

MODELING CASCADING DEMAND: ACCOUNTING FOR THE EFFECTS OF CAPTIVE CONSUMER RELATIONSHIPS

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ABSTRACT

One of the most popular, and apparently profitable, product-mix strategies involves “cascading demand,” where the sale of an initial product locks in an on-going stream of future sales. Locking in customers increases switching costs, thus decreasing the price-elasticity of demand. A firm may take advantage of this by pricing to increase profitability in the short run. However, overpricing products can create resentment and alienate customers in the long run. This paper discusses how to model the “cascading demand” phenomenon in a marketing simulation game, accounting for the both the short- and long-term effects, and addressing the conditions determining their relative impact on performance.

INTRODUCTION

One of the most common, and highly seductive, approaches to product-line strategy is what Shapiro (1991) calls *cascading demand*. This occurs when the sale of one product leads to the sale of another. For instance, buying a certain model of printer leads to the sale of print cartridges that are only compatible with that model. One application of the principle would be what we have come to call a “relationship marketer” – a company that establishes a long-term relationship with its customers, providing them with an on-going stream of compatible products on terms that the consumers find both desirable and convenient. In another application, companies strategically design cascaded products to be incompatible with others in the market, even though the variations in design offer no added functional or symbolic benefit to consumers. Such a strategy introduces monopolistic constraints into the market, locking in consumers who can then be charged higher prices. The

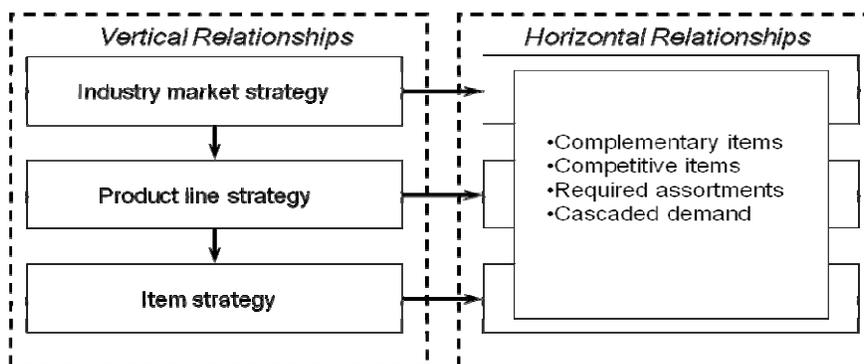
strategy appears to be commonly used in a broad range of categories, from print cartridges to camera replacement batteries to automobile parts.

By differentiating needed products so that consumers must buy them from a particular supplier, companies reduce the price-elasticity of demand. This has the direct effect of enabling companies to raise prices and extract higher margins. Second, by creating incompatibility among functionally identical products, the strategy can also have the indirect effect of reducing economies of scale, increasing costs, and subsequently raising prices still further for consumers. Third, it may increase distribution costs by forcing dealers to carry inventories of many different, incompatible products rather than a single item. Finally, the added distribution costs may cause many dealers to limit the lines they carry, thus raising transaction costs by making the needed products less accessible to consumers.

In the long run, of course, we would expect natural market mechanisms to resolve the inefficiency. If consumers find that a company locks its consumers into an unsatisfying relationship, they will naturally gravitate to other suppliers who don’t engage in this practice. In fact, we have seen this happening. America Online (AOL) dominated the Internet portal market in the 1990s and appeared to lock in its customers by means of a proprietary browser that made it hard for customers to drop the service. When attractive alternatives became available, the built-up resentment among AOL customers was so great that it all but destroyed the company’s customer franchise.

Another example involves open-source software. One of the features of the open-source movement has been to seek grass-roots support for common, non-proprietary standards for basic technologies that apply to a broad range of products and brands, a movement that has drawn increasing support from consumers who have been held captive in a proprietary relationship with Microsoft.

