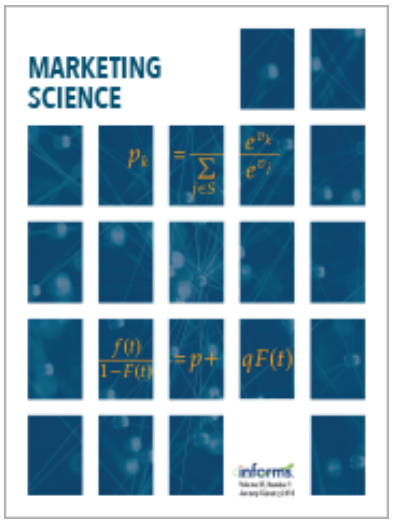

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Optimal Product Line Design When Consumers Exhibit Choice Set-Dependent Preferences

A. Yeşim Orhun
Booth School of Business, The University of Chicago, Chicago, Illinois 60637, yesim.orhun@chicagogsb.edu

In a market of consumers with varying willingness to pay, using product line as a discrimination tool may extract higher profits than serving all consumers with a single product. Local context effects, however, point to yet another consideration in designing product lines: how the appeal of a product changes with the context provided by other products in the choice set.

I present a model of product line design that incorporates both discrimination and context management goals and offers recommendations for the variety and positioning of products. To this end, the model makes use of a framework that allows preferences to be choice set dependent. Given this framework, I study how the firm manages externalities between products created by such dependencies. The firm creates distortions above and beyond those resulting from discrimination motives alone. For example, in a vertically differentiated market for quality, quality distortions exist even for the consumers with the highest valuations. The range of quality provisions, given the number of products, is compressed as the relative importance of unfavorable comparisons among products increases. Surprisingly, this compression may even lead the firm to forego discrimination among consumers regardless of the cost of offering distinct products.

Key words: price discrimination; product positioning; context effects; choice set-dependent preferences; context management; behavioral economics
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1. Introduction

Optimal product line design emphasizes the strategic use of a menu of products as a discrimination tool in a market with consumers who have private and heterogenous tastes. The design process often assumes that preferences between options do not depend on the presence, absence, or position of other options. This principle is a useful approximation in many cases, but it is violated when consumers care about the relative standing of products. In particular, previous literature on context effects suggests that product lines define a consumer's local choice context and that the consumer's choice decisions are affected by the comparisons among available products within that context.[1] For example, Simonson and Tversky (1992) observe the market share of a given brand increasing rather than decreasing when another brand is introduced. As a real-world example, they offer the Williams-Sonoma bread-making device: sales doubled after the introduction of a more expensive but otherwise fairly similar device by the same company, whereas the new device did not sell well. This observation, along with other documented context effects, suggests that managers need to consider not only a product's attribute values but also its position in the choice set. In fact, some firms may be displaying context management considerations, as suggested by the popular press discussion of the cheapest wine on the menu,[2] purportedly included on a wine list to make relatively expensive wines fare better in comparison.

The literature on context effects, however, abstracts away from the motivation to offer multiple products to consumers with heterogenous tastes. Therefore, it does not provide comprehensive strategies on optimal product lines. In particular, when consumers have private information about their valuations, product lines can be used profitably as discrimination tools. There is a long literature on the use of product line design as a discrimination tool (e.g., Mussa and Rosen 1978, Moorthy 1984, Oren et al. 1984, Shugan 1984, Reibsten and Gatignon 1984, Dolan 1987). The previous literature on optimal product line design extensively discusses such strategies in the absence of context management considerations. Narasimhan et al. (2005) promote studying the optimal response in a market with consumers who exhibit nonstandard choice

[1] Examples include Huber et al. (1982), Simonson (1989), Simonson and Tversky (1992), Mellers and Cooke (1996), Hsee and Leclerc (1998), and Brenner et al. (1999). Please see Drolet et al. (2000) for an overview of how the choice set influences the choice behavior.

[2] *Harvard Law Record* (2001) and *Wall Street Journal* (2002).

behavior. Because product lines often determine the local choice context, the need to incorporate choice set-dependent consumer behavior into the optimal product line design seems especially pertinent.

To this end, I explore strategies for product line design that take into account incentives to both discriminate among consumers and manage the context influencing consumer preferences. In the proposed model, a firm internalizes two sets of dependencies: one that arises because of consumers' valuation of comparisons and another that arises due to incentives to discriminate among consumers based on their valuations while managing cannibalization. These considerations carry novel implications for variety in a product line, the composition of consumers a firm chooses to target, and the positioning of these products. This model provides a framework to choose how to manage context depending on the variance of consumers' tastes compared to the importance of comparative valuations and the cost of providing products.

This model of product line design consists of a firm facing vertically differentiated consumers with private valuations. It rests on a descriptive preference framework that can account for the evidence of all context effects. This framework extends the baseline utility model by allowing for a comparative valuation that depends on relative standing of products, in addition to the baseline valuation that depends on absolute levels of attributes. The relative standing of each product with respect to another is defined by the distance of the product from an internal reference point. This reference point is, in turn, a function of the attributes of other products in the choice set, allowing for changes in the choice set to affect preferences. The model incorporates the theory of loss aversion, which posits that consumers care about unfavorable comparisons more than favorable ones. This approach brings together the concept that preferences are reference dependent and consumers are loss averse (Tversky and Kahneman 1991), the hypothesis that this reference is endogenous to the choice set (Bodner and Prelec 2001, Kivetz et al. 2004), and the notion that absolute valuations should be considered separately from comparative valuations (Koszegi and Rabin 2006). This specification makes the preference structure specific to a choice set and can account for the documented choice reversals across contexts. It reverts to the baseline utility model when choice set dependency is not present.

This preference framework enables a firm to design a product line that extracts the most consumer surplus by letting consumers self-select while taking into account that the product line itself can influence this surplus. In particular, the consideration of choice set dependency of preferences brings two new notions to the attention of the firm: (1) the realization that consumers' preferences are not only individual specific but also depend on the relative standing of the product (reference dependence), and (2) the understanding that this relative standing can be influenced by changes in the choice set (choice set dependence).

These notions lead to fundamentally different product line implications. The understanding of reference dependency alone allows the firm to achieve proper selection and extract more surplus than if the firm projected local trade-offs in attributes to predict the preferences for a product with a different relative standing. In addition, the understanding of choice set dependency leads the firm to consider the externalities of each product's existence and position on other products' valuations by the target consumer segment. Therefore, internalizing these dependencies, the firm introduces *spillover effects*, which are distortions in the quality provisions above and beyond distortions due to discrimination purposes.

These product adjustments result in different product offerings than those of a firm that ignores such notions. For example, contrary to previous literature, the product line has *distortion at the top*. In other words, the consumer segment with the highest value for quality receives a different quality level than would be provided if this segment were the only one in the market. Whereas distortion at the top is one surprising result, a variety of spillover effects operate throughout the product line. In general, spillover effects are in a direction that decreases unfavorable comparisons and increases favorable ones, which may or may not be in the same direction as distortions due to discrimination motives. The magnitude of a spillover effect for a given product depends on the degree to which the product can influence the perceived relative standing of other products, the weight that consumers attach to comparisons, and the importance of the segments that are affected by these comparisons. Surprisingly, even though consumers are loss averse, the spillovers created to manage favorable comparisons may prevail over those that aim to manage unfavorable ones in equilibrium. Conditional on the identity of the consumer segments served, the range of quality offered in equilibrium decreases with the degree of loss aversion over each attribute. This result is labeled herein as the *compression effect*.

Product line length is also a tool for profit management because the existence of each product affects the relative standing of other products. I find that a firm may trim the product line to serve multiple distinct segments of consumers with the same product if the increase in profits due to discrimination is outweighed by the decrease in profits induced by comparisons, a result labeled herein as the *pooling*

effect. Remarkably, the firm's incentive to pool is independent of other factors previously suggested in the study of product line design, such as costs or distribution of valuations. It arises solely as a result of context management.

