Technological Forecasting & Social Change 80 (2013) 77–87

Contents lists available at SciVerse ScienceDirect

Technological Forecasting & Social Change

An innovation diffusion of successive generations by system dynamics — An empirical study of Nike Golf Company

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A R T I C L E I N F O

Article history:
Received 19 April 2010
Received in revised form 1 September 2011
Accepted 1 August 2012
Available online 30 September 2012

Keywords:
Diffusion models
Multi-generation
Dynamic market potential
Price
System dynamics
Forecasting
Innovation

A B S T R A C T

Most multi-generation models investigate the monotonously incremental market potential of later generation by expanding applications for the product, besides, neither corporate marketing variables nor the competitive environment is considered. However, a new product introduced is not in a vacuum and the potential is more likely to be dynamic due to other influencing factors. Moreover, they tend to conduct the forecasts through trend extrapolation which normally neglects the extreme cases as outliers. This study constructs an integrated multi-generation diffusion model based on system dynamics, which considers dynamic market potential with a competitive relationship among generations and products. In addition, this study investigates how the price could be included as an explanatory variable. To verify the proposed model, an empirical study, Nike SQ SUMO and Nike SQ SUMO 5000 golf clubs, is investigated, in which their product life cycles just happen to cover the most extreme outlier, the Great Recession in 2008 and 2009. As a result, this model provides better forecasts by capturing the causes of industry dynamics. Accordingly, Nike could have been able to avoid unnecessary capacity expansion in May of 2007, August of 2008 and May of 2009 although there are peak periods, and can prepare more in December of 2007 and 2008 for Christmas holiday.

1. Introduction

During the dynamic market, the new technologies gradually replace the previous, and the time interval between successive generations has been drastically decreased. In the case of TV, CRT has been replaced by LCD. Dynamic random access memory (DRAM) has progressed from 4 k to 16 k, 64 k, 256 k, 1 M, 4 M, and now 8 M technology abounds. It is very crucial for a company to continuously improve and renew its products to survive. Accordingly, the diffusion process of new product acceptance has become a complicated issue, which is influenced by several possible elements, including market structure, promotion activities, substitution, and technical know-how incorporated, etc. (Maier [1]). From this viewpoint, it is difficult to forecast the total sales in the current number of purchase not to mention prediction of the substitution process among products under development. Nevertheless, business has to inevitably provide solid outlooks as a basis for decision making, especially while a new product is about to be introduced.

Since the Bass model in 1969 [2], studies on innovation diffusion of new products have raised a growing interest, in which most regarded the diffusion as a quasi-natural process—similar to the spread of a disease. Thus, once a new product is introduced, it spreads like an epidemic, where non-adopters are influenced by adopters as they contact them, leading to an eventual adoption. However, in many situations new products introduced subsequently are not independent or rather compete with previous ones, since they could provide more alternatives for customers. Accordingly, the extension to encompass both the substitution and diffusion effects of successive generations of technological innovations is further proposed by Norton and Bass [3].

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0040-1625/$ – see front matter
http://dx.doi.org/10.1016/j.techfore.2012.08.002

Dynamic market when competitive pressures are present leads to several key challenges: nonstationarity, changes in parameters over time, and cross-sectional heterogeneity (Heerde, Mela, and Manchanda [4]). Therefore, more marketing variables, which include price, advertising, distribution, product relationships, etc., have been included to enhance the multi-generation diffusion models. Among these marketing-mix variables, price has received a great deal of attention because of its critical role in influencing the demand for a product. The incorporation of price seems necessary, in some cases, particularly where the lower price would lead to a significant increase of growth rate for sales, and it could also capture the competitive relationship across generations. However, the previous models assume that new generations will completely replace their predecessors and the market potential of them must increase by expanding applications for the product, which is not necessarily happening in all cases due to the influences from factors such as the growth or decline of market, the competition of other products, the relative technical capability of a product, etc. There certainly exists the case for Microsoft Windows: consumers perceive Windows 7 to have less utility than Window XP, so that Windows 7 may never completely replace Window XP.

The shortcoming of the traditional models is to ignore the complexity and competition underlying the process of diffusion. Hence, these models solely concentrated on one, or a combination of some, of the relevant decision variables, and do not offer a comprehensive framework on the product growth. In addition, although a large extent innovation diffusion models can be very useful to enhance the understanding of innovation dynamics, their use can only be limited to the companies in monopolistic markets and explicitly excluding competition, or they can only serve as an aggregated model for a whole sector. However, existing or potential competitors or the risk resulting from substitutive products have a tremendous impact on managerial decision-making. Moreover, most traditional models based on statistical techniques forecast the sales volume during the product life cycle by using trend extrapolation and regression analysis, which withdraw most extreme cases as outliers.

Accordingly, the interest of this study concentrates on extending the fundamental multi-generation diffusion model and also relaxing the assumption of the monotonously incremental market potential of later generation to construct an integrated model based on system dynamics in a competitive environment which incorporate price explicitly. The use of the system dynamics approach allows the development of more complex model to investigate the structures and to further focus the processes of innovation diffusion. So that, this model can enhance insight in the essence of the problems, and explicitly describes how price competition across successive generations as well as among different products. There are two objectives in this study, which are: (1) to develop an enhanced model to successive generations of innovation diffusion to explicitly capture the impact of price and to provide more reliable forecasts, and (2) to adopt this framework as simulation instruments for the determination of reasonable scenarios for decisions and policies. In addition, an empirical study from the two successive generations of Nike golf clubs, Nike SQ Sumo and SQ Sumo 5000, are investigated in which the time frame is just about to cover the most extreme outlier in the last 70 years, the Great Recession in 2008 and 2009, for demonstration. The proposed model complies with observed phenomena to provide the empirical findings.

