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Technology products' organic growth or cannibalism? A multi-generation spatial mapping perspective
科技產品有機成長或自我蠶食：跨代空間映射觀點

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Abstract: Given their short life-cycles, the market diffusion of high-tech products can be interpreted from the perspective of biological evolution. Rather than objects with fixed characteristics, such products can be viewed as a series of continuously progressing product groups. Therefore, this study analyzes the transaction data of a MP3 music player brand by logit-type market share models and calculates price competition indices in order to estimate the attractiveness of alternative products and to assess whether decoys could create consumer compromise and "extremeness aversion". As attractiveness is incorporated in an autologistic choice model of spatial-temporal patterns, we use this model to capture the cross-selling patterns of a new product's cannibalism or intrinsic growth. Integrating product interdependence by modeling a set of spatial autocorrelation choices allows for a superior fit compared to traditional linear sales predictions. Lastly, to survey the organic growth of new cross-generational products we assess long-term survivability via intra- and inter-competition spatial mapping. The findings herein cast doubts on the use of the prospect theory to predict consumer choices.

Keywords: Compromise effect, technology trajectory, spatial mapping, marketing ambidexterity.

摘要：高科技產品生命週期短暫，市場擴散可以生物物種演進的概念去詮釋，產品為一系列不斷進步調整的群體，而非具有固定的特徵。本研究以羅吉特形式市場佔有率模型，分析 MP3 音樂播放器品牌交易資料，以價格競爭指數計算替代產品的吸引力，探索誘餌產品是否引起消費者選擇時的妥協和極端趨避心態；進一步以空間時態的自我羅吉斯模式，整合產品吸引力之估算，捕捉新產品交叉銷售之自我蠶食或內在增長的意涵。研究結果提出產品相依

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性至空間自我相關集合，比傳統的線性銷售預測有較優之配適度，經產品內和產品間空間映射檢視跨世代新產品的有機成長，本研究對展望理論的消費者選擇之論述提出質疑。

關鍵詞：妥協效果、科技軌跡、空間映射、行銷雙元性

1. Introduction

With industry around the world moving towards the post-globalization era, the competitive environment has become even more complicated and unpredictable. High-tech products are increasingly being characterized by short life-cycles, and companies must innovate and adjust their management of the product responding to external changes (Chin, Huang, and Lee, 2018; Geiger and Makri, 2006), to gain a competitive advantage and meet growing demand. Many corporations strive for more advanced products to satisfy diversified consumer needs, attempting to create new industry life-cycle peaks, but new products are intrinsically associated with a high level of market uncertainty. Changes in market competitors, uncertainty regarding new technology paradigms, and varying consumer trends all affect market performance. Thus, innovation involves more than simply launching a new concept of goods; it includes improving marketed products to provide consumers with a truly innovative experience. Along with old products continuously being replaced in favor of new ones, product types and features are growing more complex, product elimination through competition is accelerating, and businesses are struggling with product lines of their own brands.

A company's dynamic capabilities define its capacity to innovate, adapt to change, and create change that is favorable to customers and unfavorable to competitors (Teece, Peteraf, and Leih, 2016). With the multiplication of homogeneous products, businesses wanting to preempt their competitors when launching new products must understand the existing state of product competition in the market. Although the product life-cycle (PLC) theory has been widely used in product management, strategic planning, and marketing activities, its definition and application are highly controversial. Previous research has criticized the theory as being insufficiently rigorous and overly simplified, ignoring important sales-related variables, causing managers to mishandle competition and miss opportunities for product innovation, and leading to tautologies in deterministic and sequential stages (Dhalla and Yuspeh, 1976; Hunt, 1976, 2010; Tellis and Crawford, 1981; Wind and Claycamp, 1976).

In contrast to the PLC theory, the product evolution cycle (PEC) concept assumes that products are continually changing and evolving, drawing on biological evolution to explain product growth and expansion processes (Chandrasekaran and Tellis, 2007; Holak and Tang, 1990; Norton and Bass, 1987; Lau, 2014; Tellis and Crawford, 1981). Product development is seen as the transformation of a market opportunity into a marketed product (Krishnan and Ulrich, 2001). It is an intrinsic process that involves sellers' niche or habitat metabolisms, new product diffusion epidemics, and interactive marketing with up-, down-, and cross-selling (Kamakura, Kossar, and Wedel, 2004; Li, Sun, and Wilcox, 2005). Well-designed product lines push corporations to grow rather than self-cannibalize. Technological products are generally developed on the basis of an original model, to which new functions or attributes are added. The path of a technology in its life-cycle, or technology trajectory, may be expressed by the growth rate of performance improvement, product diffusion, or direction of advance within a technological paradigm (Dosi, 1982; Schilling, 2010).

When faced with the myriad choices resulting from product evolution, a consumer will attempt to determine the best reason for selecting a specific product. The diffusion of innovation theory can be used to explain the spread of commodities (Rogers, 1995). When consumers perceive an innovative product to be superior to competing goods, the product is considered to have a comparative advantage and a higher likelihood of consumer adoption, leading to a diffusion effect (Agarwal and Prasad, 1997; McDade, Oliva, and Pirsch, 2002; Taylor and Todd, 1995). Even so, according to the prospect theory (Kahneman and Tversky, 1979), consumers focus more on potential losses than potential benefits when they are unsure of their preferences and thus tend to prefer less extreme choices.

Consumers are often influenced by context (Huber, Payne, and Puto, 1982; Simonson and Tversky, 1992) and endeavor to determine the best reason for selecting a specific commodity. Particularly in cases of uncertainty, a compromise effect can systematically influence consumer choice with regard to a wide range of product sets and attributes (Chuang, Kao, Cheng, and Chou, 2012; Kivetz, Netzer, and Srinivasan, 2004; Simonson, 1989), making a moderate, compromised choice seem like the best option. When a specific brand's competitor adopts a price-cutting strategy, the ability of this brand to fight back against such price-reducing behavior (cross-elasticity) is reflected in the change of market share or sales. Competition between the brand and its competitor provides an opportunity for the brand to attract consumers, called "brand attraction power" (Francois and MacLachlan, 1995; Woodside and Walser, 2007).

When facing technology changes, organization needs to distinguish between competence-enhancing and competence-destroying innovation, or the so-called exploration vs. exploitation and ambidextrous paradox (Andriopoulos and Lewis, 2009; Tushman and Anderson, 1986; Voss and Voss, 2013). Tellis (2011, 2012) provided an excellent review on what he calls incremental vs. discontinuous innovations. This study explores incremental innovation (product memory, design, color, etc.). A product is considered a bundle of attributes, and consumer utility is a function of these attributes. Consumers' decisions often depend on a product's attributes and price, whereas the corporation's performance Porter (1985) metrics concern whether the product fits the market, gains market share, or upgrades customer utility. Competitive products are developed both across firms and within the same firm over time (Krishnan and Ulrich, 2001).

The pace of technological progress often outstrips growth in markets' demand for higher-performing technologies. As a result, incumbents can over-serve the market by producing more advanced, feature-rich products than customers need (Christensen, McDonald, Altman, and Palmer, 2016). Technological substitution is shaped by the evolution of both new and old technologies, as well as the evolution of the ecosystems in which they are each embedded (Adner and Kapoor, 2016). From the perspective of a single brand, we can observe the price competition among products (at different stages of evolution) that have the same market attributes, but different mode specifications. Rather than focus on the influence of price on sales, we investigate the alternative or complementary price relationships between different product modes and measure the attraction power of brands in price competition. We also explore whether adding a decoy product option to the choice set increases the possibility that a specific product will be selected, noting how this ecosystem has evolved from a technology change framework to a more expansive competitive response.

Strategic dualities (e.g., integration / responsiveness or exploitation / exploration) are equally important to a firm's overall success, but are to some degree in conflict with one another (Birkinshaw, Crilly, Bouquet, and Lee, 2016). To captures cross-selling or product line cannibalism by incorporating spatial mapping perspectives to understand the diffusion of multi-generation products, we aim to comprehend the spatial competition between products in a product class spanning generations. Specifically, we apply spatial competition models to analyze a national MP3 (MPEG-1 AUDIO LYER3) music player brand in terms of how the product-price variants of a specific product class (or category) influence the attractiveness of other products over different evolution cycles and probe the consumer utility function on whether aversion to losses is compromised in the considered product's choice set.