The model fleshes out the fundamental trade-offs between discrimination and context management. The implications on product positions for a given set of target consumers contributes to our intuition about the forces at play. Given a particular situation, this model can be used to provide recommendations on not only the positions of products but also on the identity of consumers served. I discuss incentives that may lead a firm to serve entirely different consumer segments, which might otherwise be unprofitable, or to stop providing otherwise profitable products that create unfavorable comparisons to augment the valuation of key segments. I refer to these trimming or extension strategies as *augmentation effects*. These strategies relate to the recommendations of experimental work that studied the effects of context changes due to the addition or elimination of products.

This paper builds on ideas presented in the existing literature and combines them in a novel way. It provides a psychologically richer preference framework with the intention of incorporating the evidence on choice set-dependent consumer behavior. Therefore, it enables the firm to design a product line that both discriminates among consumers and manages the context that influences their preferences.

2. Model: Choice Set-Dependent Preferences

To the extent that the attractiveness of an option is influenced by its standing relative to other options, current models of optimal product lines may fall short in achieving proper selection and maximizing profits because they are based on choice models that do not take into account how preferences for a given product vary with alterations to the choice set. In this section, I present a preference framework that captures choice set-dependent behavior of consumers with the intention of drawing on it for studying a firm's response to such behavior.

Any framework that incorporates choice set-dependent behavior should reflect the fact that consumers' choice decisions depend at least partly on comparisons among available products within a given context. In the framework presented below, such comparisons are modeled by introducing reference dependence, where the reference point is determined by the alternatives in the choice set. As a result, preferences travel with the choice set to the extent that changes in the choice set reflect on the reference point.

Specifically, if the alternatives in a choice set are indexed by $j = \{1, 2, \ldots, J\}$ and the attributes of products be indexed by $k = \{1, 2, \ldots, K\}$, the individual i's valuation of alternative j is composed of the baseline absolute valuation and the comparative valuation:

$$u_{ij} = \sum_{k=1}^{K} v_{ik}(x_{jk}) + \sum_{k=1}^{K} f_k(v_{ik}(x_{jk}) - v_{ik}(x_{rk})),$$

where x_{jk} is the level of attribute k in alternative j and x_{rk} is the attribute-specific reference point. The choice set-independent valuation component $v_{ik}(x_{jk})$, labeled as *absolute valuation*, is assumed to be additively separable in the attributes of the product, continuous, increasing, and differentiable. *Comparative valuations* $f_k(v_{ik}(x_{jk}) - v_{ik}(x_{rk}))$ depend on departures from a choice set-specific reference point x_{rk} for attribute k. Absolute valuations capture the baseline valuations and trade-offs such as dislike for high sugar content or the preference for more quality at a given price. This attribute-level specification of absolute valuation alone has been the workhorse for modeling choice set-independent behavior but cannot capture choice set-dependent behavior.

Comparative valuation, in turn, introduces responsiveness to changes in the relative standing of a product with respect to others in the choice set. This component incorporates reference dependency and allows for loss aversion (Tversky and Kahneman 1991) such that losses loom larger than gains in comparisons to the reference point. Although we can allow for more general forms, using a linear comparative valuation function is sufficient to capture the first-order effects of loss aversion:

$$f_k(v_{ik}(x_{jk}) - v_{ik}(x_{rk})) = \begin{cases} \lambda_k \cdot [v_{ik}(x_{jk}) - v_{ik}(x_{rk})] & \text{if } v_{ik}(x_{jk}) < v_{ik}(x_{rk}), \\ \gamma_k \cdot [v_{ik}(x_{jk}) - v_{ik}(x_{rk})] & \text{if } v_{ik}(x_{jk}) \geq v_{ik}(x_{rk}), \end{cases}$$

where $\lambda_k > \gamma_k$. The loss sensitivity parameter λ_k captures the dislike of being in the region of losses in attribute k compared to the reference point for that attribute. The gain parameter γ_k, on the other hand, captures the increase in the value of being in the region of gains compared to the reference point. For example, in the price dimension, this reflects a consumer's increased valuation for the good due to knowing that he or she paid less than expected, i.e., some form of a "deal effect." The degree of loss aversion in either attribute can be described as λ_k/γ_k. Note that the model implies that a consumer's sensitivity to changes in the losses or gains in an attribute is proportional to his or her sensitivity toward changes in the absolute levels of the attribute.

For this model to capture the existing evidence on choice set dependency, the reference point to which a product gets compared should be within the convex hull of the existing alternatives and be influenced by

the changes in the choice set. One such formulation is where the comparison of any product's attribute level to other products is modeled through the comparison of the attribute level to a reference point, which is a weighted average of attribute levels in the choice set. Therefore, the changes in the reference point of attribute k for product j resulting from changes in the other alternatives in the choice set is a weighted average of the attribute-level changes in the choice set $\Delta x^j_{rk} = \sum_{j'} \omega^j_{j'k} \Delta x_{j'k}$, where $j' \in \{1, \ldots, j-1, j+1, J\}$.

The reference point formation is similar to that in the model of Bodner and Prelec (2001), where it is modeled to be the centroid of all products. Rather than equal weights, I allow for flexible weights to study the sensitivity of product line recommendations to the spillover effects induced by the existence of comparable alternatives. The advantage of having a reference point that is affected by each additional product rather than being the midpoint of the range as in Kivetz et al. (2004) is that it allows the model to account for choice set-dependent comparisons arising from relative evaluations that do not necessarily reflect on the range of attributes.

The common concept underlying the previously proposed behavioral models for context effects has been that consumers make relative evaluations within a given context (Tversky and Simonson 1993, Bodner and Prelec 2001, Kivetz et al. 2004). These relative evaluations were modeled in different ways. Tversky and Simonson (1993) suggest a tournament model in which preference for a given product depends on the attribute-level trade-offs with other products under consideration. Bodner and Prelec (2001) propose that such comparisons within a choice set can be summarized by comparisons to a reference point. Kivetz et al. (2004) propose and empirically test many alternative models that capture context effects and find support for the unireference point model over tournament-based models. Because all of these models focus on explaining choice reversals in local contexts, focusing on only the relative evaluations to capture reversals of ranking has been sufficient.

The current framework preserves the same intuition, that consumers make relative judgements within a context, in modeling relative evaluations with the comparative valuations component. However, a key difference is that the total valuation incorporates the context-free absolute valuations as well as the choice set-dependent comparative valuation. Having both components allows for the importance of each component to be determined by the particular domain, rather than structurally imposing one component as the only determinant of behavior. This separation was suggested by Koszegi and Rabin (2006) for reference-dependent preference structures in general.

Jointly accounting for these two components of valuations has several implications. First, consumers are allowed to attach a different value to a product when they make favorable comparisons versus when they make no comparisons. Second, the general preference framework inherently yields comparisons across three nested cases of choice set dependency, reference dependency, and the baseline model of valuations. Third, it incorporates a trade-off between the importance of comparisons versus absolute valuations. These implications will be particularly useful in incorporating the preference framework into a product line design problem and identifying the exact mechanism at play in the observed differences from the baseline model.