Exhibit 1: Product-Line Strategy as Vertical and Horizontal Relationships



Why is the strategy so popular if there are so many potentially adverse long-term consequences? Because there is also an opportunity for abnormal short-term profit! First, in many cases, the natural market mechanisms take time to offer alternatives to *cascading demand*. Second, in many industries, the market is dominated by a few large companies, each of which appears to be trying to establish dominance for its proprietary standards, hoping to lock in attractive streams of future business. Those that succeed find the strategy attractive, and those that don't lack the market presence to introduce a common standard. Third, many consumers do not appear to think past the initial (often very low cost) of the product that creates the cascaded demand. They may not recognize the cost of cascaded products until they find themselves locked into future purchases. This creates an ongoing revenue stream to the company, providing short-term profits. Fourth, and most important, many companies may not have performance metrics that recognize the long-term cost of resentment created by short-term over-pricing, so there is little motivation for managers to look past the short-term profits generated by the strategy.

To illustrate these principles, consider the case of Apple's line of iPod products. Upon observing the popularity of the line, Apple apparently made a decision to introduce a proprietary interface. The products' popularity suggested that Apple would continue to sell iPods, regardless of what kind of interface the company used. No other companies had sufficient market presence to challenge Apple's approach. Apple's path was made easier by the fact that consumers appeared to be focusing their attention on the price of the iPod itself, not on the additional cost of purchasing a proprietary backup or replacement interface. In the end, of course, consumers would become aware of this cost, and would perhaps become resentful. However, it is possible that Apple was evaluating its decision based on projected short-term profits from the sale of its interfaces, not on the loss of long-term goodwill resulting from consumer resentment.

Negative effects notwithstanding, there are also many situations where a strategy of *cascading demand* might be

both appropriate and attractive in the long run. For instance, Chris Anderson's (2009) best-seller, *Free*, cites a number of different situations where consumers are apparently delighted when initial products are free and consumers pay with follow-up sales. Clearly, the strategy merits careful managerial attention. This, in turn, suggests that the strategy should be addressed in marketing simulations to give students practical laboratory experience. The purpose of this paper is to discuss the principles and how they might be incorporated into standard marketing simulation algorithms.

CASCADING DEMAND IN THE CONTEXT OF PRODUCT-MIX STRATEGY

Shapiro (1991) frames cascading demand in the larger context of product-line strategy. Exhibit 1 summarizes his approach. He distinguishes between two strategic dimensions – *vertical* and *horizontal*. Under his *vertical* dimension, he discusses three decision levels:

1. *Industry- market strategy* refers to the kinds of markets the company will pursue. For instance, Apple Computer's strategy includes lines addressing the computer market (Macintosh), the personal media player market (iPod), and the smart-phone market (iPhone).
2. *Product-line strategy* addresses how the company approaches each market. For instance, in the computer market, will the company offer multiple brands (as in the old Apple II versus Macintosh lines)? Multiple product types (desktops versus notebooks versus mini-computers)? A full line of accessories and services (complete assortment of cables, auxiliary storage, printers, warranty programs, and so forth).
3. *Product-mix strategy* refers to the specific items available within each line (specific computer configurations, types of accessories, and so forth).

Shapiro's *horizontal strategy* dimension addresses the relationships that might exist among elements within the

product line. These relationships can exist at any one of the three vertical levels. However, Shapiro identifies four types of relationships: See Exhibit 1

1. *Complementary products.* A product is complementary if its sale helps the sale of another item. For instance, a computer and a printer would tend to be complementary.
2. *Competitive products.* A product is competitive if it tends to be a substitute for the other item. For instance, two different models of a computer would tend to be competitive.
3. *Required assortments.* While Shapiro does not actually use the term “required assortment,” it is implicit in his analysis of horizontal relationships. If items are complementary, customers might reasonably expect them to be available from the same supplier, thus providing a more efficient shopping experience. Similarly, if customers wanted to compare competing models or, as would be common for industrial buyers, to purchase multiple models for use in different parts of the organization, they too might expect these to be available from the same supplier.
4. *Cascading demand.* Cascading demand occurs when the sale of one product leads to sales of another. We have already given the example of the Apple iPod’s proprietary interface.

