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The Adoption and Discontinuance of Motion Picture Attendance and Monochromatic Television: Further Tests of a Mathematical Model

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Running Head: Adoption and Discontinuance

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Abstract

Data on motion picture attendance and the number of monochromatic television sets per household were used to provide further tests of Barnett, Fink and Eckert's (in press) mathematical model of the diffusion process. This model is advantagous over earlier models because it does not suffer from a pro-innovation bias. Rather, it describes both the process of adoption and discontinuance. The results indicate that the model provides an excellent fit of the data. It accounted for 98.0% of the variance in motion picture attendance and 99.9% of the variance in monochromatic television.

This paper applies the Barnett, Fink and Eckert (1986) mathematical model to describe the process by which innovations are diffused throughout society. The model was originally developed to describe the pattern of diffusion of information within the academic community. This pattern may be described as initially increasing to a peak which over time is followed by a decline. Using data on the citation of articles in academic journals from a given year to the year in which the cited article was published, they found that the model accounted for between 97.2 and 99.2% of the variance depending on the data set. This paper represents an extention of the model to the diffusion of two communication technologies, motion pictures and monochromatic television, both of which showed an initial adoption followed by a decline due to their replacement by other innovations.

Theory

The diffusion process is typically described by an S-shaped curve in which the cumulative numbers of adopters is plotted with respect to the time of an innovation's adoption (Rogers, 1983). The distribution of adopters initially rises slowly. It then accelerates to exponential growth to a maximum until half of the population adopts the innovation. It then increases at a decreasing rate. Although still positive, the slope approaches zero. The curve becomes asymptotic with the number of members of the adopting population. The frequency of adoption at any single point may be described over time by a bell-shaped normal curve. Mathematical descriptions of these curves are presented by Barnett (1978).

Rogers (1983) suggests that these models suffer from a pro-innovation bias. This is the implication that any innovation should be diffused and adopted by all members of a society. The innovation should be neither re-invented nor rejected (Rogers, 1983, p.92). Further, communication research should facilitate to diffused the innovation more rapidly. One manifestation of this bias is the focus of diffusion research exclusively on adoption to the neglect of disadoption. Rogers (1983, p.21) labels this discontinuance "a decision to reject an innovation after it had previously been adopted." There has been relatively little research designed to investigate the nature of discontinuance, and as a result relatively little is known about this aspect of diffusion behavior. One reason for this is the lack of models to mathemaically describe this process.

Rogers (1983) identifies two types of discontinuance, replacement and disenchantment. A <u>replacement</u> discontinuance is a decision to cease using an innovation in order to adopt a better one which supersedes it. For example, the reel-to-reel tape recorder, an innovation in its time, has generally been replaced by systems which use cassettes.

A <u>disenchantment</u> discontinuance is a decision to cease using an innovation as a result of dissatisfaction with its performance. The dissatisfaction may come about because the innovation is inappropriate for the individual and does not result in a perceived advantage over an alternative. For example, consider the use of chemical fertilizers, pestisides and herbisides. There use has declined as farmers become aware of their negative impact on the environment.

This paper presents a mathematical model of the diffusion of innovations which is not inherently pro-innovation. Originally, developed by Barnett, Fink and Eckert (1986), the focuses on disadoption as well as adoption. Since then the proposed model has been modified to confirm mor closely to its theoretical derivation (Barnett, Fink & Eckert, in press). In this paper the revised model will be used to describe the adoption/discontinuance of motion picture attendance and monochromatic television.

Mathematical Model of Disadoption

Rogers (1983) suggests that researchers can investigate how a practice is discontinued, and almost as an after-thought he presents a graphic representation of the "discontinuance curve." It describes a decaying exponential. Coleman (1969) and Hamlin, et al. (1973, 1979) provide precise mathematical descriptions of the curve. A decaying exponential has been empirically observed for the use of information over time by Goffman (1966), Meadows (1974), Dieks and Chang (1976) and Levy and Fink (1984).

<u>The model</u> . According to Barnett, Fink and Eckert (in press) the adoption/discontinuance process may be modelled as,

$$y(t) = a \{\exp[-(bt)+d] - \exp[-(ct)]\}$$

where $y(t)$ is the proportion of adoptors at a given point in time and a, b, c, and d are non-negative constants, with $c > b$. The a parameter is the product of the theoretical probability of adopting an innovation and an exponential term ($\exp[-d]$).