2.1. Workings of the Proposed Preference Framework

To examine how the proposed framework changes indifference curves of a hypothetical consumer, consider an example in which consumers have linear baseline valuations of attributes x and y and linear comparative valuations. In Figure 1, the linear indifference curves labeled with the letter **A** trace the trade-offs of a consumer with no sensitivity to deviations from the reference point. Such preferences can be captured by the absolute valuations alone, which is the baseline model. The indifference curves labeled **B** represent the same level of valuation as their **A** counterparts when the consumer is sensitive toward losses with respect to the reference point. When the consumer is sensitive to losses, his or her level of valuation is lower than or equal to that in the baseline case, where the consumer only cares about the absolute valuations. Therefore, the indifference curves labeled

Figure 1 Effects of Loss Parameters

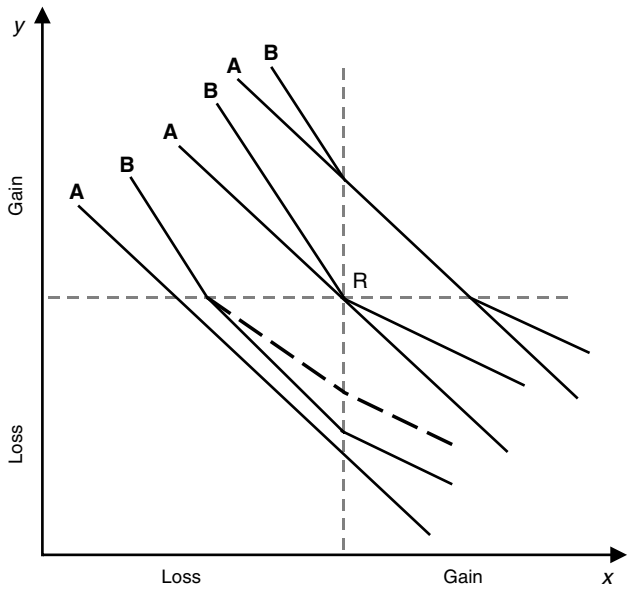


Figure 2 Effects of Loss and Gain Parameters

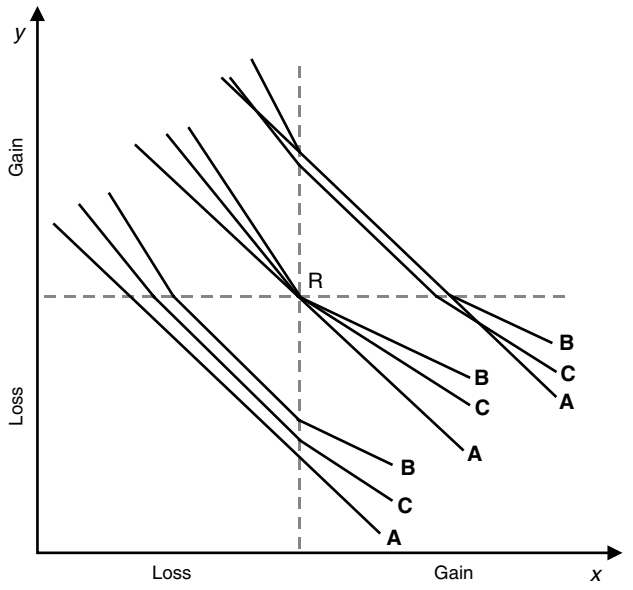
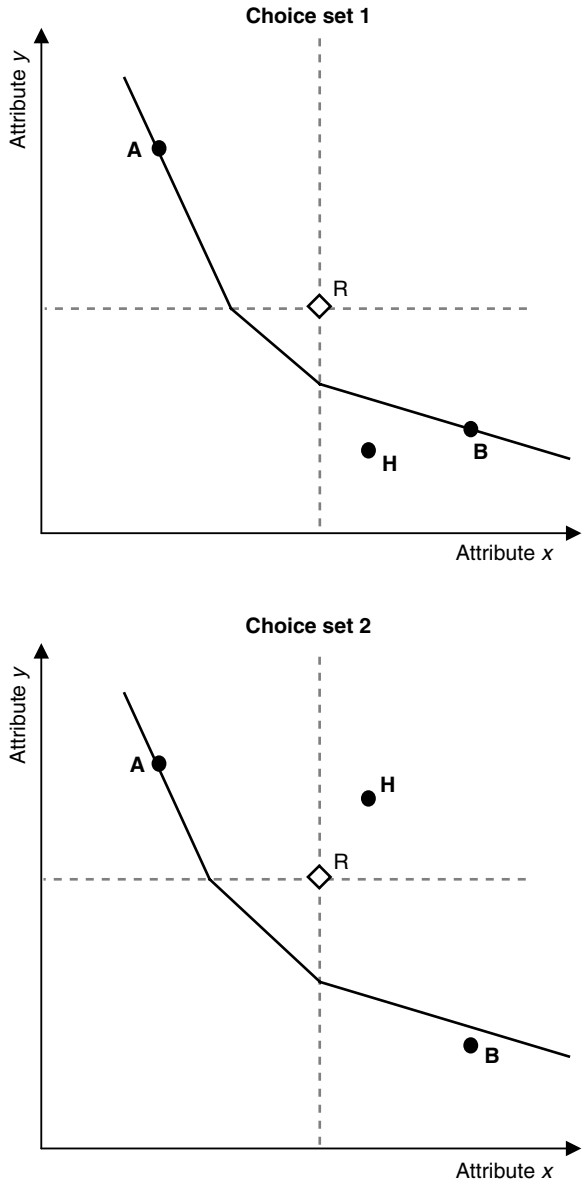


Figure 3 Preference Reversals Across Choice Sets



with **A** envelope those labeled with **B**. Within regions in which the consumer perceives a loss in only one of the attributes, the consumer is more sensitive to the attribute he or she perceives a loss in, as the difference in the slopes across regions of gain and loss reflect.

If the degree of loss sensitivity is the same for both attributes, the indifference curve in the domain of losses in both attributes is parallel to the counterparts with no loss sensitivity. However, this does not need to be the case as depicted by the dashed line, an example of losses in attribute x being less important than the losses in attribute y.

Figure 2 depicts an example of how the indifference curves may appear when the consumer cares about both gains and losses with respect to the reference point while exhibiting loss aversion. The indifference curves labeled **C** illustrate how the valuation changes compared with the baseline model **A** or with a model that considers only loss sensitivity (**B**). The separation of gain sensitivity from the baseline absolute valuations allows for the relative standing of a product to have a bearing even when products are not in the loss domain for either attribute.

A particular preference reversal, as demonstrated in Figure 3, depicts how changing the choice set leads to unstable preferences. Consider two choice sets in which the position of the products, denoted as **A** and **B**, are the same across choice sets, but product **H** is shifted along the vertical dimension. Given the reference point in the first choice set, the consumer is indifferent between alternatives **A** and **B**. If preferences are choice set dependent, the reference point depicted in the first choice set is partially affected by the position of **H**. Therefore, a vertical shift in the position of **H** also moves the reference point along the vertical dimension. As a result of the change in the position of **H**, ranking of alternatives **A** and **B** change, where **A** is preferred to **B**.[3] The increase in alternative **B**'s loss (in the vertical dimension) compared to the reference point decreases its utility. As a result of loss aversion, this decrease is larger than alternative **A**'s utility reduction due to the same amount of decrease in its gain in the vertical dimension.

This framework links reference dependency and context dependency by allowing the reference point to be influenced by changes in the choice set. As a result,

[3] The indifference curves trace all products in the continuous space of attributes x and y. If any consumption bundle were to affect the reference point, the indifference curves would not be piecewise linear. For demonstration simplicity, assume that only the products **A**, **B**, and **H** influence the reference point.

indifference curves may cross due to changes in the reference point across choice sets. This is how the model reconciles the evidence of preference reversals in the presence or absence of other options. The model is consistent with the evidence on context effects such as the extremeness aversion, asymmetric dominance, asymmetric advantage, enhancement, and detraction effects (Huber et al. 1982, Simonson and Tversky 1992). For further details, please see the appendix.

2.2. Specification of Valuations for the Product Line Design Problem

Having a framework that captures consumers' choice set-dependent behavior enables a firm to develop suitable discriminating product line strategies. The previous section presents a preference framework to capture such behavior in its general form. The focus of the paper is to study how choice set-dependent preferences affect the design of a discriminatory product line. To this end, for the analysis of the firm's problem, I focus on consumer heterogeneity in preferences for vertically differentiated alternatives.

In particular, I consider a firm providing products that can be identified by a vertical dimension, which can be quality. Consumers have heterogenous tastes for the trade-off between price and quality that the firm can exploit with an optimal product line design. The heterogeneity in the vertical dimension is modeled with two discrete segments: high-type consumers, who have a high willingness to pay for quality, and low-type consumers. The low-type consumer segment is identified with l and the high type with h. I assume that the absolute valuation of a consumer belonging to segment $i \in l, h$ for purchasing a product of quality q and paying a price of p is $\theta_i q - p$, where θ is a segment-specific willingness-to-pay parameter for quality. Because consumers in a given segment have the same taste parameters, they either all buy a product or none buy it. If a consumer does not purchase one of the options in the product line, he or she gets no utility.

