Developments in Business Simulation & Experiential Exercises, Volume 14, 1987

THE EXPONENTIAL LOGARITHM FUNCTION AS AN ALGORITHM FOR BUSINESS SIMULATION

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ABSTRACT

Business simulation designers have taken two distinct approaches to defining the functional relationships necessary to make the simulation as realistic as possible. The first approach is the generalized multiplicative model. The second approach is the interpolation model.

This paper is presented as a less complex alternative to the generalized multiplicative model and uses the exponential logarithm function as the basis for the simulation. The method described here incorporates the use of independent variables such as marketing expense and sales force size to produce a dependent variable which is used as a multiplier in an equation to determine total company sales.

INTRODUCTION

Designers of business simulations all have a common objective of making their model as realistic as possible at a chosen level of sophistication. As Goosen[i] pointed out, "Games designers for the most part have relied upon mathematical equations to create quantitative relationships among business simulation variables."

As Goosen[ii] goes on to explain, a problem with those mathematical equations is the tendency for equations to control the simulation parameters. Goosen developed a logical, though perhaps tedious, alternative approach to establishing relationships among simulation variables. His method is based upon graphic representation of each modeled functional relationship. Essentially, each functional relationship between two variables, e.g., sales and advertising, is graphed and then the graphical representation is interpolated to arrive at a multiplier to be incorporated into a sales generating function. The sales function consists of multipliers for all relevant variables such as price, product quality, company image! reputation, sales force size or expertise, etc.

Additional criticisms of business simulations have been made by Teach[iii]. It is his contention that demand equations used in simulations are not easily changed or altered by the administrator. His analysis of the Gold and Prays model showed that the administrator would have great difficulty in determining the effects of any changes in the parameters. Most of the problems arose because the translation between parameter values and elasticity coefficients is not obvious.

Another admonishment made by Teach is that many simulations provide for a cost structure that remains constant during a course of play. These fixed cost levels do not take into account the reality of cost changes due to any number of factors.

Chiesel[iv] has made the case that many business simulations do not take into account the reality of a continuously changing business environment. A situation in which decisions are made monthly or quarterly is entirely too unrealistic and does not represent the complex workings of today's business world. The more accurate method of portraying realistic business simulations is to use a model that incorporates continuously changing states with no discrete time intervals.

Most business simulations/games, that involve the area of market demand, have a sales potential function that is similar to:

Potential Sales = (Base Sales) x (Advertising Factor)
   x (Sales Force Factor) x (Product Quality Factor)
   x .... x (Remaining Significant Market Factors)

The number of factors chosen by the simulation designer is dependent on the purpose of the simulation and the level of sophistication desired. As Goosen, Gold and Pray, and others have pointed out, careful attention must be paid to the limits put on each variable to avoid one single factor having an unrealistic effect on the final functional value.

The method offered here provides a continuous mathematical relationship, subject to the constraints set by the simulation administrator, for each set of relevant factors. Therefore, the situation parameters control the equation. This method is moderately easy to establish, and provides flexibility in controlling the limits on each factor. The number of significant factors and the constraints on those factors are under the complete control of the simulation administrator.

<u>Using the Exponential Logarithm Function</u>

Because some variables affect sales in a positive manner and some in an inverse manner, we must actually use two functions. The F-value of the multiplicative equation acts as the upper limit of the function. This upper limit, which can be changed by the simulation administrator, depending on the variable being analyzed, allows control of the degree of effect of the variable and thereby shifts the multiplier function. The basic equation is:

Price Multiplier =

$$\frac{(F - .06875)}{(1 + \log F) \times \left(\frac{\text{Actual Sales Price}}{\text{Optimum Sales Price}} \right)^{2} + .06875}$$

This equation is used for variables that affect total company sales in an inverse manner such as the selling price when demand is constant.

The F-value of the equation acts as the upper limit of the entire function over the relevant range. The F-value and relevant range are specified by the
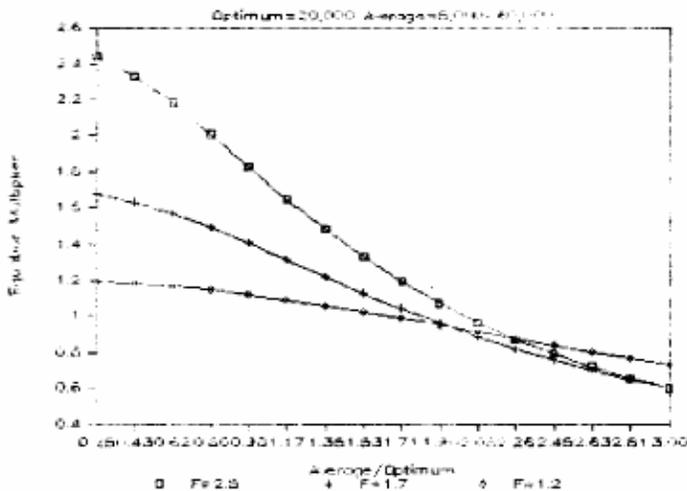
program administrator. The upper limit can be changed depending on the desired effect of each variable on the total company sales equation. For example, if the desired influence of the variable on the total sales equation is dramatic change, a larger F-value can be chosen. If the desired effect is a small influence on the total sales equation, a lower F-value can be specified. The value of F selected determines the magnitude of the function over the relevant range.

