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ABSTRACT

The cumulative growth in innovations such as new media has been modeled with S-curves. However, the S-curve model has not been applied to mature innovations that have reached their peak of diffusion and begun to decline. This study explores the potential extension of the use of the S-curve to model decays in the availability or usage of traditional media. Using annual data from declines in telegrams, afternoon newspapers, vinyl records, outdoor movie theaters, and VHS tapes, this study finds that declines in incumbent media often follow a dramatic downward path that is more abrupt than that of media undergoing growth. Implications for media management and theory are discussed.

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MEDIA DISCONTINUANCE: MODELING THE DIFFUSION "S" CURVE TO DECLINES IN MEDIA USE

Communication media come and communication media go. For example, telegraphers no longer tap out Morse codes, and society accepts the loss of telegrams as a reasonable price to be paid for innovations such as telephones, and more recently, electronic mail. Electronic mail may itself be supplanted by text messages, and social media programs may change the dynamics of person-to-person communication (Chan, 2013). But while models are available to explain how new communication media diffuse, we have few tools with which to understand how media decline in the face of new competition.

The purpose of this study is to consider declines in media availability and consumption. First, this study will discuss media displacement effects in an effort to understand why society can experience simultaneous growth in both incumbent and new media. Then, this study will address the pro-diffusion bias of innovation literature to understand what happens on the backside of the diffusion curve. Can the S-curve that portrays growth of innovations also show the path by which former innovations decline? Finally, this study will compare data from a sample of declining media forms to a reverse S-curve.

Research Objectives

For the bulk of the 20th century, researchers, especially those working in the diffusion of innovation paradigm, focused almost exclusively on how innovations take hold in society. Innovations were considered to be a priori improvements over embedded practice, with customs, businesses and regulations seen only as barriers to innovation. The objective of this research is to explore the effects of change on embedded—and

successful—media forms. This research focuses not on the innovation itself, but on the paths taken by declining media forms that are in competition with new media. It looks at a collection of 20th and early 21st century media forms, from telegrams through VHS tapes, that have all had extensive availability and usage, only to see near extinction over the long term. The contribution of this research is to open a dialog that focuses not on the new, but on the current, and provide ways of understanding a fuller spectrum of outcomes from media changes.

As incumbent media such as printed newspapers face dark days in many parts of the world, this research will help provide an understanding for media managers and academic researchers of the potential for using diffusion of innovation concepts to understand the rate and process of the decline of media forms.

Media Displacement and Discontinuance

Defining Media

There are multiple ways of defining media. One approach sees media as any means of transmitting information (Danesi, 2009; Hart, 1991). Another definition takes a technological perspective. Janowitz (1968) indicated that media are technological devices such as press, radio, and films that can disseminate symbolic content to large, heterogeneous and widely-dispersed audiences. Similarly, Turow (2009) defined mass media as the technological instruments through which mass communication takes place. Danesi (2009) also related media to mass communication and describes media as "the various forms, devices, and systems that make up mass communication considered as a whole" (p.192).

In this research, we adopted the technological perspective as our definition of media, so that we may consider changes in availability and use of representational as well as mechanical and electronic media.

Media Displacement Effects

Concerns about the decline of incumbent media in the face of new communication technologies are widespread in the media competition literature. There is a wave of inquiries on media displacement effects whenever a new medium or technology gains popularity (Lin & Atkin, 2007). Multiple studies have been based on a media displacement perspective (For example, Kayany & Yelsma, 2000; Lazarfeld, 1940) that assumed that media consumption and availability are played out in a zero-sum game in which limited amounts of time or financial resources are parceled between new and old media (McCombs, 1972). The introduction of a new medium therefore reduces the amount of time or money individuals allocate to incumbent media that serve the same function for users (Robinson, 1969), ultimately leading to the decline of incumbent media.

Time displacement and functional displacement are two dimensions to explain the potential effect of new media on old media (Kayany & Yelsma, 2000). The rationale behind time displacement effect is clear: mass media consumption may reach asymptote because of the scarcity of time (McCombs, 1972). This assertion has been received support from a number of studies (James, Wotring, & Forrest, 1995; Lee & Leung, 2004; Nie, Hillygus, & Erbring, 2002). James *et al*. (1995) conducted a study on pre-Web electronic bulletin board usage and its impact and found that television watching suffered

dramatic reduction, followed by book reading, phone talking and letter writing in that order. The time-diary study by Nie *et al*. (2002) found a time displacement effect that demonstrated that time is a zero-sum game phenomenon, in which time can be reshaped and redistributed but cannot be expanded. Lee and Leung (2004) reported reduced newspaper reading, radio listening and television watching among Internet users.

Functional displacement is a more complicated dimension. Henke and Donohue (1989) examined how the VCR displaces other media at the individual user level and indicated that displacement effect could be distinguished on the basis of the intended function of the VCR, convenience taping is positively related to television watching while is negative associated with going out to a movie theater. McCombs (1972) used this functional alternative to explain the effect of movies, TV, and radio on newspapers, and found that to some extent each of the newer media eroded the per-household circulation of daily newspapers. However, an incumbent medium is not necessarily destined to be replaced with a new medium: consumers who perceive both old and new media formats as satisfying their needs are willing to purchase multi-format bundles with the same content on multiple formats (Koukova, Kannan, & Kirmani, 2012). The result can be a co-existences of competing media formats.

While co-existence of new and old media is possible (Greer & Ferguson, 2014), some media forms dwindle over time. For example, Meyer (2009) declared that, based on the downward circulation trends in the last three decades, the last newspaper to appear

would be in April 2040. The publisher of the New York Times predicted a discontinuance of a print version of the paper sometime in the future[1].

Predictions of the demise of old media are as old as the media themselves. However, there are studies that show old and new media might coexist and complement each other, with an end-result of something other than extinction (Adoni, 1985; Belson, 1961; Coffey & Stipp, 1997; Dimmick, 2003; Newell, Pilotta, & Thomas, 2008).