The adoption/discontinuance process is presumed to start at time equal to $-d$. The d parameter corrects for this situation as much as possible, given the data set. The parameter d is the time, necessary to adjust $t(0) = y(0)$, the date the process is initiated. When $t+d$ equals zero, $y(t)= 0$, and as $t \rightarrow$ infinity, $y(t) \rightarrow 0$.

The model assumes that the diffusion process involves an initial increase in the adoption of an innovation which is described by the second term in the model ($\exp[-(ct)]$). It is followed by a decline which eventually reaches zero. This is described by the model's first expression ($\exp[-(bt)+d]$). Most innovations decline in use after a peak, since new innovations ultimately replace them and after a period older innovations no longer are needed. For this curve to increase (adoption) and then decrease (discontinuance) c must be greater than b. Further, the speed of the growth and decline in the adoption process is indicated by the relative size of the c parameter compared to the b parameter.

This model has been used to describe drug concentration in the blood (the "two compartment" model), which is also a process that goes to zero as time increases (Burghes & Wood, 1980, pp.73-73; see also Simon, 1972). Thus, one consequence of this model is that the diffusion process involves a decline which eventually reaches zero. Even complex innovations (Barnett, 1978) decline in use after a peak, since new ones ultimately replace them.

One way to evaluate the trajectory of adoption/discontinuance over time is to find that point in time on the curve derived from the model at which the proportion of adoption is at a maximum. This point, which we call t^*, is

$$t^* = \{(\ln c - \ln b - d)/(c - b)\} .$$

The maximum proportion of adoption (y_{MAX}) may be determined simply by substituting the empirically obtained values and the value of t^* into the model.

This model has been used to describe drug concentration in the blood, which is also a process that starts at zero, rises, and then returns to zero as time increases (Burghes & Wood, 1980). Most diffusion curves, as already pointed out, do not allow for disadoption over time, which is a fundamental aspect of the problem here.

In sum, the Barnett, Fink and Eckert model allows the adoption proportion to go from zero to a positive value and back to zero. It provides for the prediction of the point in time at which adoption is set at a maximum (t^*), and also for that proportion (y_{MAX}). Utilizing this model, comparisons between innovations are possible and useful, since the extent that the model's parameters differ across innovations may be examined.

Methods

The Data

The model was tested with data which described the adoption and discontinuance for two communication innovations, motion picture attendance and monochromatic television sets. These two data sets were reported by DeFleur and Ball-Rokeach (1982, pp.63, 96-97). These data were historical statistics collected by the U.S. Bureau of the Census. The first data set provided the weekly rate of motion picture attendance from 1922 to 1977. It contained 27 data points. There was data for the even years from 1922 to 1950, data on motion picture attendance for 1954, 1958, 1960 and 1965, and annual figures for 1970 to 1977.

While people have viewed motion pictures since the end of the 19th century, the first year for which there is recorded attendance data is 1922. In that year, average weekly movie attendance was 40 million and the total number of households was 25,687,000. Hence, the weekly attendance per household was 1.56. The weekly attendance per household rose through out the 1920s reaching its peak, 3.0 in 1930. It dropped drasticaly between 1930 and 1932 due to the Great Depression. Nevertheless, during the late 1930s and the decade of the 1940s, moviegoing was still popular and scholars term those years the Golden Years of Film. The rapid growth of television in the late 1940s and early 1950s exerted a great impact on movie attendance. The existing practice, motion picture attendance, an innovation in its time, was replaced by a new innovation, television. During the 1950s, weekly motion picture attendance per household dropped to .79. By 1970, film going hit its lowest rate and remained relatively constant with a weekly attendance rate between .22 and .28.

The other data set described the ownership level of black and white television sets, starting in 1946 and ending in 1977. In total, there were 22 data points. There was annual data for 1946 to 1950 and 1960 to 1972 with additional data for 1955, 1975, 1976 and 1977. In 1946, the rate of ownership of monochromatic television sets per household was .0002. It was adopted rapidly reaching its highest level at 1.175 in 1964. They were widely adopted during the 1960s. However, ownership began to decline being replaced by colored television sets. By 1977, there were .923 monochromatic sets per household.

[illegible] two data sets provide accurate and stable measures of adoption/disadoption behavior. They are longitudinal and use the entire population of the United States as the unit of analysis.

As such, they are appropriate to evaluate models of social processes, such as the Barnett, Fink and Eckert (1986) model of the adoption/disadoption of innovations (Hamblin, et al, 1973; Rogers & Kincaid, 1981; Barnett, 1982).