2. Literature review

In the model to be developed for growth and decline of market potential for successive generations, the competitive effects among the different competitors and substitution among successive generations should be investigated simultaneously. An important model of innovation diffusion of successive generations is proposed by Norton and Bass [3]. Building upon the Bass single-generation diffusion model, which assumes products to be introduced subsequently are independent and addresses the adopters are influenced in their purchase behavior by two sources of information: an external, like mass-media communication and an internal, word-of-mouth, they provide a multi-generation model which incorporates diffusion effect and substitution effect. Each of successive generations diffuses through a population of potential adopters over time. The later products will not be adopted by all potential customers immediately and the previous may continue to grow even as the substitution process occurs.

One of the main assumptions in the Norton–Bass model is that new generations completely supplant older ones and the market potentials of the later generations are positive and monotonously increasing. This is indeed expected if each generation "can do everything the previous generation could do, and possibly more" (Speece and MacLachlan [5]). However, this situation does not necessarily hold in all cases. There might be a circumstance that the new generation doesn't perform well enough to attract customers, which implies the great potential of the earlier with difficulty to be supplanted. In addition, although the above models can enhance insights into the essence of innovation diffusion, their use is limited to companies in monopolistic markets. For above reasons, some efforts are necessary to extend the fundamental models through structural elements to map competition across generations and among different products. Speece and MacLachlan [5] introduced a growth term and price factor into the multi-generation model to explicitly account for price competition among generations and the fact that one market is growing, whereas the other is declining. A choice-based substitutive diffusion model is proposed by Kim et al. [6] to incorporate the choice behavior of the consumer into the dynamics of product diffusion, where customers choose a product to maximize their utility. In addition, the market potential may even be affected by the exogenous variables and expressed as a function of them, which include population (Niu [7]), prices (Jain and Rao [8]), advertising expenditure (Nguyen and Shi [9]), number of competitors (Versluis [10]), income (Duval and Biere [11]), etc. Others used exponential, Gompertz, or logistic (Pearl) curve to model the total number of potential customers, that include studies from Kreng et al. [12], Yokum et al. [13] and Chu et al. [14].

Another major criticism of the Norton–Bass diffusion model is that it is of little use to the new product development since it considers diffusion only as a function of time and the marketing program of a company does not enter explicitly as a variable over the entire life of the product growth. Neither corporate marketing variables, such as pricing or advertising, nor structural elements, e.g., a competitive environment, are considered. Therefore, most of the research efforts in diffusion models in the last three decades were directed at extending this model to include more marketing variables. Kamakura and Balasubramanian [15] proposed that the price effect could be divided into two types. One is that price affects the market potential and the other could assume that price affects the rate of diffusion. More recently, Padmanabhan and Bass [16] explored the optimal pricing strategies for successive generations. Danaher, Hardie and Putsis [17] develop an empirical model of cellular telephones which explicitly captures the effect of marketing-mix variables through a proportional hazards framework and demonstrates the role that a single marketing-mix variable (price) played in the development of successive generations.

System dynamics, initially proposed by Forrester in 1959, is an approach to modeling the dynamics of complex systems, that differs from other methodologies is the use of feedback loops creating non-linear behaviors. In contrast to the above, the use of the system dynamics could consider all factors that cause the behavior of a system and develop more complex models with feedback relations to investigate the process of innovation diffusion. There are two types of feedback loops, positive or reinforcing and negative or balancing. Positive loops amplify the behavior of the system while negative loops counteract and oppose change (Daim et al. [18]). A feedback loop is described as the output of the system influencing the input to the system (Sterman [19]). Milling [20] first applied the system dynamics to develop an innovation diffusion model using the possible communications between potential customers and adopters for a monopolistic market. If the Bass model is reviewed from a system dynamics perspective, $Nt = (N - Xt)$ and Xt are the state variables of the system, the so-called market potential and the adopters of a product. If no capacity restrictions are considered, the sales in a period consist of innovative and imitative demand, which can reduce the market potential and increase the number of adopters. The conceptual framework of the mixed influence diffusion model with system dynamics approach is illustrated in Fig. 1. A comprehensive competitive market model proposed to map competition by Milling and Maier [21] is used to develop adequate strategies for new product introduction, combining a subset of pricing strategies, policies of budgeting for research and development, market-entry timing decisions, and advertising strategies. Another interesting application in the system dynamics applied to forecast is presented by Maier [22], which developed a comprehensive model for a competitive market and demonstrated its usefulness as a simulator for policy making in the case of substitution among successive product generations.

3. Modeling

In this study, the fundamental multi-generation diffusion model is extended to construct a system dynamics approach towards innovation in a competitive environment which is consistent with the established theories of individual behavior. In contrast to the traditional Norton–Bass model, competitive effect among the different product brands (or categories) and substitution relationship within successive generations of each product brand (or category) are included with the introduction of an important marketing variables, price. In addition, a detailed interpretation of transfer mechanisms, which results in the flow of individuals from one segment to the next in the diffusion process, is addressed. In general, there are five transfer mechanisms included: (1) mass-media communication, (2) word-of-mouth communication, (3) other marketing efforts (e.g., pricing, advertising), (4) individual experience with the product, and (5) exogenous factors (e.g., general economic conditions) (Mahajan and Muller [23]).