Although Belson (1961) admitted that television exerts a dampening effect on the frequency of reading and buying of newspapers and magazines, he thought that the influence was small. Newell *et al.* (2008), in reviewing consumption of media use data for a seven-year period, found an accumulation of media use whereby incumbent media use grew, albeit slowly, while new media use increased rapidly, thus countering the assumption, at least over the short term, that new media cannibalize the usage of incumbent media. The introduction of handheld video reception devices such as iPads has not yet resulted in a decrease in television set-based viewing. Instead, heavy viewers of television layer TV set use with handheld use to increase their overall consumption (Greer & Ferguson, 2014).

The interplay of new and incumbent media is dynamic: the managers of old media typically are not waiting for extinction, instead implementing different strategies and tactics to adapt to changing competitive environments. Dimmick (2003) argued that the

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1 Blodget, H. (2010). Sulberger concedes: 'We will stop printing the New York Times sometime in the future'. Business Insider. Retrieved October 9th, 2010 from http://www.businessinsider.com/sulzberger-we-will-stop-printing-the-new-york-times-2010-9.

maturation of new media does not bring exclusion and extinction, but alters the niches of existing media and result in even greater complexity of niche relationships.

Adoni (1985) introduced the functional interchangeability idea to explain the coexistence between media (in his case, television and print) and identifies a positive correlation between the degree of functional interchangeability of any two media and the degree of their simultaneous coexistence in terms of production, distribution, and consumption. Such interaction between media was found by Coffey and Stipp (1997) as well. They noted that computer users continued to embrace the television usage following the introduction of computers, with media consumption are evolving in a manner that is quite different from the "PCs will replace TV" scenario.

The displacement versus niche studies suggest outcomes for existing media that are different from extinction. However, the pace of change in media seems is quickening, and we have few tools with which to understand how and when media decline. This study will attempt to fill this gap in media decline research by focusing on applying the Diffusion of Innovations model (Rogers, 2003) to explore not how a innovation grows, but the effects of that growth on incumbent behavior.

Diffusion of Innovation: The Pro-Innovation Bias

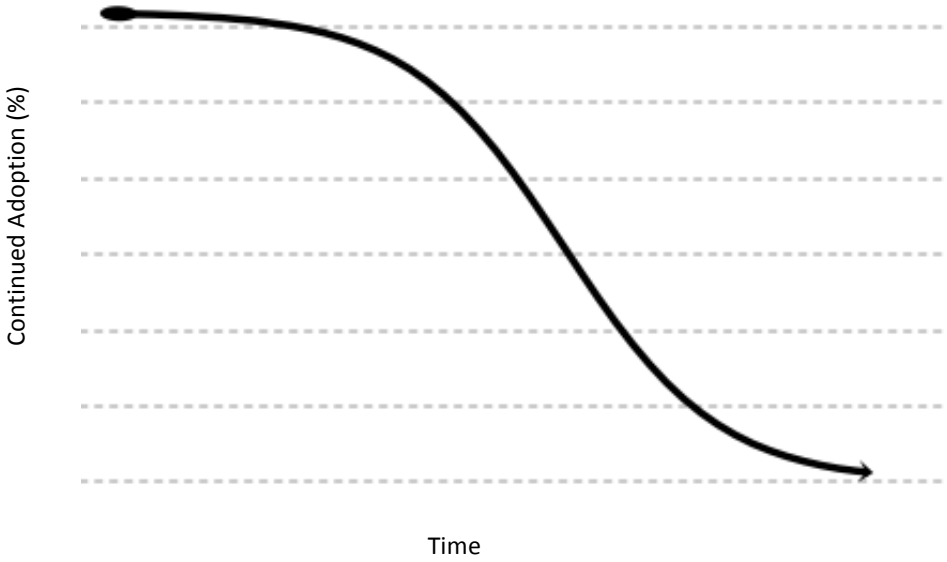
Diffusion of innovation is a theory that focuses primarily on adoption. But Rogers (2003) admitted that an innovation may be rejected at any time during or after the adoption process. He used the term "*discontinuance*" to define the decision to reject an innovation after it has previously been adopted. However Rogers gave scant attention to discontinuance, identifying pro-innovation bias as one of the most serious shortcomings

of diffusion research. Post-adoption behavior, including discontinuance, is largely an unexplored area.

The focus of diffusion of innovation on adoption behaviors has resulted in post-adoption behavior, including discontinuance of prior behaviors and usage of incumbent innovations, has been given short shrift in the literature as innovation, are presumed to offer societal and economic improvements (Sveiby, Gripenberg, & Segercrantz, 2012, p. 25). While some of the diffusion literature has focused on unintended or negative consequences of innovations, in general diffusion literature paints existing practices as impediments to the introduction of innovations (Foster, 1986; Pae & Lehmann, 2003), discussing outcomes primarily in terms of effects on the incoming innovation (Greve, 2011). However, building upon Pae (2003), Michalakelis et al. (2010) developed a more nuanced view of innovations that focused on the multiple innovations in the same domain occurring over a relatively short time, and the effects of each preceding innovation on the new innovation.

Rogers (1983) suggests that researchers can investigate how a practice is discontinued. He shows the following figure as the theoretical path of discontinuance: a reverse S-curve, in which the continued usage of an innovation declines over time. The decline starts out slowly, picks up speed, then slows as the continued usage approaches the point of extinction (See Figure 1).

Figure 1: *Theoretical Discontinuance Curve*



Adapted from Rogers (1995)

Similar to Rogers, DeFleur (1965) expected old media to discontinue, calling for a "curve of abandonment" for once institutionalized behavior forms that are dropped from social or cultural system of a given group or society, suggesting that "the obsolescence should show a kind of 'reverse' diffusion curve" (p. 318).