Product-line strategy has generally been addressed in the simulation literature through the discussion of *product mix*. The two concepts are closely related. Product mix usually refers to what Shapiro terms *horizontal relationships* – the products included in a particular line, or at a higher level, the lines a company carries or even the types of lines it handles (as determined by Shapiro’s *industry market strategy*). Shapiro argues that these decisions are driven by both a company’s capability and the benefits potential lines deliver to the company’s customers. These, in turn, lead to a planning process in which managers make product-line/product-mix decisions in light of four factors:

1. Customer needs
2. Competitive offerings
3. Operating capabilities
4. Marketing strategy

Our concern here is how to model the underlying organizational and market dynamics that make these decisions meaningful, so they can be incorporated into business simulation games. Andrews, Cannon, Cannon, and Low (2009) discuss four, non-mutually-exclusive approaches:

1. *The competitive interaction approach.* This grows out of positioning theory (Johnson 1971) and has

been adapted to the simulation literature in the form of Teach’s (1984, 1990) “gravity flow” model. The impact of marketing-mix decisions is determined by the distance of each product’s attributes to the idea attributes for each of the market segments, relative to those of the competition. Game participants are rewarded for effective product-mix decisions by incorporating the distance measure for each product into the demand equation for each market segment (Gold 2005).

2. *The desired portfolio approach.* This approach is an adaptation of the *competitive interaction* approach, developed by Cannon, Cannon, and Schwaiger (2006), draw on the work of Rust, Zeithaml, and Lemon (2000). They argue that the *competitive interaction* approach ignores the effect of what we have referred to above as “required assortments” in our discussion of Shapiro’s (1) discussion of *horizontal relationships*. A supplier that fails to provide a required assortment becomes relatively less attractive as a source for all its products. Cannon, Cannon, and Schwaiger (2006) account for this by adapting Teach’s gravity flow model, treating the supplier as if it were a product and the assortment of products it provides as if they were product attributes. The resulting distance measure is reflected in a customer loyalty factor. Game participants are rewarded for effective product-mix decisions by incorporating customer loyalty into a measure of customer lifetime value, following a procedure developed by Cannon, Cannon, and Schwaiger (2005b).
3. *The volume-oriented resource utilization approach.* In contrast to the *competitive interaction* and *desired portfolio* approaches, which use customer needs as a criterion for evaluating product-mix alternatives, the *volume-oriented resource utilization* approach looks at production capabilities. Game participants achieve greater production volume, and hence, economies of scale by selecting items for the marketing mix that share fixed (capital) and variable (labor and materials) cost factors. Game algorithms yield these economies by spreading fixed capital investments over greater unit volume and/or by providing volume-oriented discounts to achieve lower unit variable costs (Gold 1992).
4. *The constraint-based resource utilization approach.* In this approach, Andrews, et. al. (2009) draw on the theory of constraints (Goldratt and Cox 1992) to link production capabilities with customer needs. The theory argues that production and demand factors are never perfectly balanced in a real organization. If production capabilities exceed customer demand, a company may want to adjust the product mix, shifting to markets with

that yield higher margins with lower unit demand; if production capabilities fall short of demand, the company may want to adjust the mix to utilize the scarce factors more efficiently, shifting to more labor-intensive or more capital-intensive products, depending on which factor is in greater supply; and so forth. A game structured to address this approach would feature a number of product-mix and/or market-demand alternatives, where the supply of the various factors of production are constrained. This rewards game participants for optimizing the use of scarce factors to maximize profitable throughput (Chakrovorty and Verhoeven (1996).

Looking again at Shapiro's (1991) *horizontal relationships, complementary products* and *required assortments* are addressed by the *desired portfolio approach*. Treating products within the mix as attributes of the supplier's overall product offering, game participants would be penalized through falling customer equity for any failure to offer a required assortment. While consumers do not necessarily require a supplier to carry complementary products, the fact that they do no doubt makes the supplier more attractive. This can be addressed by assigning an importance weighting to each of the products in the portfolio to reflect their degree of complementarity.

The *competitive interaction approach* models the effect of *competitive products*. Two products are competitive when they offer similar attribute profiles, as reflected in their proximity on a positioning map. Clearly, competitive products within the same product line are likely to cannibalize each other's sales. However, a company will often introduce potentially competitive products to capture sales that might otherwise go to competing companies. Furthermore, Shapiro (1991) notes that competitive products are often part of a required assortment, especially in industrial marketing. For instance, a company might want to purchase a number of different, potentially competitive models of computer, whereas a consumer is likely to buy only one. This could be addressed by including both the *competitive interaction* and *desired portfolio approaches* in the same simulation.