Analysis Procedures

SAS NLIN was employed to evaluate the model with the two data sets described above. NLIN performs nonlinear regression. Goodness of fit is determined through the method of least squares. It is an iterative process in which users provide a theoretical model and inital estimates for the model's parameter values. These starting values are continually improved until the sum of the squares of the error is minimized. NLIN provides several different methods to determine best fit. DUD was used to fit the data to the model. DUD, the multivariate secant method uses the Taylor Series,

$$F(B) = F(B_0) + X(B - B_0) + \ldots$$

where,

$X = \partial F/\partial B$ is evaluated at $B = B_0$

to minimize the error. The derivatives are estimated from the history of the iterations rather than being supplied analytically. The method is also known as the method of false positioning (Ralston and Jennrich, 1979). If only one parameter is estimated, the derivative for iteration i+1 can be estimated from the two previous iterations.

$der_{I+1} = (Y_I - Y_{I-1})/b_I - b_{I-1})$

when K parameters are estimated (four in this model), the method uses the last K + 1 iterations.

Since NLIN requires the user to provide theoretical start values for the model before it can provide the best fit estimates for the parameters the inital estimates were as follows:

Motion Picture Attendance:

a = 10.0;

b = .08, with a lower limit of 0.0, to conform with the theoretical assumptions of the model;

c = .09, with a lower limit of 0.0, to conform with the theoretical assumptions of the model. Further, c was constrained to be greater than b.

d = 1.0. The unit of time in this data set was the year. d was allowed to assume any positive value because the true time zero for motion picture attendance was some time prior to 1900. These values were chosen after a number of preliminary trials to restrict the range of the coefficients.

Monochromatic Television:

a = 2.25;

b = .025; with a lower limit of 0.0, to conform with the theoretical assumptions of the model;

c = .095; with a lower limit of 0.0, to conform with the theoretical assumptions of the model. Further, c was constrained to be greater than b.

$d = -.1.$

Similarly, these parameter values were determined after a number of preliminary trials. After initial attempts to fit the model, it was concluded that a cube root transformation was necessary due to the pattern of the residuals. Consequently, a cube root transformation of the data on the number of monochromatic television sets per household was performed to test the best fit between the data and the model.

To evaluate the goodness of fit of the Barnett, Fink and Eckert model, several tests were employed. The R-squared from the nonlinear regression and the plausibility of the derived parmeters, particularly d, t^*, and y_{MAX}, were examined. Further, the residuals from the nonlinear regression for the model should be homoscedastic, normal, and not exhibit any systematic patterns (see Bauer and Fink, 1983). To the extent that the data fail to conform to these assumptions, regardless of transformation, the model will be considered incomplete: i.e., some important factor that "explains" the systematic character of the residuals has been left out.

Results

The results of the test of the model for the two data sets are presented in Table 1. Scatterplots showing the actual and predicted values for both innovations (level of use on time) are presented in Figures 1a and 1b. The model fit the two data sets very well, explaining 98.0% of the variance for motion picture attendance and 99.9% for monochromatic television. All coefficients are within the specified theoretical limits. Coefficients b and c are greater than 0.0 and the values of c (+.108, +.127) are greater than b (+.096, +.020). The values of a are 63.19 and 1.71. For d, they are -.001 and +.016.

Table 1 and Figures 1A and 1B About Here

The values for t*, the point on the curve at which the adoption is at a maximum, are 8.14 for motion picture attendance and 9.21 for monochromatic television. The actual time points when adoption is at its maximum level are time 8 for motion picture attendance and time 11 for black and white television. Thus, the obtained values for t* are plausible.

The values for y_{MAX}, the maximum level of adoption, are 2.95 for motion picture attendance and 1.06 for monochromatic television. The actual maximum levels of adoption were 3.00 and 1.06. The obtained values are nearly equivalent.

The residuals are generally distributed normally and are not significantly correlated with either the dependent variable (the level of adoption) or time. For motion picture attendance there are 16 residuals greater than the mean (0.02) and 11 less. The skew is .00 and the kurtosis is 1.01. The correlation between the residuals and the level of adoption is .13 ($p = .51$) and the correlation between the residuals and time is .05 ($p = .79$). For monochromatic television there are 11 residuals greater than and less than the mean (0.00). The skew is -.09 and the kurtosis is 3.26. The residuals are peaked about zero. The correlation between the residuals and the level of adoption is .06 ($p = .79$) and the correlation between the residuals and time is .00 ($p = .99$). None of the relationships are significant for either innovation.