An Alternative To Diffusion Of Innovation: The Product Life Cycle

The concept of decline and extinction is built into the Product Life Cycle (PLC). Levitt (1965) described stages that characterize the PLC: introduction, growth, maturity, and decline. Takeoff and slowdown are two essential turning points in the product life cycle (Golder & Tellis, 2004). After the slowdown point, sales become a slow increase, even a temporary decrease. If we combine the PLC and diffusion of innovations model the five levels adoption process suggested by Rogers have a relationship with the four stages of the Product Life Cycle (Hill, Action, & Farren, 2006).

A significant contribution by linking the product life cycle to diffusion of innovations was made by Bass (1969), with the development of a growth model for the

timing of initial purchasing of new products. Tested against data for eleven consumer durables, the Bass model found exponential growth of initial purchases to a peak, followed by an exponential decay. Subsequent research extended the Bass model to include other dimensions of diffusion as well as economic factors that may influence product growth (Dodson & Muller, 1978; Golder & Tellus, 1998).

To simplify the mathematics, Bass (1969) did not take the repeat purchases into consideration. Also, because of excluding the influence of repeat purchases, the timing of the peak in sales is earlier (Bass, 1969). Bass (2004) noted that although taking changes in prices and other decision variables that might influence the diffusion process into consideration, the basic shape of "Bass Curve" would still be maintained. However, there remained uncertainty about the speed of growth and decline.

Golder and Tellis (1998) proposed a growth model based on affordability and find sales slow down due to a slowing economy or a flattening out of the price curve. They extended this model (2004) by incorporating informational cascades in product life cycle research. Informational cascades, a phenomenon in which discussion of a subject expands geometrically as more and more people are pulled into the conversation, are driven by observing the behavior of other consumers. New products can be classified into time-saving products and leisure-enhancing products (Horsky, 1990). Products such as TVs, radios, and CD players are more leisure enhancing, and are more visible and discussed by consumers. Thus, they are affected more strongly by informational cascades.

Informational cascades can produce both positive and negative momentum. Once some consumers discontinue their purchases and other consumers become aware of these

decisions, a negative cascade begins. Affected by such negative momentum, the slowdown might be a drop in sales at the onset of maturity rather than a gradual flattening of the sales curve.

Dodson and Muller (1978) identified a similar effect to information cascades as word-of-mouth. Good word-of-mouth has positive effect at the growth stage while bad word-of-mouth affects the decline stage negatively. When the word-of-mouth effect is relatively large, they show us the similar curve of diffusion to Rogers'.

The Discontinuance Hypothesis

Turning to media, some incumbent media, such as newspapers, books, and radio may have reached the maturity or decline stage in their life cycle (Achtenhagen, 2005; Golder & Tellis, 2004). Maisel (1973) claimed that "the mass media are actually shrinking in size relative to the total economy" (p. 168).

If this assertion is correct, we are facing the reality that we have few tools to predict when and how a media declines. The limited literature on discontinuance does not explicitly set out the pathway by which former innovations come to an end. Thus, our research is exploratory (Babbie, 2014) in that we explore the dimensions of discontinuance. Will the decline follow a reverse S-Shaped curve, like Rogers (1983) and DeFleur (1965) suggest? Rogers (2003) does not tell us clearly if human interaction factors have the same influence on discontinuance of an innovation as they influence diffusion process.

No matter if the discontinuance rationale is disenchantment or replacement, we suggest that at the very beginning, only a few individuals are aware of their

dissatisfaction of the innovation and the existence of alternatives, and thus in a position to discontinue the current adoption. Those few discuss their feelings with other members of a social system, with the expansion of discontinuance accelerating as more individuals become aware of alternatives. The increase in discontinuance among the few leads to the discontinuance among the many, and eventually leads to the unavailability or extinction of the innovation. Thus, for media we hypothesize that:

The decline of a media follows a reverse S-shaped curve, in which the number of continued adopters decreases over time, approaching zero.

To explore this hypothesis we consider the following growth curve models for each media under consideration: the 3- and 4- parameter Logistic model, the 3- and 4-parameter Rodbard model, the Gompertz model, the Log-Logistic model as well as a First-order Decay Kinetics model (See Table 1). The selection of these models from a larger class of nonlinear growth curve models is based on a visual inspection of the data. If a model provided a first visual plausible fit the model was selected to be a viable candidate.

Table 1: *Sigmoid Curve Models*

Model	Model Equation
3-parameter Logistic	$Y(t) = b_1 / [1 + b_2 * \exp(b_3 * t)]$
4-parameter Logistic	$Y(t) = b_1 + (b_2 - b_1) / [1 + \exp(b_3 * (t - b_4))]$
3-parameter Rodbard	$Y(t) = (1 - b_4)/[1 + (t/b_3)^{b_2}] + b_4$
4-parameter Rodbard	$Y(t) = (b_1 - b_4)/[1 + (t/b_3)^{b_2}] + b_4$
Gompertz	$Y(t) = b_1 * \exp(- b_2 * \exp(- b_3 * t))$
Log-Logistic	$Y(t) = b_1 - \log(1 + b_2 * \exp(- b_3 * t)$
First-order Decay	$Y(t) = b_1 * \exp(- b_2 * t) + b_3$

Note: Y(t) represents the percentage of continuing users or availabilities of medium at time t.

Method

To investigate the hypothesis of discontinuance as a reverse S-curve, we explored data from a number of declining media in the 20th and early 21st century. As this study focused on the consumption of media, as opposed to the revenue generated by media use, our exploration focused on media in which availability (for example, the number of drive-in theaters), or usage (for example, shipments of vinyl records) data were recorded and publicly accessible. Revenue data were excluded, as increases in unit prices could mask declines in consumption. Also excluded were data unavailable on an annual basis. Data were sourced from the US Census and trade associations for US media companies. (See Appendix 1 for the data set and sources.)