To begin with, this study proposes a conceptual framework in Fig. 2 to depict the cycle of innovation diffusion and explain the transfer rates across different segments. Furthermore, it will be central to subsequent development of model construction. The untapped market represents persons with potential as latent customers. Early in the product life cycle, the level of untapped market will be reduced by the increasing awareness and attraction of the new product and then lead to accelerating demand. The industry market potential represents the remaining potential customers within the specific period of time. The level of potential customers is increased by the influxes of the untapped market and the previous buyers, who expect to replace their worn or out-of-date products and to purchase the latest version repeatedly. It is treated as a homogeneous group and divided into several

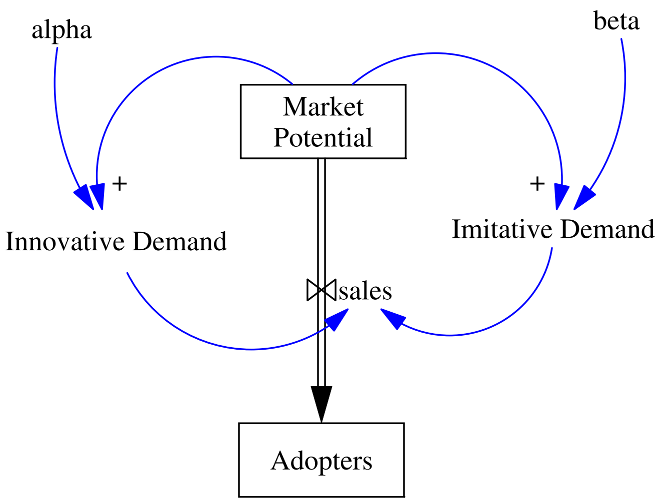

Fig. 1. The mixed influence diffusion model with system dynamics approach.

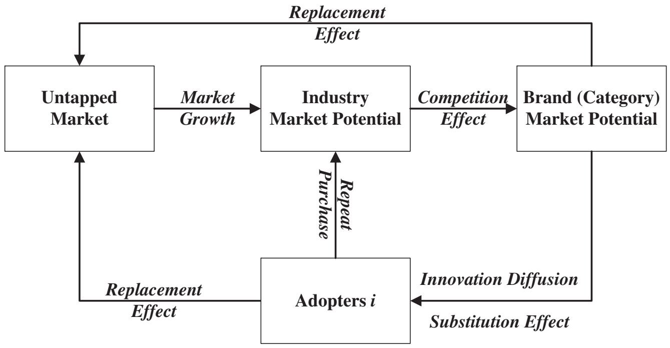

Fig. 2. Conceptual framework of the cyclical innovation diffusion.

brand (category) market potentials for each product in a competitive environment. Several brands compete to fulfill the same function, and the more attractive the product is, the larger the potential will gain.

Furthermore, the adopters represent the persons who purchased the product cumulatively, where the level is increased by the sales of the products from innovative demand and imitative demand. The brand market potential and adopters as well as their associated transfers (Innovators, Imitators) constitute the kernel model of innovation diffusion. Additionally, successive generations introduced subsequently are not assumed to be independent, in which a new generation represents an innovation over the earlier. However, the later generation competes with its predecessor and continuously supplants it, which is the substitution effect. In the later period, the demand of the product decreases because the levels of potential customers become depleted, with more and more buyers increasingly shift towards another substitution. In addition, there is a replacement effect within competing product categories for the superior technological or inventive attributes. Accordingly, a fraction of the brand market potential and the adopters may turn to untapped market. Nevertheless, the authors developed this conceptual model to provide more accurate forecasts of successive generations for durable goods, such as are television sets, power lawn mowers, or cellular mobile telephones, and neglect the replacement effects of substitutions. Furthermore, the main components and causal loop diagram of this system dynamics model are illustrated in Fig. 3, which is constructed from industry market potential sector, competition sector, and substitution and diffusion sector.

4. Industry market potential sector

This model is constructed as an enhancement to the traditional diffusion model with dynamic market potential. The untapped market (UM) covers latent consumers, which will be transferred to the industry market potential ($N(t)$) if they are willing to

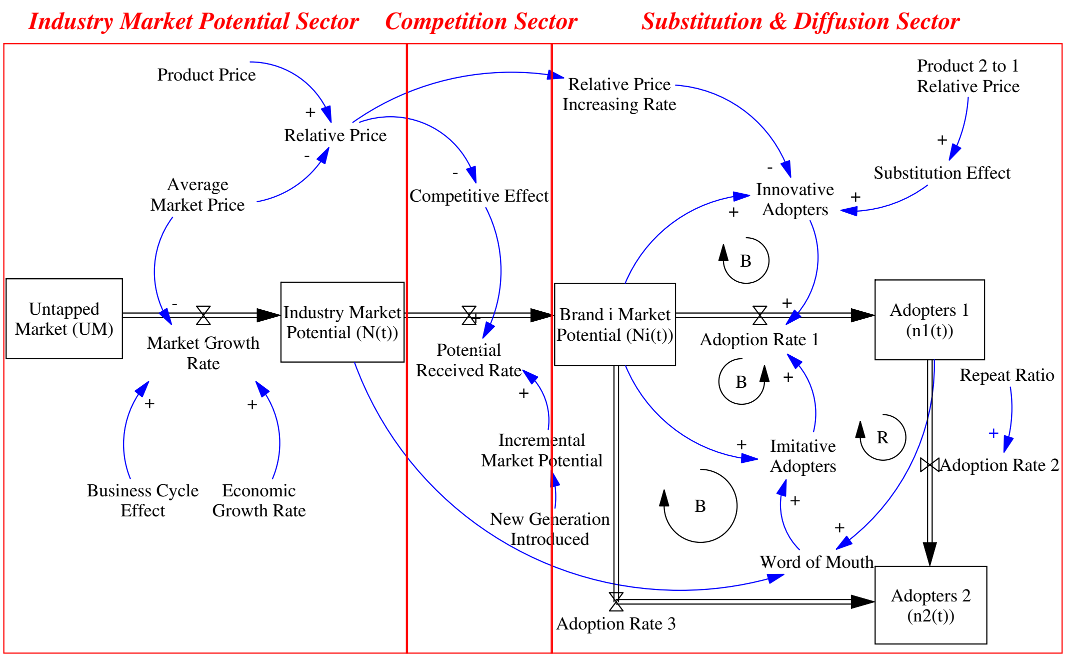

Fig. 3. Causal loop diagram of the system dynamics model.