Our contributions are three-fold. First, we provide a structured process of intra-brand product development research with the implementation of spatial science. We hope that this approach encourages researchers to be flexible about incorporating critical factors, multiple points, and multiple generations into their models. Second, we present an evolution cycle approach for organizing the product price competition, using the marketing perspective of several product generations to examine the compromise effect. Product attributes and consumer behavioral interactions enable marketers to target their communications more effectively. Third, we identify the technology's trajectory and discuss design possibilities for future product lines. Assuming a consumer's inner drive for selecting a preferred product and vendors' inner drive for satisfying their growing demand by product joint space, we acknowledge the role of individual behavior and marketing in the effectiveness of product development processes. This interdisciplinary research complements previous studies on entry and technology marketing.

2. Literature review

2.1 Product life-cycle and evolution cycle

The PLC theory is used to explain the product life-cycle from a new product's entrance in the market until its elimination through competition (Vernon, 1966). From a marketing perspective, Kotler (1991) defined PLC as the sales variation of the product over its lifetime. Most products go through four stages of their life-cycle: introduction, growth, maturity, and decline. While the PLC theory has been widely discussed, many scholars have questioned its validity. Because the four fixed stages have a bell-shaped distribution, Hunt (1976) argued that it is tautological to define the stage of one product by its sales and then to forecast sales by the defined stage. Wind and Claycamp (1976) indicated that the PLC theory neglects important variables affecting sales, such as a firm's marketing activities, competitive reactions, and other relevant environmental factors. Dhalla and Yuspeh (1976) proposed that managers may mistakenly believe that a product has entered an early decline when they are not satisfied with its sales conditions, leading them to miss innovation opportunities. They concluded that the PLC theory is a very dangerous tool for managers. Tellis and Crawford (1981) claimed that although the PLC theory describes the biological state, it is an over-simplified model when used in product development. They further proposed PEC to interpret product growth and diffusion from a biological perspective.

Product evolution mainly includes four changes. (1) Cumulative change involves aggregated product evolution, wherein a product progresses step-wise on the basis of prior successful experiences. (2) Motivated change involves three forces (general, selective, and intermediary) that contribute to a product's continued evolution. (3) Directed change encompasses the linear results of change, so that a product is more efficient, complex, and progressive through evolution. (4) In patterned change, the product evolution models of divergence, development, differentiation, stabilization, and demise are developed from biological radiation models of cladogenesis, anagenesis, adaptive radiation, stasigenesis, and extinction, respectively. In the first empirical study of PEC, Holak and Tang (1990) considered the value of evolutionary cycles and assessed the influence of the general, selective, and intermediary forces on the relevant product. In their investigation, they found that the effect of advertising on the US cigarette sales was gradual, but markedly decreased as products with lineage that is more distant coexist and compete. Holak and Tang (1990), who defined their own independent and dependent variables, proposed that the PEC is an information-laden framework for reaching marketing-mix decisions.

Evolutionary cycles are abstract and difficult to measure; few researchers hereafter have assumed the challenge to continue developing operational models. Lau (2014) explored the drivers of change in product evolution. The active management of influential bodies (e.g., NGOs and the media), managerial creativity, and market factors were found to be associated with company performance. This provides insight into why some firms can maintain leadership in the market in terms of brand recognition. Whereas products in the PLC theory possess single and fixed characteristics, PEC theory includes the assumption that products are continually evolving and are based on an original model to which new functions or attributes are added. For example, product variants of the MP3 music player include differences in capacity, color, and mode (or type). Technological change can create entirely new markets that take on new products, new customers, and exploding demand. For example, MP3 technology facilitated the iPod revolution, with massive demand for related products, services, and accessories (Sood and Tellis, 2011). These in turn can be translated into next-generation technologies or being incorporated into the features and design of new products.

2.2 Compromise effect

Huber *et al.* (1982) proposed the "context effect," which states that consumers' choices are influenced by the related characteristics of different program choices. The probability that a certain product will be chosen increases if a decoy product is introduced into the set of possible choices. Simonson (1989) assumed that consumers will attempt to find the best reasons for selecting a specific product among different options and obtained three results for the predicted compromise effect and attraction effect: (1) the market share of the alternative will increase when the product choice set contains a compromised alternative; (2) the influences of attraction and compromise will be greater when consumers want to rationalize their and others' decisions; and (3) the choice between a dominant and a compromise brand is related to complex decisions. Chen, Hsu, and Wu (2019) mentioned that because consumers always prefer attractive objects, the impact of attractiveness on consumers' attitudes comes through their recognition. Consumers encode information to give meaning and, subsequently, compare it with their interests.

Agreeing that consumers' choices are influenced by their context (set of considered choices), Simonson and Tversky (1992) addressed two hypotheses related to the choice set. The "trade-off contrast" hypothesis states that consumers compare certain product attributes when they make a selection in a particular set, and that different results will be generated under different comparison baselines. The "extremeness aversion" hypothesis states that consumers wish to avoid an extreme choice outcome when there is no explicit preference. Consequently, they will select products with more moderate attributes. Kiverz *et al.* (2004) established a theoretical mechanism for the influence factor of the compromise effect. They suggested investigating whether joining the compromise effect to previous consumers' choice models would yield better prediction ability. Importantly, this model uses a single reference point, which can be helpful for market analyzers in drafting a product launch strategy and increasing the attraction of a specific product. The compromise effect can systematically influence consumers' choice under a larger product set.

Chuang *et al.* (2012) explored the compromise effect involving incomplete purchase information and demonstrated that consumers are more likely to choose the middle option when they have incomplete information. The compromise effect decreases when consumers can choose to defer their decision in an incomplete information scenario. Wu, Huang, and Wang (2015), who based their research on extremeness aversion and extended the principle of loss aversion, highlighted that the levels of extremeness aversion and the compromise effect in a wide range of pricing are higher than that in a narrower one. To summarize the literature, the compromise effect implies that consumers are loss-averse and prefer the middle commodity of their consideration set.

2.3 Brand attraction and analyzing brand competition

Previous studies have presented a multidimensional view on the definition of brand attraction. Srivastava and Shocker (1991) indicated that the idea of brand equity is derived from a multidimensional concept of brand attraction and brand value. Brand attraction denotes the potentials for performance profitability, life weaknesses, and growth scalability. In discussing brand attraction, Francois and MacLachlan (1995) considered firms' and competitors' actions from internal (essential) and external (nonessential) perspectives. The internal perspective includes consumers' long-term experiences with particular brands. The external perspective covers short-term stimuli, such as the ability of a specific brand to resist a competitor's price-reduction behavior, which may involve the market share or sales reaction of a competitive firm implementing marketing tools.

Woodside and Walser (2007) defined brand attraction as a brand's relatively greater attraction for consumers compared to other brands or the product attributes of a given brand. This definition implies that the intensity of competitive brands is an inconsistent and relative concept. Regarding methods for measuring brand attraction, MacLachlan and Mulhern (1991) recommended the use of questionnaires and conjoint analysis through survey questionnaires that can be offered to existing and potential customers. Farquhar and Ijiri (1993) used internal records as measures of brand strength from a business perspective. Russell and Kamakura (1994) suggested beginning with the transaction data of the existing market, such as supermarket scanner data in calculating brand attraction.

Russell (1992) proposed a latent symmetric elasticity structure model, decomposing the elastic matrix into two parts: symmetric alternative indicators (illustrating competition intensity among brands) and brand coefficient (measuring the overall impact of a brand on its competitors). Symmetric substitution elasticity has also been applied with the multidimensional scaling method. DeSarbo, Grewal, and Wind (2006) employed a space method to express a competitive market structure chart, which assumes a correlation between brand distance and the degree of substitution of price changes. González-Benito *et al.* (2009) divided the cross-price effect in the market response model into two elements, stating that price changes of a brand will have different effects on (1) the prices of other brands and (2) the competition brand. The asymmetric matrix derived from cross-price elasticity can be portrayed as a positioning map.

2.4 Spatial science

Spatial statistical methods involve the analysis of geo-referenced data, through which locations (especially relative ones) are explicitly taken into account (Heikkinen, 2011). These methods often include a map projection of a geographic region onto a plane, but they can also be applied to abstract spaces spanned by covariates. Researchers have applied this concept to model intra-household behavioral interactions and market basket selection (Boztuğ and Hildebrandt, 2003; Russel and Petersen, 2000; Yang, Zhao, Erdem, and Zhao, 2010). For example, Boztuğ and Hildebrandt (2003) tested whether products chosen on a supermarket shopping trip indicate the preference interdependencies between products or brands. They used the chosen product bundle as an indicator of a global utility function, in which the function related to a product bundle is the result of the marketing mix of the underlying brands, and adopted a spatial statistics-based multivariate logistic model. Comparing cross-nation buying behavior, they found strong effects for cross-category variables, but non-significant effects for base variables, such as the price and time effects of purchases. The existence of a global utility function implies cross-category dependence of brand choice behavior.