Sample Selection

The media under review had to meet several tests in order to be selected for analysis. First, data had to be available for either the availability of the media or the use of the media. This approach excluded, for example, CB (Citizens Band) radios, which were popular in the US in the 1970s (Carey & Moss, 1985), but whose usage declined after its initial peak. An investigation of government documents and trade publications found no tracking of usage. Second, the medium had to be predominantly consumer-based and not business-to-business communication. This limitation excluded business-only technologies such as pneumatic tubes that connected business offices in the late 19th and 20th century. Third, the medium had to have undergone a substantial decline in usage or availability. We arbitrarily set as the inclusion criteria a loss of 50% of availability or usage. This excluded media that have had "ups and downs" such as theatrical admissions to motion pictures, media that have not undergone declines, such as television, or have undergone declines smaller than 50%, such as radio listening and magazine circulations. Finally, the media had to have been tracked for a substantial number in year in order to support the statistical modeling. This excluded relatively recent media such as pre-recorded compact discs (CDs) and pre-recorded digital video discs (DVDs). While both media formats are undergoing steep declines, the limited number of years since peak distribution did not allow for model fitting. Throughout this research, media examples are presented in chronological order of their peak year of distribution or availability, starting with telegrams (peak year 1945) through pre-recorded VHS tapes (peak year 1999).

Data Manipulation

Diffusion curves typically compare time against growth. The growth variable starts from a zero point, where the innovation has not yet begun the diffusion process, to

100%, where the innovation reaches its maximum penetration, regardless of whether or not the innovation has been adopted by the entire society. For this research, the beginning of the curve was set at the maximum penetration of the medium. Data were normalized to percentages of the maximum penetration, with 100% selected as the peak point. Declines were then shown as percentage decreases from the peak. Additionally, diffusion curves typically are cumulative, assuming that adoption decisions are irreversible. As cumulative data were not available, the one-way assumption was relaxed for this research. As a result, the discontinuance curves can show increases as well as decreases.

Statistical Methodology

The data analysis involved the fitting of nonlinear regression models in the form of growth curve models. Nonlinear regression models are appropriate when the relationship of the response variable of interest with its explanatory variable cannot be reasonably well described through a linear model but rather a nonlinear function such as S-curves as posited in the hypothesis of the paper. We performed all statistical analyses using *R* software version 3.0.1 and JMP Pro software version 11.0.0. *R* is an open-source program for statistical computing and graphical analysis, while JMP Pro is a product of the SAS Institute Inc. The JMP Pro software's capabilities were used to visually inspect the plotted data for reasonably well fitting S-curve models and to subsequently obtain numerical starting values to fit the postulated nonlinear model. Obtaining a reasonable set of starting values is crucial in the mechanics of nonlinear regression as nonlinear functions are fitted to the data through a series of successive model approximations. Successful convergence of the fitting algorithm requires that the starting values be reasonable initial estimates of parameter values. The fitting of all nonlinear models was

performed in R using the default Gauss-Newton algorithm employed by the R nls() function. Quality of model fit was initially judged using residual based diagnostics including the R-square value, residual standard error (RMSE), i.e., the smaller the residual standard error, the better the fit of the model, and visual inspection of residuals through residual plots. Additionally, we assessed model fit by conducting a time series analysis of the residuals found by subtracting the estimated growth curve from the observations over time. To check that an estimated curve appropriately captured the trend in the data, we examined the residuals to determine if these could be modeled as a realization of a stationary, but not necessarily independent, time process. That is, after removing the growth curve trend, remaining variability in the data could then be explained as time dependent noise. We analyzed residuals to select an autoregressive-moving average model (ARMA) (Box, Jenkins, & G. C. Reinsel, 1994) with lowest AICC criterion using statistical software ITSM 2000 (cf. Brockwell & Davis, 2001).

For each media under consideration we defined the explanatory variable as the number of years that had passed since the medium reached its peak availability or usage level. We began with the value zero corresponding to the year of the observed peak level. We defined the response (outcome) variable as the relative percent decline of the media from the observed maximum level. For year zero, the response consequently corresponds to a value of 1, indicating the maximum availability or usage. (See Appendices 2 and 3 for comparisons of the declines for each medium and model fit.)

Results

The sample of declining media data included the usage of telegrams, the number of afternoon newspapers, circulation of afternoon newspapers, the number of drive-in movie theaters, shipments of prerecorded VHS tapes, shipments of long playing vinyl records, and shipments of vinyl music singles in the United States, each reported beginning with its peak year of usage or availability. The mean number of years of decline was 29. The earliest peak year from which declines were measured was 1945 for telegrams. The latest year of decline for which data were available was 2008, for newspapers, drive-in movies, VHS tapes, and vinyl records (See Table 2).

For all but newspapers, the initial rate of decline was quite rapid. Within the first five years of decline, it was typical to see drops from peak usage or availability of 25% (for example, telegrams) to more than 50%, for drive-in theaters. The mean decline over the first five years was 24% (SD = .20). However, extinction was not the fate of all media. While VHS recordings and audio cassettes did decline to the zero point, and news reports have cite the "last telegram" as being sent in the U.S. in 2006, media forms such as afternoon newspapers, drive-in theaters and vinyl records are still in existence, although in far smaller numbers than their peak diffusion.