purchase the products. In other words, $N(t)$ can change over time and may be affected by some appropriate actions such as general economic conditions, the diminution in product price, match demand with innovative products, government actions, etc. In this study, the market growth rate ($MG(t)$) is a function of $S(t)$, $MG(t)=f(S(t))$, where $S(t)$ is a vector of all relevant exogenous and endogenous factors with both controllable and uncontrollable effects towards $MG(t)$. $MG(t)$ is the product life cycle times the level of market momentum, ($MM(t)$), which represents the compound effects from economic growth rate, business cycle and average market price.

$$N(t) = N(t-1) + MG(t) - PR_i(t) \tag{1}$$

$$MG(t) = f(S(t)) = LT * MM(t) \tag{2}$$

$$MM(t) = GR(t) * BC(t) * AP(t) \tag{3}$$

where

$N(t)$	represents the industry market potential at period time t
$MG(t)$	represents the market growth rate at period time t
$PR_i(t)$	represents the potential received rate of brand i at time t
LT	represents the average life time of the product
$MM(t)$	represents the market momentum at period time t
$GR(t)$	represents the effect of economic growth rate at period time t
$BC(t)$	represents the effect of business cycle at period time t
$AP(t)$	represents the effect of average market price at period time t.

Accordingly, the mathematical model is constructed to obtain the level of market momentum. Table 1 shows the sales volume arranged by time. Various categories of cyclical month in the diffusion process were different from each other. Y_{ij} represents the jth value of the ith month, where $i=1,2,\ldots,r$, and $j=1,2,\ldots,c$. Therefore, the effect of business cycle can be obtained as follows:

$$BC(j) = \mu_j/\mu = \left(\sum_{i=1}^{r} Y_{ij} \Big/ r\right) \Bigg/ \left(\sum_{j=1}^{c} \mu_j \Big/ c\right). \tag{4}$$

For the sake of excluding business cycle, this study proposes $U(t)=Y_{ij}/BC(t)$ with linear regression to represent the effect of economic growth rate. Through estimating the population parameters, the linear regression between selected values of the economic growth rate ($R(t)$) and observed values of $U(t)$ is constructed. Similarly, to eliminate the impact from economic growth rate, $V(t)=U(t)/GR(t)$ is introduced with regression analysis to understand how $V(t)$ changes when the average market price ($P(t)$) varies.

$$GR(t) = a1 + b1 * R(t) + \varepsilon_1 \tag{5}$$

$$AP(t) = a2 + b2 * P(t) + \varepsilon_2 \tag{6}$$

where

$$a_1 = \bar{U} - b_1\bar{R} \text{ and } a_2 = \bar{V} - b_2\bar{P}$$

$$b_1 = \frac{n\sum UR - (\sum U)(\sum R)}{n\sum R^2 - (\sum U)^2} \text{ and } b_2 = \frac{n\sum VP - (\sum V)(\sum P)}{n\sum P^2 - (\sum V)^2}$$

$R(t)$	represents the economic growth rate at period time t
$P(t)$	represents the average market price, that is, the sales-weighted average prices from all products at period time t.
ε_1, ε_2	are the error terms.

Table 1
Sales volume.

Year	Month			
	1	2	…	c
1	Y_{11}	Y_{12}	…	Y_{1c}
2	Y_{21}	Y_{22}	⋮	Y_{2c}
⋮	⋮	⋮	⋱	⋮
r	Y_{r1}	Y_{r2}	…	Y_{rc}
Mean	μ_1	μ_2	…	μ_c

5. Competition sector

Normally, a new product is not introduced into a vacuum nor do they exist in isolation. Since all similar products share the identical market, and they may possess a competitive relationship upon the product life cycle. Products compete for the common group of market potential, and the impact of competition among the brands is captured by making the market potential of each brand a function affected by its attractiveness. That is to say the industry market potential will be divided among all alternatives in proportion to the attractiveness of each. In this study, the attractiveness is assumed to be dependent on the price since recent products share almost identical functionalities with necessary quality. Moreover, Speece and MacLachlan [5] indicated that there are two forms of pricing function investigated in diffusion research.

$$G(P_i) = \left(\frac{P_i(t)}{P(t)}\right)^{\eta} \text{ and } G(P_i) = \exp\left[\eta\left(\frac{P_i(t)}{P(t)}\right)\right]. \tag{7}$$

When prices of brand i are above market price, sales will be restrained, whereas prices of brand i below market price might encourage sales. Hence, the competition effect of product is assumed to be inversely related to the relative price level of product, which is equal to the product price divide by average market price.

$$N_i(t)N_i(t-1) + PR_i(t) - AR_i(t) \tag{8}$$

$$PR_i(t)N_i(t) * CE_i(P_i(t)/P(t)) \tag{9}$$

where

$N_i(t)$ represents the brand market potential of brand i at time t
$AR_i(t)$ represents the adoption rate of brand i at time t
$CE_i(t)$ represents the competition effect of brand i at time t
$P_i(t)$ represents the price of brand i at time t.

6. Substitution and diffusion sector

If the customers from market potential actually make the expected decision of purchasing, they turn into the adopters. The adoption rate is, therefore, determined by two groups, which are innovative adopters and imitative adopters. The number of innovators is solely a function of the number of brand market potential and is not influenced by whether there are already adopters of the product. Mathematically, it is defined by the number of market potential times the level of substitution effect and the coefficient of innovation, α, that is the ratio of innovative adopters to market potential. In this study, $\alpha(\Delta(P_i(t)/P(t)))$, a function of product price is proposed to address that the number of innovative adopters is influenced by the increasing rate of relative price level of the product. And this variable has a direct impact on the probability of a purchase, which serves as a multiplier that then affects the coefficient of innovation α. The lower the product price is, the larger the fraction of potential customers will purchase.

