MODELING THE IMPACT OF MARKETING MIX ON THE DIFFUSION OF INNOVATION IN THE GENERALIZED BASS MODEL OF FIRM DEMAND

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ABSTRACT

In the field of business simulation and gaming there has been much attention given to the modeling of demand, but very limited research on the role of the marketing mix for new and innovative products. This study examines how the marketing mix impacts the diffusion of demand for new and innovative products using the framework developed by Frank Bass (1969). The Bass Model was chosen because it is widely accepted within academia as a structured and disciplined approach for forecasting the intertemporal diffusion of demand. Our concern with the Bass Model is the assumption that market potential is fixed and independent of the marketing mix. Based on a careful review of the literature, revisions to the model were derived and tested by running twenty-eight computer simulations with changes in the pre-specified levels of both price and advertising, given varying assumptions with respect to the elasticity coefficients in the marketing mix function. Our research suggests that management of the marketing mix effects all the key elements of the Bass Model including the coefficients of innovation and imitation, the total market size and thereby the rate of diffusion. These findings are significant with respect to the forecasting of demand and the effective design and internal validity of business simulations used for management education.

INTRODUCTION

The diffusion of innovations into a market and the role of the marketing mix has been a topic of scholarly research in multiple disciplines, including but not limited to marketing, economics, operations management, statistics, and technology management. The topic is important to both academics and practitioners because the expected pattern of diffusion impacts a firm's decisions about its supply chain, manufacturing, inventory, and marketing investments.

In the field of business simulation and gaming there has been much attention given to the modeling of demand, but very limited research on the role of the marketing mix for new and innovative products despite the fact that fifty percent of business profits are from products that are less than five years old (Teach and Schwartz, 2003). Goosen (2010) notes that most business simulations have demand algorithms which are based on *classical* economic theory, which does not address the issue of the intertemporal diffusion of new and innovative products. With respect to the important role of advertising in the marketing mix, in the 37 years of ABSEL history (an academic association focusing on business simulations) only a few papers can be found that deal directly with the algorithmic modeling of advertising as a demand variable (Goosen, 2010). The recent studies by Goosen (2010, 2011) and several past studies explore the impacts of the marketing mix and advertising on firm demand, including papers by Gold and Pray (1983, 1998), Goosen (1986), Carvalho (1991), Teach (1990), Thavikulwat (1988) and Cannon (1994, 1996), but do not deal with the complexities of diffusion of new and innovative products.

The word "diffusion" originally was applied to the acceptance of a technology-based innovation within a social group over time (Brown, 1991, Stoneman, 2002). This "technology insertion" perspective on diffusion manifested itself in the influential theories of Everett Rogers described in the Rogers 5 Factors framework (Rogers 1995) and more recently in the concept of chasm crossing developed by Geoffrey Moore (Moore, 1991, revised 1999).

Because of the wide acceptance of the idea of the diffusion of technological innovations as a social phenomenon the concept has been adopted by strategists and marketers in a variety of non-technical product categories. For example the social nature of diffusion is now being applied to the entertainment industry (movies, TV shows, music, concerts, plays), video games, restaurants (through on-line reviews, blogs, and tweets), fashion (think of Crocs), and wines (South America and Spain versus "old country" wines). To be most relevant, the product's diffusion must be influenced by the communication within a social system of an event or events which are the proximate cause for an increased product demand. The event or events themselves need not be innovative; and the word "product" is used in

its most expansive meaning. "Product" refers to a physical good, service, idea, or even a person (Madonna, Lady Gaga, and "the Donald" all are marketed as products). The product need not be technology based or innovative.

PURPOSE AND PROCEDURE

The purpose of this study is to examine and critique how diffusion impacts demand for new and innovative products using the framework developed by Frank Bass (1969). The Bass Model was chosen because it is widely accepted within academia as a structured and disciplined approach to forecasting new product demand and the diffusion of innovation. In addition the Bass Model has gained wide acceptance by practitioners as a forecasting methodology (Gueso and Guidolin, 2009).

The paper is composed of five major sections and will proceed as follows:

- Describe the Bass Model and one of its extensions referred to as the Generalized Bass Model. We will discuss the strengths and weaknesses of the model, and make recommendations for change. The recommendations will focus on the way the marketing mix elements affect the total market size in the Bass model. It is our hypothesis that the market size is dependent on the marketing mix, necessitating an important change in the structure of the Bass model.

- Review the literature on the impacts of the marketing mix on market size, focusing on two key elements, price and promotion. The review is segmented into two parts. The first part examines the literature from a *practitioner's* perspective; and the second part from an *academic* perspective. We find high consistency between these two perspectives and much support for our hypothesis.

- Develop a revised Bass Model, making the market size a function of the marketing mix. The revised model is illustrated with a numerical example, assuming parameters estimated for the adoption of optical scanning equipment. The example serves as a standard of comparison to test the behavioral impacts of changes in the marketing mix on diffusion of new and innovative products.

- Test the revised Bass Model by developing a set of examples and simulating the market demand. In this study twenty-eight computer simulations are tested with changes in the levels of both price and advertising, given varying assumptions with respect to the elasticity coefficients in the marketing mix function. Figures illustrating the results of each of the major simulations are shown and explained.

- Conclude by highlighting our findings and the significance of the behavioral changes in the revised Bass Model and implications with respect to effective business strategies and the design of business simulations.

BASS MODEL BACKGROUND

In 1969 an analytical model for forecasting the first purchase of a new product category was published by Frank Bass in the journal *Management Science* (Bass, 1969). Bass' model is now described as a diffusion model because its hypothesis posits that the growth in demand for a new product category is a function of how information about that product is diffused in a social system. Bass' work is now referred to as "The Bass Model." (Elie Ofek, 2005). In 2004 Bass' original article was selected as one of the ten most frequently cited papers in the 50 year history of *Management Science* (*Management Science* 15[5] 2004). It was the only marketing related article on the list.

The significant contribution of Bass is his assumption that the probability of additional first-time adoptions of a new product in a future time is the function of the number of consumers who have already adopted the product. Thus Bass considers new product diffusion to be viral, essentially stating that diffusion occurs in a way similar to the spread of a viral disease in society.

The model has been widely accepted. Over 200 academic articles have been published about the application of the model. The model was initially applied by Bass to forecast the demand curve for durable goods, a product such as machine tools, cars, or home appliances that have a long life-cycle and that are purchased infrequently by consumers and businesses. Over the past 20 years businesses have employed the model to forecast adoption of a wide variety of products, including satellite TV, satellite radio, refrigerators, calculators, CD players, home PC's, and cell telephones. The Bass Model has also been extended to forecasting demand for individual brands and niche products (Krishman and Bass, 1994). Norton and Bass (1992) applied the model to a wide range of non-durable product classes including pharmaceuticals and recording media. Jain et.al. examined how supply constraints can be integrated into the model. Companies such as Kodak, RCA, IBM, Sears, and AT&T have used the Model internal to their businesses (Mahajan et.al., 1990).

Application of the Bass Model creates a curve that specifies the period and cumulative first-time adoptions of a new product category. The model itself is relatively simple. Bass identifies two types of new product adopters:

- Innovators: Adopt new products independent of the actions of others within a social system. They adopt through "internal influence" (Vijay Mahajan et.al., 1995). In the model their adoption rate is represented by the letter p. The value of p is referred to as "the coefficient of innovation."

- Imitators: Their adoption of new products is influenced by the adoption rate of others in a social system. They respond to input from others, specifically the communications of those who have already adopted the product. In the model their adoption rate is represented by the letter q. The value of q is referred to as

"the coefficient of imitation."

Bass states that the likelihood of additional first-time adoptions of a new product by imitators in a future time is a linear function of the number of previous adopters, with the actual number of adopters limited by the total market size, represented by m in the model. In other words previous adopters influence the adoption rate of new adopters in the current time period (for example, this month) and in future time period (for example, for the rest of this year).

THE MODEL ITSELF

As mentioned above the output of the Bass Model is a curve that represents period and cumulative adoptions of new products by both innovators and imitators. In the model:

m = the total market (expressed as unit sales) for a product category

p = the probability of adoption by innovators (referred to as the "coefficient of innovation")

q = the probably of adoption by imitators (referred to as the "coefficient of imitation"). Because q is influenced by the number of previous adopters within a social system q is multiplied by the number of consumers who have already adopted the product at the start of time period t. This calculation captures the idea at the heart of the Bass Model: The probability of adoption by a new imitator is a function of the number of consumers who have already adopted.