Following the framework presented above, the comparative valuations in the quality dimension can be expressed as

$$f_q(v_{iq}(q_j) - v_{iq}(q_r)) = \begin{cases} \lambda_q \cdot \theta_i(q_j - q_r^j) & \text{if } q_j \le q_r, \\ \gamma_q \cdot \theta_i(q_j - q_r^j) & \text{if } q_j \ge q_r. \end{cases}$$

Similarly, for the price dimension, the comparative valuations are

$$f_p(v_{ip}(p_j) - v_{ip}(p_r)) = \begin{cases} -\lambda_p \cdot (p_j - p_r^j) & \text{if } p_j \ge p_r, \\ -\gamma_p \cdot (p_j - p_r^j) & \text{if } p_j \le p_r, \end{cases}$$

because the valuation of price is negative. The reference point for each product is assumed to be influenced by the other product $dp_r^l/dp_h = \eta_h$, $dp_r^h/dp_l = \eta_l$, $dq_r^l/dq_h = \mu_h$, $dq_r^h/dq_l = \mu_l$, where $0 \le \eta_h, \eta_l, \mu_h, \mu_l \le 1$.[4] The reference point is assumed to be in the convex hull of the offered products' attributes. This assumption ensures that the regions of gain and loss are determined by the local comparisons as long as these consumers are served with two products. It focuses the attention to product positioning decisions when local context effects are salient. However, to the extent that the reference point remains within the convex hull, the weights are allowed to be smaller than one to study how the relative weight of an internal reference point versus an external reference point would affect the optimal positioning of the product line.

If high-type consumers purchase the high-end product (q_h, p_h) and low-type consumers purchase the low-end product (q_l, p_l), they get the following valuations:

$$U_h(q_h, p_h \mid q_r^h, p_r^h) = \theta_h q_h - p_h + \gamma_q \theta_h (q_h - q_r^h) - \lambda_p (p_h - p_r^h), \quad (1)$$

$$U_l(q_l, p_l \mid q_r^l, p_r^l) = \theta_l q_l - p_l - \lambda_q \theta_l (q_r^l - q_l) + \gamma_p (p_r^l - p_l). \quad (2)$$

Obviously, preferences change with the domain of losses or gains in which the product lies in. For example, if the low-type segment consumed the high-end product, the valuation would be of a different form than in Equation (2):

$$U_l(q_h, p_h \mid q_r^h, p_r^h) = \theta_l q_h - p_h + \gamma_q \theta_l (q_h - q_r^h) - \lambda_p (p_h - p_r^h).$$

In a sorting equilibrium, high-type consumers purchase the high-end product and low-type consumers purchase the low-end product. To ensure this self-selection, the firm has to price the products accordingly while choosing the most profitable quality provisions.

3. Model: Setup of the Product Line Design Problem

In designing the optimal product line, the firm offers a menu of products to the extent that these products profitably induce consumers to self-select into

[4] The product's own effect on the reference point to which it gets compared is abstracted away from; i.e., $dk_r^i/dk_i = 0$. The reference point could alternatively be the weighted average of all products in the menu including the product itself. This would result in the same reference point for all the products, which may be attractive in some applications. This is allowed in the preference framework outlined in the previous section. Allowing for positive weights is unattractive for purposes of comparison across different models of product line design because the changes in the attributes of a given product alone would also affect the reference point to which it is compared. Therefore, for the purposes of clarity in demonstration, this assumption is used. Note that this assumption does not change the results presented herein.

the product intended for their segment. Given a preference structure that satisfies the sorting condition,[5] the setup of the product line design can be obtained directly from the existing literature (e.g., Moorthy 1984). The firm maximizes profits while ensuring that it sets prices, such that (1) each segment of consumers will buy the product intended for that segment (incentive compatibility constraints), and (2) each segment that was intended to purchase a product actually does so (individual rationality constraints). The profits of the firm can be described as

$$\max_{q_l, q_h}[\alpha_l(p_l^* - c(q_l)) + \alpha_h(p_h^* - c(q_h))], \tag{3}$$

where α_i is the proportion of the segment $i \in \{l, h\}$ and $c(q)$ is the marginal cost of providing quality q. The marginal cost function is assumed to be twice differentiable and strictly convex. The prices in equilibrium p_h^* and p_l^* are determined by the individual rationality (IR) constraint for low-type consumers and the incentive compatibility (IC) constraint for high-type consumers. Only the IC constraint for high-type consumers and the IR constraint for low-type consumers bind in equilibrium, as shown in the appendix. The IR constraint for the low-type consumer segment is

$$\begin{aligned} &U_l(q_l, p_l \mid q_r^l, p_r^l) \geq 0 \\ &\quad \Rightarrow \ \theta_l[q_l - \lambda_q(q_r^l - q_l)] - p_l + \gamma_p(p_r^l - p_l) \geq 0, \end{aligned} \tag{4}$$

and the IC constraint for the high type is

$$\begin{aligned} &U_h(q_h, p_h \mid q_r^h, p_r^h) \geq U_h(q_l, p_l \mid q_r^l, p_r^l) \\ &\quad \Rightarrow \ \theta_h[q_h + \gamma_q(q_h - q_r^h)] - p_h - \lambda_p(p_h - p_r^h) \\ &\qquad \geq \theta_h[q_l - \lambda_q(q_r^l - q_l)] - p_l + \gamma_p(p_r^l - p_l). \end{aligned} \tag{5}$$

In the next section, I demonstrate how product line design strategies change as a result of taking the importance of comparisons in consumer valuations into account. I consider two distinct ways in which the proposed framework differs from the *baseline model*, which is the product line design problem when consumers only care about the absolute valuation.

The first way a model with comparative valuations is different from the baseline model is the fact that the sensitivity to an attribute depends not only on the consumer segment-specific taste parameter θ_i but also on the domain on which the product's attribute level lies with respect to the reference point. This loss and gain domain (or reference) specificity holds regardless of whether the reference point is completely external or fully determined by the choice set under consideration. This particular difference from the baseline model with standard preferences is labeled as *reference dependency*.

The second way in which this model is different than the baseline model is that the reference point to which each attribute level gets compared is influenced by the alternatives in the choice set. Therefore, the positions of all products in a product line influence the shape of the indifference curves. This explains how indifference curves may cross different choice sets. I refer to *choice set dependency* as the fact that preferences depend on the choice set due to the effect of the choice set in local comparisons. In this framework, choice set dependency operates through reference dependency.

4. The Design and Analysis of the Optimal Product Line

Although choice set dependency is needed to capture the behavioral evidence of local context effects, I present the mechanism of reference dependence independently to separate its outcome from the baseline model even when the choice set does not influence comparisons. The first motivation for this exercise is to show that even if the reference point is exogenously determined, considering comparative valuations changes the equilibrium prices and the quality provision in the market. The second motivation is to lay the groundwork for an analysis of the separation of the outcomes related only to reference dependency from the dependencies across product positions induced by choice set dependency.

4.1. Optimal Product Line Design with Reference-Dependent Preferences

The distinction between how much the reference point can be influenced by local product attributes versus how much is out of the firm's control is crucial in distinguishing the mechanism of reference dependency from the additional effects that arise due to choice set dependency. To focus on reference dependency, assume for now that the reference point is completely external to the choice set.