In addition, when the later generation is introduced, it begins to substitute the earlier and obtains the number of innovators by two ways, as shown in Eq. (15). First, the customers, who have not purchased the old version, go direct to the new with expanding applications and inventive attributes. The others consist of the customers, who have adopted the earlier but still repeatedly adopt the later. The substitution effect, $(SE(t))$, represents a central mechanism to control the substitution and diffusion processes and simultaneously captures them in Eqs. (13) and (15). In contrast to the Norton and Bass model, once it begins, the process does not change. In this study, the process is determined by the relative technical capability and the relative price between successive generations. The later generation can obtain a higher level of substitution effect by increasing technical capability or decreasing price and result in the innovators to buy the later version.

The actions of the innovative adopters induce the other group to imitate their behavior, where the imitative adopters are initiated by innovators and the momentum of procurement from the communication between remaining market potential and the increasing level of adopters. Mathematically, it is determined by industry market potential, brand market potential, adopters and the coefficient of imitation (β). β is defined by the probability that the possible contacts between the brand market potential and adopters have been established, and actually leads to the decision of procurement. In addition, the adopter rate is the sum of innovators and imitators in each period, which establishes the basic equation for the growth and diffusion of a new product and comprises different models of the product life cycle.

$$AR_{ij}(t) = \text{Innovative Adopters}_{ij} + \text{Imitative Adopters}_{ij} \tag{10}$$

$$AR_i(t) = AR_{i1}(t) + AR_{i2}(t) \tag{11}$$

$$n_{ij}(t) = n_{ij}(t-1) + AR_{ij}(t). \tag{12}$$

For the first generation, $j = A$,

$$\text{Innovative Adopters}_{i1} = \alpha_{i1}(\Delta(P_i(t)/P(t))) * N_i(t) * SE_{i1}(t) \tag{13}$$

$$\text{Imitative Adopters}_{i1} = \beta_{i1}/N(t) * n_{i1}(t) * N_i(t). \tag{14}$$

And for the second, $j = B$,

$$\text{Innovative Adopters}_{i2} = \alpha_{i2}(\Delta(P_i(t)/P(t))) * (N_i(t) + N_i{}'(t)) * SE_{i2}(t) + \alpha_{i2}(\Delta(P_i(t)/P(t))) * n_{i2}(t) * RR \tag{15}$$

$$\text{Imitative Adopters}_{i2} = \beta_{i2}/N(t) * n_{i2}(t) * N_i(t) \tag{16}$$

where

$\alpha_{ij}(P_i(t))$ represents the coefficient of innovation of product j of brand i at time t
$n_{ij}(t)$ represents the cumulative adopters of product j of brand i at time t
β_{ij} represents the coefficient of imitation of product j of brand i
$\Delta(P_i(t)/P(t))$ represents the increasing rate of relative price of product i at time t
$SE_{ij}(t)$ represents the substitution effect of product j of brand i at time t
$N_i{}'(t)$ represents the incremental market potential served by the later generation
RR represents the repeated rate while the earlier purchasers replace the later.

The multi-generation diffusion model based on system dynamics described above considers an additional variable "price", which affects the substitution and diffusion processes and releases the assumptions in the monotonously incremental market potential of later generation and the fixed rate of substitution in a competitive environment. Such a comprehensive model can map the characteristics of diffusion processes so as to enhance an understanding of the complexity, dynamics and impacts of the influencing factors towards marketing. The model developed in this manner can also serve as a simulator to provide more reliable forecasts for new product introduction and to analyze different business strategies for better decisions against the threats.

7. Illustration—the Nike Golf Company

The system dynamics model discussed above is demonstrated with an empirical example from the Nike Golf Company, in which the illustration is used to identify the influencing factors of dynamic diffusion process and to further provide better forecasts to avoid unnecessary capacity expansion in business downturns. The golf clubs sector, now dominated by Taylor Made, Callaway, Ping and Nike, has short experienced boom and bust cycles. In this study, the data collected by Golf Datatech, which provides timely and accurate sales data of golf clubs collected directly from each channel through a representative of retail outlets, including over 600 on-course pro shops and 250 off-course golf specialty shops in USA, consist of 33 monthly observations of sales quantity for two successive generations of Nike Golf from January of 2007 to September of 2009. The first generation, Nike SQ SUMO, began sales in January of 2007, and after the second generation, Nike SQ SUMO 5000, was introduced in February of 2008 the demand of earlier began to decrease. From July of 2008, the market has been dominated by the later. The situation, faced with these two serial products reveals high cyclical behavior. These patterns show the growth and decline of demands from each product and simultaneously capture substitution effects across generations and diffusion effects within each generation. The sales volume is the highest in May and starts to decrease from July each year due to the seasonal cause. The later product introduced to the market and gradually replaced the previous product in February of 2008. Due to the severity of the business cycles and the fluctuation of economics and market, the associations between companies and sector devote considerable efforts towards forecast.

Through literature review about the golf clubs, monthly sales quantity of total market is regarded as the analytic foundation of industry market potential. The relevant factors influencing the monthly sales quantity can be classified into the three elements, which are:

(1) The industry business cycle: the men's major golf championships are the four most prestigious annual tournaments in professional golf, which begin to be held on the second Sunday in April each year. Before these tournaments, the golf club companies devote to publicizing the new product with intensive promotion. Hence, there are increasing sales volume from January to June, with downturns from July to November each year.
(2) The economic growth rate: general economic conditions, such as GDP and personal income, affect the demand of golf clubs for recreation and sports activities. For example, the Great Recession in 2008 results in significant reduction of sales volume. Fig. 4 demonstrates that there is a positive correlation between the economic growth rate and total market sales.
(3) The average market price: Christmas and New Year holidays are always the time for celebration and exchange gifts. In order to take this golden opportunity to catch consumers' attention and raise their interests in new products, all of the companies make plans of big promotion and offer a special discount. Fig. 5 shows that, in general, there are lowest average price and sudden sales volume increase happened in December.