The above leads to the following equation:

The probability of adoption by a new imitator in time period t = $p + (q/m)N_{(t-1)}$

Where:

$N_{(t-1)}$ = the cumulative adoptions from the prior time period

An important and constraining assumption in the Bass Model is that the total market size (m) is a constant. The market size is not impacted by externalities or by the actions of participants in the industry, such as significant changes pricing, advertising, or other elements of the marketing mix.

EXTENSIONS TO THE BASS MODEL

The most important extension of the Bass Model is referred to as the Generalized Bass Model (Bass et.al 1994). The Generalized Bass Model examines the impact of marketing mix variables such as pricing and increased advertising and promotion on demand levels. Within the Generalized Bass Model changing these marketing mix elements shifts the demand curve in time, e.g. the shape of the demand curve is changed, but total demand is unchanged. Importantly changing pricing and advertising

have no impact on market size: m remains as a constant.

Strengths and weaknesses of the Bass Model

The most important strength of the model is that it seems to work. It has accurately forecast the rate of diffusion for a large number of product categories over multiple decades.

One of the best examples of the forecasting accuracy of the Bass Model is a presentation given in 2001 by Frank Bass and others (Bass et. al. 2001). In 1992 Bass was hired as consultant by DirecTV and asked to use his model to forecast the diffusion of the satellite TV product category. DirecTV had previously completed a stated intentions market research study where consumers were asked about the probability of purchasing satellite TV. A prior study by Jamieson and Bass (1999) allowed Bass and his colleagues to estimate m from the results of the stated intentions study. Bass "guessed by analogy" (to use his own words from his slides) on the value of p and q, extrapolating from the actual diffusion rate of similar previously introduced products. The forecast of satellite TV adoptions developed by Bass was stunningly accurate. Bass estimated a first year penetration of satellite TV of 1.37% of US households; actual adoptions were 1.21%. Bass' 1992 forecast of cumulative demand from 1994 through 1999 was also accurate. Bass forecast 9.4 million cumulative adoptions by 1999; actual adoptions were 10 million.

Another example of the Bass Model's relative accuracy is the forecast of the adoptions of satellite radio in cars. In 2005 Elie Ofek published an article that reviews multiple approaches to forecasting satellite radio adoptions. The forecasts were done between 1997 and 1999, when the product category first emerged. Subject area experts from Warburg Dillon Read, Donaldson Lufken Jenrette, and CE Underberg developed forecast using their own proprietary methodologies. Ofek's forecast using the Bass Model, deriving values for p, q, and m by triangulating from the actual diffusion curve of what Ofek concluded were products similar to satellite radio. In 2005 actual cumulative sales of satellite radio were approximately 3 million units. Ofek's Bass Model forecast was for about 7 million; Unterberg forecast 22 million, Donaldson Lufken 35 million, and Warburg Dillon 42 million. Ofek's forecast was off by over 100%, but it was much closer to actual demand than the other three forecast methodologies.

Obviously the accuracy of the Bass Model is only as good as the assumptions for the model's three critical variables: the coefficients of innovation and imitation (p and q), and an estimate of the total market size (m). Bass et. al. (2001) recommend arriving at values for p and q by "guessing by analogy" accomplished by a review of actual p and q values from previously introduced products. Estimating m is more problematic. One potential source for m is "intent to purchase" studies, which have been shown to be accurate for non-durable consumer products, but less

accurate for consumer and business durables. Tigert and Farivan (1981) compared Bass Model forecasts to actual demand for quarterly and annual sales of optical scanning equipment for supermarkets in the United States. They concluded that the model failed to predict sales levels correctly. They acknowledged that the model "forces a disciplined approach to estimating market potential", but they cautioned that "in-depth analysis of product/market structure is a mandatory requirement in order to justify the choices made regarding…initial estimates of market potential." They observed that key data related to this in-depth market analysis must include a macro-economic analysis, actual price trends, and marketing efforts including sales force and advertising spending.

The Tigert and Farivan study mentioned above identifies the major weakness of the model: the assumption that the market size is a constant. The Model assumes that neither exogenous nor endogenous factors will impact the total market opportunity for a product. Thus the total market demand for the product category is determined at the time of its introduction and does not change over the life of the product. Mahajan et.al. (1990) indicate that "there is no rationale for a static potential adopter population. Instead, a potential adopter population continuously in flux is to be expected."

Mahajan et. al. discuss the implications of the assumption of a fixed market size. The number of buyers in a product category is not increased by any of the following actions:

- Effective management of the marketing mix by market participants, such as introducing new products, lowering prices, increasing advertising, or expanding distribution.

- An expansion in the size of the social system within which buying decisions are made (as is the case with modern social media such as blogs, tweets, and Facebook postings).

- The rate of innovation for a product category such as has recently been experienced in the smart phone industry

Related to the above, the intensity of competition in an industry, as is currently being experienced with the actions of Apple with its iPhone and Google with the Android operating system where the firms themselves and their partners have aggressively managed all aspects of the marketing mix.

Accepting that market size is a constant has important implications for marketing strategy. The Bass Model assumes a market that is a zero sum game. The only way a firm can increase demand is by taking market share from a competitor. If correct a completely static market would result in hyper-competitive "red ocean" (Kim and Mauborgne, 2005) markets, lowering prices and margins of market participants. Firms would have less incentive to

invest in innovations or increased capacity, creating market stagnation in the product category.

Making "*m*" a Variable

The Generalized Bass Model is the starting point for our analysis of the impact of the marketing mix on period and cumulative demand within the model. As mentioned above our concern with the Generalized Bass Model is the assumption that total market size, expressed as *m* in the model, is fixed and can not be impacted by the marketing mix. We propose changing the market potential, *m*, in the model from exogenous to endogenous, and making *m* a function of the effective execution of the marketing mix.

In this paper we limit our examination of the impact of the marketing mix on total market size to pricing and promotion (advertising, sales promotion, public relations, etc.). Pricing and promotion are analyzed independently. We limit our scope to pricing and promotion for two primary reasons:

- To reduce the complexity of our analysis by isolating their separate effects on market size; and

- In recognition that pricing and promotion are the market mix elements most frequently manipulated by marketers in an effort to increase demand for their assigned products. The other two P's in the marketing mix, place (channels) and product, are important longer term demand creation strategies. Both have relatively long lead-times – it often takes years to develop new products or open new channels. Price and promotion are employed by marketers as both strategic and tactical marketing actions. We believe that product and brand managers will be particularly interested in the impact of price and promotion on total market size, and hence on product category demand.

LITERATURE REVIEW OF MARKET SIZE – PRACTIONER'S PERSPECIVE

One of the authors of this article was a marketing and strategy practitioner for a Fortune 100 firm for 30 years, 15 of them at the marketing and strategy vice presidential level. He observed first hand the growth of the global copying and printing markets during the decades of the 70's, 80's, and 90's. From personal experience he observed that the actions of major market participants, specifically multiple frequent new product introductions, aggressive pricing action, product and brand focused advertising, and expansion of distribution channels separately and in aggregate results in significant product category growth.

Anecdotal evidence from different industries suggests that maintaining the market size as a constant in the Generalized Bass Model does not match actual experience. There are multiple examples of changes in the marketing mix increasing the size of the total available market. For example:

- When AOL introduced its unlimited Internet usage for $19.95 pricing plan the number of adopters of the service increased dramatically.
- When the price of first desktop PC's and then laptop PC's broke through the $1000 price point demand increased substantially.
- Advertising for on-line brokerage services such as e*Trade, ScotTrade, and TD AmeriTrade increased the number of brokerage accounts.
- The combination of advertising and Internet-based social network spread the word about the independent movie *My Big Fat Greek Wedding* and turned it into one of the highest grossing movies of that year.
- The government limited cigarette advertising because of multiple research studies (cite) indicating that cigarette advertising increased the number of new users and reinforced the behavior of existing smokers, a clear indication of the impact of promotion on total market size.
- Advertising by pharmaceutical companies appears to create a market for new drugs that address medical problems that many consumers probably did not know they have, such as Peripheral Artery Disease (PAD), and toe nail fungus. Advertising was instrumental in creating and growing the market for ED drugs such as Viagra and Cialis.

Recently Apple's pricing and advertising for the iPad created the market for tablet computers – a market that did not exist as a mass market before Apple's success.