The use of 0.06875 in the equation is simply to insure the denominator of the equation remains above zero. Should the denominator become zero, the equation obviously becomes undefined. It is used in both the numerator and denominator to cancel its effect on the total sales equation.

The optimum sales price value is specified by the administrator to indicate the ideal selling price given demand. The value chosen is random but should reflect industry/product insight on the part of the administrator.

Shown in figure 1 is the decreasing function as used for the price multiplier in the total company sales equation. The function is plotted at three different F-values, 1.2, 1.7, and 2.5. As mentioned earlier, the smaller the F-value chosen, the smaller the effect in the total sales equation.
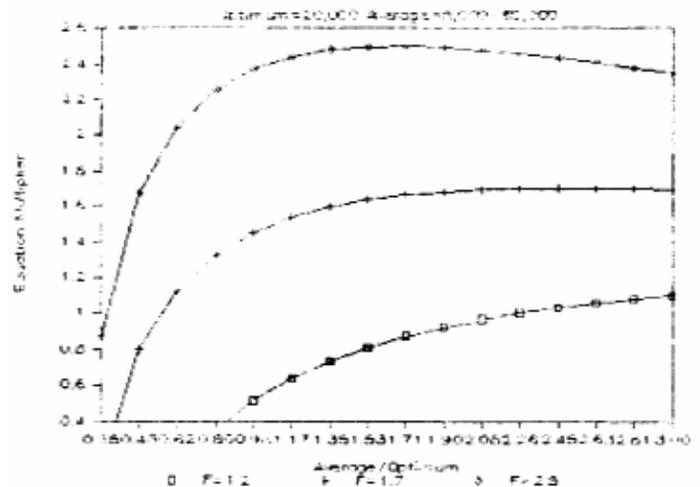
A similar argument holds for abnormally high prices. As the selling price increases, the number of units sold will decrease at a rate determined by the price multiplier equation. The maximum effect of this price decrease is compensated for by the F-value chosen.

A similar though inverse procedure is used to determine the multiplier values of the increasing function equation. The variables used in this case are those directly relating to sales, e.g., advertising, personal selling budgets, product development budgets, etc. Again, the number of variables chosen is completely determined by the simulation administrator depending on the types of variables affecting Figure 2 shows the increasing function. the actual industry. The basic equation is:

$$\text{Multiplier} = (F = .0875) \times \left(1 - \log \frac{F - 1}{F} \times \frac{\text{Actual } 2}{\text{Optimum}} + .0875\right)$$

FIGURE 2
INCREASING FUNCTION

FIGURE 1
PRICE MULTIPLIER (DECREASING FUNCTION)

As the ratio of the actual industry selling price to the optimum selling price approaches zero, the value of the equation multiplier approaches the F-value chosen. This accurately depicts realistic supply/demand conditions. Given adequate supply, lowering the selling price will increase sales units at a rate determined by the price multiplier equation. The maximum effect of this lowering in price is controlled by the F-value chosen which is the maximum value of the equation.

REFERENCES

[1]   Chiesel, Newell, "Simulation with Discrete and Continuous Mathematical Modeling," <u>Developments in Business Simulation and Experiential Exercises,</u> vol. 13, 1986.

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[3]   *Pray, Thomas F. and Steven Gold, "Inside the Black Box: An Analysis of Underlying Demand Functions in Contemporary Business Simulations," <u>Developments in Business Simulations and Experiential Exercises,</u> vol. 9, 1982.

[4]   Wolfe, Joseph and C. Richard Roberts, "The External Validity of a Business Management Game," <u>Simulation and Games</u>, vol. 17, no. 1, March 1986.

ENDNOTES

[1]   Goosen, Kenneth R., "An Interpolation Approach to Developing Mathematical Functions for Business Simulations," <u>Developments in Business Simulation and Experiential Exercises</u>, vol. 13, 1986, p. 2L18.

[ii]   Ibid.

[iii]   Teach, Richard D., "Building Microcomputer Business Simulations," <u>Developments in Business Simulation and Experiential Exercises</u>, vol. 13, 1986, pp. 239_2L10.

[iv]   Chiesel, Newell, "Simulation with Discrete and Continuous Mathematical Modeling," <u>Developments in Business Simulation and Experiential Exercises</u>, vol. 13, 1986, pp. 244-245.