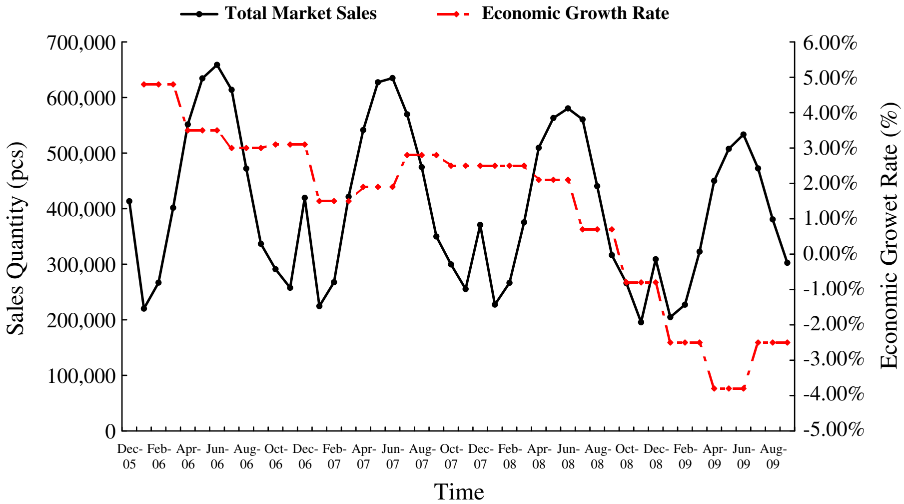

Fig. 4. Plots of economic growth rate versus total market sales.

The system dynamics diffusion model of Nike SQ SUMO and Nike SQ SUMO 5000 is illustrated in Fig. 6. Accordingly, this figure clearly indicates that there are seven "negative" or balancing loops and three "positive" or reinforcing loops in this model. Contained within these loops, there are several important "stock" variables—adopters, brand market potential, industry market potential, etc. While the dynamics of these loops have been addressed in detail, the essence of the diffusion process and the causes of consumer behavior can be understood.

In the first generation analysis, Nike SQ SUMO, around the major balancing loop, the greater the increasing rate of relative price of product *A* is, the more the innovation adopter *A* as well as adoption rate *A* will decrease. And then, relatively, it will lead to the increase of the brand market potential. Furthermore, the addition of innovation adopters *A* resulted from the increase of brand market potential will balance the initial depletion caused by the effect of increasing rate of relative price. Around the other balancing loop, when the product price decreases, it will become more attractive than the competitors and gain a larger proportion of the brand market potential. And then, the increasing brand market potential leads to the growth of imitative adopters *A* and adoption rate *A*. Last, the decrease of brand market potential resulted from the addition of adoption rate *A* will balance the previous amplification. Around the reinforcing loops, the adoption rate *A* augments the adopters *A*, which can generate the word of mouth leading to the increase of imitative adopters *A* and adoption rate *A*. In other words, the adoption rate *A* is reinforced by the word of mouth driven by recent purchasers who are still excited by the product and have not yet come to take it for granted. The strength from the word of mouth effect (the number of purchases generated per quarter by each recent purchaser) is a treatment variable in the experiment (Paich and Sterman [24]).

In the second generation analysis, Nike SQ SUMO 5000 obtains the number of customers who would have adopted the earlier in the first place and now decide to switch due to the favor of the later, that is adopter rate *B*2, and from who have already owned the earlier, and want to further adopt the later as well, that is adopter rate *B*1. Both approaches individually possess two balancing

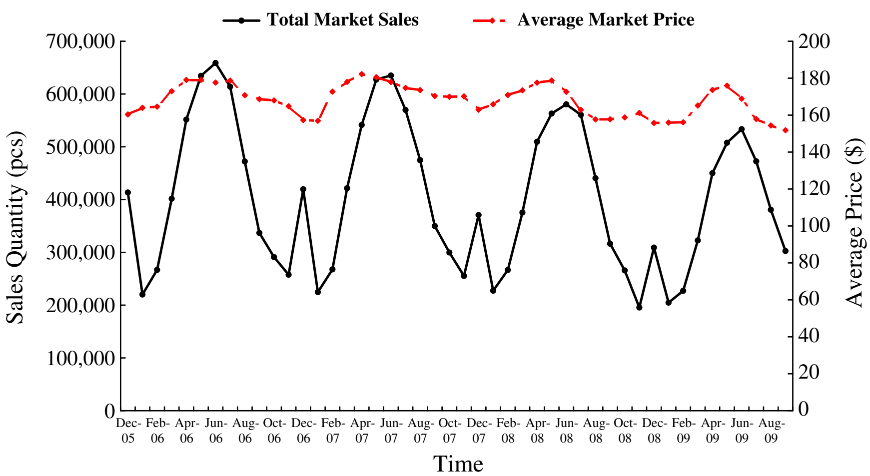

Fig. 5. Plots of market average price versus total market sales.