Geoffrey Moore's book, *Crossing the Chasm, Marketing and Selling High Tech Products to Mainstream Customers* (1991, revised 1999) has had an important impact on the thinking of practitioners about how marketing strategies impact the total market opportunity for a product category. Troy Byers of Stanford Technology Ventures Program commented in 2006 that the book is "still the Bible for entrepreneurial marketing 15 years later" (Byers, 2006). As the title suggests Moore's book emphasizes marketing high technology products. But its concepts – particularly the idea of the "chasm" itself and the need for marketers to create the "tornado" to cross the chasm have been adopted widely in a wide variety of industries. For example, previewing summer blockbuster movies on the Super Bowl which is broadcast in early February, is an example of creating the "buzz" that starts the "tornado" that starts the film "across the chasm".

Moore borrows from the theories of Everett Rogers (1988) in developing the concept of chasm crossing. Rogers identified five factors that influence the diffusion of innovations: superior product performance compared to alternative methods, compatibility with the customer's value set (e.g. "this is the way things should be" – for example expensive wines should have corks, not screw tops), lack of

complexity, convenient trialability, and easy observability (e.g. non-users can observe others using the product). The willingness of early adopters of iPhone and iPad to demonstrate their product to their friends is a good example of both trialability and observability.

Rogers' concept of trialability and observability are similar to Bass' theory of the diffusion of innovations as a social phenomenon. Trialability and to a even greater degree observability depend upon prior adopters sharing their user experience with non-adopters. Moore adds to Bass' and Rogers' thinking by arguing that there is a chasm between early adopters of a product (whom Moore calls technology enthusiasts and visionaries) and the early majority pragmatists. The early adopters behave like Bass' innovators; the early majority like Bass' imitators. As Bass before him Moore states that these customer segments, the early adopters and early majority, have different buying motives and different buying behaviors.

Moore says that specific marketing strategies are required to cross the chasm between the early adopters and early majority. Much of Moore's recommendations are focused on the need for identifying a specific target market and developing the "whole product" that satisfies the needs of the identified target market. The whole product must be supported by a focused marketing strategy, including advertising, promotion, public relations, and viral marketing to build "buzz" about the product, and also supported by appropriate pricing and distribution strategy.

Moore clearly believes that by following his prescription for crossing the chasm a firm can increase the market opportunity for its products, that is, increase the size of the market. Moore identifies five customer segments: innovators, early adopters, early majority, late majority, and laggards. He suggests that success with one customer segment (early majority for example) depends upon success with the prior segments (first innovators and then early adopters, for example). Because the buying behaviors for each segment are different Moore says that marketers should focus on one customer segment at a time, tailoring marketing messages and media to appeal to that group of customers. Crossing the chasm creates market momentum for the diffusion of the product, expanding the market opportunity one customer segment at a time and continuously increasing market size.

Malcolm Gladwell's popular book *The Tipping Point* (Little Brown, 2000) builds on the work of Rogers, Bass, and Moore by using the analogy of a disease virus to explain the diffusion of products and ideas into a market. Gladwell compares the diffusion to the rapid spread of viral epidemics. He refers to ideas as "infections"; new fashions are "outbreaks"; new products are "viruses. The role of advertising is to infect new consumers and build momentum for the epidemic of mass diffusion. A product, a trend, or an idea reaches the "tipping point" when a critical mass of adopters catches the infection. The "tipping point" is somewhat analogous to crossing Moore's "chasm" – ideas "tip" when the epidemic crosses a threshold and mass in-

fections occur.

Gladwell uses a different vocabulary to explain ideas already discussed in this article. The "Law of the Few" directly relates to Moore's early adopters; "The Stickiness Factor" is a build on Roger's need for relative advantage, "The Power of Context" relates to Bass' idea of diffusion as a social phenomenon and Roger's concept of compatibility.

In the "Law of the Few" Gladwell states that epidemics are initiated by a small number of socially active people who transmit their infection to others. He calls these people "connectors, mavens, and salespeople." Connectors network effectively, mavens are recognized subject area experts, salespeople are articulate and persuasive champions. All three are well connected, speak well and speak often, and start the contagion that spreads the virus.

Gladwell emphasizes the importance of the "stickiness factor", which is borrowed in part from Everett Roger's "relative advantage". Products and ideas will not become viral unless they are compelling to a broad audience beyond the initial enthusiasts. Getting through "the few" requires winning over the connectors, mavens, and salespeople. But if the idea or product doesn't offer significant relative advantage the lack of enthusiasm of "the many" will cause the virus to die – it will not "tip". Gladwell says that stickiness is difficult to define and therefore is more complex than Roger's relative advantage. Its presence depends on "context" (discussed below) and it may happen in an unexpected way that is contrary to conventional wisdom.

Gladwell's most creative contribution to the concept of the diffusion of product and ideas is what he refers to as "The Power of Context." Context strongly influences whether a product or idea will "tip" into general acceptance. "Context" encompasses broad environmental, historical, and social factors that influence whether an idea is embraced by the mass audience and thus reaches the tipping point. In some ways Gladwell's "context" is similar to Roger's "compatibility" – is this idea or product consistent with "the way things should be?" Gladwell uses a broken window analogy to illustrate context, suggesting that when touring a neighborhood if a person sees broken windows that person will conclude that crime is a problem in that neighborhood and that property owners do not have pride of ownership. Products and ideas will not "tip" unless they are consistent with the general public's judgment that the context is right for the acceptance of the product or idea.

The Tipping Point message for marketers is that diffusion of ideas and products follows a predictable pattern. It is essential to attract the endorsement of "the few." As Roger's states, relative advantage is essential to "stickiness." Product endorsed by the few will not "tip" unless they have stickiness. "Context" means that the idea or product is compatible with society's broader attitudes; the idea of context is similar to Roger's compatibility and reinforces Bass' concept of diffusion as a social phenomenon. Gladwell states that marketers must understand and,

to the degree possible, control context. This can be done by creating strong emotional connections between consumers and products, such as is done with effective branding campaigns.

When marketers attract the endorsement of the few, when the product has stickiness, when the broader societal context is willing to accept the product, the market opportunity for the product will grow. Thus, *m* will no longer be a constant; market size will increase.

It is not the purpose of this paper to critique the concepts of chasm crossing or the tipping point. We observe that both books reach the same conclusion: diffusion of products and ideas follows a pattern, and when that pattern is understood and effectively managed diffusion will be successful, the market will develop stage-by-stage, and market size will increase. The books reinforce the intuitive belief of marketers that effective implementation of focused marketing strategies will increase the size of the market for their products. In other words, the belief that market size is not a constant.

LITERATURE REVIEW OF MARKET SIZE - ACADEMIC PERSPECTIVE

As mentioned earlier diffusion of innovations into a social system generally, and the Bass Model specifically, have been a popular topic for academic researchers. Mahajan et. Al. (2009) includes a bibliography of 145 articles on this topic. Multiple academic articles identify potential problems with and attempt to improve on the assumptions of the Bass Model (Mahajan et.al 1990, Nguyen and Shi, 2006). Many of these articles identify Bass' assumption of a static market size as potential problem area.

The hypothesis of this paper is that industry participants do affect market potential through the management of their marketing mix. Our specific focus, as mentioned above, is on the impact of price and promotion on market size.

THE POLAROID VS. KODAK LEGAL CASE

Perhaps the most thorough analysis of the affect of the marketing mix on market size is the examination of Kodak's entry into the instant photography market that was then completely dominated by Polaroid. (Mahajan et.al. 1993). Immediately after Kodak's 1976 entry into the instant photograph market Polaroid sued for patent infringement. In October 1990 a federal judge ruled for Polaroid and ordered Kodak to pay $909.5 million to Polaroid as compensation for patent infringement. Testimony and documents presented at the trial provided detailed information about Polaroid's sales of instant cameras prior to Kodak's entry, and the combined sales of Polaroid and Kodak instant cameras when both competed in the market. From a legal perspective the market data was important to establish sales and profits lost by Polaroid because of Kodak's infringe-

ment. Polaroid completed detailed research to establish what the market size would be if Polaroid maintained its monopoly on instant cameras, how many potential Polaroid sales were diverted to Kodak cameras (providing the basis for calculating actual damage to Polaroid), and how many of Kodak's camera sales were incremental (e.g. sales Polaroid would not have achieved, and thus an increase in the size of the market). This case related research provided a rich trove of data for analysis.

Kodak argued that because of its well established brand, the advantages of its instant camera products, and its well executed positioning and marketing strategy it created significant incremental demand for instant cameras, and therefore damages to Polaroid should be minimal. In fact following Kodak's entry sales of instant cameras increased substantially, from 3 million units in 1975 to more than 8 million units in 1978.