An examination of the scatterplots of the residuals by level of adoption and time does not exhibit any systematic pattern. However, it does indicate heteroscedasticity. For motion picture attendance, the variance in the residuals is greater the greater the level of attendance. These levels occurred early in the adoption/discontinuance process. For monochromatic television, there is greater variance in the residuals for those data points whose values are small. These levels also occurred early in the process. Heteroscedasticity occurred despite the cube root transformation to remove other systematic patterns in the residuals for monochromatic television.

Discussion

The results indicated that the Barnett, Fink and Eckert (in press) model fit the two data sets very well. It explained 98.0%

of the variance in the rate of motion picture attendance and 99.9% of the variance in the adoption and discontinuance of monochromatic television. The model fit both sets of data significantly better than did a linear regression. The r^2 for motion picture attendance was .736. For monochromatic television, $r^2 = .601$. The difference between these correlations clearly demonstrates that the model represents an improvement over existing methods.

The excellent goodness of fit occurred despite the fact that there is only limited and incomplete data describing the adoption/discontinuance process for these two communication technologies. There were only 27 datapoints for motion picture attendance and 22 for monochromatic television. Generally, this is far too few to get an accurate fit of a nonlinear model with four parameters to estimate. Also, the initial diffusion of motion picture attendance was not included in the data, since the first time point was 1922 rather than sometime around 1900. Further, the discontinuation process of both innovations is still ongoing. Yet despite these limitations, the model fit the data well.

Another indication of the quality of the fit was the distribution of the residuals. They were normally distributed and did not have a systematic pattern when plotted against time and level of adoption. Also, in the case of motion picture attendance the largest residuals can be explained by exogenous factors. The greatest error terms occurred during the Great Depression (1932, time 10) when attendance was suppressed due to economic factors. The model over estimated attendance. During the late 1940s motion picture attendance was high but the model accomodated the datapoints from the 1950s when attendance greatly dropped due to the rapid diffusion of the replacement innovation, television.

While the goodness of fit and the behavior of the residuals are generally excellent, the results are problematic in two areas, heteroscedasticity of the residuals and the size of the standard errors of the parameter estimates. In both models the variance of the residuals are not distributed normally. They are greater early in the diffusion process. Similar results were reported by Barnett, Fink and Eckert (1986, in press). This is due, in part, to the stabilization of the level of adoption later in the process. As t--> infinity, y(t)--> 0, due to the discontinuation of use of the innovation. As a result, there is little variance in the level of adoption and thus, little variance in the residuals. Therefore, despite numerous transformations of the data the heteroscedasticity remains.

The size of the standard errors are significant (See table 1). This is due to the limited number of data points available to fit the model. There were only 27 points for motion picture attendance and 22 for monochromatic television. Thus, despite the high levels of goodness of fit, one should place little confidence in the specific estimated values of the reported coefficients.

Overall, the results suggest that the Barnett, Fink and Eckert model is excellent for the description of the adoption/disadoption process. In this paper the model was applied to describe the diffusion and subsequent discontinuance of two technological innovations which are related to mass communication, motion pictures and black and white television. Previously (Barnett, Fink and Eckert, 1986) it was used to describe the adoption and disadoption of academic information by scientists and engineers, social scientists and individuals writing in the arts and humanities, accounting for over 97% of the variance in the three cases.

Finally, the Barnett, Fink and Eckert model represents an important contribution to the study of the diffusion of innovations. Communication Science now has a model which does not suffer from a pro-innovation bias. It has been shown to accurately describe the adoption/disadoption process of a number of innovations. For this reason the diffusion process should no longer be characterized by an S-shaped curve. Rather, it should be characterized as an inverted U-shaped curve with the first part describing the adoption process and the second discontinance.

Summary. This paper used data on motion picture attendance (1922-1977) and the number of monochromatic television sets per

household (1946-1977) to provide further tests of Barnett, Fink and Eckert's (in press) mathematical model of the diffusion process. This model is advantagous over earlier models because it does not suffer from a pro-innovation bias. Rather, it describes both the processes of adoption and discontinuance. The results indicated that the model provides an excellent fit for the data. It accounted for 98.0% of the variance in motion picture attendance and 99.9% of the variance in monochromatic television, despite problems of high standard errors and heteroscedasticity of the residuals.