Table 2: *Media Declines from Peak Usage or Peak Availability*

Medium	Peak Year	Years of Decline	1st Year Decline	Decline by 5th Year	Overall Decline
Telegrams	1945	43	10.00%	26.00%	89.00%
Afternoon Newspapers (Publications)	1952	49	0.07%	0.48%	62.58%
Afternoon Newspapers (Circulation)	1968	41	1.22%	0.72%	84.09%

Music LP Vinyl	1977	32	0.78%	14.19%	99.16%
Music Single Vinyl	1979	30	25.94%	41.13%	99.81%
Drive-In Theaters	1988	22	28.00%	57.00%	69.00%
Music Cassettes	1989	21	0.87%	18.60%	99.98%
Pre-recorded VHS	1999	10	6.56%	43.44%	100.00%
Mean		28.56	9.00%	24.00%	85.00%
Standard deviation		14.24	0.11	0.19%	0.1700

The Reverse S-Curve of Media Declines

Supporting the hypothesis, we can conclude that all of the media under consideration can be described by a response curve commonly known as an S-curve or sigmoid curve. (Note that S refers to sigmoid here.) Because the decline of a medium is of primary interest, this implies that the shape of the models is more specifically a reverse S-curve. Generally speaking, the class of S-curves includes all mathematical functions that follow an S- (or reverse S-) shape. Well-known functions include, for example, the logistic curve, generalized logistic curve, and Gompertz curve.

Detailed analyses of all media considered revealed, however, that within the class of S-curve models no single curve, e.g., logistic or Gompertz, fit the decline of media over time sufficiently well for all media. Instead, we noticed the following grouping: afternoon newspaper availability and afternoon newspaper circulation both can be described by the three- or four-parameter Rodbard curve as well as a four-parameter Logistic curve. Differences in the R-square value and RMSE are negligible from a

practical point of view. In other words, these curves yielded larger R-square values and smaller RMSE values in comparison to the Gompertz model (See Table 3). Visualization of model fit and residuals in Appendix 2 confirm this finding. Note that in favor of a simpler model the F-Test for parsimony suggests that the reduced model, i.e. the three-parameter Rodbard curve suffices to explain the continued adoption in afternoon newspaper availability and afternoon newspaper circulation (see Table 3). The three-parameter Rodbard curve corresponds to a general form of the logistic function (De Lean, Munson, & Rodbard, 1977).

Table 3: *Optimum Fit Models for Declining Media*

Medium	Optimum Model	R-square	RMSE	b1	b2	b3	b4
Telegrams	3-p Rodbard$_1$	0.9659	0.0474		1.1393	24.8498	-0.3505
Afternoon Newspapers (Publications)	3-p Rodbard	0.9979	0.0102		4.5580	35.1358	0.2590
Afternoon Newspapers (Circulation)	3-p Rodbard	0.9980	0.0143		3.2270	24.2442	-0.0028
Music LP Vinyl	Gompertz	0.9955	0.0247	1.1234	-2.3231	-.0214	
Music Single Vinyl	Gompertz	0.9796	0.0432	1.4995	-0.7838	-0.1278	
Drive-In Theaters	LogLogistic	0.9531	0.0367	0.3373	-0.7575	0.4545	
Music Cassettes	Gompertz	0.9931	0.0331	1.1727	-2.1092	-0.2118	
Pre-recorded VHS	Gompertz	0.9984	0.0190	1.0470	-3.5874	-0.6070	

Note: $_1$ *Multiple models provided adequate fit.*
Fit statistics and parameter estimates provided for all models under consideration in Appendix 3.

The Gompertz curve provided the optimal fit for VHS, cassette, LP and vinyl singles sales. Again, while differences in RMSE and R-square values are negligible, the Gompertz model provides the better fit visually. Data were further available for the

number of telegrams sent and the number of drive-in movie theaters available. Both of these variables exhibited interesting behavior (artifacts) throughout their decline such that it was not possible to model these artifacts reasonably well using any of the available S-curves. We obtained convergence and reasonably well fitting models using a loglogistic curve for drive-in movie screens. For telegram usage any of the models provided a reasonable fit.

We also conducted a time series analysis of the residuals for all media and viable models. Results tended to agree as seen with the observed fit statistics. For example, with the afternoon newspaper availability and afternoon newspaper circulation, low level ARMA (2,2) models were fitted to the residuals of all models. Inspection of these fitted ARMA model residuals through sample auto- and partial-correlation plots, in addition to Portmanteau tests for white noise (e.g., Ljung-Box and Li-McLeod tests with p-values > 0.6), indicated that the ARMA models fitted the residuals from the original curve estimation (cf. Brockwell and Davis, 2002). For the LP and cassette sales we obtained similar results after accounting for a structural break in the residuals due to residuals dying off towards the end of the diffusion process. Thus, these analyses provide further evidence supporting the validity of the estimated growth curves.

In sum, we found support for the hypothesis that the decline of media follows a reverse S-curve that can be seen as a mirror of the diffusion of innovation. However, we found no single reverse S-curve model that adequately fit all of the available data, suggesting that there may be no predictive model for media declines. Some will decline

slowly to a tipping point, then pick up speed. Other media may decline quickly from a peak.

Media Declines: Fitful or Freefall?

This research sought to explore the phenomenon of media declines. Against a backdrop of limited literature on consumption declines, this research sought to expand the ideas in diffusion of innovation research to the discontinuance of former innovations. The hypothesis, drawn from diffusion literature, drew the downward path of a declining medium using the same sigmoid curve of a diffusing innovation. An analysis of several media in decline showed that a reverse S-curve could was an appropriate model for understanding media in decline. The slow-fast-slow pattern of an innovation undergoing diffusion was mirrored by the slow-fast-slow pattern of decline of media tracked in this research.

The slow fall-off in incumbent media in the first years of decline may help explain the counter-intuitive findings of several researchers. Newell (2008) looked at consumer usage of an array of consumer media, finding growth, albeit slow, in the use of the traditional media at a time when new media was growing quickly. Those findings were mirrored by Greer (2014), who found a similar lack of decline in television-set viewing among iPad users. The reason for both findings may be timing. Fully-diffused media may have a significant amount of user inertia, which would be exert a powerful force at the top of a medium's trajectory. The time when the medium is, by definition, at its apogee may be masking the declines to come.