The authors used established models of diffusion of innovation to forecast, based on Polaroid's actual unit sales prior to 1976, how many cameras it would have sold if Kodak had not entered the market. The analysis was complicated by the facts that both Polaroid and Kodak had multiple models of their cameras in the market, with different features and at different price points. The analysis concluded that:

"More than two-thirds of the sales of Kodak instant cameras would not have been made by Polaroid if Kodak had not entered the market. Kodak's entry expanded the US instant camera market by 11.095 million units, which it drew from its own pool of prospective buyers.... This implies that if Kodak had not entered the total US instant camera market demand during 1977 through 1985 would have been 32.635 units. Kodak's entry expanded the market by 12.055/32.635 (million units) = 37%, with most of this expansion taking place in the early years of the period."

Thus the market size for instant camera was not a constant when Polaroid first created the product category. Kodak's entry increased the size the market by 37%. The authors conclude that: "The addition of a new competitor may expand total market volume because market entry is usually accompanied by increases in product variety, promotional activity, and distribution, as well as the reduction in price." Obviously the sentence above refers to the classic "4 P's" of marketing: product, price, promotion, and place (distribution channels). Because of the detailed demand information available the Polaroid/Kodak example presents a compelling argument for the effect of the combination of all four marketing mix elements (the 4P's) increasing the market potential for a product category.

PERSPECTIVES ON THE MARKET SIZE

To understand how the marketing mix affects consumer buying behavior and overall market opportunity requires that we examine buyer behavior. The core assumption of the Bass Model is that endorsement of a new product category by members of a social system results in increased unit sales, e.g. the probability of a purchase by a non-user of the product is a function or prior users. Assuming that Bass' hypothesis is correct, it raises the question of how the social system influences non-users to purchase the product. Answering this requires an examination the psychology of buyer behavior.

Buyers are risk averse (Gourville, 2006). Buyers' purchase behavior is impacted primarily by two factors: increasing awareness of the details of the new product, and the perceived price/value relationship (Kalish, 1985). The more the consumer knows about the performance of the product (for example: features, reliability, warranties for many durable goods; entertainment value, food taste, ambience for many intangible products) the lower the buyer's

Figure 1A
Standard Case of New Adopters per quarter with Market Size fixed
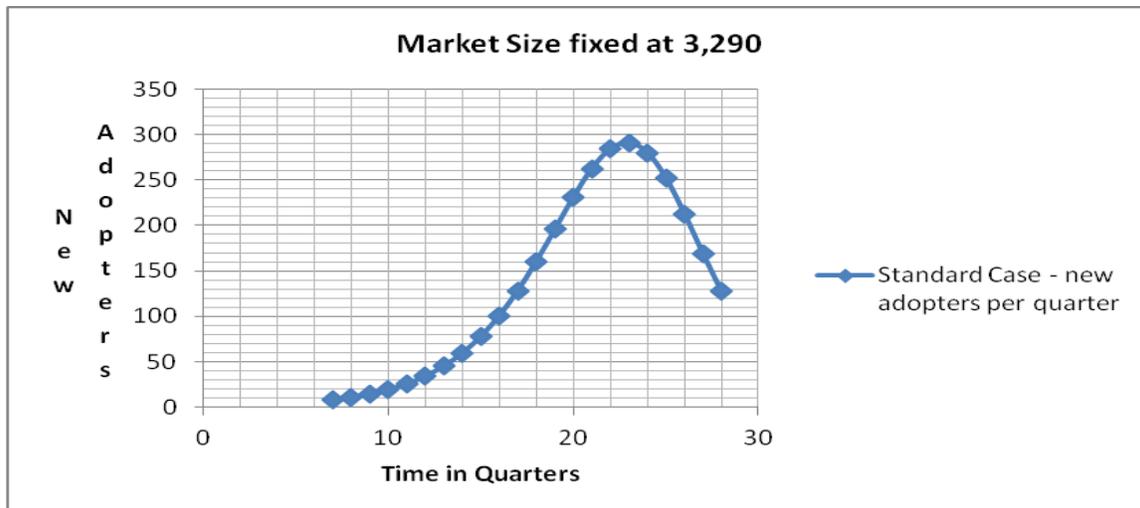
uncertainty about the quality of the product and/or the experience. Information about the product is available from two sources: (1) actual users of the product or service – the social aspect of diffusion; and (2) the company marketing the product, through its promotional activities. Endorsement by actual users of the new product is a credible information source for non-users. But if the firm marketing the product has brand equity that creates consumer trust the firm's marketing message is also credible. Over time non-users receive more information about the product through both the social system and the actions of the firm marketing the product. This decreases perceived risk and increases the likelihood of adoption.

Price operates on the consumer's mind in a similar way. Potential buyers are heterogeneous with respect to their willingness to pay for a new product because of differences in needs, income, and the perceived product value (Kalish, 1985). Because they are risk averse consumers discount the value of the product because of uncertainty over the value of the product to them specifically. In this situation the seller of the product can influence diffusion. By pricing the product aggressively at launch, or by executing either permanent of temporary price promotions (for example through coupons) the seller reduces the buyers perceived risk and makes the buying decision easier.

Endorsement by the social system, advertising and promotion, and pricing work together to reinforce the value of the new product offering, reduce buyer risk, and create new sales and increased diffusion. As Kalish concludes: "The rate of adoption is therefore determined by awareness diffusion, which is controlled by advertising, and the rate of growth of the potential adopter population, which is controlled by price" (Kalish, 1985).

EXAMINING THE IMPACT OF PRICE ON MARKET SIZE

A wide variety of academic studies related to the impact of pricing on diffusion conclude that pricing impacts both the rate of diffusion (both the coefficient of innovation and the coefficient of imitation) and the total market potential for a product category. The impact of pricing may vary for durable versus non-durable goods, for products versus services, and for expensive versus low priced products, but the overall affect of pricing is to increase diffusion and increase market opportunity (Karine et.al., 2004).

We earlier discussed Kalish's finding that the combination of previous users endorsement and price directly addresses consumer purchase uncertainty. Parker (1992) found that pricing affects the diffusion of some low priced durable goods. His empirical study says that price almost always affects imitation, and that for some products it impacts both innovation and imitation. If price is low enough innovators will accept the reduced risk of being an early adopter, information about the product will spread more rapidly in the social system, creating two effects: (1) imitators buy the product sooner (the shape of the curve changes), and (2) more imitators are encouraged to buy the product (the market size increases).

Tsai et.al. (2009) studied the global LCD TV market. The study applied a growth model that examined the impact of price on imitating behavior in diffusion of high technology consumer durables. They conclude that "decreasing LCD TV prices stimulates the growth of internal influences and then facilitates more adoption of LCD TV's. In general the imitating tendency of potential consumers is substantially driven by the price cuts", increasing

Figure 1B
Standard Case of Cumulative Adopters with Market Size fixed
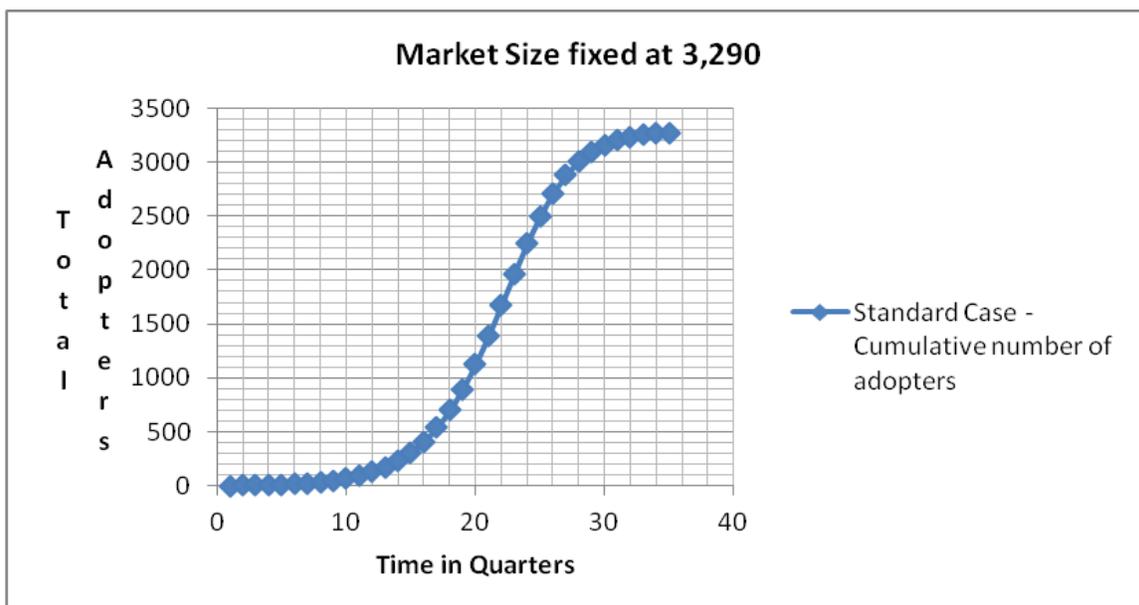
the size of the market. The authors claim that their price related model "explicitly performs superior in fitness than the Bass Model." Masek (1996) observed the similar affect in his study of market potential for the cable television industry. His empirical findings are that price influences the coefficient of innovation, advertising affects the diffusion rate (imitation), and expanding distribution channels increases the size of the market opportunity.