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TABLE 1

Descriptive Parameters For Adoption/Discontinuance Data for Motion Picture Attendance and Monochromatic Television

	Motion Picture Attendance		Monochromatic Television	
	coefficient	s.e.	coefficient	s.e
a	6.319E+01	4.896E+03	1.713E+00	1.856E-01
b	9.595E-02	2.844E-01	1.981E-02	3.297E-03
c	1.085E-01	3.207E-01	1.270E-01	1.331E-02
d	-1.143E-01	4.354E-02	1.583E-02	8.691E-02
t^*	8.143E+00		9.210E+00	
y_{MAX}	2.946E+000		1.058E+00	
R^2	.980		.999	
r^2	.736		.601	
Residual Analysis:				
mean	9.328E-02		1.632E-06	
skew	5.229E-04		-9.890E-02	
kurtosis	1.018E+00		3.266E+00	
correlation with level of adoption	.131 (p = .513)		.061 (p = .787)	
correlation with time	.053 (p = .7[illegible]		.004 (p = .986)	
N	27		22	

FIGURE 1A

The Actual and Predicted Values of Motion Picture Attendance Against Time

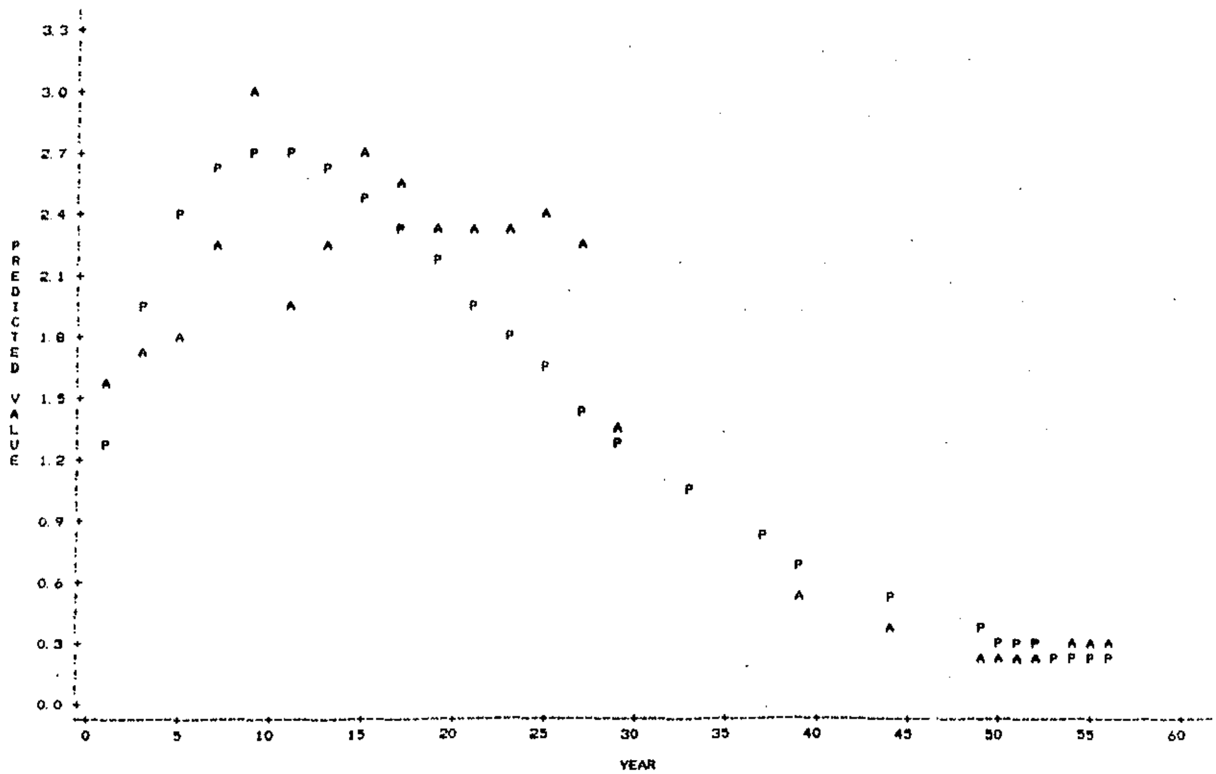

FIGURE 1B
The Actual and Predicted Values of Monochromatic Television Per Household