Cascading demand appears to be closely related to the *desired portfolio approach*. It involves a required assortment, where the supplier must provide the cascaded product. However, the phenomenon potentially affects loyalty in two other ways, both of which are fairly easily accommodated by the *desired-portfolio* algorithm as Cannon, Cannon and Schwaiger (2006) present it. First, the desired-portfolio algorithm evaluates the quality of a product-mix by the degree to which it includes desired products. Cascaded products would always be included, because inclusion is central to the cascading strategy. However, the quality of product-mix is also a function of the quality of each product's features relative to customer expectations. Therefore, loyalty may be negatively affected

by the inclusion of an important (even requisite) cascading product that is a poor quality fit within the customer's ideal portfolio.

Second, as mentioned above, firms may attempt to gain short-term profit by charging high prices for cascading products. This would also adversely affect loyalty through the quality of the portfolio price relative to customer expectations. The magnitude of the cascading product price effect on loyalty is proportionate with the importance of the product within the portfolio, which in turn is proportionate with the strength of the proprietary relationship.

Let us now turn our attention more specifically to the cascading demand problem. To properly account for the value of the *cascading demand strategy*, we need an algorithm that balances abnormal short-term profit generated by high prices associated with locked in purchases of the cascaded product against the potential long-term losses resulting from consumer resentment.

MODELING THE EFFECTS OF CASCADING DEMAND

Factors Influencing the Revenue Resulting from Cascading Demand

To simplify our discussion, we assume that the profit impact of *cascading demand* is due to the inelastic demand resulting from the cascading strategy. The costs are easily addressed within the basic algorithms proposed by Gold (2005). Our task here will be to develop a theoretical basis for estimating the revenue effect of the strategy.

We have defined cascading demand as a situation where the purchase of one product leads to the purchase of another. We can state this mathematically as a conditional probability, $p(b|a)$, where a represents the purchase of an initial branded product that conditions b , purchase of the cascaded product. This, of course, can describe any *complementary products* or a member of a *required assortment*, as suggested above. The key to our dilemma is the fact that both a and b are branded products, not merely members of broader product categories, which we might represent as A and B . In its extreme (albeit, common) application, cascading demand makes b both necessary to the use of a and a incompatible with B , so the company has a virtual monopoly on the cascaded product, yielding a probability of $p(b|a) = 1.0$. This would be the case with a printer (product a) that requires a uniquely configured, proprietary cartridge (product b) to function.

In less extreme applications, product b might not be absolutely necessary to the use of a , leading to a high, but less than 1.0 probability. This would be the case for Apple's proprietary iPod interface cord, where the iPod (product a) came with a cord, and product b would only be purchased as a replacement or additional cord.

This suggests, then, that a simulation modeling cascading demand would need to include environmental cues enabling participants to estimate $p(b|a)$. First, to what

degree is b necessary to the effective use of a ? Can consumers get along without it?

If b is necessary to the effective use of a , how likely are consumers to forego the use of a due to the cost of b , the inconvenience of obtaining it, or simply because of resentment at being coerced by the company? How central or necessary is the function of a to the consumer's life? Are there non-cascaded substitutes available? How expensive are they? How well do they deliver the desired benefits?

A third set of questions helping to estimate $p(b|a)$ are potential substitutes for b . For example, in the case of printers, we now find a host of suppliers available on the Internet who supply generic replacement cartridges for virtually any brand and model of printer, as well as refill kits that provide another type of substitute at an even lower price. Again we ask, are there substitutes available? How expensive are they? How well do they deliver the desired benefits? Are there risks, such as potential incompatibility, invalidation of product a 's warranty, ethical questions regarding potential violation of patents or intellectual property?

