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Full Length Article

Measurement of interactions in non-linear marketing models: The effect of critics' ratings and consumer sentiment on movie demand

Tirtha Dhar [a,*], Charles B. Weinberg [b]

[a] College of Business and Economics, University of Guelph, Guelph, ON, N1G 2W1, Canada
[b] Sauder School of Business, University of British Columbia, 2053 Main Mall, Vancouver, BC, V6T1Z2, Canada

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ABSTRACT

In nonlinear models, a typical way to determine the interaction effect between variables is to linearize the model for estimation purpose, add an interaction term, and then use the estimate of the parameter of the interaction term to determine the presence (or absence) and the extent of the interaction effect. In this paper, we show that in many cases such an approach is problematic. By design, non-linear models inherently include interactions, and as a result the interaction coefficient does not capture the full extent and complexity of the interaction effect. After exploring the complexities of interaction effects in non-linear models, we outline methods to estimate and understand the interaction effects in two widely used marketing models. We use 26 years of weekly US movie market data to test the interactions between critics' ratings and consumer sentiment about economic conditions on box office attendance. In addition to finding that movie attendance is counter-cyclical, an expected but not previously documented result, we also show, contrary to popular belief, that critics' ratings have larger impact during economic downturns than during periods of economic expansion.

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1. Introduction

In marketing research, the measurement of interaction effects of variables, such as those in the marketing mix, is critical for understanding, both theoretically and practically, the impact of controllable and uncontrollable factors on individual and market-level outcomes. For behavioral researchers, the theoretical reasoning behind interactions and their measurement is a mainstay of the research inquiry. Its importance in quantitative research is growing, as demonstrated by the call for more research on the interaction effects of marketing-mix variables by Narayanan, Desiraju, and Chintagunta (2004).

In non-linear models, a typical way to estimate the interaction effect is to linearize the model for estimation purposes and then add an interaction term. The estimate of the parameter of the interaction term is used to determine the presence (or absence) of an effect, the direction, and the extent of the interaction effect. The key objective of this paper is to show that such an approach can be problematic and to discuss ways to better understand interaction effects. Overall we show that: [1] non-linear interaction models provide a richer set of results than linear interaction models; [2] given non-linearity, it is better to evaluate these models at different points in the variable space; and finally [3] given that most non-linear models are interactive by definition, the use of extra interaction terms needs to be justified by theoretical reasoning and/or statistical diagnostic tests.

Focusing on the empirical literature in the movie industry, the work of Basuroy, Desai, and Talukdar (2006) exemplifies the typical approach to estimating interaction effects using data from the movie market. They use the significance and sign of the parameters of the interaction terms to test hypotheses on interactions—for example, of advertising expenditures and critics' ratings

* Corresponding author.
E-mail addresses: tdhar@uoguelph.ca (T. Dhar), Charles.weinberg@sauder.ubc.ca (C.B. Weinberg).

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and of sequel success and critics' ratings on box office performance. The use of the value, sign, and significance of the parameter of the interaction term as the key measure of interaction is highly prevalent in marketing research. To further explore the extent of the problems, we conducted a search using Google Scholar over four top-ranking marketing journals (*International Journal of Research in Marketing*, *Journal of Marketing*, *Journal of Marketing Research*, and *Marketing Science*) and readily found 15 papers published between 2009 and 2014 that used extra interaction terms in non-linear models to estimate and measure interaction effects.[1] Use of the interaction term as part of an approach to understanding interaction effects can be justified by theory or empirical results, as we discuss below. However, given the number of papers that add an interaction term to models that are inherently interactive, we believe that focused research in marketing is needed to better understand and develop rigorous approaches to estimate non-linear interaction effects.

This measurement issue is common in economics and other social science disciplines, not just marketing. In economics, Ai and Norton (2003) have shown in the context of discrete-choice models (i.e., logit and probit) that in the case of interaction of two continuous variables on the probability of choice, a single parameter-based test of significance is problematic. While questions about the measurement of interaction effects using discrete-choice models have yet to be settled, in this paper we focus on another class of multiplicative models that are widely used by marketing researchers. We argue that these popular non-linear models in marketing are interactive by definition and, as a result, researchers should justify the use of extra interaction terms, preferably using both theoretical and statistical reasoning. Our primary goal in this paper is to address challenges and pitfalls in estimating interaction effects in multiplicative models. We hope this paper will shed light on commonly observed challenges in estimating and interpreting non-linear interactions.