No Single Extinction Curves

While the general path of decline was described by a reverse S-curve, there was no single curve model that was well-fitted to all of the cases. Four models were needed to approximate the declines of eight media. Tolstoy oft-repeated line of "every unhappy

family is unhappy in its own way" is appropriate for media undergoing decline. The search for a single diffusion curve has received attention in the literature (for a review see Naseri & Elliott, 2013), with limited success in describing a single growth curve. The findings in this current research portray a mirror image: the way down is as variable as the way up.

Do media decline in fits and starts, as media owners respond to declining usage by altering the product, price, availability or promotion? Or is there a predictable shape to the downward part of the curve, as the market version of gravity pulls a former innovation towards extinction? This research found, in general, that while declines can sometimes be temporarily reversed, the downward pressure cannot be denied. Additionally, the media tracked in this research tended to fall quickly once the decline started. Slow initial declines were followed by fast falls.

Theoretical Implications

Diffusion of innovation research has a well-known bias towards the new. The research was developed during a time of economic and technological growth, and reflects an interest in new practices, with little illumination of the effects of innovations on incumbent behavior. Thus, it is understandable that the diffusion of innovation research would try to describe declining practices as mirroring the rising acceptance of innovations. However, this research has shown some of the limitations of that approach. While in the most general sense declines do mirror growth, as both can be described with S-curves. However, the comparison weakens as specific cases are examined. The slow initial rise of early acceptance, followed by a majority rise, does not seem to occur in the same magnitude. Instead, both the line turns quickly downwards. From a theoretical

standpoint, more development is needed to create the framework for understanding the rationale that underlies the decision to discontinue the use of a fully-diffused innovation.

Implication for Practice

Incumbent media should have the advantage of mass over their not-yet diffused competition: the distribution systems of incumbent media are complete, users are familiar with the product and the brand, and the costs of production can be spread over the large user base. However, this research has shown that mass is no advantage once declines set in. The ability to successfully fight back from extinction is limited, if the tracks seen in this research are repeated in the future. The implication for traditional media management is that declines are both rapid and irreversible.

The situation is particularly acute in the case of newspapers. The decline of afternoon newspapers beginning in the middle of the last century might be preview of declines in this century. For afternoon newspapers, the number of newspapers first declined while circulation stayed high. Subscriptions presumably slowed the year-to-year decline, as users had to make positive a positive effort to cancel a newspaper subscription. But once the declines set in, the falloff mirrored those of other outgoing media. The implication of this research is that managers of incumbent media must consider that extinction is an empirical possibility, and once decline sets in, may happen at a rate in excess of what might allow an orderly transition to a new business model.

However, extinction is not immediate. On average, media retained three-quarters of its peak availabilities or usage even after five years of decline, and the duration of the decline in some cases was measured in decades. Media managers need to handle the optimization of expenses and revenue in contraction, as well as expansion, modes. The

lessons presented in the declines of major media types in the 20th and early 21st century offer guidance for projecting the long term value of subsiding media assets.

The impact of social media on the pace of media change remains to be seen. In the early 2000s the dominant website in terms of traffic was MySpace, not Google. The networking effects that create fast growth in terms of availability and usage of social media products may also have rapid effects on incumbent media, leading to a new orientations for media makers and media users (Couldry, 2009). In sum, this research presents for managers not only a warning of eventual demise of a medium, but also the opportunity to understand and optimize business activities. Extinction is hardly inevitable, and typically occurs over a long period in which efficient operations can be productive.

Limitations

This research is exploratory, and exhibits several limitations that should be kept in mind, especially when trying to generalize the cases here to all media. First and perhaps most importantly, cases were chosen on a post hoc basis. Like much research in the diffusion of innovation, the data come from phenomena in which the outcome is already known (Katz, 1999). Other media have been challenged with declines during the same time period that saw the extinction of media in this research, but have not yet suffered the same fate. For example, theatrical motion pictures declined radically with the diffusion of television, yet have fought back in terms of usage (numbers of tickets sold) and availability (numbers of movie screens), thus were not included. The post hoc analysis means that we may be blind to the activities of media that found ways for self-resurrection.

More specifically to this research, gathering data about declining media presents challenges. The same innovation bias that appears in academic literature also occurs in industry. Declining industries sometimes do not have a consistent data source, as trade magazines turn their coverage to areas of growth. Additionally, industries in decline may have also undergone consolidations, resulting in sales or usage data moving from the public sphere to corporate archives. Our data is not complete, as industry and government may lose interest in tracking products to their final days.

Future Research

There is a rich literature in diffusion of innovation that explicates the steps in the diffusion process. The literature provides concepts to describe the characteristics of adopters, and the steps of the diffusion process are so well-know to be repeated in popular culture. Further research is needed to understand the rationales of discontinuance: to what extent are adoption and discontinuance characteristics linked? We also propose that research be conducted to generate generalized steps in the discontinuance process. The discontinuance tracks in this research appear to show a different mechanism than innovation research, especially as it pertains to identifying points at which the rate of decline increases.