Yang *et al.* (2010) argued that quantitative models in marketing typically focus on the household as the unit of analysis, while ignoring the behavior of individuals and behavioral interactions among household members. Therefore, they developed a model to capture multiple agents' simultaneous choice decisions over more than two choice alternatives in the context of family members' television viewing. They estimated the individual's intrinsic and extrinsic preferences from a joint consumption with other members and utilized an autologistic choice model and hierarchical Bayesian to test group decision-making heuristics. The results showed the behavioral interaction that family members may exhibit in joint consumption occasions.

The literature has also looked into building agility within the new product development process and the assessment of technological opportunities (and threats) in relationship to customer needs (Teece *et al.*, 2016). Companies commonly increase product modes in their product lines to provide consumers with alternatives, but few studies have considered the implications of this practice. It is also unclear from the literature how product attributes affect product attractiveness over a product's evolution. In this paper we elucidate these important aspects of spatial science and provide new insights into consumer behavior and marketing.

3. Proposed model

3.1 Conceptual overview

This study probes the effect of the prices of different product modes for a single brand category on the relative attractiveness of other products. We discuss evolutionary stages for determining the structure of market competition, choices made by consumers among a product set, innovation types in inter-generational products, the potential product evolution path, and next-generation development. Figure 1 depicts the research concept. The decoy effect is an extension of the compromised effect that consumer may be persuaded to switch from an existing offer to another on under the presence of a third option (i.e., the decoy) that judiciously should have no influence on the consumer choice decision. For example, when asked to choose between an MP3 music player with a higher memory capacity but a poor design (unlike Apple iPod) and an MP3 player with a lower memory capacity but silver color design (iPod lookalike), customers

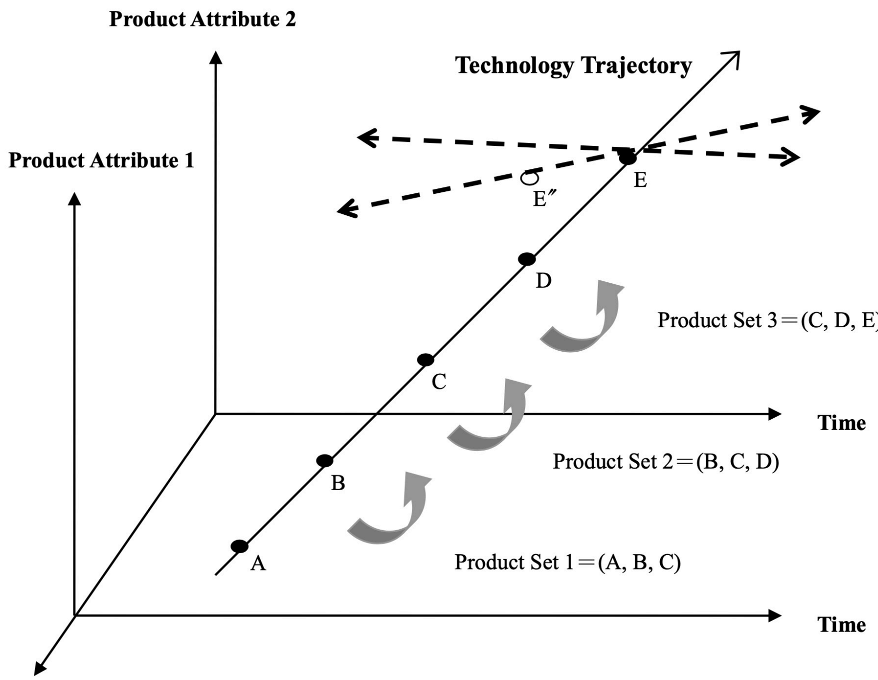

Figure 1
Sketch of the research concept

may be convinced to deviate from their choices if the product bundle is packaged by a third MP3 player that has the memory capacity as good as the latter, but even a worse design (e.g., generic product).

The focus of this study is on the dynamics of a new product's diffusion path. Studies in diffusion usually take a static viewpoint, with few discussing the dynamic complexity. We use multiple generations of intra-brand products and implement spatial science to analyze the competition of products in each evolution cycle. We assume that the considered set of product choices includes products A, B, and C in the first generation. If a consumer's aversion for losses is compromised, then the probability of option B in product set {A, B, C} will be larger than in set {B, C, D} of the second generation. Innovation, acceptance, and diffusion are related continuous processes. The compromise effect implies that brands gain shares when the product selected is the intermediate rather than the extreme option. Consequently, we assess interactions between new products in each generation and detect whether a decoy creates consumer compromise and an "extremeness aversion" mentality.

With time and technological advancement, new-generation products are introduced into the market and compete with previous-generation products. According to the diffusion model of high-tech products by Norton and Bass (1987), a new product may not immediately become a huge success, with sales growth being a gradual diffusion process. New-generation products may expand the company's sales through better specifications, wider applications, and improved features, but may also cannibalize existing products' sales. We analyze how a product's attributes influence every other product's attractiveness over various generations so as to identify interactions among multiple products and product diffusion characteristics. The technology trajectory is defined by the type of vertical or horizontal diffusion. Under different diffusion rates, product development may move towards E or E" (i.e., consumer choice for the latest product does not occur immediately, but after some time buffer) and then proceed on new trajectories, indicating various new product developments. By combining discussions of consumer psychology and the product's physical attributes, we can understand the nature of competition and market evolution.

3.2 Joint-space mapping

To investigate the interaction between new products released on the market by a multi-product brand at different points in time, we extended the results of Tang, Wu, and Lin (2011) in our research by using a logit-type market share model (González-Benito *et al.*, 2009). Through this model, we calculated the price competition index (PCI) of each product, which reflects the relative product attractiveness caused by product price changes. This calculation helps us to define the direction towards which the consumer's compromise tendency moves as technology progresses. A technological trajectory can be represented by the movement of multi-product trade-offs over different generations and the trajectory in the multi-generation space defined by these analyzed price and product attractiveness variables.

To take this analysis one step further, we integrate the competitive interaction model of market sales and the autologistic model of spatial patterns to view the product's intrinsic growth. The autologistic model is flexible at predicting the presence or absence of disease in an agricultural field on the basis of soil variables (Gumpertz, Graham, and Ristaino, 1997). Here, we apply this model to the marketing field to analyze whether a product possesses attractiveness, by considering the spatial correlation between products. As shown in Figure 2, the procedure involves three steps. In the first and second steps, we construct a PCI using the target product's actual purchase histories by all customers for different generations. This analysis includes prices and sales volumes of each product specification to determine an attraction model based on the PCI outcome. In the third step, we use the predictive autologistic choice model to forecast the probability that each product specification has an effect as if a tugging action were applied.