As outlined in §3, the IR constraint of low-type consumers (Equation (4)) and the IC constraint of high-type consumers (Equation (5)) bind in equilibrium. They are repeated here for convenience. The IR

[5] I consider the parameter values such that the preference ordering of different segments for the products is the same across domains of gain and loss. This sorting condition puts an upper bound on the relative importance of sensitivity to comparisons: $\theta_l(1+\lambda_q)(1+\lambda_p) < \theta_h(1+\gamma_q)(1+\gamma_p)$. In other words, high-type consumers should always have a higher observed willingness to pay for quality than low-type consumers across all domains. This assumption focuses the analysis to those regions of comparison parameters such that a firm naively using the baseline model would also observe the same ordering of types.

constraint and the IC constraint pose the following restrictions on the prices that can be charged:

$$\theta_l[q_l - \lambda_q(q_r^l - q_l)] - p_l + \gamma_p(p_r^l - p_l) = 0,$$
$$\theta_h[q_h + \gamma_q(q_h - q_r^h)] - p_h - \lambda_p(p_h - p_r^h) = \theta_h[q_l - \lambda_q(q_r^l - q_l)] - p_l + \gamma_p(p_r^l - p_l).$$

Therefore, the prices charged in equilibrium are

$$p_l^* = \frac{\theta_l[q_l - \lambda_q(q_r^l - q_l)] + \gamma_p p_r^l}{1+\gamma_p}, \tag{6}$$

$$p_h^* = \frac{\theta_h(q_h + \gamma_q(q_h - q_r^h)) - (\theta_h - \theta_l)(q_l - \lambda_q(q_r^l - q_l)) + \lambda_p p_r^h}{1+\lambda_p}. \tag{7}$$

These prices reflect the understanding that the high type's preference structure is dependent on the product he or she consumes. The IC constraint reflects that consuming the product targeted to the high-type consumer leaves the consumer in the loss domain for prices and gain domain for quality, whereas consuming the low-end product leaves the high-type consumer in the loss domain in quality and gain domain in prices. The deviation strategy for the high-type consumer (choosing the low-end product) decreases in its attractiveness as the reference quality level q_r^l increases and/or the loss sensitivity in quality λ_q increases. High-type consumers' effective quality sensitivity versus price sensitivity is higher in the case of deviation. This realization allows the firm to satisfy the IC constraint with less information rent to the high type.

The equilibrium quality provisions, which follow from the first-order conditions of the firm's maximization problem, consequently internalize the change in the preference structure of the high-type consumer in the case of deviation:

$$c'(q_l) = \frac{1+\lambda_q}{1+\gamma_p}\theta_l - \frac{\alpha_h}{\alpha_l}\frac{1+\lambda_q}{1+\lambda_p}(\theta_h - \theta_l), \tag{8}$$

$$c'(q_h) = \frac{1+\gamma_q}{1+\lambda_p}\theta_h. \tag{9}$$

When there are no fixed costs of offering a product and when the firm wants to sell to both segments, it serves each segment with a distinct product as $c'(q_h) > c'(q_l)$ for all parameter values. The distortion[6] to the quality provision for type l consumers due to the IC constraint achieves the proper selection under these preferences. Because of the changes in the comparisons in the case of deviation, the distortion of quality of the low-end product is greater than it would have been if the firm did not consider reference dependency.

[6] The term "distortion" refers to the discrepancy of the quality provision from which this segment would have been served had it been the only segment in the market.

Proposition 1. *A firm that considers the reference dependency of preferences will provide a lower quality to the low-type consumers compared to a naive firm that observes the same consumers. Both firms offer the same quality to the high-type consumers.*

Proof. The naive firm observes consumer segments' sensitivity to quality versus price, $\partial U_l/\partial q_l = \theta_l(1+\lambda_q)/(1+\gamma_p)$ and $\partial U_h/\partial q_h = \theta_h(1+\gamma_q)/(1+\lambda_p)$, yet assumes that sensitivities are only type specific. The IR constraint for the low type and the IC constraint for the high type in such a setting are, respectively,

$$U_l(q_l, p_l) \geq 0 \;\Rightarrow\; \theta_l\frac{1+\lambda_q}{1+\gamma_p}q_l - p_l \geq 0,$$
$$U_h(q_h, p_h) \geq U_h(q_l, p_l) \;\Rightarrow\; \theta_h\frac{1+\gamma_q}{1+\lambda_p}q_h - p_h \geq \theta_h\frac{1+\gamma_q}{1+\lambda_p}q_l - p_l.$$

It can be seen that the IC constraint implies the same effective trade-offs between quality and price in the case of deviation as in the case of purchasing the intended product. The resulting naive quality choices that maximize profits while satisfying these constraints are

$$c'(q_l) = \frac{1+\lambda_q}{1+\gamma_p}\theta_l - \frac{\alpha_h}{\alpha_l}\left(\theta_h\frac{1+\gamma_q}{1+\lambda_p} - \theta_l\frac{1+\lambda_q}{1+\gamma_p}\right),$$
$$c'(q_h) = \frac{1+\gamma_q}{1+\lambda_p}\theta_h. \quad \square$$

Such a naive firm will lack the understanding that relative quality sensitivities may change for choices that are out of equilibrium. The firm believes that the local trade-offs, $\partial U_l/\partial q_l$ and $\partial U_h/\partial q_h$,[7] apply for every choice occasion regardless of the relative standing of products. Although out-of-equilibrium choices will not be observed under successful discrimination, attribute sensitivities in the case of deviation are relevant for extracting the most surplus from the consumers due to the IC constraint. Because the high-type consumers would be in the loss domain when purchasing the low-end product, their effective quality sensitivity in the case of deviation is larger than in the case of purchasing the high-end product.

[7] Note that these sensitivities are different than θ_l and θ_h, respectively. Because in the standard case the firm operates with a model that assumes that consumers do not value comparisons, we need to be careful not to inject differences across models due to differences in parametrization. For example, we do not want to cause an increase in the quality sensitivity of the low type as a result of allowing for reference dependency in preferences. This standardization allows for proper comparisons across different levels of firm sophistication. One can interpret these sensitivities as the naive trade-offs the firm would infer from observing choice data resulting from small local changes in attributes.

The downward distortion to the low-type segment's quality provision increases in this sensitivity. The firm that considers reference dependency can more effectively prevent the high-type consumer from deviating by distorting the low-end product.

The high-type consumers' quality provision is the same regardless of whether a firm considers reference dependency or not. This is because the high-type consumer's optimal product position does not depend on the valuations of the low-type segment because the IC constraint only binds downward.

This proposition underlines how the existence of comparative valuations, even with an external reference point, interacts with the discrimination incentives of the firm. In addition to reference dependency, if the comparisons within a product line matter, consumers' valuations will then depend on what other segments are offered and new dependencies between product offerings will emerge. I will discuss these dependencies next.

4.2. Optimal Product Line Design with Choice Set-Dependent Preferences

In a typical product line design problem, to achieve the most profitable discrimination, the firm needs to manage the cannibalization within the product line. This consideration leads to dependencies across product positions, resulting in distortions to the quality provided to all consumer segments except for the one with the highest valuation for quality. The distortion to the low-end quality provision when consumers have reference-dependent preferences is of the same discriminatory nature.

In the case of consumers with choice set-dependent valuations, the firm has other reasons to distort quality. If consumers have choice set-dependent preferences, they make comparisons not only between a product and an external reference point but also within the choice set. Because the valuation for each product depends on the position and existence of the other products, each product in the product line creates an externality on the valuation of other products through comparisons. The firm internalizes such dependencies across alternatives in the consumers' decision of picking one product.[8] Thus, such context management considerations lead to further distortions across product position choices. These distortions are beyond those induced by pure discrimination motives and may be in the opposing direction. I refer to these types of distortions as spillover effects among the products in a product line.

Definition 1. *Spillover effects* are quality distortions in a product line caused by the firm's context management considerations.