Factors Influencing the Customer Satisfaction or Alienation Resulting from Cascading Demand

All else being equal, cascading demand would appear to be an attractive policy whenever the nature of the product makes it feasible. This is no doubt the reason it is so popular in marketing today. But all things are not equal. As we have noted, the strategy may lock in sales to create virtual monopolies. Monopolistic pressure is distasteful, both to society as a whole and to individual consumers. Society suffers because it decreases the economic efficiency of our market system, decreasing our overall standard of living. Individuals suffer through the lack of responsiveness to consumer needs that inevitably result from decreasing competition. They pay higher prices, often for inferior products (requiring more frequent replacement), with less convenience (more difficult to purchase, due to limited distribution resulting from the greater variety of functionally equivalent products). This results in customer alienation.

Alienation results when consumers are constrained to purchase products (product b) that deliver less value than might otherwise be available in an unconstrained market environment. This creates resentment when consumers perceive this difference in value and when the value relates to aspects of the product that are important to consumers. Stated more formally, it is the perception of a value-discrepancy -- $v(b)-v(B)$, where $v(b)$ is the value of product b as compared to $v(B)$, the value of some other product that delivers the same functional benefits.

Of course, a company might very well create cascaded products where $v(b)$ is greater than $v(B)$, thus creating extra value for customers, creating greater satisfaction rather than alienation. Apple provides a useful example. The company relies heavily on a strategy of cascaded demand. While this has created a great deal of customer alienation, many customers appear to find Apple's exclusivity a positive

attribute, symbolic of the brand's uniqueness and innovative tradition. However, a more concrete example might be the development of a printer technology that used a proprietary cartridge to produce Laserjet® speed and quality at Inkjet® prices.

The potential for customer satisfaction or alienation has a number of drivers. The most obvious is whether there is a real positive or negative value discrepancy. But more important is the perception. The presence of alternatives is obviously important. However, if all the brands are using the same cascading-demand strategy, all the alternatives will feature the same incompatibilities across brands. This will cause many consumers to perceive the cascading model as normal. Introducing generic alternatives in the market makes the value discrepancy more obvious and weakens the proprietary nature of the strategy. We would expect the greatest contrast between high profit and consumer alienation to occur when a number of different companies are all practicing a highly effective cascading-demand strategy at the same time as a high-profile public outcry against the costs to consumers and society as a whole. This type of discussion is becoming increasingly present with the advent of Internet-based social media (blogs, etc.) and the growth of the "open-source" movement and the concomitant call for industry-wide standards for compatibility. Establishing this kind of market context goes beyond the simulation algorithm to the description of the game situation itself.

Long-Term Effects

Both the added revenue and the increase in customer loyalty resulting from cascading demand are confined to a single purchase cycle. If nothing else happens, the effect of increased customer satisfaction or consumer alienation comes when consumers are ready to replace product a . Again, the expression of this alienation depends on the availability of alternatives. If consumers resent Hewlett Packard Corporation (HP) for locking them into the purchase of replacement printer cartridges that cost almost as much as the printer itself, the loyalty expressed through their purchase of HP print cartridges is not likely to persist to their selection of a replacement printer.

If meaningful alternatives are available, consumers might express their resentment with a determination never to darken the commercial doors of HP again. This is analogous to what happened to AOL, as described earlier. When meaningful Internet connections and portals became available, customers left in hords.

Incorporating Cascading Demand into Marketing Simulations

Our task is facilitated by the availability of established models for incorporating both added revenue and the effect of consumer alienation. If we can establish the incremental revenue created by the strategy, we need only add it to the conventional demand equation proposed by Gold (2005) – what Cannon, Cannon, and Schwaiger (2005a) refer to as

the “Gold standard.” In order to capture the impact of consumer alienation, we need only establish an adjustment to customer loyalty, and from there, an adjustment to the effectiveness of our marketing budget, a problem addressed by Cannon, Cannon and Schwaiger (2005b, 2006).