Jain et.al (1990) examined "diffusion models for durables that incorporate price explicitly." They hypothesize that the price of durable goods appears to monotonically decline over time and that this price decline causes market growth. The article applied three separate statistical models to the examination of price affects on both total market size (m in the Bass Model) and the rate of diffusion (primarily q in the Bass Model) of four different consumer durable products. Below is a summary of their findings:

- Room air conditioners from 1949 to 1961. The authors conclude that price affected positively both the market size and the rate of diffusion.
- Clothes dryers from 1949 to 1961. Price declines had a "significant effect" on both the market size and the rate of diffusion of this product category.
- Color televisions from 1963 to 1970. Effects were similar to those observed for clothes dryers, e.g. significant price elasticity impacting market size and the rate of diffusion.

Can openers from 1958 to 1970. Here the results are different; price declines did not impact either market size or the diffusion rate. The authors suggest that the reason is the low price of the product: "Price does not seem to matter much for this product." This finding suggests that there may be a threshold point for the affects of price on both market size and the rate of diffusion. This is a topic for future research.

The authors' general conclusion from their study is that:

"*We see that the estimated market potential, as well as the eventual probability of adoption, have an increasing trend…. Therefore if price has a declining trend…the estimated market potential, as well as the eventual probability of adoption, increases over time…. (P)rice influences a consumer's decision to buy the product; whereas the diffusion process determines the timing of the purchase.*"

The conclusions of Jain and Rao confirm those of Kmakura and Balasubramanian (1988) who also studied the affect of price on the market size and diffusion rate for consumer durables. They conclude that price positively affects both market size and diffusion: "(P)rice has a predictable effect on whether or not adopters are in the market", and "Price does effect the diffusion of consumer durables…. The effect of price is to increase sales from remaining adopters." Kalish (1985) reached a similar conclusion: the market potential for a product category is a function of the price of the product and the reduction in consumer uncertainty about the product because of its increased adoption.

EXAMINING THE IMPACT OF PROMOTION ON MARKET SIZE

The impact of advertising on demand and financial results for multiple product categories has been studied over multiple years by both academics and practitioners.

However, advertising impacts on the diffusion of new products, on market size, and on the market share of indus-

FIGURE 2
Impact of price on market size
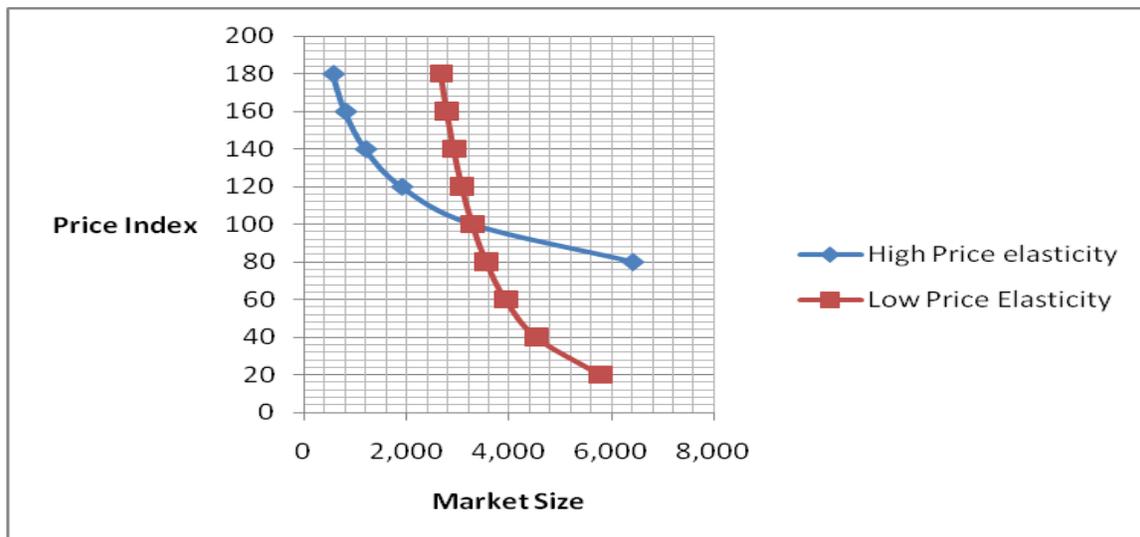
try participants has not been fully studied (Nguyer et. al., 2006). Nguyer et. al. (2006) undertook a study to "formulate and analyze a formal model of competitive advertising strategies under market-size dynamics." Referencing the data that Mahajan et. al. (1990) used in the previously discussed analysis of the Polaroid versus Kodak legal case, the authors attempted to use the Bass Model to determine the affect of Kodak's and Polaroid's combined advertising spending on total market demand for instant cameras. Their models failed to "fit" with actual market demand. They conclude that "we tend to believe that the rather poor performance of the... (model) may be due to the assumption of a static, fixed market size for this particular product."

Fosfur and Giarratana (2009) echo the findings of Nguyer et. al. They point out that "little research has been conducted on the effect of rival moves along non-price dimensions of the market mix." Their empirical study of the affect of advertising in the carbonated soft drink industry concludes that "...new advertising affects the firm's financial market value through increasing total demand (market size dynamics)...." Specifically: "We show that in the CSD market advertising increases a firm's and its rival's financial value by increasing total demand...."

Fosfor's and Giarratana's findings are consistent with prior studies of the affect of advertising. Both practitioners and academics distinguish between generic product category advertising and brand-specific advertising (Bass, 2005). These two categories of advertising have different market impacts. Generic advertising increased market size by attracting new customers to the product category (Berndt et. al., 1997). These findings build on Lancaster's (1984) pioneering study of advertising impacts, where he concluded that market size dynamics is the most common effect of advertising, suggesting that even brand advertising increases demand for all market participants in multiple product categories. Lancaster studied the effect of advertising on demand for mature consumer non-durable products, specifically deodorants, shaving cream, ready-to-eat breakfast cereals, laundry detergents, bar soap, and cigars. In three product categories (deodorants, shaving cream, and cereals) brand advertising increased primary demand, increasing sales both for the brand being advertised and for the category in general. For laundry detergent brand advertising increased total category demand with nearly all of the increase accruing to the brand being advertised. Bar soap and cigar advertising did not increase the total market nor brand market share. This result suggests that for bar soap and cigars the market is not elastic, perhaps because of an already high household penetration for bar soap and the relatively limited market appeal for cigars.

