Teaching Nonlinearity in Marketing Research Classes: A Case Example

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ABSTRACT

Despite the existence of nonlinear relationships in marketing theory, marketing research textbooks devote little space to modeling these relationships. Developing an interesting and easily used scenario that helps students to understand nonlinearity in marketing relationships thus provides a valuable addition to pedagogy. This paper uses a publicly available data source as the basis for a case example that allows instructors to use a variety of pedagogical formats to illustrate nonlinear concepts, from classroom lecture through hands-on student analysis.

BACKGROUND

When marketing educators discuss causal relationships in marketing (e.g. advertising vs. sales), they tend to discuss these relationships in straight line terminology so as to simplify the concepts for pedagogical purposes. However, marketing theory indicates that many of these relationships are not linear, but are curvilinear. For the purposes of this paper, three important marketing relationships will be discussed here for illustration: market demand; customer satisfaction; and market growth.

The market demand function (e.g. Kotler 2003), states that the market demand for a product is a nonlinear function of marketing mix expenditure. Low levels of expenditure have little influence on market demand, but increasing levels of expenditure cause the market to increasingly notice and desire the product, thereby increasing demand. However, as market saturation occurs demand levels off, regardless of the level of marketing expenditure.

A second important marketing theory is the relationship between product performance in meeting customer needs, and customer satisfaction with the product. Nonlinearity in this relationship has been determined (e.g. Oliver 1997) for two theoretical reasons: the "zone of indifference", and attributes which may be either "satisfiers" or "dissatisfiers". Under the former concept, there is a range of performance level that is acceptable to the customer, and satisfaction is not effected within this range. However, when the range is exceeded, either positively or negatively, then satisfaction is effected, both positively (satisfaction) or negatively (dissatisfaction). The latter concept holds that there are types of attributes which may only lead to satisfaction; others may only lead to dissatisfaction. When the basic meeting of needs effected by these attributes is exceeded, either positively or negatively, then there is no further impact on satisfaction level. Under this concept, while small excesses (positive or negative) have only a small satisfaction impact, slightly larger excesses may have quite large impacts, thus the nonlinear relationship.

The third theoretical concept is one of new product form growth over time. Under this concept (e.g. Lilien and Kotler 1983), market growth begins slowly after new category of product introduction, then word of mouth is accelerates growth. Finally, as the market approaches saturation, growth slows, then plateaus.

These and other models of marketing relationships, have found their way into both marketing management and pedagogy (e.g. Lilien and Kotler 1983). A model may be defined as "a representation of the most important elements of a perceived real world system" (Naert and Leeflang 1978, p. 9). While there are several approaches to modeling a system, our discussion will center on mathematical models.

The purpose of this paper is to utilize an interesting and commonly available set of data to provide an example of a marketing application of nonlinear relationships. These analyses illustrate both the complex nature of business situations and the advisability of using the appropriate analysis in drawing conclusions. Instructors who do not use student hands-on analysis in their classes (e.g. an introductory marketing class) may use this data in a lecture context, to illustrate the power of nonlinear analysis and the complexity of "real world" marketing applications, to whatever level of analytical detail desired.

RESEARCH TEXTBOOKS MODELS

The most likely place for marketing students to encounter discussion of nonlinearity is in marketing research textbooks, which usually contain several chapters on statistical analysis (e.g. Kumar, et al 2002). The multivariate analysis topics have been receiving increasing emphasis, as computer capacity and software improvements have allowed comparatively easy analysis of data.

For the purposes of this paper, the models discussed will be bivariate regression models utilizing continuous variables. Other mathematical formats and models, including econometric and other forecasting methods, will not be considered in this discussion.

TEACHING STATISTICAL CONCEPTS

Over two decades of teaching research methods to graduate and undergraduate students has yielded the author's conclusion that the statistical chapters of research textbooks tend to be the most difficult in the book for students to comprehend. This observation is neither unique to the author, nor specific to the business discipline, as noted by the following.

Connors, et al (1998), summarizing several relevant studies, note that student difficulties in learning statistics is a part of the more general "math anxiety", which they define as "an emotional dread of future math-related activities" (p. 40), and that "about half of college students ... will have difficulty thinking hypothetically to understand concepts like probability and sampling distributions" (p. 41). Piotrowsky, et al (2002) note that "... Mathematics anxiety has always maintained a central focus in the education literature."

Recently, however, there has been "... a focus on 'statistical anxiety' as experienced by undergraduates" (p. 97). Garfield and Ahlgren (1988) contend that "The experience of psychologists, educators, and statisticians is that a large proportion of students do not understand many of the basic statistical concepts they have studied ...". Kranzler and Moursund (1999) have gone so far as to write a statistics text called "Statistics for the Terrified", observing that most statistics texts are written for those with strong mathematics skills and "... Most of my students in counseling and education programs are not like that" (p. 2).

Various efforts have been made to overcome student difficulties. e.g. Piotrowsky, et. Al (2002). The remedies for this anxiety, however, are numerous. Kranzler and Moursund (1999), for example, suggest that students employ visualization in the form of "rational-emotive therapy (RET)" prior to undertaking application exercises (p. 187), while Connors, et al (1998) cite research showing that "students acquire concrete concepts more easily than abstract concepts" (p. 41). While not addressing the RET approach, this paper follows the latter advice: using an easily visualized example that is clearly important to the business situation involved, but is also of some general interest to undergraduate students.