Modeling Revenue Effects. Let us begin with the revenue effects. In order to evaluate these effects, presumably a game player would estimate the increase in revenue resulting from the cascading approach. However, from a modeling perspective, we need only determine the actual sales of product “*b*” in the current year. These are captured in Equation (1). For convenience, we have adapted the notation used in Cannon, Cannon and Schwaiger’s (2006) “desired portfolio” approach for modeling product strategy, replacing product “*a*” from our earlier discussion with d_1 to denote the purchase of the lead product that creates the cascading demand. The cascaded product “*b*” becomes d_i , denoting the purchase of one or more cascaded products. Again, drawing on the printer case as an example, d_i would represent the purchase black and/or color ink cartridges.

$$q_{i,j} = \sum_{t=-n}^0 q_{1,j,t} \cdot p(d_i | d_1)_j \cdot u_{i,j} \quad (1)$$

Where

- $q_{i,j}$ = Unit demand for cascaded product i in segment j .
- n = The average life of product d_1 .
- $q_{1,j,t}$ = Unit demand for the lead product 1 in segment j for year t .
- $\sum_{t=-n}^0 q_{1,j,t}$ = The total number of lead-product units in use by customers, as determined by the sum of purchases over the average life of the product.
- $p(d_i/d_1)_j$ = The conditional probability that ownership (purchase within the life of the product) of lead product 1 will result in a purchase of product i in segment j
- $u_{i,j}$ = The usage rate, or average number of purchases of product i per year in segment j .

Beginning with the simplest case, where $p(d_i/d_1)_j$ is equal to 1.0, we would find a perfect cascading demand effect. The number of customers would be equal to the number of lead-product units in current use, which is the sum of lead-product purchases over the life of the product. Current sales of the cascaded product ($q_{i,j}$) times the average number of units of the cascaded product i ($u_{i,j}$) consumed each year. For instance, suppose a printer had an average useful life of three years. The number of printers (the lead product) would be the cumulative number of printers purchased over a three-year period. Usage ($u_{i,j}$) would be the average number of ink cartridges used per year. In the case of the iPod interface cord, it would probably be something less than 1.0, assuming that the average consumer would

likely purchase fewer than one cord in the life of the iPod, and certainly fewer than one per year.

In the case of the iPod interface cord, we would also expect $p(d_i/d_1)_j$ to be less than 1.0 as well, since many consumers would probably not buy a supplementary or replacement cord. It would, however, be larger for the segment of consumers who tended to use the iPod in various locations, interfacing with multiple computers. Clearly, $p(d_i/d_1)_j$ could also be treated as a variable, perhaps as a function of where the product is in its life cycle and/or its sales volume. For instance, a printer cartridge that sells very well would no doubt stimulate competitors to enter the market with compatible substitutes, thus decreasing $p(d_i/d_1)_j$. This might motivate some companies to change models frequently, introducing a need for new incompatible cartridges to discourage generic competition.

Modeling Customer Alientation. Cannon, Cannon and Schwaiger (2005b) suggest that customer alienation can be expressed through a customer loyalty variable ($L_{j,t}$). This, in turn, is reflected in falling customer lifetime value (CLV), and hence, the value invested in customer equity. According to their model, loyalty is a function of relative price, product, and marketing budget effectiveness, as expressed in equations (2) through (5) below:

$$L_{j,t} = a \cdot \left[L_{\min} + (L_{\max} - L_{\min}) \cdot \left(\frac{(\tilde{P}_{j,t} \cdot \tilde{D}_{j,t} \cdot \tilde{M}_{j,t})^b}{c + (\tilde{P}_{j,t} \cdot \tilde{D}_{j,t} \cdot \tilde{M}_{j,t})^b} \right) \right] + (1-a) \cdot L_{j,t-1} \quad (2)$$

$$\tilde{P}_{j,t} = \left(\frac{\bar{P}_{j,t}}{P_{j,t}} \right) \quad (3)$$

$$\tilde{D}_{j,t} = \left(\frac{\bar{D}_{j,t}}{D_{j,t}} \right) \quad (4)$$

$$\tilde{M}_{j,t} = \left(\frac{M_{j,t}}{M_{j,t}} \right) \quad (5)$$

where

- $L_{j,t}$ = The customer retention probability for segment j at time t
- L_{\min} = The minimum loyalty the company can be expected to achieve
- L_{\max} = The maximum loyalty the company can be expected to achieve
- $\tilde{P}_{j,t}$ = An index of relative price advantage in segment j
- $\bar{P}_{j,t}$ = a reference price, against which the relative performance of the company would be compared in segment j (generally that of the next closest competitor)
- $P_{j,t}$ = The company’s effective price in segment j
- $\tilde{D}_{j,t}$ = An index of relative product-market fit in segment j
- $\bar{D}_{j,t}$ = a reference product-market fit, against which the relative performance of the company would be compared in segment