Academic studies have addressed the impact of advertising on the coefficient of both innovation and imitation in the Bass Model as well as its affect on total market size. Horsky and Simon (1983) studied the diffusion of new banking services. They conclude that advertising provides important information to innovators and suggest that the coefficient of innovation in the Bass Model should be a function of advertising with diminishing returns over time. Simon and Sebastian (1987) argue that advertising has more impact on the coefficient of imitation during the intermediate stages of the product life cycle. The effect of advertising is cumulative over the life of the product, and both the market size and the rate of diffusion are positively impacted. This is reinforced by the previously referenced work of Mesak (1999) who completed an empirical study of the US cable industry, concluding that price influenced the coefficient of innovation, advertising affected the coef-

FIGURE 3
Impact of advertising on market size
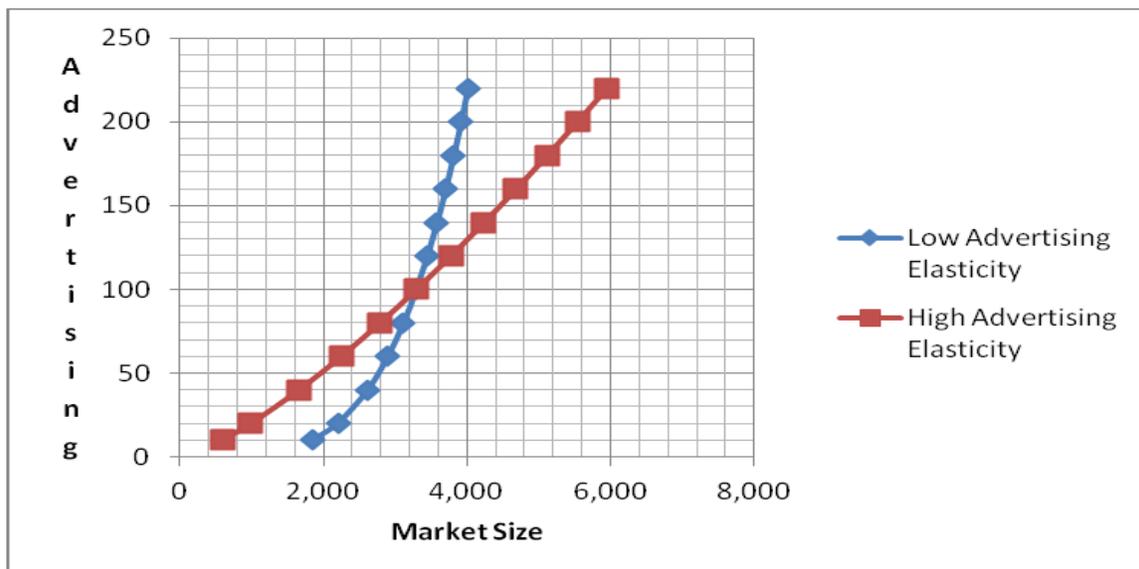
ficient of imitation, and additional distribution increased total market size.

CLOSING REMARK – PRACTITIONER'S AND ACADEMIC PERSEPCTIVES

Our extensive review of the literature in this paper, including academic and practitioner perspectives, provides compelling evidence that both price reductions and increased promotional spending positively affect the total market opportunity for a product. This provides a strong case for revising the Bass Model to make the market size a function of the marketing mix. In what follows, in the next section, we develop such a model.

DEVELOPMENT OF A REVISED BASS MODEL INCLUDING MARKETING MIX

In this section we revise the Bass Model, based on our findings from the review of the literature, to include the impact of changes in the marketing mix on market size and the diffusion of innovation on the demand for new products. We then test the behavior of the revised model on the intertemporal growth in demand by running a set of simulations with changes in the marketing mix with respect to pricing and advertising.

To begin to develop the revised model, we start with the reduced form of the generalized Bass model as:

$$S_t = (pm + (q - p)N_{t-1} - (q/m)N_{t-1}^2)*Z_t \qquad (1)$$

Where:

S_t = number of new adopters in time period t

p = probability of adoption by innovators (or "coefficient of innovation")

m = total market size

q = probably of adoption by imitators (or "coefficient of imitation").

N_{t-1} = cumulative number of previous buyers

Z_t = time dependent term that is a function of marketing mix variables

The total number of adopters or total demand at time t (N_t), is then equal to:

$$N_t = S_t + N_{t-1} \qquad (2)$$

Since the number of new adopters in period t (S_t) is a function of past levels of total demand (equation 1) the expression for the total number of adopters or the level of demand at time t (N_t) can be found by substituting equation 1 into equation 2:

$$N_t = pm Z_t + (1 + (q - p) Z_t)N_{t-1} - (q/m)Z_t N_{t-1}^2 \qquad (3)$$

Although the generalized Bass model includes the marketing mix term Z_t, our concern is the assumption that the market potential, m, is fixed and independent of the mar-

FIGURE 4
CASE A: Impacts of a High Price Strategy with Advertising Fixed
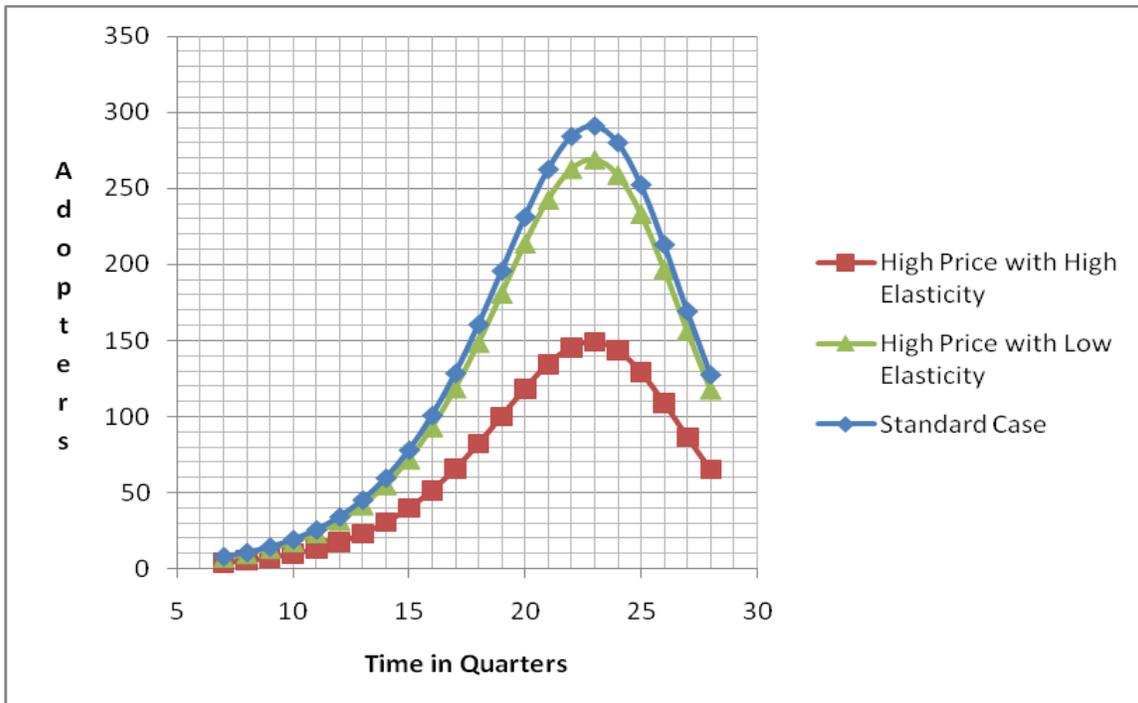
keting mix. Now we propose changing the market potential, m, in the model from exogenous to endogenous and make it a function of the marketing mix (Z_t) rather than including it as an independent term as shown previously in equations 1 and 3.

In our revised model we use only two primary marketing mix variables and assume the following multiplicative expression for the market potential, where "m" is a function of price (P) and advertising (A):

$$m = sP^{-e}A^f \tag{4}$$

Where:
    m = market potential (size)
    s = scaling factor
    P = price
    A = advertising expenditure
    e = coefficient of sensitivity (elasticity) for price
    f = coefficient of sensitivity (elasticity) for advertising

The functional form for market potential (equation 4) was selected because it is a standard Cobb-Douglas function which is widely used in economic studies owing to its robust properties with respect to stability and ease of estimating parameters. The coefficient "e" represents price elasticity of demand; and the coefficient "f" represents advertising elasticity.

The marketing mix, represented by only two variables in equation 4, can be easily extended to include any number of factors. We selected only two marketing mix variables in this paper for illustrative purposes.

Substituting equation 4 into equation 3, which now includes the marketing mix term Zt as a factor influencing market potential, we get:

$$N_t = psP^{-e}A^f + (1+q-p)N_{t-1} - (q/sP^eA^f)N_{t-1}^2 \tag{5}$$

Given that price (P) and advertising (A) are fixed during the interval t, we can simplify the expression for equation 5, the total number of adopter in the current period (N_t) as:

$$N_t = a + bN_{t-1} - cN_{t-1}^2 \tag{6}$$

Where:
    $a = psP^{-e}A^f$
    $b = 1+q-p$
    $c = q/sP^{-e}A^f$

In this case the total number of adopters or the demand in the current period depends not only on the past levels of demand, but also on the marketing mix, i.e. the price and advertising levels.

ILLUSTRATING THE STANDARD CASE OF THE BASS MODEL

To show how changes in the marketing mix affect the behavior of demand in our revised Bass model, we first illustrate the standard case assuming the market size is fixed.

To do this we utilize the Bass model parameters estimated by Tigert & Farivar (1981) with respect to the adoption of optical scanning equipment. Quarterly data was utilized and Table 1 shows the value of their estimated parameters. But the accuracy of their parameter estimates is not the issue in this study. The purpose here is to show how sensitive the demand forecasting model would be to changes in the assumptions with respect to the marketing mix; as well as the precise nature of the change.