NONLINEARITY IN MARKETING MODELS

The consideration of relationships between continuous variables, in the marketing context, indicates that there are four different types of mathematical forms (Naert and Leeflang 1978), which will be briefly discussed below:

- Linear in both parameters and variables
- Nonlinear in the variables, but linear in the parameters
- Nonlinear in the parameters, but linearizable
- Nonlinear in the parameters and not linearizable

Linear in Both Parameters and Variables

This is the basic form of the "general linear model", or linear additive model. Each independent variable in the model (in the case of multivariate analysis) exhibits a straight line relationship with the dependent variable. Further, the predictive contribution of each variable is added to the contribution of the other variables in the model. This form will not be discussed further in this paper.

Nonlinear Variables, But Linear Parameters

This form is also known as the nonlinear additive model, and is the one most commonly referred to in marketing research textbook discussions on nonlinear relations (e.g. Kumar, et al 2002). Models of this form simply define a new variable that is some nonlinear transformation of one or more of the variables in the model, thus forming a linear additive model. From the view of estimation, these equations are not different from the basic linear additive model, though interpretation becomes more problematic.

A wide variety of mathematical transformations are common in this approach: squares and square roots, reciprocals, logarithms, and combinations of these transformations. A useful example of the latter is the logarithmic-reciprocal relation (Naert and Leeflang 1978, p. 73), which produces the S-shaped curve found in market demand and market growth models, discussed above. An example of this would be the following relation:

$$\text{Ln Sales} = a + b/\text{Advertising}$$

Sales and advertising data would be used to determine the parameters "a" and "b". The "a" parameter would represent market saturation in the market demand model.

This fairly versatile approach also allows a limited inclusion of variables that are nonlinear in the parameters, i.e. interaction terms. For example, Sales may not only be related to Advertising and Product Price, but the combination of these two. A new interactive variable may be formed by the multiplication of Sales and Product Price, and included in the model. This approach is limited to the inclusion of a small number of interactive terms; a large number of interactions can lead to estimation and interpretation difficulties (Naert and Leeflang 1978).

Nonlinear Parameters, But Linearizable

This form generally has the independent variable(s) as an exponent; for example:

$$\text{Sales} = a\,(e^{b(\text{Advertising})})$$

This form may be linearized by taking logarithms of both sides. In a similar way, fully interactive models may be transformed to a linear additive model format. The reader is referred to Naert and Leeflang (1978) for further discussion.

Nonlinear Parameters and Not Linearizable

While this form was previously considered "intractable", increasing power of computers has led to the development of nonlinear analytical methods (Naert and Leeflang 1978). Thus, some very useful marketing model applications have been developed, including exponential and logistic model formats. The logistic model is another S-shaped form that asymptotically approaches a limit, thus useful in the market demand type of models discussed above. An example would be:

$$\text{Sales} = \frac{a}{1+e^{b(\text{Advertising})}}$$

Various forms of this and other asymptotic models have been found to be useful in marketing applications.

THE DATASET

Pedagogically, the optimal dataset used to illustrate nonlinear marketing applications would be one that is of interest to students, is clearly nonlinear, illustrates an important application of marketing theory, and has managerial usefulness. Over the years, the author has found that the weekly list of the top ten movies in the US meets these criteria fairly well. These lists, appearing in newspapers and other public arenas, include the movie title, weekend receipts, number of weeks in release, and the total receipts for each movie (Exhibitor Relations Co. Inc. 2003).

The total receipts data is illustrative of the market demand model, discussed above, thus is both theoretically applicable and clearly nonlinear. Movies are inherently interesting, especially to undergraduate students, thus serving to help reduce the "statistical anxiety" discussed above. Continuing releases of new movies allows an instructor to have a list of contemporary interest, with related events fresh in student memory.

The marketing discipline is quite active in the movie industry, participating both before a film is produced, as well as after production has been completed (Rocco 2003). Preliminary film budgets and general strategy development occur prior to production, while promotion and distribution decisions tend to be considered after production has been completed, but prior to distribution.

The movie total receipts data typically fit asymptotic models quite well, with R-squares usually over .90, and frequently in the .98 to .99 range. Given this very strong fit, movie marketing managers may utilize this and other information in various ways. For example, pre-release testing with relevant target markets may allow a fairly accurate forecast using "standard" marketing mix applications (e.g. pre-release advertising level, number of theaters initially showing the movie). Then a different level of the marketing mix may be tried, the differences between actual and forecast noted, and the impact on profits of changes in marketing mix calculated. A series of such experiments with a variety of movie releases could lead to the development of marketing strategies relevant to various types of movies and competitive environments.

SAMPLE DATA ANALYSIS USING SPSS

One of the very useful features of Statistical Package for the Social Sciences (SPSS) software is their nonlinear relationships option. Under this option, the student simply clicks on the dependent variable, clicks on the independent variable (or time), and clicks on one or more of the 12 preprogrammed models. The output includes the computed R-square, significance, and the model parameters. A plot of the data and the model(s) is automatically included, enhancing the students' understanding of the analysis.

An example of this output for the movie "Finding Nemo", using the reciprocal, the logarithmic-reciprocal (the "S" model), and the logistic. All models are good fits of the data (greater than .90) which is a typical result. In the author's experience, the logarithmic-reciprocal model provides an excellent fit across a wide range of movies. While the logistic model also tends to fit well, it has the "real-world" drawback of requiring an estimate of total receipts, which is the value most desired to predict from the model. An example of a class exercise used may be obtained on request from the author.

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EXHIBIT

Example of Nonlinear Analysis for the Movie "Finding Nemo"

Independent: Time (weeks after initial release)

Dependent	Meth	Rsq	d.f.	F	Sigf	Upper bound	b0	b1
FDNMO	INV	.902	9	83.19	.000		325.648	-287.80
FDNMO	S	.990	9	851.81	.000		5.901	-1.7134
FDNMO	LGS	.963	9	231.81	.000	340.0	0.0091	0.6707