- $D_{j,t}$ = j (generally that of the next closest competitor)
the company's product-market fit in segment j (average difference, or gap, between the actual product attributes and the ideal product attributes based on customer preferences in the segment)
- $\tilde{M}_{j,t}$ = An index of relative budget performance in segment j
- $\bar{M}_{j,t}$ = a reference budget, against which the relative performance of the company would be compared in segment j (generally that of the next closest competitor)
- $M_{j,t}$ = The company's effective marketing budget in segment j
- a = a smoothing factor to account for customer "inertia" in withdrawing loyalty (suggested $a=1- M_{j,t,3}$, or the complement of the proportion of loyalty due to retention equity)
- b = a parameter determining the slope of the response curve (suggested $b=10$)
- c = a parameter determining the shape of the response curve (suggested $c=1$)

Drawing on Cannon, Cannon and Schwaiger's (2006) "desired portfolio" model, we can conceptualize product effectiveness as a function of the degree to which the company offers consumers a desired portfolio of products. As suggested by equation (6), the desirability of the portfolio is a function of its distance ($D_{j,t}$ or D_j , omitting the time subscript t for convenience) from a segment's ideal. Each product is weighted by its relative importance ($w_{i,j}$) to the segment. The product weighting ($w_{i,j}$) and product attractiveness ($d_{i,j}$) will be particularly important to our discussion, because it is through these that the cascading and long-term customer satisfaction/alienation effects will be expressed.

$$D_j = \sqrt{\sum_{i=1}^{n_j+1} w_{i,j} (I_{i,j} - d_{i,j})^2} \quad ; \quad \sum_{i=1}^{n_j} w_{i,j} = 1 \quad (6)$$

where

- $I_{i,j}$ = the components of the ideal product portfolio for segment j , with "1" indicating that product i was included in the portfolio.
- $d_{i,j}$ = the components of the actual product portfolio, ranging from "0" to "1", with "1" indicating that product i was ideally suited to customer needs and "0" indicating that it was either missing from the portfolio or is so poorly suited to consumer needs that it is effectively missing.
- $w_{i,j}$ = a weighting factor (between "0" and "1") representing the relative importance of product i in segment j 's ideal product

- portfolio
- n_j = the total number of products included in the ideal portfolio for segment j .

Following the logic of Teach (1984), n_j+1 represents a fictitious attribute for which the ideal value is always "1" but that is always missing from the portfolio, so at least one value of $d_{i,j}$ is "0." This, in turn, ensures that the value of D_j is never "0," as demanded by equation (4).

Addressing the weighting issue first, let us consider the simple situation where $p(d_i/d_j)$ is equal to 1.0, that is, where purchase of the lead product ($d_{1,j}$) locks in the purchase of the cascaded product ($d_{i,j}$). This creates a need for the company to offer the cascaded product as part of its portfolio. To make this more concrete, we are saying that offering a printer with a proprietary cartridge means the company must also offer the cartridges (or ensure that someone else does) if the product is to be viable. We can capture the logic of $w_{i,j}$ in equation (7):

$$w_{i,j} = \frac{w'_{i,j} + \sum_{i=2}^{n_j} p(d_{i,j} | d_{1,j}) \cdot w'_{1,j}}{\sum_{i=1}^{m_j} w_{i,j} + \sum_{i=2}^{n_j} p(d_{i,j} | d_{1,j}) \cdot w'_{1,j}} \quad (7)$$

Where

- $w'_{i,j}$ = the initial weighting of product i in segment j 's ideal portfolio prior to introducing any effects of cascading demand.
- $w'_{1,j}$ = the initial weighting of the lead product in segment j 's ideal portfolio prior to introducing any effects of cascading demand.
- m_j = the number of products in segment j 's ideal portfolio, including the lead product that creates the cascaded effect.
- n_j = the number of cascaded products in segment j 's ideal portfolio.