Table 1
Bass Parameters for Optimal Scanning Equipment by Tigert & Farivar (1981)

Bass Parameters	Estimated Values
p	0.000388
q	0.353
m	3,629

Given these parameter estimates, the demand forecasts in the Bass Model behave as shown in Figure 1A. The figure shows that number of "new" adopters <u>per quarter</u> initially increase at an increasing rate, reach a maximum, and then decline. The number of new adopters per quarter eventually reaches zero and at this point the <u>total</u> (cumulative) number of adopters' peak at the market size of 3290. Figure 1B shows the cumulative or total number of adopters per quarter as time advances.

SPECIFYING THE MARKETING MIX PARAMETERS

Next we need to make assumptions concerning the parameter values of the marketing mix, equation 4. To be

TABLE 2
Marketing Mix Parameters in Cobb-Douglass Demand Function

Parameters	Low	Medium	High
e	0.35	1.00	3.00
f	0.25	0.50	0.75

consistent with marketing theory, the value of the advertising coefficient is constrained between 0 and 1. This constraint reflects the common finding that there are diminishing returns to advertising. With respect to price elasticity, Feenstra (2003) notes that there has been a "blizzard" of studies over the past decade on this topic. In a well detailed study, Foekens, et. Al (1998) estimates the price elasticity to range from inelastic (-0.33) to highly elastic (-3.15), which is consistent with the findings of others. As a result, we test the impacts of low, medium and high values for both price elasticity and advertising values as specified in Table 2.

The scaling factor, s, was set to yield a pre-specified market size of 3290, at the middle range for price and advertising levels, to be consistent with the Tigert & Farivar (1981) study used to select the parameters of the Bass model (specified in Table 1). Given these parameter estimates, the relationship between price and advertising on market size is illustrated in Figures 2 and 3. In both of these Figures the price and advertising levels are normalized for ease of illustration and comparison, where an index value of 100 represents the median value.

In Figure 2 the high price elasticity of demand is a relatively flatter curve, showing that the impact of price on the total market size increases much more rapidly as price declines relative to the low price elasticity. (Although slope is not the same as price elasticity, for any given price range, the flatter the slope the greater the elasticity.) For example at a price index of 100 the market size is 3200 for both curves. If price drops to 80, the market size of the high elasticity of demand doubles to about 6400, while the low

price elasticity increases by only 400 units to 3600.

In Figure 3 the high advertising elasticity of demand is a relatively flatter curve, showing that the impact of advertising on the total market size increases much more rapidly with increases in advertising relative to the low advertising elasticity. Also, there are diminishing returns to advertising. As advertising increases we see that the low elasticity demand curve becomes much steeper (more vertical) indicating that the gain in market demand eventually becomes very small as advertising increases. For example at an advertising index of 100 the market size is about 3200 for both curves. If advertising increases to 200, the market size of the high elasticity of demand almost doubles, increasing about 2800 units to a market size of 6000, while the low price elasticity increases by only 800 units to 4000.

TESTING THE IMPACT OF THE MARKETING MIX ON REVISED BASS MODEL

In this study twenty-eight computer simulations were run of the revised Bass Model with changes in the pre-specified levels of both price and advertising, given varying assumptions with respect to the elasticity coefficients in the marketing mix function. In particular, sensitivity analysis was done on the following scenarios:

The impact of a high price strategy given relatively high and low price elasticity coefficients with advertising fixed.

The impact of a low price strategy given relatively high and low advertising elasticity coefficients with adver-

FIGURE 5
CASE C: Impact of High Advertising with Price fixed
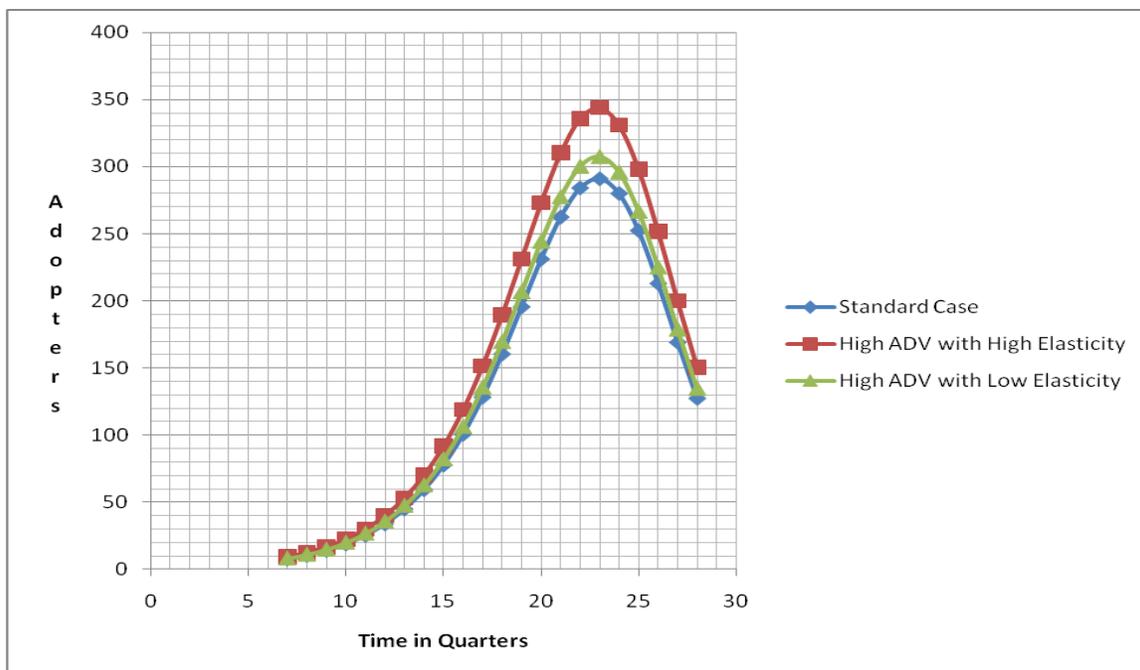
tising fixed

The impact of a high advertising strategy given relatively high and low advertising elasticity coefficients with price held constant.

The impact of a low advertising strategy given relatively high and low advertising elasticity coefficients with price held constant.

The impact of a 2% quarterly growth rate in advertising with high and low advertising elasticity.

The impact of a 2% quarterly growth rate in both advertising and price with high and low advertising elasticity.

To be succinct, only cases A, C, E and F are illustrated in Figures 4 to 7 below but all cases are discussed. Case B is discussed along with the findings of case A; and case E is discussed with the findings of case F.

Case A shows that a high price will dampen the speed of diffusion, and that the higher the price elasticity the greater the dampening effect. Adopters per quarter reach a peak of almost 300 in the standard case, but only 265 with low elasticity, and only 150 with high elasticity. Case B (not illustrated in a figure) provides the same results but in the opposite direction. A low price will heighten the speed of diffusion, and it will be greatest with a high elasticity.

Case C shows that a high advertising level will increase the speed of diffusion; and the higher the advertising elasticity the greater the effect. Adopters per quarter reach a peak of only 290 in the standard case, but the peak increases to 320 with high advertising even if advertising elasticity is low; and increases even further to 350 with high elasticity of advertising. Case D (not illustrated in a

figure) provides consistent results but in the opposite direction. A low advertising level will dampen the speed of diffusion, and the higher the advertising elasticity the greater dampening effect.

Case E shows the impact of advertising growing at a rate of 2% per quarter. The significant finding in this case is that the length of time of diffusion increases before the peak is reached along with increases in the speed of diffusion and the peak level of demand (quarterly adopters). This finding is independent of the level of the elasticity of advertising. In the standard case, the peak is reached after 23 quarters at a level of 300 adopters. But with growth in advertising, coupled with a high elasticity of advertising, the peak is not reached until 25 quarters at a peak demand level of 500 adopters per quarter.

The final set of simulations, case F, shows the impacts of growth in both advertising and price of 2% per quarter. Here the rate of diffusion and the peak level of demand that is reached are dependent on the level of the advertising elasticity. If the advertising elasticity is high enough the rate of diffusion will increase over the standard case. But an interesting finding is that the rate of decline is higher after the peak is reached.