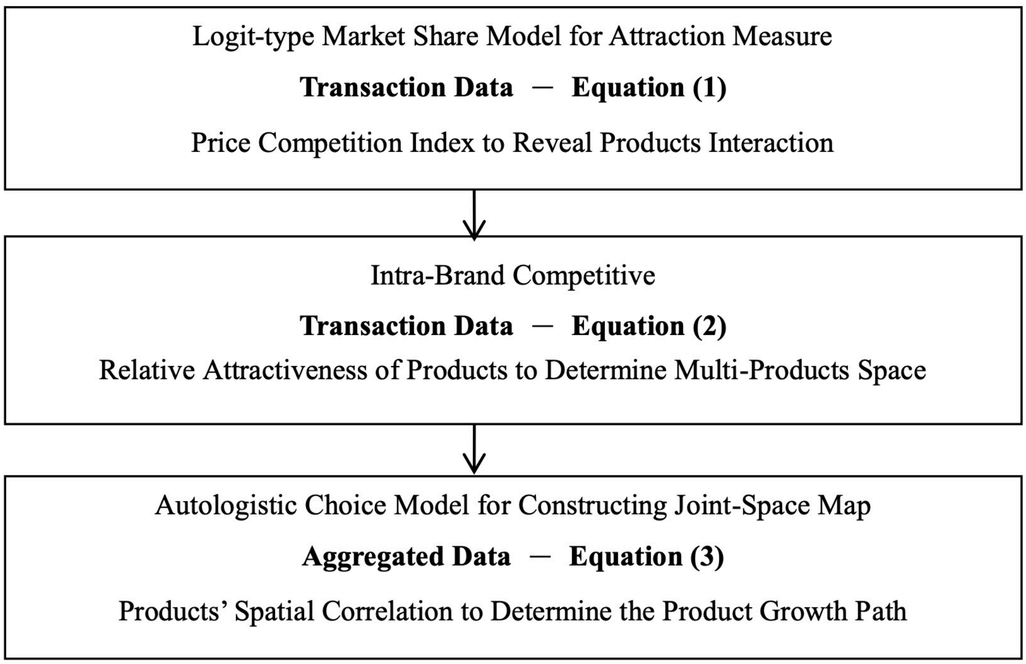

Figure 2

Conceptual overview of models

3.3 Mathematical calculations

The logit-type market share model assumes that price is the determining factor in market share. The response variable is a particular product's attractiveness. Price cross-effects are split into: (1) price changes in other products due to the price change in a certain product; and (2) the interaction influence on other competitive products due to the price of each product. Here, the subjects are various product modes under a single brand from three generations. In this way, the original relative attractiveness model among brands is transformed into a model among products of a certain brand category. The models are analyzed as follows:

$$A_t(j) = e^{\left(\alpha_j + \sum_{j' \neq j\, j' \leftarrow J} \beta_{jj} P_{t(j')}\right)} \tag{1}$$

$$\pi_t(j) = \frac{A_t(j)}{\sum_{j' \leftarrow J} A_t(j')'} \tag{2}$$

Where $\pi_t(j)$ is the relative attractiveness of product j in period t; $A_t(j)$ is the attraction of product j in period t; α_j is the interior attraction of product j independent of price effects; $\beta_{jj'}$ is the PCI of products j and j'; and $P_{t(j')}$ is the price of product j' in period t. Equation 2 calculates the relative attractiveness of product j in period t as the ratio of the attraction of product j in a certain time period (from Equation 1) to the competing products' attractiveness. Attraction is considered both without regard to prices and when influenced by prices. We focus on the latter when the attraction is caused by the prices of other existing products in the market.

In the autologistic model, the log odds (logit) of attraction in a particular quadrat (herein, a product mode or specification) are modeled as a linear combination of high or low attraction in neighboring quadrats, together with the price and memory variables. Neighboring quadrats can be defined as adjacent quadrats within a generation, quadrats in adjacent generations, quadrats two generations away, etc. This model is well-suited to the study of spatial patterns of attractiveness, for three reasons: (1) it specifically applies to binary response variables (e.g., high or low attraction); (2) it can incorporate explanatory variables; and (3) the probability of high attraction in a quadrat depends explicitly on whether the neighboring plots are attracted.

Logistic regression (LR) has traditionally been used to model non-spatial binary data (Gumpertz *et al.*, 1997). We incorporate spatial correlation into LR models by modeling the probability of high attraction in a given quadrat (product mode) as dependent on the attraction status of neighboring quadrats. This method was originally developed by physicists to model the electron spin at each site in a magnetic field (Cressie, 1991). It has been extended to ordered categorical data, such as disease ratings on a scale of 1 to 4 (Strauss, 1992). Similarly, we rate a categorical scale of product memory attributes as independent variables, because the marketing communication mechanism lies in capacity attributes, especially for technology goods. For rectangular lattices, there are some standard systems of neighbors (Besag, 1972). We apply and modify these standard systems, as shown in Figure 3. A first-order system includes only the four adjacent quadrats in the set of neighbors: two within and two in adjacent generations; a second-order system includes the four diagonal neighbors and the quadrats of the first-order system; and a third-order system includes quadrats two generations or columns away.

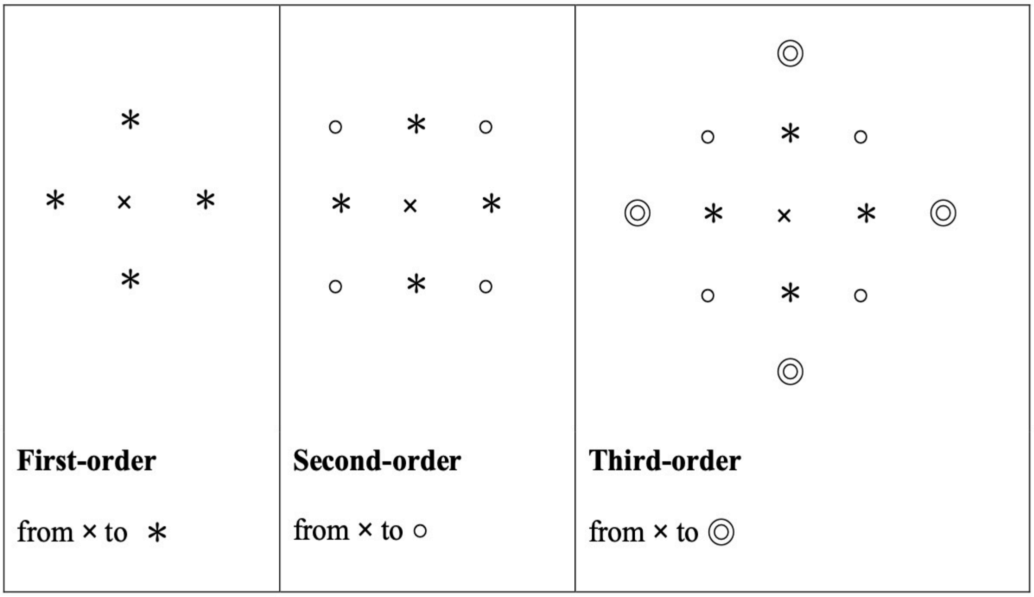

Figure 3

Modified standard systems of spatial mapping

A set of products can be defined for each quadrat in the lattice; if quadrat i is a neighbor of quadrat j, then the converse is also true. For binary data, if the response at site i depends in a pair-wise fashion on the observed number of neighbors with attraction presence and on covariates, then the conditional probability of a particular response, *yi* = 1 (high attraction) or *yi* = 0 (low attraction) is $P_r(Y_i = y_i|x_i, y_i, j \in N_i) = \frac{exp\left\{\sum_{k=0}^{r} \beta_k x_{ik} y_i + \sum_{j \in N_i} \gamma_j y_i y_j\right\}}{1+exp\left\{\sum_{k=0}^{r} \beta_k x_{ik} + \sum_{j \in N_i} \gamma_j y_j\right\}}$, where the set of products of the i[th] site is denoted as N_i. Because y_i takes the value 1 if attraction is high, the log odds of attraction being present can be expressed by Equation 3.

$$logit(P_r(Y_i = 1|x_i, y_i, j \in N_i) = \sum_{k=0}^{r} \beta_k x_{ik} + \sum_{j \in N_i} \gamma_j y_j \quad (3)$$

The spatial dependence is first-order when it is of the same magnitude both down and across generations. Here, $\sum_{j \in N_i} y_j$ is the sum of the number of high attractions in the four neighbors, and β_k quantifies the effects of the covariates, given the attraction status of the neighbors. For instance, if price is the considered covariate, then this parameter measures the log of the increase in odds of high attraction due to increasing price, after accounting for the effect of attraction in any neighboring quadrats. This type of model has flexibility, in that neighbors may be defined in any way that makes sense. If spatial correlation is present, then the covariates alone are not sufficient to account for the observed spatial variability. In some settings, spatial correlations can be completely eliminated by regression on covariates. In the present application, however, attractiveness is actually spread or whittled away from one product to another. Therefore, even after considering the variables, it is likely that the attractiveness status of the neighboring quadrats could be an important predictor of attractiveness presence.

4. Empirical application

4.1 Industry property and data sources

For the target industry, we choose the MP3 music player, a market that has already entered the saturation phase in most developed countries. After a first purchase, product sales rely on consumers purchasing upgraded products or discarding old products in favor of a repurchase. Therefore, use of the PEC rather than PLC theory can provide a more comprehensive perspective for understanding the interaction and competition among products in each evolutionary cycle. This understanding provides a basis for determining the future development trends of products when formulating marketing strategies.