The Future of Discontinuance

This research has explored the use of concepts in the diffusion of innovation literature to help understand "the back side of the curve." Incumbent media that are beloved by some and used by nearly all are facing vast changes. This research offers a mechanism with which to understand, and perhaps predict, those changes\

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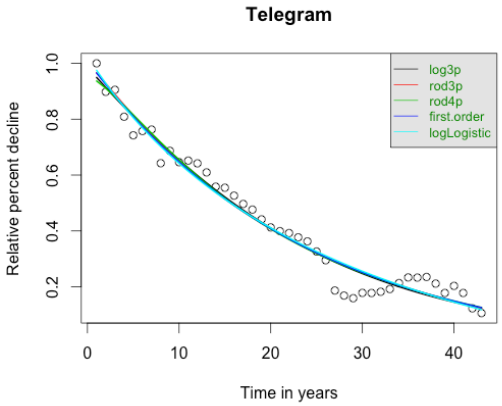
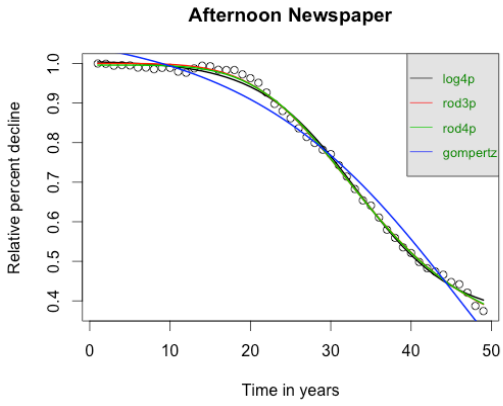
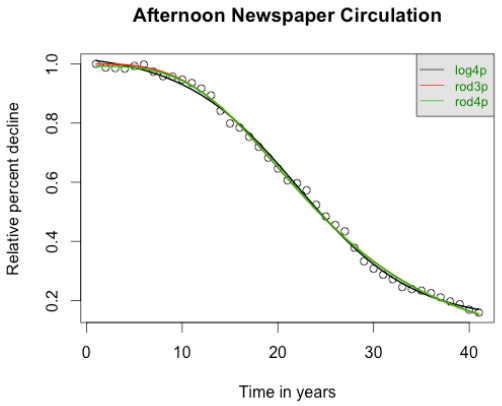
Appendix 1: *Declining Media Availability and Use*

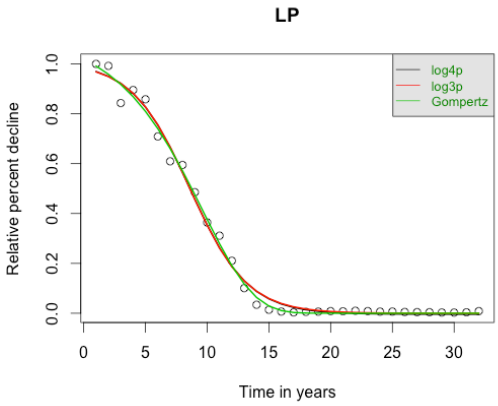
Year (begins with year of peak availability or usage)	**Telegrams** (units in millions) Sources: US Census (1975) Historical Census Through 1970, series R56, and Western Union annual reports (1970-1988)	**Afternoon Papers** (publications). Source: Editor & Publisher 1940-2008	**Afternoon Papers** (circulation in millions). Source: Editor & Publisher 1940-2008	**Music LP Vinyl** (units in millions). Source: RIAA 1973-2008	**Music Single Vinyl** (units in millions). Source: RIAA 1973-2008	**Drive-In Movies** (screens). Source: NATO 1987-2008	**Music Cassettes** (units in millions). Source: RIAA 1973-2008	**VHS** (units in millions). Source: Video Software Dealers Association
1945	236							
1946	212							
1947	214							
1948	191							
1949	175							
1950	179							
1951	180							
1952	152	1459						
1953	162	1458						
1954	153	1448						
1955	154	1454						
1956	152	1454						
1957	144	1453						
1958	132	1456						
1959	131	1455						
1960	124	1459						
1961	117	1458						
1962	112	1451						
1963	104	1453						
1964	97	1452						
1965	94	1444						
1966	93	1444						
1967	89	1438						
1968	86	1443	37					
1969	77	1443	36					
1970	70	1429	36					
1971	44	1425	36					
1972	40	1441	36					
1973	38	1451	37					
1974	42	1449	36					
1975	42	1436	35					
1976	43	1435	35					
1977	45	1435	35	344				
1978	50	1419	34	341				
1979	55	1405	34	290	212			
1980	55	1388	33	308	157			
1981	56	1352	31	295	155			
1982	50	1310	29	244	137			
1983	42	1284	29	210	125			
1984	48	1257	28	205	132			
1985	42	1220	26	167	121			
1986	29	1188	25	125	94			
1987	25	1166	24	107	82	2084		
1988		1141	22	72	66	1497	450	
1989		1125	22	35	37	1014	446	
1990		1084	21	12	28	910	442	
1991		1042	19	5	22	899	360	
1992		996	18	2	20	870	366	
1993		954	17	1	15	837	340	
1994		935	16	2	12	859	345	
1995		891	14	2	10	848	273	
1996		846	12	3	10	826	225	
1997		816	11	3	8	815	173	
1998		781	11	3	5	750	159	
1999		760	10	3	5	683	124	253
2000		727	9	2	5	683	76	242
2001		704	9	2	6	683	45	235
2002		692	9	2	4	666	31	231
2003		680	8	2	4	634	17	227
2004		653	8	1	4	640	5	218
2005		645	7	1	2	648	3	215
2006		614	7	1	2	650	1	205
2007		565	6	1	1	635		188
2008		546	6	3		636		