When the firm realizes that the comparisons among products can be managed, it views the reference quality and reference price points in the relevant IR and IC constraints (Equations (4) and (5)) as decision variables. Therefore, the resulting equilibrium prices are functions of one another. For example, because the low-end price will depend not only on the low-end quality but also on the reference quality and reference price, the high-end quality provision and price will affect it. Therefore, $dp_l/dq_h = (\partial p_l/\partial q_r^l)(\partial q_r^l/\partial q_h) + (\partial p_l/\partial p_r^l)(\partial p_r^l/\partial p_h)(dp_h/dq_h)$, whereas it would be equal to zero without choice set dependency. Similarly, the effect of the high-end quality on the high-end price will not only depend on the valuation of quality but also on the effects of comparisons in quality and price,

$$\frac{dp_h}{dq_h} = \frac{\partial p_h}{\partial q_h} + \frac{\partial p_h}{\partial q_r^l}\frac{\partial q_r^l}{\partial q_h} + \frac{\partial p_h}{\partial p_r^h}\frac{\partial p_r^h}{\partial p_l}\left(\frac{\partial p_l}{\partial q_r^l}\frac{\partial q_r^l}{\partial q_h} + \frac{\partial p_l}{\partial p_r^l}\frac{\partial p_r^l}{\partial p_h}\frac{dp_h}{dq_h}\right),$$

which the high-end quality provisions may influence directly and indirectly. These derivatives speak to how the firm internalizes the externality that each product's quality level exerts on the surplus that can be extracted from the other product. I show that the internalization of comparisons across products results in quality distortions above and beyond those caused by discrimination motives.

Proposition 2. *The equilibrium quality provisions when consumers exhibit choice set-dependent preferences are such that*

$$\begin{aligned} c'(q_h) = {} & \frac{1}{(1+\gamma_p)(1+\lambda_p) - \gamma_p\eta_h\lambda_p\eta_l} \\ & \cdot \left\{ \theta h(1+\gamma_q)\left(1+\gamma_p + \frac{\alpha_l}{\alpha_h}\gamma_p\eta_h\right) \right. \\ & - \lambda_q\mu_h\left[\theta_l\left(\frac{\alpha_l}{\alpha_h}(1+\lambda_p) + \lambda_p\eta_l\right)\right. \\ & \left.\left. - (\theta_h - \theta_l)\left(1+\gamma_p + \frac{\alpha_l}{\alpha_h}\gamma_p\eta_h\right)\right]\right\}, \end{aligned}$$

[8] This model focuses on the effects of choice set-dependent preferences where each consumer purchases and consumes one product. However, other types of dependencies among preferences for products arise in the choice of multi-item assortments. Previous work on multi-item decisions shares a similar modeling approach to the current work because the models account for dependencies across items in the set of choices. Dependencies in evaluating a bundle choice have been captured in the balance model (Farquhar and Rao 1976) by allowing for interactions between components of a bundle of products to influence the valuation of the bundle. Subsequent research (Bradlow and Rao 2000, Chung and Rao 2003) extended the modeling of bundle choice and studied the optimal product assortment in response to such dependencies arising from demand complementarity across products. Complementarities among products have been incorporated into multivariate discrete-choice models by allowing for cross-effects to account for such dependencies (see, e.g., Manchanda et al. 1999, Song and Chintagunta 2006; also, see Seetharaman et al. 2005 for an overview).

$$c'(q_l) = \frac{1}{(1+\gamma_p)(1+\lambda_p) - \gamma_p\eta_h\lambda_p\eta_l} \cdot \left\{(1+\lambda_q)\theta_l\left((1+\lambda_p) + \frac{\alpha_h}{\alpha_l}\lambda_p\eta_l\right) - \left(\frac{\alpha_h}{\alpha_l}(1+\gamma_p) + \gamma_p\eta_h\right) \cdot [(\theta_h - \theta_l)(1+\lambda_q) + \theta_h\gamma_q\mu_l]\right\},$$

and reduce back to those implied by reference dependency alone when the reference point is not endogenous to the choice set; i.e., $\mu_h = 0$, $\mu_l = 0$, $\eta_h = 0$, $\eta_l = 0$.

Proof. Derivation of equilibrium quality provisions follow directly from the differentiation of $\sum_i \alpha_i(p_i^* - c(q_i))$ with respect to q_i. Complete details are presented in the appendix. □

Corollary 1. *The following observations on equilibrium quality provisions hold*:

1. *The equilibrium quality provisions exhibit spillover effects due to choice set dependency;*

a. ***Distortions at the top:*** *If* $\gamma_p > 0$ *and* $\eta_h > 0$, *there exists a positive distortion to* q_h. *If* $\lambda_q > 0$ *and* $\mu_h > 0$, *there exists a negative distortion to* q_h.

b. ***Distortions at the bottom:*** *If* $\gamma_q > 0$ *and* $\mu_l > 0$, *there exists a negative distortion to* q_l. *If* $\lambda_p > 0$ *and* $\eta_l > 0$, *there exists a positive distortion to* q_l.

2. *These distortions increase in the importance of the relevant comparison, influence of the product on the reference point, and the size and the relative quality price trade-off of the segment that benefits from the distortion.*

Proof. Spillover effects can be identified by comparing these implicit functions of quality provisions to those implied by reference dependency alone in Equations (8) and (9). □

A surprising result of the model is the existence of distortions at the top. With just the same baseline absolute valuation specification used in this model, distortion at the top would never be observed as a result of discrimination motives alone. In fact, the finding that the highest-valuation consumer always gets the same quality product regardless of the existence of other segments is an important characteristic of results obtained in the previous literature. However, because of choice set dependency and the firm's incentives to internalize the externalities between products, the high-end quality provision in equilibrium is not independent of other types' valuations. These types of dependencies, referred to as spillovers, operate throughout the product line, not just at the top. These spillovers may go against the distortions due to discrimination motives. The overall effect of the spillovers on each quality provision is ambiguous. I discuss these spillover effects in detail and provide conditions for directional results.

4.2.1. Discussion of Spillover Effects. When distorting a segment's quality provision, the firm trades off profits from that segment versus the segment, whose comparative valuation it manages by the particular distortion. For ease of exposition in identifying and discussing spillover effects, I consider comparisons in each dimension separately and compare these quality provisions to those generated only by reference dependency.

Comparisons in the Quality Dimension. If consumers only care about comparisons in the quality dimension, the quality distortions compared to no consideration of choice set dependency (i.e., $\mu_l = \mu_h = 0$) can be readily seen by comparing the following to Equations (8) and (9):

$$c'(q_l) = (1+\lambda_q)\left[\theta_l - \frac{\alpha_h}{\alpha_l}(\theta_h - \theta_l)\right] - \frac{\alpha_h}{\alpha_l}\theta_h\gamma_q\mu_l,$$

$$c'(q_h) = \theta_h(1+\gamma_q) - \frac{1}{\alpha_h}(\theta_l - \alpha_h\theta_h)\lambda_q\mu_h.$$

In particular, the gain sensitivity γ_q distorts the low-end quality downward above and beyond the distortion stemming from discrimination considerations. This results from the fact that decreasing the reference quality increases the price the firm can charge for the high-end product. This spillover effect increases in the proportion of type h consumers and their marginal value for quality. The loss sensitivity in quality λ_q imposes a negative spillover on the high-end quality provision. The firm realizes that by decreasing the high-end quality, it can extract more rent from the type l consumer for the product he or she consumes in equilibrium. However, to the extent that the firm can make the reference quality higher, it can make deviation less attractive for the high type and extract a higher rent from this segment. However, it is more profitable to increase rent extracted from the low type than to minimize the information rent induced by the IC constraint. Therefore, $\{\theta_l - \alpha_h\theta_h\}$ is positive because we consider a case in which the type l consumer segment has enough valuation for the product to make separation a profitable policy. Therefore, the high-end quality provision is distorted downward.