CONCLUSION

There is growing interest in the modeling and forecasting of demand for *new and innovative products* owing to the rapid pace of technological change. For this purpose, the Bass model is a widely respected and utilized diffusion

FIGURE 6
CASE E: Impact of growth in Advertising with Price fixed
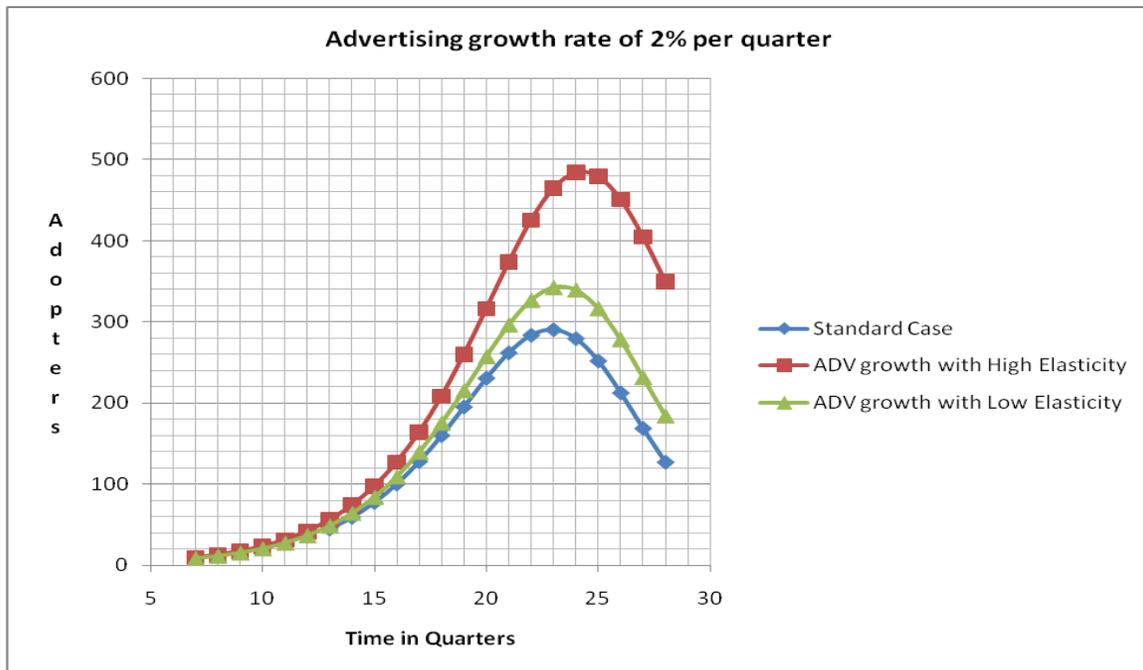
model. But one key element of the model has been brought into questions in our research, that is, the assumption that the market potential is constant, even with changes in the firm's marketing mix. There is compelling evidence from both academic studies and anecdotal evidence from practitioners that price reductions and increased promotional spending positively affect the total market opportunity for a product. It is recommended that those who develop models to forecast demand and those involved in the design and development of business simulations should consider the impact of the market mix in general, and pricing and promotion specifically, on both the total market opportunity for a product and the shape of the diffusion curve.

In this paper we have revised the Generalized Bass model to include the complexities of modeling the effects of the marketing mix on market size. The simulations developed from our revised model show that high prices will slow down both the rate of diffusion and level of demand; while high advertising levels will increase the speed of diffusion and level of demand. The precise nature of the impacts is influenced not only by the level of price and advertising but also on the elasticity of the marketing mix variables. High price elasticity will increase the speed of diffusion when prices are kept low but will dampen the speed of diffusion when price is high. In contrast, high advertising elasticity will quicken the speed of diffusion independent of the growth in advertising.

These conclusions have important implications for the strategies of firms competing in specific product markets. Using price reduction and/or increased promotional spending as tactics to increase market size is a rational marketing strategy if one or both of the following criteria is achieved:

- The market size is sufficiently elastic so that the increased demand from the price reduction overcomes the financial exposure associated with the lost revenue and margin from customers who would have purchased the product at the higher price.
- The market size is elastic in a similar way to increased promotional spending. Promotional investments increased the awareness of potential buyers for a product, and reduce buyer's risk by providing information about the product. Increase promotional spending is justified when each additional $1 spent on promotion provides a satisfactory return to the firm.

Importantly both of these criteria may require that the firm make additional investments in capital (to increase production capacity), in operating expenses (to acquire additional components from suppliers and to invest in the marketing mix), and in people (to manage both the increased demand and the cost-related process improvements).

Mahajan et. al. (1990) observed that "The diffusion process consists of four key elements: innovation, communication channels, time, and the social system." This conclusion is only partially correct. Our research suggests that management of the marketing mix may impact all the key elements of the Bass Model: the coefficients of innovation and imitation and, important, the total market size. The focus of our study is the impact of price and promotion on the market opportunity for a product category as represented in the Bass Model. We conclude that price and promotion generally have a positive impact on market size. There

FIGURE 7
CASE F: Growth in both Advertising and Price
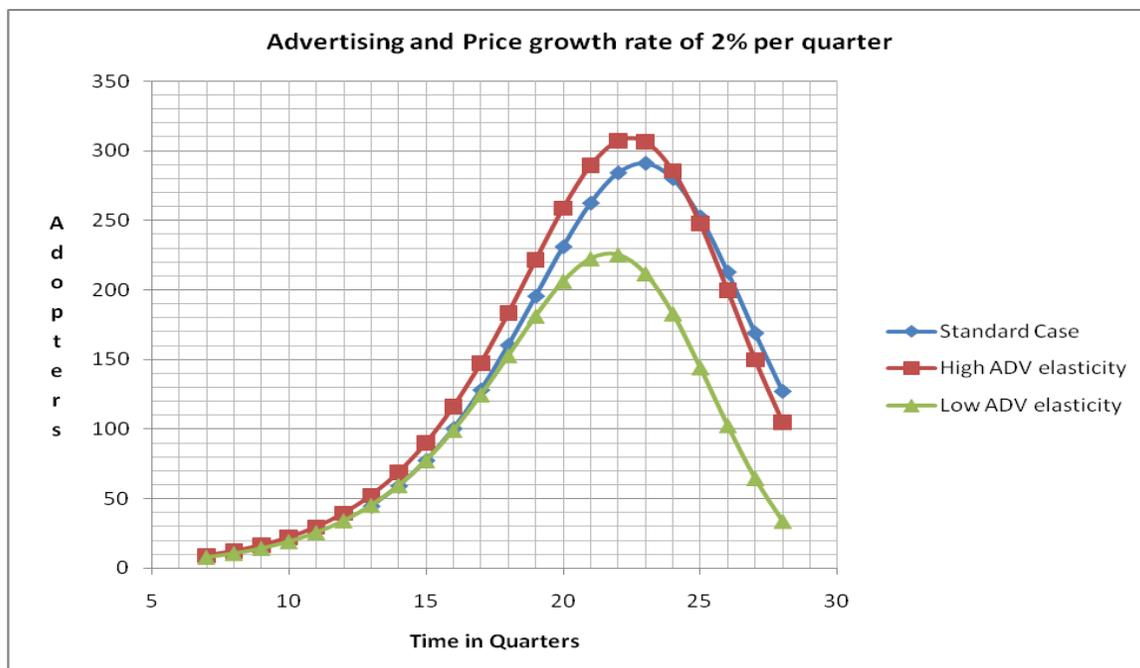
are two caveats related to this conclusion:

- Changes in pricing and advertising may not have any effect on the market size for certain product categories. We hypothesize that where the consumer already perceives that the product price is low (as in the case of electric can openers) or when the market itself in inelastic because of the nature of the product (as in the case of cigars) the total market opportunity may not increase as a result of pricing or advertising actions by market participants.

- The degree of the impact of price and promotion on the increase in market size likely is not uniform and varies by product category. For example pricing action or advertising campaigns for desirable consumer products such as electronics (iPad as an example) or fashion (UGGS as an example) may result in substantial increases in both market size and diffusion, while similar actions for consumer or commercial durables may have a more modest effect.

These findings are significant with respect to the effective design of business simulations. If a business simulation were designed to accept market size as a constant, as in the Bass model, there would be a zero sum game. In this case, the only way a firm would be able increase demand is by taking market share from competitors. If correct a completely static market would result; and in hyper-competitive markets, lowering prices and margins of market participants. In this scenario, firms would have less incentive to invest in innovations or increased capacity, potentially causing market stagnation in the product category. The idea or assumption of a fixed market size would certainly send the wrong signal to business strategists, and to students learning experientially from business simulations.

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