There is further decline in sales as MP3 music on smartphones absorb most of the original market. Consumers' first purchases will not be the main source of sales in the future. Firms must provide more powerful product features, such as advanced wireless connectivity and high-end displays, to attract consumers to buy new products (iSuppli, 2008). Apple, Samsung, Microsoft, and iRiver have adjusted their strategic directions to pursue the development of multimedia products. They no longer manufacture only pure music-playing products, but have introduced more polybasic portable multimedia player (PMP)-related products, using innovation to stimulate a market with limited growth.

We analyze transaction data for Taiwan's market leader. Following brands MSI, Creative, and Panasonic have sequential market shares. Tang *et al.* (2011) probed the effect of the price of different product modes belonging to a single brand category on the relative attractiveness of other products. Using the database systems of certain distributors in Taiwan, they collected 15 months of sales records on MP3 transaction data (7,936 entries of observed data for 53,197 units sold). Information on the different product types sold in the observation period includes product memory, mode, buyers' name, and purchasing time. This research employs quantitative techniques that enable comparisons across time. The survival time observed for each mode of product in the market runs from 7 to 16 months; the shortest is for mode 720 (7 months from February 2005 to August 2005), and the longest is for modes 200 and 210 (both 16 months from December 2004 to February 2006).

Although dynamic random access memory (DRAM) was expensive before and after 2004, this type of memory has more memory capacity and therefore became the greatest force that pushed consumers to make purchases at that time (Yoffie and Kim, 2010). The following discussion of products is divided into three stages, with products classified according to the PEC concept. The first phase of product specifications contains 128 / 256MB products, the second contains 256MB products, and the third contains 512MB, 1G, and 5G products. Firms adjusted their product price over time. Total sales of existing products changed with new product launches. Corporations used the product mode as their communication mechanism in advertising. Modes were prioritized according to memory capacity and organized by launch dates. Apart from memory capacity, consumer purchases also depended on the order of mode.

4.2 Joint-space reasoning

The first PEC includes the 128MB generation, and the firm sold three modes. In the second PEC, the firm led in sales of the 256MB generation, with product specifications for five modes. The third PEC includes the complete product line (all generations), with product specifications for seven modes. We investigate whether the compromise effect is due to the influence of price elasticity on choice or of brand attraction on market share. Using regression equations, we derive the relationship between the price of each product and the price of other product modes in each evolution stage. Most of the reasoning is supported. By observing the positive or negative sign of the index, we are able to discern the intra-brand interaction.

In the first PEC stage, all indices reach statistical significance. Compared to the first stage, two other product modes are promoted in the second PEC, including a low-priced product. The average price of existing products in the first phase decreases in the second stage. In the third PEC stage, two products drop out, and four new specifications enter the market (modes 130, 200, 210, and 720). Modes 200 and 720 enter the market at a high price. The average price of existing products in the second phase decrease in the third stage. Regression analyses for all seven products in the third stage are statistically significant. From the PCI, the effect of a low-priced good can be summarized as generating a positive impact on other modes, thereby increasing the attraction of other products. High-priced products 200 and 720 exhibit positive influences on other the modes, adding attraction to middle-priced products. Table 1 shows the relative attractiveness of products

Table 1
Relative attractiveness of products in each pec

Mode	PEC								
	110	120	150	102	180	130	200	210	720
1	.5136	.9418	.2131						
2	.3720	.7111	.0873	.0813	.1874				
3			.0177	.0199	.0230	.1439	.3104	1.3483	.0037

stratified on each PEC stage on the basis of the above results.

4.3 Spatial correlation

After investigating the interactions between products, we integrate the findings in the spatial pattern. The autologistic model incorporates spatial autocorrelation by conditioning the probability that a high or low attraction quadrat will be attractive in neighboring quadrats, which are defined as a set of products tailored to a particular situation. We establish a categorical scale of product memory capacity, with a rating of 1 for 128MB, 2 for 256MB, 3 for 512MB, 4 for 1G, and 5 for 5G. The average critical value of attractiveness is 0.37082, from which attraction could be considered as high or low. The independent variables are price and memory; the dependent variable is the high/low relative attractiveness of products.

Three models are fitted to the data. MODEL1, defined as $logit\ (p_{ij}) = \beta_0 + \beta_1 P_{ij} + \beta_2 M_{ij}$, is an LR model to probe the effects of price and memory on attractiveness, ignoring spatial correlation. Here, P denotes product price, M is product memory capacity, and the subscripts i and j indicate generation and quadrat, respectively. This preliminary model is used to check whether the covariates alone can explain the spatial patterns. If spatial correlation is still present in the residuals, then covariates alone are insufficient to account for the observed spatial variability. As we have proven, the attractiveness status of the neighboring quadrats could be an important predictor of attractiveness. MODEL2, defined as $logit\ (p_{ij}) = \beta_0 + \beta_1 P_{ij} + \beta_2 M_{ij} + \gamma_1 W_{ij} + \gamma_2 A_{ij} + \gamma_3 D_{ij1} + \gamma_4 D_{ij2}$, is a second-order autologistic model with product price and memory as covariates. It is constructed by adding terms for attraction in adjacent quadrats within the generation (W), in adjacent generations (A), and diagonally (D). MODEL3, defined as $logit\ (p_{ij}) = \beta_0 + \gamma_1 W_{ij} + \gamma_2 A_{ij} + \gamma_3 D_{ij1} + \gamma_4 D_{ij2}$, is a purely autologistic model without covariates. These predictions, which are based solely on attractiveness in the neighboring quadrats, are used to check whether covariates can be dropped from MODEL2.

In these models the number of high-attraction neighbors is indicated by $W_{ij} = Y_{i,j-1} + Y_{i,j+1}$, referring to the number of highly attractive quadrats of two adjacent quadrats within the same generation. Here, A_{ij} is the number of highly attractive quadrats of the two adjacent quadrats in first-order neighboring generations; D_{ij1} is the number of highly attractive quadrats of the two diagonal quadrats in the (1,1) and (-1,-1) directions; and D_{ij2} is the number of highly attractive quadrats of the two diagonal quadrats in the (-1,1) and (1,-1) directions in second-order neighboring generations. Table 2 diagrams the types of neighbors of site T_{ij}.

By including four separate terms for neighbors, we can examine whether correlations across generations are as strong as those within generations, and whether any diagonal gradients in product growth exist. If we suspect that a gradient exists in a different direction, such as the (1, 2) direction, then we could add terms to the model to capture the expected pattern. All models are fitted to the inner 3 × 9 lattice of 27 quadrats, in order to accommodate models involving adjacent quadrats and quadrats two spaces away. In each PEC, nine quadrats have price and memory information (values from 1 to 5). The regression coefficients estimate the increase in odds of attraction if neighbors within a generation or in adjacent generations show attraction symptoms. In this way, we can obtain information about the degree of spread in different directions.

We implement the omnibus test of model coefficients on an overall hypothesis that general significance is likely for at least one of the parameters involved and on a rational quadratic statistic, such as chi-squared ($\chi 2$) in LR. Because significance is observed, the regression model containing the covariates presents explanatory ability. Results for $\chi 2$ and Cox & Snell show that MODEL1 and MODEL2 are significant, but MODEL3 is not (Table 3). The Hosmer and

Lemeshow test provides a formal statistical test of goodness-of-fit for LR models, assessing whether the predicted probabilities for covariates match the observed probabilities. This test is used frequently in risk prediction models. The models are fit by p-values > 0.05; therefore, the observed event rates match the expected event rates in the subgroups of the model population (Hosmer and Lemeshow, 2000). Comparing the three models, MODEL2 has better explanatory ability and less misclassification; thus, we subsequently focus on this model.

Although the omnibus test achieves significance, it does not specify the differences among the coefficients. Table 4 shows parameter estimates and the proportion of misclassified quadrats (i.e., quadrats for which the predictions do not match the observed attraction status) for each model. No predictor variables in MODEL2 are statistically significant. This result may be because consumers" risk awareness when considering new-generation products may overshadow other

Table 2

Types of neighbors of site T_{ij}

		Quadrat		
		$j+1$	j	$j-1$
	$i+1$	D_{ij1}	A_{ij}	D_{ij2}
Generation	i	W_{ij}	T_{ij}	W_{ij}
	$i-1$	D_{ij2}	A_{ij}	D_{ij1}

Table 3

Chi-square statistics for comparing models

	Omnibus			Hosmer-Lemeshow			R-square	
Model	Chi-square	df	Sig.	Chi-square	df	Sig.	Cox & Snell	Nagelkerke
MODEL1	7.793	2	.020	3.138	6	.791	.251	.407
MODEL2	15.086	6	.020	2.605	7	.919	.428	.694
MODEL3	7.600	4	.107	4.570	6	.600	.245	.398

existing differences. The regression coefficients give estimates of the increase in odds of attraction if neighbors within a generation or in adjacent generations show attraction symptoms; thus, we are able to obtain information about the degree of spread in different directions.