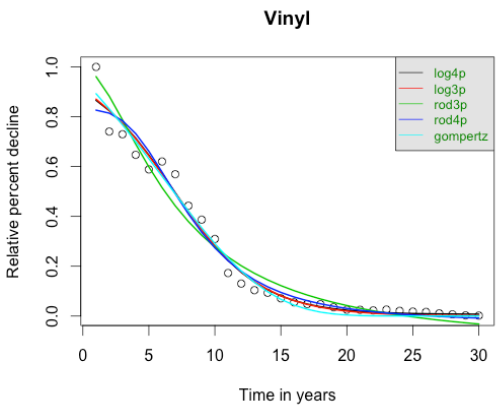
Appendix 2: *Media Decline Models*

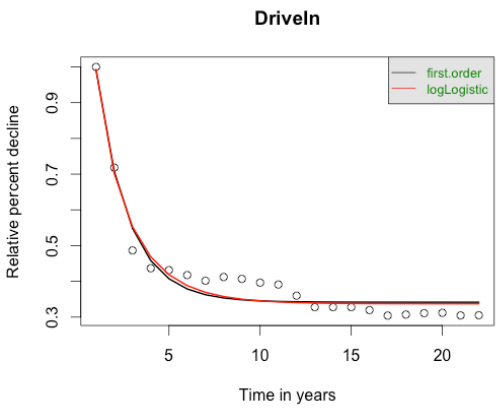


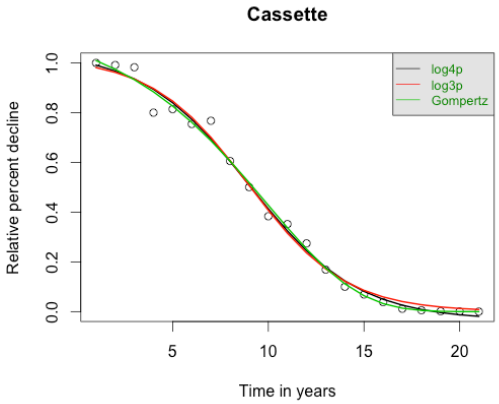


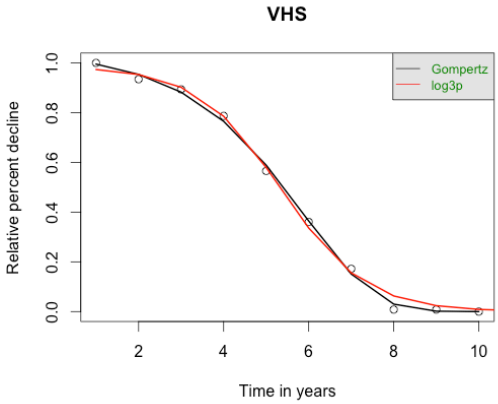









Cassette
log4p
log3p
Gompertz
Relative percent decline
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
Time in years


VHS
Gompertz
log3p
Relative percent decline
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
10
Time in years

Appendix 3: *Extension of Table 3: Complete Fit Statistics for All Models*

Medium	Fitted Models	R-square	RMSE	b1	b2	b3	b4
Telegrams[1]	3-p Rodbard	0.9659	0.0474		1.1393	24.8498	-0.3505
	4-p Rodbard	0.9664	0.0477	0.9537	1.3706	21.3176	-0.1904
	3-p Logistic	0.9682	0.0457	2.8988	1.9398	0.0570	
	First-Order-D	0.9672	0.0465	1.0586	0.0419	-0.0495	
	LogLogistic	0.9655	0.0477	0.2334	-0.7158	0.0205	
Afternoon Newspapers[2] (Publications)	3-p Rodbard	0.9979	0.0102		4.5580	35.1358	0.2590
	4-p Rodbard	0.9980	0.0101	0.9960	4.7095	35.0037	0.2687
	Gompertz	0.9788	0.0324	1.0958	-2.9720	-0.0646	
	4-p Logistic	0.9968	0.0128	0.3584	1.0070	0.1658	33.1410
Afternoon Newspapers[3] (Circulation)	3-p Rodbard	0.9980	0.0143		3.2270	24.2442	-0.0028
	4-p Rodbard	0.9981	0.0141	0.9925	3.3319	24.1489	0.0107
	4-p Logistic	0.9980	0.0147	0.1324	1.0371	0.1669	22.0626
Music LP Vinyl[4]	Gompertz	0.9955	0.0247	1.1234	-2.3231	-0.2414	
	3-p Logistic	0.9927	0.0313	1.0050	0.0247	0.4315	
	4-p Logistic	0.9928	0.0317	-0.0041	1.0079	0.4259	8.5813
Music Single Vinyl[5]	Gompertz	0.9796	0.0432	1.4995	-0.7838	-0.1278	
	3-p Logistic	0.9786	0.0441	1.0318	0.1377	0.2960	
	4-p Logistic	0.9788	0.0448	0.0067	1.0061	0.3097	6.8545
	3-p Rodbard	0.9701	0.0584		1.7042	7.0293	-0.1190
	4-p Rodbard	0.9796	0.0532	0.8283	2.9270	8.1071	-0.0263
Drive-In Theaters	LogLogistic	0.9531	0.0367	0.3373	-0.7575	0.4545	
	First-Order-D	0.9481	0.0386	1.1510	0.5730	0.3417	
Music Cassettes[6]	Gompertz	0.9931	0.0331	1.1727	-2.1092	-0.2118	
	3-p Logistic	0.9911	0.0378	1.0229	0.0287	0.3965	
	4-p Logistic	0.9922	0.0364	-0.0342	1.0511	0.3547	
Pre-recorded VHS	Gompertz	0.9984	0.0190	1.0470	-3.5874	-0.6070	
	3-p Logistic	0.9964	0.0280	0.9853	0.0044	1.0144	

F-Test for nested models:
[1] 3-p Rodbard vs. 4-p Rodbard, F-value = 0.5511, df = (1,39), p-value = 0.4623
[2] 3-p Rodbard vs. 4-p Rodbard, F-value = 2.2494, df = (1,45), p-value = 0.1407
[3] 3-p Rodbard vs. 4-p Rodbard, F-value = 1.9683, df = (1,37), p-value = 0.1690
[4] 3-p p Logistic vs. 4-p Logistic, F-value = 0.2492, df = (1,28), p-value = 0.6215
[5] 3-p Rodbard vs. 4-p Rodbard, F-value = 6.5506, df = (1,26), p-value = 0.0167
[5] 3-p Logistic vs. 4-p Logistic, F-value = 0.2069, df = (1,26), p-value = 0.6530
[6] 3-p p Logistic vs. 4-p Logistic, F-value = 2.467, df = (1,17), p-value = 0.1347

Note: *Multiple models provided adequate fit.*