Because understanding interaction effects is foundational for theory and practice in marketing, we believe it is important to have a formal and comprehensive discussion of non-linear interactions in marketing models. In both simulated and actual data, we show that inclusion of an interaction term in a non-linear model can change the estimated values of both the interaction effects of two variables and the main effects of the independent variables on the dependent variable. That is, as we show below, the partial and cross-partial derivatives of x and z (the independent variables), on y (the dependent variable), can depend upon the inclusion of an interaction term.

To provide insights into the nature of the issue and probable solutions, we use US movie market data over 26 years to test the interaction effect between consumer sentiment and critics' ratings. It is generally argued by industry observers and critics that during periods of economic hardship when consumer sentiment regarding economic conditions is low, consumers tend to prefer "lighter" (i.e., less depth, lower-quality) movies. On the other hand, critics' preferences are presumably driven by the true quality of the movies. If that is the case, then critics' ratings will have greater impact during economically good times, and we should observe a positive interaction between critics' ratings and consumer sentiment affecting movie attendance. Our empirical analysis using the preferred parsimonious model provides the first systematic evidence that movie attendance is higher than average when consumer sentiment is low and, contrary to popular belief, that critics' ratings are more closely associated with movie attendance during periods of low rather than high consumer sentiment. Interestingly, the conclusion will vary significantly if we rely solely on models with extra interaction terms and base our decisions only on the parameter of the interaction terms.

2. Interaction effect in marketing models

In a regression model with one dependent variable (y) and two independent variables (x and z), there is an interaction effect of x and z on y if the effects of x and z are non-additive. In marketing and social sciences more generally, significant interaction of the independent variables also implies moderation effects. That is, the effect of x on y depends on z and vice versa. Mathematically the interaction effect measures the effect of a simultaneous change in x and z on y, and this is the cross partial of x and z on y: $\frac{\partial^2 y}{\partial x \partial x} = \frac{\partial^2 f}{\partial x \partial z}$ where $y = f(x,z)$. Next we will provide a broad classification of functions widely used by marketing researchers and then explore the functional forms of the interactions utilizing some of the most popular marketing models.

2.1. Functional forms

In marketing we use both linear and non-linear models to test theories and develop predictive models. Non-linear models can be either non-linear in variables or non-linear in parameters. The most widely used models in marketing (including the logit, probit, exponential, and other multiplicative models) are all variations of non-linear in parameter models. One of the reasons for their popularity is that these models can be linearized and, as a result, they are broadly classified as Generalized Linear Models (GLM) and readily estimated using standard statistical packages.

Linear model: Let's consider a linear model such that $y = \alpha + \beta_x x + \beta_z z + \beta_{xz} xz$. In this case the interaction effect of x and z will be: $\frac{\partial^2 y}{\partial x \partial z} = \beta_{xz}$. So, if we use regression to estimate this function then we can safely claim that the interaction effect is equal to β_{xz}. In this context, to test a hypothesis or to make policy-related decisions, the sign and magnitude of β_{xz} will be enough for researchers and practitioners.

If both x and z are dummy variables, then the coefficient β_{xz} captures difference in difference (DiD) of the averages, such that: $\beta_{xz} = (\bar{y}_{x=1,z=1} - \bar{y}_{x=0,z=1}) - (\bar{y}_{x=1,z=0} - \bar{y}_{x=0,z=0})$. Program and policy evaluation research in economics has used DiD techniques

[1] Here we are neither claiming that the use of the interaction terms was not warranted, nor are we questioning the findings of these papers. Whether these papers need the extra interaction terms to estimate interaction effects can only be determined through replication studies. Also our suggestion is that in such cases further diagnostics and analysis could lead to additional insights about the nature of interaction in the model. In the online appendix of the paper we provide a list of the papers.

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