers causing an acceleration and deceleration of sales has become quite noticeable in the last decade, especially in the auto industry. Rebates and interest rate reduction promotions have been said to “steal future sales without increasing overall demand” because the auto market is at the maturity phase of the PLC. From the model presented it can be seen that this phenomenon can occur at any other stage of the PLC, and would be recognized as a fluctuating industry backlog of orders.

As presented, the new model has a ceiling on demand. This would be a problem for teachers who keep a simulation running, that is the succeeding class starts wherever the previous class stops. The present model can be easily adapted for this type of usage by modifying Eq. 9 so that Sm is a function of the product’s replacement rate and the population growth rate.

The decline phase of the PLC is not modeled by the model presented above. This is not considered a major defect in the model for several reasons. First, the existence of the decline phase is problematic (Rink & Swan, 1979). If it does exist, it applies to a limited number of products. Second, if it is desired to have students learn how to manage a business in decline, the simulator could be designed using the inverse of Eq. 8 with the parameters set to get the rate of decline desired. Since some products have demonstrated growth followed by a decline and then a plateau (Bass, 1969), the inverse of Eq. 8 would be empirically correct. Third, if it is desired to have students manage a business through growth and decline, the growth curve of Bass (1969) with $q > p$ could be used.

CONCLUSION

The new model of market demand presented in this paper is derived directly from theory by using the results of Carvalho’s (1991) proof, the theory about the forces influencing consumers’ purchase decisions, and the theory of the PLC. In this respect it is significantly different from the models reviewed above, each of which is more or less a “construction” and not a mathematical derivation that starts with a verbal statement of the theory. The new model has been shown to have considerable flexibility to model actual product/market situations by the choice of parameters and the use of actual industry ratios to calculate the standard or average values for the product/market being simulated.

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