Because the weights must sum to 1.0, we begin with an initial set of weights ($w'_{i,j}$) that express the relative weights of the various products. We then add in the effects of cascading demand and allocate the weights proportionately to equal 1.0. Failure to include any products in the desired portfolio will be reflected proportionately to its final weight through the calculation of $D_{i,j}$ and ultimately in loyalty itself, as shown in equations (6), (4) and (2).

Turning now to product attractiveness, we note that Cannon, Cannon and Schwaiger (2006) based their "desired portfolio" model on the assumption that a product's presence in a company's portfolio was sufficient to meet a segment's need for the product. They point out, however, that a more realistic model might combine the "competitive interaction" approach with the "desired portfolio," allowing a company's products to be present in the company's product mix, but fall short of meeting the segment's ideal.

They don't advocate this approach, because increases the complexity of the game might distract students from the issues raised by customers' needs for a "desired portfolio." However, it provides an extremely useful method of accounting for the potential effects of exploiting cascading demand. Consider equation (8):

$$d_{i,j} = \frac{1}{\sqrt{\sum_{k=1}^{m_j+1} w_{i,j,k} \cdot (I_{i,j,k} - a_{i,k})^2}} \quad (8)$$

where

- $d_{i,j}$ = the individual product fit for product i relative to the corresponding ideal within the portfolio for segment j .
- $I_{i,j,k}$ = the ideal level of attribute k relative to product i and segment j .
- $w_{i,j,k}$ = a weighting factor (between "0" and "1") representing the relative importance of attribute k relative to product i in segment j 's portfolio.
- $a_{i,k}$ = the level of attribute a possessed by product i in the company's product mix.
- m_j = the number of relevant attributes for product i in segment j 's ideal portfolio.

Recall that cascaded demand may create monopolistic power, once consumers have purchased the lead product. If consumers buy an iPod and want an extra interface cord, they must buy it from Apple. The danger of customer alienation is twofold: First, in order to increase short-term revenue, Apple might increase the price of the cord beyond its intrinsic market value, relying on the cascaded effect to protect sales. This creates a price dissatisfaction and reduces loyalty, as shown in equations (3) and (2).

The second danger is that a company will skimp on attributes and produce a product that falls short of segments' ideals, solely relying on the cascaded effect to support sales. As with over-pricing, producing a deficient product reduces the value of the product ($d_{i,j}$), thus reducing overall product-portfolio effectiveness (D_j) as shown in equation (8). This will again reduce loyalty, based on equations (4) and (2).

The reverse is also true. An attractive price, notwithstanding the company's monopolistic position created by cascaded demand, may reduce short-term profits, but buy customer loyalty. Similarly, investing in superior cascaded products, notwithstanding the fact that short-term sales may not require them, also buys customer loyalty.

SUMMARY AND CONCLUSIONS

Within the general category of product-mix models, one of the most topical issues involves the strategic interactions among products. These are particularly topical with the

development ever more complex combinations of products and pricing schemes. One of the most popular is what Shapiro (1991) calls *cascaded demand*, where the sale of one product locks in future sales of another. We have cited the example of printers and print cartridges, and of iPods and its proprietary interface cord. However, the applications are legion – purchasing cameras with proprietary batteries and cords, automobiles with incompatible aftermarket parts, cell phones with incompatible SIM cards to prevent changing carriers.

In theory, consumers would anticipate the full costs of the entire package, including future follow-on sales. However, in practice, the long-term implication of the initial purchase decision may not become apparent until the cascaded follow-up sales actually occur. This creates a monopolistic situation that managers may exploit to create short-term profits by extracting high prices and/or delivering low-value follow-on products. However, such strategies can hurt long-term profits by decreasing customer loyalty, thus reducing customer equity. Managers can also capitalize on these situations by foregoing short-term profits to deliver greater value than consumers expect, strengthening loyalty and customer equity.

Notwithstanding their widespread application and timely application, neither of these possibilities is typically addressed in marketing simulation games. In this paper, we have discussed how they can be addressed by adapting existing demand and customer-lifetime-value models. This is useful because it facilitates their incorporation in simulation games with minimal extra programming or redesign of existing algorithms.

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