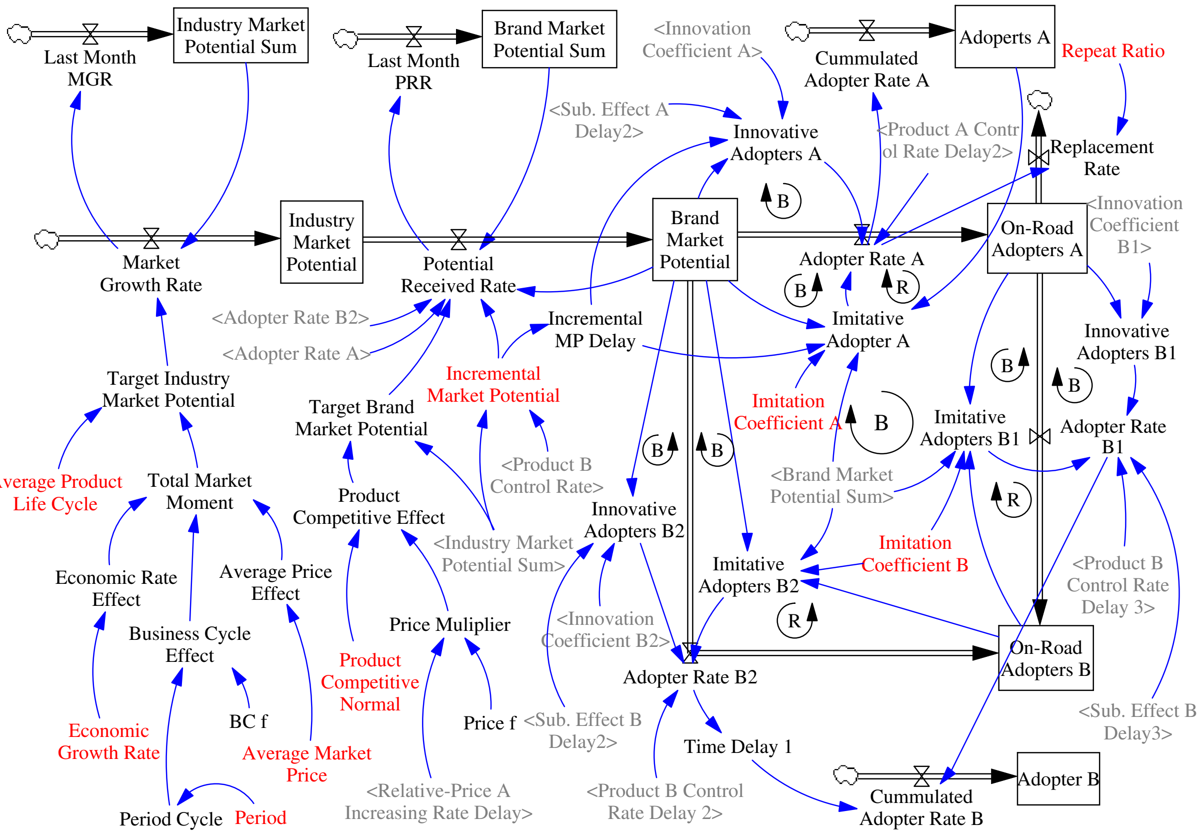

Fig. 6. The system dynamics diffusion model of multi-generation of Nike SQ SUMO and Nike SQ SUMO 5000.

loops and one reinforcing loop, and they are the identical as in the first generation. About the substitution effect between the successive generations, there is a major balancing loop. While the price decreasing rate of new version is more than the earlier, new version will become more attractive and gain a higher substitution effect. And then, it leads to the increase of innovative adopters *B*2 and adoption rate *B*2. On one hand, the addition of adoption rate *B*2 further results in the increase of adopter *B*. On the other hand, relatively, it will lead to the decrease of the brand market potential. And then, the lower the brand market potential is, the lower the adopter rate *A* and adopter *A* are. At last, the reduction of adopter *B* resulted from the drop of adoption rate *B* caused by the decreasing adopter *A* will balance the previous amplification.

The loops just described above are the essential causes of cycles in the diffusion process. In addition, the exogenous variables, which are external factors, including the drop in average market price or product price, the upturn of economic growth rate, the boom of business cycle, and the addition of attractive effects or repeat ratio, can also accelerate the diffusion process.

Most traditional models are based on statistical techniques, which typically forecast the sales volume as a function of past data or of changes in economic conditions. Normally, the results don't fit well since they cannot capture the industry structure, which creates behavior over time, and ignore the forces driving the processes of diffusion. However, this proposed system dynamics diffusion model could provide an instrument to understand the causes of industry behavior and to further enhance insights towards the essence of the problems.

Mahajan and Muller [25] separated the data into two groups, which are the fitted group and the forecast group, to validate the predictive performance of the models. In this study, the data are also divided into the fitted group, from January of 2007 to September of 2009, and the forecast group, from October of 2009 to December of 2009, as of Mahajan and Muller. In the fitted group, in order to investigate whether this model is appropriate in forecasting forward or not, the historical data of these two product generations is utilized to compare. The differences between the actual demand and the forecasts from this study since the beginning of 2007 are illustrated in Fig. 7, where it clearly demonstrates a well fitness and provides a reliable and accurate forecast towards the cyclical peaks and the subsequent downturns. In the forecast group, the parameters of the model are estimated from the previous data intervals, and then the forecasts from October to December of 2009 could be projected by using these parameter estimates and some exogenous inputs, including product price and the economic growth rate. As a result, the Nike Golf Company could avoid unnecessary capacity expansion and obsolete inventory. Although there are peak periods in May of 2007, August of 2008 and May of 2009, Nike still could accurately predict the possibility of the orders being canceled or delayed when the subsequent bottom fell. In addition, Nike can also prepare to manufacture more products for the upcoming events in December of 2007 and 2008 for Christmas holiday.