Comparisons in the Price Dimension. On the other hand, if consumers only care about comparisons in the price dimension, the price that can be charged to each type in turn depends on the prices charged to other types, as seen in the IR and IC conditions above. The prices for each segment are increasing in the reference price, and the optimal quality provisions

$$c'(q_l) = \frac{\theta_l(1+\lambda_p+(\alpha_h/\alpha_l)\lambda_p\eta_l) - ((\alpha_h/\alpha_l)(1+\gamma_p)+\gamma_p\eta_h)(\theta_h-\theta_l)}{(1+\lambda_p)(1+\gamma_p) - \gamma_p\eta_h\lambda_p\eta_l},$$

$$c'(q_h) = \frac{\theta_h((1+\gamma_p)+(\alpha_l/\alpha_h)\gamma_p\eta_h)}{(1+\lambda_p)(1+\gamma_p) - \gamma_p\eta_h\lambda_p\eta_l},$$

reflect the positive feedback of increasing a product's price on the price that can be extracted from the segment that buys the other product. Therefore, the firm provides higher quality and thus higher-priced goods in equilibrium than it would if there were no choice set dependencies; i.e., $\eta_h = \eta_l = 0$. The amount of distortion to each product provision because of this context management motive depends on the relative sizes of segments α_h/α_l as well as the influence of each product on the other product's reference price η_h and η_l, which is a measure of the degree of choice set dependency. In particular, as the effect of the high-end product's price on the reference price increases and/or the low-type segment size increases, the firm has more incentive to increase the price of the high-end product by offering a higher quality. Similarly, the upward distortion to the low-end product will be higher if the high-type segment is larger in size and if the firm can influence the reference price by changing the low-end product's price. Because of the trade-off between the profitability from a given segment and its spillover effect on the other segment's profitability, the degree of upward quality distortion to either segment increases in that segment's marginal value of quality.

The firm also has an additional downward distortion incentive for the low-type segment's quality provision. Because of the deviation strategy becoming less appealing for the high type, the high-end price is higher for lower values of q_l, which introduces the usual downward distortion to the low-end quality. Moreover, this incentive to distort now is much stronger because of the existence of comparisons in the price dimension. The higher the high-end price, the more profits the firm can extract from the low-end consumers because of more favorable comparisons in price. Therefore, this feedback loop puts a bigger downward pressure on the low-end quality.

The denominator $(1+\gamma_p)(1+\lambda_p) - \gamma_p\eta_h\lambda_p\eta_l$ enters the optimal quality provisions as a result of the feedback loop each price has on the other price because of prices affecting the reference price. As the choice set dependency increases (in other words, as η_h and η_l get bigger), this denominator decreases, leading to a greater positive feedback loop. Thus, this multiplier on the previous spillover effects leads to further increases in quality provisions.

Interaction of Comparisons in Both Dimensions. When consumers care about comparisons in both dimensions and the comparisons can be influenced by the products, some distortions are increased because of the interaction of spillover effects from different comparisons while others are softened. When consumers care about the gains in both dimensions, the existence of γ_p increases the downward distortions because of γ_q on the low-end quality provision. This is because the downward distortion in q_l leads to an increase in the high type's quality gain and thus to a higher p_h. A higher p_h makes the comparison in prices even more favorable for the low-end segment and thus increases the price that can be extracted. Therefore, the coexistence of sensitivity to gains in price and to gains in quality provides the firm even more incentives to distort the low-end quality provision.

Recall that q_h is distorted downward because of the firm's incentive to decrease the losses in quality for the low-type consumer. If consumers also care about comparisons in price among products, two interaction effects of context management considerations arise. On one hand, if the low-end price point affects the reference price for the high-end consumers who are in losses in that dimension, then the firm has even more incentive to distort q_h downward. Because a lower q_h will generate more favorable quality comparisons for the low-end consumers, the price that can be extracted from them for a given quality level increases. This, in turn, leads to the high-end consumers' reference price increasing, which increases the price that can then be extracted from this segment. This positive feedback loop leads the firm to distort the high-end quality more when both loss aversion in prices as well as loss aversion in quality are prevalent. On the other hand, distorting the high-end quality downward decreases the quality reference for the high-end consumer in the case of deviation, which decreases the price that can be extracted from the high-end consumer. Because the price that can be extracted from the low-end segment increases in the reference price and a higher p_h will generate a higher reference price, the firm has fewer incentives to distort q_h downward to increase the low type's utility because an opposing comparison effect exists from the sensitivity to gains in prices. Overall, the total interaction effect of the existence of sensitivity to price comparisons on the distortion because of loss aversion in quality depends on the loss aversion in prices, and its magnitude is determined by $\theta_l\lambda_p\eta_l - (\theta_h - \theta_l)\cdot(\alpha_l/\alpha_h)\gamma_p\eta_h$.

4.2.2. Directional Results of Spillover Effects—Comparative Statics. The impact of considering choice set-dependent preferences in designing the product line goes beyond those that may result from changes in the differentiation between segments, as seen in the comparison between the baseline model and extended model. These structural changes in the way the firm thinks about dependencies across products results in novel implications for the product line.

The overall impact of the spillovers on quality provisions is ambiguous. The comparisons in the price dimension lead to an increase in the quality levels of both products. The comparisons in the quality dimension lead to a decrease in the quality levels of

both products. For a given segment's quality provision, loss and gain sensitivities result in spillovers of opposing directions. The relative importance of different spillover considerations depends on the relative sizes of the affected segments, their relative absolute valuations with respect to each other, and the potential of a product to influence the reference point.

The fact that the impact of gain sensitivities on the quality provisions in the market may be greater than the effect of loss sensitivities is a surprising result because gain sensitivities are by assumption smaller than loss sensitivities. This result highlights the need to consider gain sensitivities separately from absolute valuations.

Corollary 2 (Compression Effect). *Spillover considerations lead to a compression in the equilibrium quality range when loss aversion in the comparative valuation of either attribute is sufficiently large.*

Proof. Please see the appendix for the derivation. □

The difference between the high-end and low-end quality provisions, compared to the difference in the absence of choice set-dependent preferences, decreases in the loss sensitivity and increases in the gain sensitivity in either dimension. In particular, if comparisons are made only on the quality dimension distortions because of spillover effects alone will decrease the range of quality provisions if $\alpha_h\gamma_q\mu_l\theta_h$ is larger than $\alpha_l\lambda_q\mu_h(\theta_l - \alpha_h\theta_h)$. If the consumers care only about the price comparisons, loss aversion in prices will lead to compression when $\lambda_p\eta_l/\gamma_p\eta_h > \alpha_l(\theta_h - \alpha_h\theta_l)/(\theta_l\alpha_h^2)$. Clearly, when there is no sensitivity to gains, the existence of comparative valuations *always* leads to compression.

In the case of severe loss aversion in the quality dimension, the firm may find it optimal to serve both segments with the same product and not discriminate among consumers.

Corollary 3 (Pooling Effect). *If the loss aversion in quality is large enough, it will be profitable for the firm not to separate highest-value consumers from other types. The degree of loss aversion in quality necessary to induce pooling decreases in the loss aversion in prices.*

Proof. The firm will serve both types with the same product if

$$\lambda_q(\mu_h\alpha_l + \alpha_h)[\theta_l(b+w) - \theta_h w] - \gamma_q(\alpha_h\mu_l + \alpha_l)\theta_h w \geq \theta_h w - \alpha_h\theta_l(b+w),$$

$$w = \alpha_h + \alpha_h\gamma_p + \alpha_l\gamma_p\eta_h,$$

$$b = \alpha_l + \alpha_l\lambda_p + \alpha_h\lambda_p\eta_l.$$

This follows directly from the condition $c'(q_h) - c'q_l \leq 0$, as presented in the appendix. □

Serving both segments with the same product, i.e., pooling, is profitable for the firm when the profit loss because of unfavorable quality comparisons made by low-type consumers is greater than the additional profits obtained by discrimination.[9] An increase in the loss aversion in prices, through its interaction with the loss aversion in quality, makes pooling more appealing.

That a firm would forego the possibility to discriminate even when the absolute valuations makes discrimination a profitable proposition otherwise[10] is a surprising finding in the light of previous literature. On the other hand, it is intuitive that the firms trade off the discrimination motives with context management motives and thus end up creating a negative spillover of the high-end product onto the valuation of the low-type consumer for the low-end product. This intuition that generates pooling at the top extends to markets with more than two types of consumers.