We model the log odds of attractiveness in a particular quadrat (logit) as a linear combination of price and memory capacity in the quadrat and high attractiveness in neighboring quadrats. Under the logit of the autologistic model with covariates, if a variable increases by 1 unit while the other variables remain constant, then the logit of the attracted product increases by β units. The odds ratio (OR) for a 1-unit increase takes an exponential index as its parameter. For every unit increase in price, an OR = 0.99 means that the odds of attractiveness decrease 1%.

For memory rating, OR = 0.00001, or nearly zero, indicating that memory may not be a main determinant of consumers‟ choice. Because the OR for across-generation selling is also nearly zero, the multi-product does not seem to have vertical diffusion. Within-generation selling demonstrates a product interaction characteristic; OR = 0.7305 for increasing product specifications, with the odds of high attraction decreasing 26.95%. Comparing the diagonal effect, OR = 0.986, indicating that the odds of attractiveness decrease 1.39% for every increase in (1,1). The odds of attractiveness increase 1.0544 times for increases in (-1,1) neighboring quadrats.

Table 4

Parameter estimates and proportion on quadrats

Model	Intercept	Price	Memory	Within-generation Selling	Across-generation Selling	Diagonal (1, 1)	Diagonal (-1, 1)	Missclass
MODEL 1	9.456	-0.001	-3.438*					14.8%
MODEL 2	63.111	-0.001	-20.542	-.314	-20.491	-0.14	.053	7.4%
MODEL 3	6.649			-1.291	-3.499	.754	-.697	14.8%

* is significance the level of 0.1

5. Discussion

5.1 Compromise phenomenon

Figure 4 illustrates the variation of the compromise effect according to the relative attractiveness of each product mode when the axes are set as the attributes. In the first PEC, mode 150 has the lowest relative attractiveness, but highest price, in the product set. Its existence generates a positive attraction for other product sales. Prices between products segment each other. Mode 120 is moderately priced in the product portfolio, but has the highest sales volume, reflecting the compromise effect. Thus, in the first PEC, consumers did not choose extreme-priced goods, but rather preferred middle-attribute items. In this case, corporations can set decoys to encourage consumers to buy the main product when introducing new products. However, firms should be careful to explore the meaning of the negative PCI with regard to goods. For example, mode 120 makes other products seem less attractive, but that does not mean that it should be excluded from the product set. According to its relative attractiveness, it is the best item in the first phase of the market.

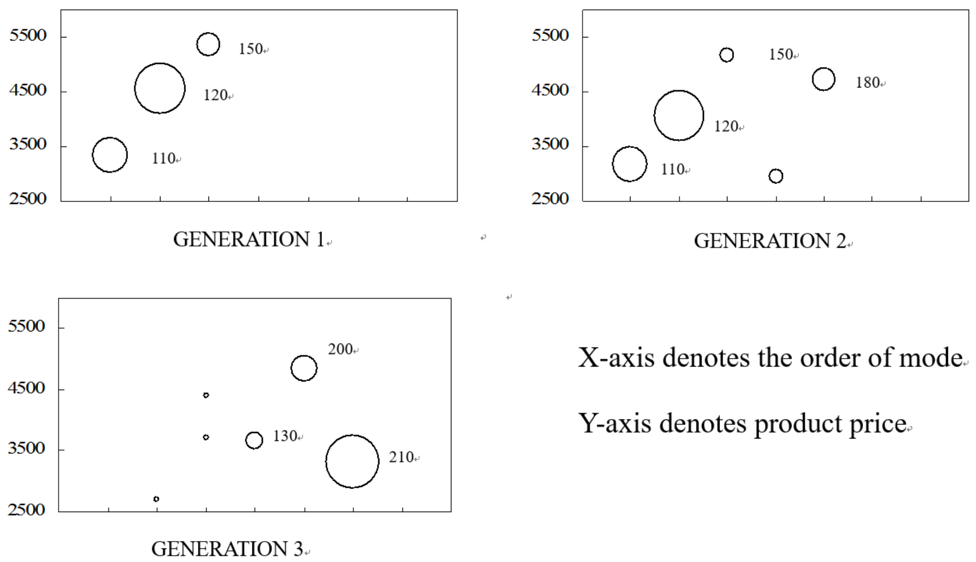

Figure 4

Product attribute position of the choice set

In the second PEC, low-priced mode 102 has a positive PCI for other products and substitutes for other modes. This finding is consistent with the extremeness aversion effect, in which consumers tend to prefer the medium-attribute product. Although its relative attractiveness is not high, mode 102 increases the attractiveness of other products, segments the prices of products in the product line, and produces positive attraction for others due to its extreme price. In the third PEC, the prices of newly introduced modes 130 and 210 mainly have a negative relationship with the attractiveness of other products, indicating that the synergy effect is not large for the whole product set. The highest priced mode 720 has a positive impact on the attractiveness of other modes and contributes to product positioning; its presence differentiates prices, generating extremeness aversion through the consumer compromise effect.

The average price of the lowest-priced mode 210 is importantly much lower than that of existing products. At that time this product was also the top seller, owing to its low price and high memory capacity. However, such a situation allows cheap goods to enter the market mainstream and could result in future product portfolio problems. In particular, this scenario does not support the prospect theory concept that an individual's best choice should be found in the intermediate and not the extreme (Kahneman and Tversky, 1979). Consumers compare product attributes when they select from a particular set, with a primary concern that their product choice will meet certain needs. Only once those needs are met will a consumer consider his or her preferences. In the situation of mode 210, the attribute level of an extreme option is beneficial and could upgrade the consumer's utility. This scenario may undermine the premise that the option of a compromise product is related to complex decisions, or it may imply that there is no explicit preference on each attribute (Simonson, 1989; Simonson and Tversky, 1989). The probability that an advantageous new product will be chosen should increase even when relevant decoy products are introduced. However, for compromise decisions, this logic is not that strong.

The direction of change in PCI is not necessarily positive, and the attraction of the price of a specific product mode compared to the other products is not necessarily positive or negative (Tang *et al.*, 2011). The extreme-priced products in a portfolio are likely to generate positive attraction, verifying the extremeness aversion of consumers. Extremely high-priced products present more stable extremeness aversion effects. When prices are too low, consumers' choices move towards the low end. In some cases, consumers may select extremely low-priced products, thereby negating the effects of midway compromise and decoy options. These findings result from the net effects of consumers' rational decisions and corporations' marketing diffusion to satisfy market needs by incremental innovation.

5.2 Multi-generational spatial diffusion

From the proposed analytical process and empirical results, we can derive a convergent thinking. The OR for across-generation selling is nearly zero. For within-generation selling, product interactions lead to increased product modes, which increase the odds of high attraction. The multi-generation products reveal horizontal rather than vertical diffusion. The attractive effect of the positive slope in Table 4 is greater than the negative diagonal slope. A negative diagonal slope (1,1) means that the product goes to the next generation and next mode, reflecting technological improvement and evolution. A positive diagonal slope (1,-1) means that the product goes to the next generation, but decreases the mode choice. Thus, we infer that the rate of technological progress is faster than the speed at which customers could absorb it, leading companies to provide more than customers demanded.

Mode 150 spans across three generations and thus can be regarded as the core product for researching the influence of horizontal and vertical diffusion. It has a diagonal neighboring effect on other products and shows a negative impact, reflecting the occurrence of cannibalism. A joint probability distribution of the attractive occurrence of multiple products can be derived when the probability of the event occurrence is properly specified, conditional on the occurrence of other modes. Product interactions possess substitution relationships, but also complementary and competitive equilibria. Because of the diagonal effect, if a product goes to the next generation but the mode choice is decreased, then the product will generate positive attraction for the sale of other products. The results provide some clues that the analyzed product category has not reached the diffused market takeoff. We recommend that corporations focus more on the core item when bringing innovations to market.

As expected, price and memory are statistically non-significant. This result may have been influenced by our consideration of only new cross-generational products. New products may be risky in consumers' profit calculation. Risk-averse consumers prefer tried-and-tested items, even if the latest ones seem better; tech-savvy consumers want the latest items, even if they are potentially risky. New-generation products may perform worse than old-generation ones. As a result, product attributes are no longer important; new technological products may not survive under the conditional probabilities of existing products.