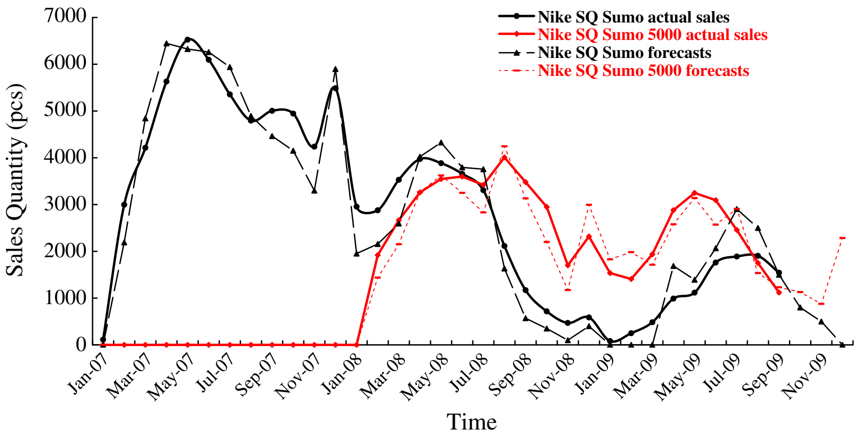

Fig. 7. Actual vs. forecasts of Nike SQ SUMO and Nike SQ SUMO 5000.

Although this study seems to perform well, it still possesses several limitations. The main limitation is the competition effect of brands $CE_i(t)$ and the substitution effect of successive generations ($SE(t)$) are functions of the product price alone. The incorporation of other market variables, which includes advertising, product technology, promotion, etc., is a major direction for future research. Second, the adopter's choice in each time period can be independent of his/her choice from previous periods and depends only on the utility of the new product. Third, the model is best applicable to situations of a highly cyclical product, and the durable is not mostly appropriate. Moreover, the model needs to be applied to data wherein the distinction between the two successive generations can be discerned, since information must be able to track separately those who choose the second generation instead of the first and those who have already adopted the first and switch to the second. Finally, let the repeat ratio associated with applications be independently and identically distributed with a constant overall mean rate. In this study the data collected by the questionnaires from the sales department of Nike Golf Company.

In addition, new technology is normally assumed to definitely expand uses for the product and monotonously increase demand, which can account for the substantial growth of market potential. However, the new technology might sometimes only cause a shift out of the market potential from the earlier, not an absolute increase. The introduction of competition and substitution effects can assist to deal with this situation well. Since the diffusion model is capable of accurately predicting the sales volume, this proposed approach can further serve as an instrument to simulate the consequences from various scenarios. Furthermore, system dynamics can provide important inputs to specific business decisions and to the design of policies that improve performance (Lyneis [26]). For example, in this model, product price is a variable that control the process of diffusion and substitution since it strongly influences the innovation and substitution multipliers. Different pricing strategies can be utilized as inputs to simulate and analyze the consequences to seek adequate decisions individually in boom and off-season period. On one hand, a later generation introduced into the market with lower price or too early could lead to product cannibalism. On the other hand, being too late or with higher price might cause a sharp decline in sales. Furthermore, the economic growth rate, business cycle and average market price are also sensitive model variables, based on estimations, that all can be treated as exogenous factors. According to the sensitivity of changing in these exogenous inputs, this system dynamics model can serve as an early-warning or a useful means for better understanding the impacts of various changes in the environment. In addition, simulations also allow time and space to be compressed, accommodate rapid accumulation of “experience” and permit controlled experimentation (Paich and Sterman [24]), that can be used as a guidance to design adaptive mechanisms.

8. Conclusions

In order to provide better forecasts during the product life cycle with particularly the competition and substitution effects between successive generations occurred, this study constructs an innovation diffusion model for multi-generation products based on system dynamics, which considers dynamic market potential with fluctuation due to competitive relationship among generations and products. In addition, this study investigates how the product price could be included as an explanatory variable in this dynamic model. Besides, a holistic overview can be achieved to obtain benefits for the innovation diffusion of new product acceptance.

To sum up, this system dynamics model is able to accurately forecast the cyclical peaks and the subsequent downturns by investigating the structures and forces driving the processes of innovation diffusion. The illustrations of Nike golf clubs, Nike SQ SUMO and Nike SQ SUMO 5000, are presented, in which their product life cycle just happens to cover the most extreme outlier, the Great Recession in 2008 and 2009, is examined. The results reveal that this system dynamics model provides reliable and accurate forecasts by capturing the causes of industry dynamics.

Second, this proposed model also can provide significant insights towards the complexity of business structure and the dynamic relationship caused by all the relevant influencing factors through feedback loops from non-linear behaviors. It can provide a means of understanding the causes from industry behavior, for example, while the economic growth rate turns down, the sales will begin to decrease. In addition, the sales quantity is also influenced by the business cycle and price, where special discount for Christmas holiday and the beginning of the four most prestigious annual tournaments of golf make drastic volume increase. The purpose of such forecasts is to foster improved, early understanding of changes in the environment, as a guide to construct adaptive strategies.

Third, this model can be extended toward a simulator to analyze the consequences with different exogenous inputs. Since only the impact from price change can determine the overall pricing strategy. In addition, this study reveals the evidence of an important interaction in price response across generations. A later generation introduced into the market too late or with higher price might cause a sharp decline in sales. Nevertheless, most single-generation models are not able to account for these intergenerational interdependencies might overlook such important component of the price impact over time. For future research, optimal phasing out of previous generations and optimal timing of the entry of later ones have to be investigated. Accordingly, it can also incorporate additional influencing marketing-mix variables or brand choice modeling.

Ultimately, most of the studies in diffusion models seem to perform well in describing and explaining the spread only for a specific sector, however, they have not been tested on others. Lyneis [27] indicated that market models are less threatening and more standard procedure than company model. Here, an empirical case of Nike golf clubs is used to demonstrate that this model can be deployed to an application in company level instead of only associated with industries or market.

Acknowledgments

The detailed data and information regarding the golf clubs market are provided by Golf Datatech. The authors would like to express their gratitude towards the above party.

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