From our findings, we conclude that evolutionary adjustments result from cumulative change, the consumer's utility function is expressed by the attraction function, and the technology trajectory is propelled by the consumers' and corporation's inner drives. In addition to the price mechanism, the scientific and technological trajectories play important roles in the compromise effect. Attractiveness moves from one generation to other; thus, the attractiveness of neighboring quadrats could be an important predictor. As the attractiveness of previous-generation products and the development of new-generation products increase, a consumer's aversion suffers more negative impacts.

Because the diffusion is mainly horizontal, we can define "organic growth" as cases in which a product not only increases the attractiveness of others, but also contributes to product positioning. This concept was originally proposed by educators in the early 1950s to entail teaching a child a group of base words, over which the child's vocabulary could later be expanded. The organic growth of products is a similar concept related to diffusion. We base the growth on a previous- or existing-generation product and see how this growth increases as new-generation products are introduced.

5.3 Intra-brand price competition

For technology companies, there is a focus on how to create a unique competitive advantage for homogeneous products and how to earn customers' support. Our results show that price is a non-significant factor in the consideration of product attractiveness; thus, the consumer compromise effect is not the only determinant of technology trajectory. More specifically, we find that the prices of future generations continued to decrease over time. From the retailer's perspective, price promotions are commonplace and have a significant effect on consumers' purchasing decisions (Blattberg, Eppen, and Lieberman, 1981; Guadagni and Little, 1983). Retailers develop promotion depth for specific product price decreases. Previous research has indicated that a higher promotion depth increases the quality-per-dollar equivalent of brands, accompanied by an accelerated purchase effect, which may change consumer brand loyalty by degrees (Bell, Chiang, and Padmanabhan, 1999; Raju, 1992).

This research uses business-to-business procurement to reflect the business-to-consumer sales situation. For a leading domestic brand, because price does not have a large influence on product attractiveness (especially in a product saturation cycle), we believe that it is important for a corporation to focus on introducing new functions or insights through research and development (R&D). Essentially, there is inherent tension between R&D and marketing when given scarce resources. Managers should allocate resources to and between two different types of activity that are both important to the company's immediate profitability and long-term sustainability (Liou, 2018). If a company makes many launches, these products are likely to cannibalize each other, and their life-cycles are likely to be short. Life span is also affected by the rate of technological progress, which may cause consumers to trend towards newer products. This phenomenon should be studied further, with an aim towards designing products with increased life spans.

6. Managerial and theoretical implications

6.1 New product development

Business growth and sustainable development are highly sought-after goals for enterprises. The autologistic model is employed to analyze the spatial-temporal pattern of new product development and its intrinsic growth. It is challenging to keep the reasoning of the research manageable when attempting to probe whether and why compromise exists, in light of the reviews of several academic communities. We argue for a synthesis of these paradigms in the product development perspective. Using an actual transaction database helps us to survey the compromise effect and may enable further decision making regarding new product launches.

Our results are an important reference for managers who are arranging their product line design and new-product launching strategy. Because consumers tend to choose lower- or even extremely low-priced products, nullifying the compromise effect and benefits of decoys, corporations should pay attention to product price segments. In our study, the average price of the products continued to decline during the sample duration, reflecting that firms in Taiwan use price reduction as a main strategy. Price reduction of a specific good does not increase the attraction of competitive items in the same brand, revealing that promoting reduction is not necessarily a good pricing strategy. To improve the attraction of a product set through pricing, corporations should observe the interactions between products to prepare the most appropriate price reduction program.

In different evolutionary cycles, the prices of some products do not have a consistently attractive effect on the sales of other modes. For example, mode 180 in the second phase did not increase the attractiveness of other commodities. In other words, even the introduction of more items did not necessarily increase the attractiveness of other products. Figure 5 shows a space scatter plot of product attractiveness, price, and generations, based on the surveyed transaction data. The results show that price segmentation and positioning in the same brand are not sufficient for brand attraction. We suggest that corporations rely on the positive price index as a strategic direction for product management and retain those products that lead to positive price competition with other products in the entire portfolio.

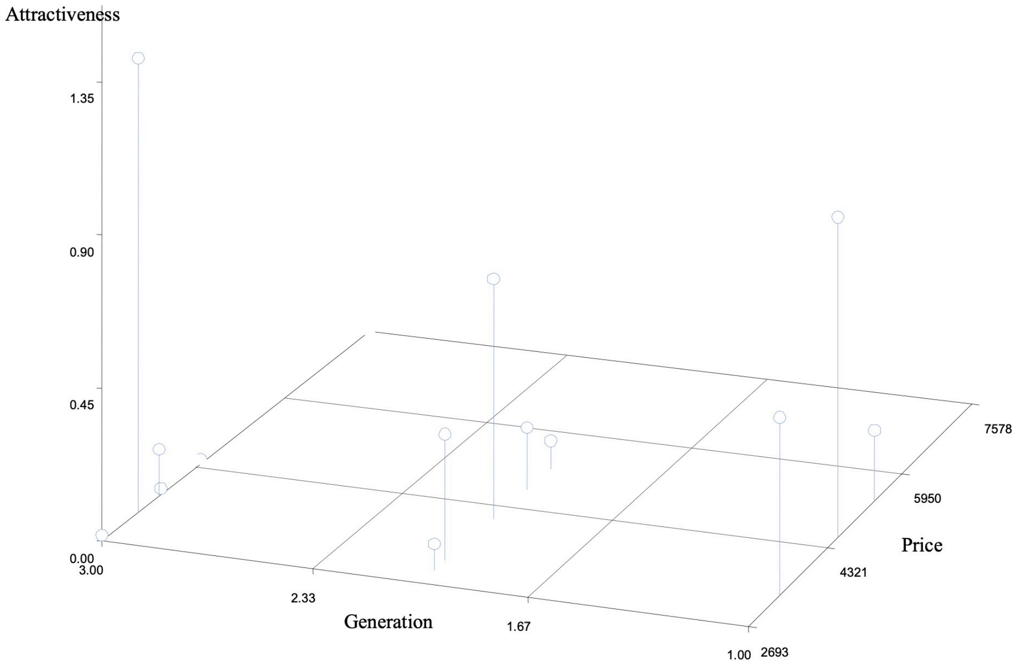

Figure 5
Three-dimensional scatter plot for different generations

Dynamic capabilities enable firms to develop innovative products or reconfigure business processes to adapt to an ever-changing competitive environment and then sustain their competitive advantages (Bi, Davidson, Kam, and Smyrnios, 2013; Pan, Pan, and Lim, 2015; Shang, Chen, Ye, and Yu, 2019; Teece *et al.*, 2016). The competitive advantage theory of Porter (1985) indicates that sustained advantage is based on long-term performance that is higher than the level of the industry. Advantages and disadvantages of organizations can be summarized as goods that are relatively low cost or exhibit differentiation. This research suggests that if brand differentiation is not apparent, not to mention the formation of competitive advantage, then there is a difference and there is a follow-up compromise.

From the perspective of global competition, although the domestic brand of the MP3 music player examined in this study is a market leader in Taiwan, its emphasis is on fine-tuning existing product features and functions, such as changing colors and increasing memory capacity. It did not inject new features and only adopted a follower strategy in its development evolution. Our research supports the arguments made for organizational ambidexterity, which include the claim that a firm cannot merely rely on effectively managing its existing resources; it must build new competencies to seize new business opportunities, markets, or technologies (Shang *et al.*, 2019). We expect that global producers of digital audio players, such as Apple, will continuously inject new functions and features into their products. To meet the rapidly changing market trends, products cannot simply be permutations and combinations of existing products, but must have completely new lives - that is, going back to the basics, to meet consumers' desires and to exceed their imagination, as they are fundamental to marketing.

Apple continues to launch multi-generation products. Apple's supplier, TPK, anticipates that the "touch screen" is the new technology trajectory (e.g., Dosi, 1982; Levinthal, 1997, 1998) and has devoted resources to technology R&D and production capacity development. Similarly, from 1984 to 2004, Microsoft continued to update its Windows operating system (Casadesus-Masanell and Mitchell, 2010). Do such multi-generational activities have a role in attracting customers who are without a product, or do companies need to expand into new markets to meet their demand for internal growth? Will Windows be able to resist being replaced by Linux, Google Android, or Apple iOS (Edelman and Eisenmann, 2011)? An incumbent naturally wants to prevent its resources from diffusing to new market entrants by creating barriers. With this study, we hope to provide a basis for reflection on the meaning of product diffusion. By considering multiple academic perspectives, we can integrate these perspectives and identify interdependencies among them.

6.2 Price mechanism

Firm innovations require considerable time to complete the development process; for example, a typical patent trial requires a minimum of two years to be completed (Chang, Lee, and Wong, 2019; Craig and Yetton, 1993). Customers demand more functions, entertaining applications, and superior quality from new products. In the smartphone industry, the average development cost per product increased by about 40% over the past decade. Apple's OEM supplier, Foxconn, has had to shorten the iPhone's time-to-market from several months to less than two weeks; such proactive and responsive market orientation is positively related to product innovation performance (Chin *et al.*, 2018). Consumer electronic products often have a leading brand dominating the industry, even though they appear to have a minority of entrants. The diffusion of these products has drawn a lot of attention, due to the sharp increase in technological improvements. To date, the popular smartphone has latent market capacity. The analysis of MP3 music players in this study should provide insights into product paths for new product categories.

Previous research on entry deterrence has suggested many strategic actions for an incumbent firm (Gruca and Sudharshan, 1995). Although we consider a single brand, the results reveal that competition in the industry usually results in lower prices with multi-generation development. This phenomenon supports prior research stating that competition results in price promotion (Narasimhan, 1988). The results can provide managers with insights about market behavior when launching new products. For example, using these insights, a manager can successfully argue why he thinks a proposed launch strategy from senior management might not achieve the desired objectives.

When a firm introduces a new product, the time and money invested in product quality, attractiveness, and pricing are critical management decisions that can dramatically affect a market entry strategy. If a product operates in many product modes in each generation, then its resources become thinly spread, which may hamper the core item's attractiveness. In contrast, use of a product segment ensures that the necessary product differencs enter more product modes in each generation. In this way, corporations can obtain improved performance from increased market share and/or upgraded customer utility.

6.3 Continuation of disruptive innovation

In the battle between consumer psychology and a product's physical attributes, we find interesting results that differ from the traditional theory of disruptive innovation. Figure 6 shows a three-dimensional surface of product attractiveness, price, and sales volume based on the surveyed transaction MP3 data. We see that the corporation reinforced its product line over time, and that the relationship between product attributes and choice form a surface, especially in the complete product-line stage. According to Christensen (2013), disruptive innovation seeks to provide simpler and more convenient products, whereas destructive innovation is often an important strategy for market followers to beat the market leader. Previous research explained disruptive innovation as a simple linear relationship, ignoring the interdependency among commodities and multi-generation space.

Assuming the rationality of individuals, we propose that the technological

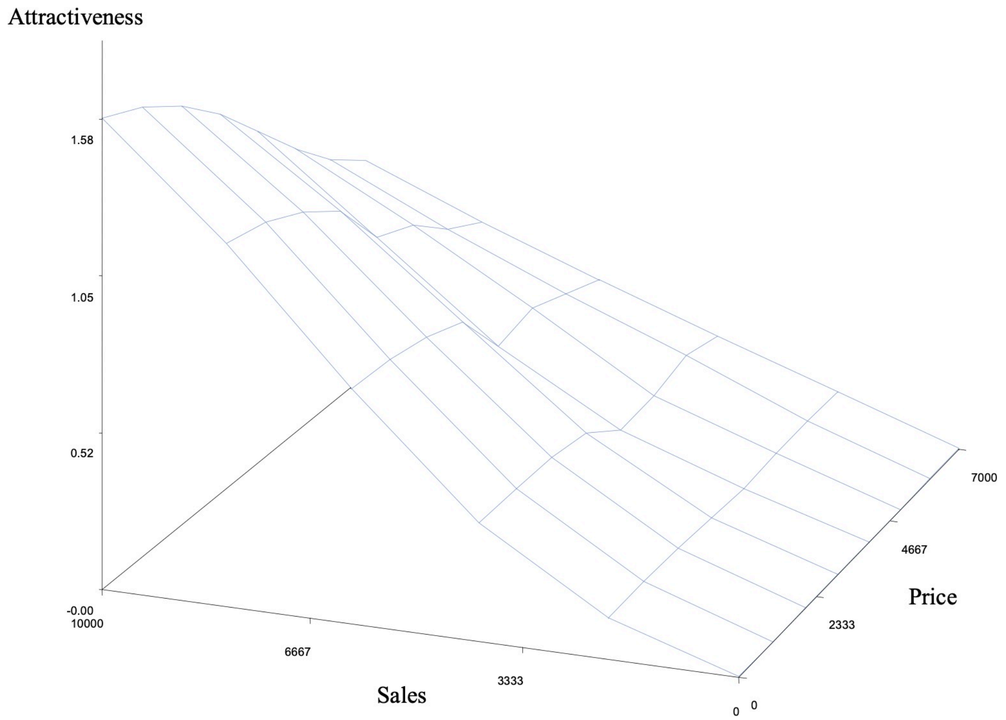

Figure 6
Three-dimensional surface for the third generation

trajectory can be represented by the movement of trade-offs among multiple products. Consumers are motivated to explore the environment and engage in selecting a preferred product. Vendors satisfy their growing demand through the product joint space. Thus, a technological trajectory is a cluster of possible technological directions whose outer boundaries are defined by the nature of the paradigm itself. We acknowledge the interaction of individual behavior and marketing in the effectiveness of the product development processes.

7. Conclusion

7.1 Concluding remarks

This study represents interdisciplinary research of marketing, statistics, strategy, and technology topics, including the interpretation of market diffusion through the biological evolution concept and consumer behavior with new product pricing, multi-product price competition in a single brand, the consumer compromise effect and extremeness aversion mentality, and spatial-temporal correlation based on a statistical model. We explore the implications of a technology product's cross-selling patterns on intrinsic growth through the integration of these theories. A model-building process is used to conceptualize the launch of an innovative product. The model considers whether a consumer will likely select products with more moderate attributes, a product pricing hazard, and the market survival of the new product over time. For a product with a bundle of attributes, the compromise effect exists within a product set of a specific generation, and consumer decision variables occur at the levels of product attribute and price.

Through spatial mapping on intra- and inter-competition of a single brand across generations, we find that the surveyed product category only diffused horizontally. The price mechanism in the autologistic model is non-significant, leading us to conclude that compromise is not the only determinant factor in a long-time technology trajectory. Thus, although corporations increase alternatives for consumers as a market entry strategy, this approach is sometimes only a transitive policy. Addressing the struggle between psychology and physical attributes, we note that a brand must meet rapidly changing market needs and trends, continuously inject new functions into their products, and provide brand differentiation to gain competitive advantage. Through product interdependence in a product line, a product not only increases the sales attractiveness of other products, but also contributes to product positioning to achieve organic growth.

Bringing together spatial science can help trace a structured process of intra-brand product development as it evolves from a technology-change framework. Our primary contribution is an updated and integrated conceptualization of multiple generations' innovation, while clarifying several of the underlying constructs. Moreover, to invite renewed academic attention in an effort to research on PEC, we propose topic areas as technology trajectories and compromise effect. Thus, as our second contribution, we articulate productive pathways forward for scholars studying product competition. Finally, the positioning of our article remains evolutionary. In many markets, the performance improvement provided by innovators exceeds the rate of improvement customers can absorb, which is sometimes referred to as "overshooting" the market (Christensen, 2013; Christensen *et al.*, 2016), and it means that a product or service is more than customers can actually use. The basis of competition then shifts to other product dimensions such as customization, price, and so on (Christensen *et al.*, 2016, 2018). In particular, ambidextrous marketing is equivalent to compromised effects, may contribute to the effectiveness of product development processes and thus make organic growth domains ripe for exploration.

7.2 Limitations

This study does have some limitations. The consumer purchase decision is the trade-off between old and new products and other attributes. Product modes reflect the channel arrangement. This study has been limited by the contents of the database and thus focuses only on the effect that a price has on product attractiveness. The conclusions target to identify the competitive relationship between the price and variation of products. We adopt the marketing idea that a product is a bundle of attributes and that performance metrics must fit with the market; however, attractiveness may vary due to other attributes. Future research should analyze the actual influence of other attributes upon product price. Possible directions include the use of the economic game theory to find a compromise solution and an appropriate number of specifications.

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