These results are novel recommendations for the product line design that deviate from recommendations stemming from the baseline model in a fundamental way. These effects have also not been captured in the behavioral literature because they involve discrimination motives and concern the position of products relative to each other rather than the inclusion or exclusion of alternatives. The model that generates these results can also speak to the decision of which products to include in the product line given a specific cost function for quality. Next, I will discuss the implications for the number of products in the product line and how the model's primitives relate to a choice between different strategies.

4.3. Implications for Number of Products

Thus far, I have considered effects of context management considerations on the positions of products when the firm finds it profitable to serve both segments in equilibrium. The firm decides on product positions conditional on finding that serving both segments with different products is in fact the best strategy. However, because the firm can also manage comparative valuations through the decision of which products to carry, it is important to consider the strategies that pertain to the identity of segments served and the number of products offered.

Pooling at the top decreases the number of products in the market, leaving the identity of segments

[9] This analysis is made under the assumption that the firm still finds it best to serve both segments rather than just the high-type consumers. If the loss aversion in quality is high but the type l consumer segment is small, the firm may find that it is best not to serve the type l consumer segment at all.

[10] Please see Salant (1989) and Anderson (2005) for conditions on demand and cost functions when the firm may not find it profitable to discriminate.

served the same. However, it is possible that the firm serves different sets of consumers with the sole intention to manage considerations. Such strategies aim to augment the value of products consumed for the key segments by manipulating the existence of other products. Because the profits are increasing in the reference price and decreasing in the reference quality, such "*augmentation effects*" will push the reference price up and the reference quality down. Whether the firm trims or extends the product line and in which direction depends on the relative degree of sensitivity toward comparisons in each attribute, the size and responsiveness of the beneficiary consumer segments, and costs of product introduction. These trade-offs are readily seen from the profits based on the equilibrium prices in Equations (6) and (7).

For example, note that the profits from serving both segments rather than only the high-end segment is increasing in the reference price and decreasing in the reference quality. If loss aversion in prices is high and the low-end product contributes largely to the comparisons that the high-end consumers make, the firm may stop serving the low-type consumer segment altogether. When loss aversion in prices is high, and the firm finds it profitable to serve the low-end consumer, we know that the low-end quality increases in the price loss sensitivity. However, when choice set dependency makes the low-end product's existence more costly for the profits that can be extracted from the high type, the firm may actually drop this product all together and not serve the low-end segment instead of serving it with a higher quality to mitigate its negative externality. Thus, there is a discontinuity in the direction of distortion at the low end. Alternatively, the firm can alleviate the high type's sensitivity to losses in price by introducing a premium product. This product would serve a segment with an even higher taste for quality that was not profitable to serve otherwise because of costs of product introduction. Whether the firm will eliminate the low-end product or introduce a premium product (or both) to manage the losses in price for the high type will depend on the relative profitability of high and low segments as well as the fixed costs of product introduction. Similarly, when comparisons in the quality dimension are substantial, the firm can decrease the quality reference either by pooling at the top as demonstrated before or by extending the product line at the bottom.

Extensions at the top and at the bottom resonate with the compromise effect that demonstrates a preference to avoid options on either extremity of the product line. Although this is an intuitive recommendation, because of considerations of discrimination and costs, extensions may not always be the optimal strategy. The firm may prefer to keep the number of products the same or even to trim, depending on the particular cost function. The model above contains all the incentives that factor in the trade-off between alternative strategies. The analysis in this paper focuses on changes in the structure of a product line of a certain target consumer base, to understand how recommendations differ from those of either considering only discrimination motives or taking experimental studies on context effects as strategy recommendations. Given a particular cost function, it can also be used to evaluate alternative strategies of augmentation effects. Whether the firm modifies the position of products for a given set of consumers or decides to change the consumer segments, its targets will depend on the firm's exact cost conditions and the distribution of consumers.

5. General Discussion

The model's assumptions simplify the marketplace to make the underlying structure clear. However, in providing strategy recommendations to real firms or in analyzing data from the marketplace, it will be necessary to allow for further flexibility. For example, although the preference model allows for the reference points to be influenced by factors other than the choice set, it does not allow them to lie outside the convex hull of the choice set because I focus on cases where within choice set comparisons are of primary interest. However, reference points may be influenced by prior experience, expectations, and aspirations among other factors. In an empirical application, it is important to allow for the reference point to be influenced by external factors as well as by the choice set itself, and to study the existence and the relative importance of any type of comparisons consumers make. Empirical research on price comparisons depending on prior experience and expectations has produced mixed evidence. Hardie et al. (1993) find evidence for loss aversion in prices when prices deviate from their expected means. However, Bell and Lattin (2000) argue that the loss aversion effects may disappear when consumer heterogeneity is controlled for. Recently, Klapper et al. (2005) have shown that the degree of loss aversion can be explained by consumer characteristics. It would be worthwhile to empirically examine how the prior experience of prices affects choice when allowing for context-dependent reference prices.

The preference framework can be used to estimate a discrete-choice model to investigate the magnitude and effect of choice set dependency. The ideal data set would include the consumer-level response to changes in the attributes or the price of a product across different choice sets. The variance in the choice sets across purchase occasions or locations should be exogenous to the preferences of consumers and

be of the magnitude such that the consumers realize the change in the consideration set. In the case of vertically differentiated products, it is important to account for how the target consumer groups change as choice set changes. Therefore, it may be beneficial to track a long panel of consumers facing different choice sets on different occasions. In general, the estimation needs to account for both the change in the selection of consumers across products as a result of an alteration to the choice set and the change in their preferences.

An implied assumption in the model is that the consideration set and the choice set are the same. Although this assumption is realistic in light of the current model, it excludes other questions such as how the intensity of comparisons within the choice set varies with the number of products or whether comparisons to products closer in the attribute space matter more than the whole range. It is clear that the consumers will have different processes of comparisons in a choice set of a hundred products versus a choice set of two or three products. Moreover, it rules out the question of whether the firm should introduce a dominated alternative that no consumer would consider buying. The model concentrates on the choice set where local comparisons take place. Therefore, in an empirical setting, one needs to pay attention to the implications of having a larger choice set than the consideration set.

Recent research shows that increasing the number of alternatives offered may lead to less choice (Dhar 1997, Tversky and Shafir 1992, Chernev 2003, Iyengar and Lepper 2000) and lower revenues (Boatwright and Nunes 2001). Even though the number of products is an important consideration in product line design, I abstract away from the possible interaction of this phenomenon with context management. Considering choice overload may have interesting implications, but Gourville and Soman (2005) show that increased variety along a single, compensatory dimension does not result in increased propensity of no choice. Gourville and Soman (2005) find that variety that is vertically differentiated on one attribute dimension, such as the case studied in this paper is not subject to the choice overload problem.

The model concentrates on one type of heterogeneity, namely, differences among consumer segments in the trade-off between price and quality. This approach focuses the study on the effect of choice set dependency on the design of discriminatory product lines. Other orthogonal forms of heterogeneity among consumers, such as horizontal, will not affect these results, and many dimensions of such heterogeneity may be allowed for in an applied investigation. The model also assumes that there is no heterogeneity across consumers in their sensitivity to comparisons, beyond allowing comparative valuations to be stronger for people who also have strong preferences for that attribute. If heterogeneity in comparison sensitivity is unrelated to consumer types, the model's predictions will not change. However, if for example the high-type consumers care only about comparisons in quality and the low-type consumers care only about comparisons in price, the model predictions should be calibrated accordingly. For a discussion of using more than one dimension of heterogeneity for discrimination in a product line design problem with standard preferences and an extension of relaxing this assumption, the reader is referred to Desai (2001) and Armstrong (1996).

The paper focuses on how the strategies of a single firm will change in response to consumer behavior stemming from choice set-dependent preferences. In doing so, it abstracts away from the complications that competition would bring to the equilibrium outcomes. The effect of competition on pricing the product line has been an active topic (please see Moorthy 1988, Shugan 1989, Stole 1995, Villas-Boas and Schmidt-Mohr 1999, Villas-Boas 1999, Desai 2001, Armstrong and Vickers 2001, and references therein). Future work can incorporate dependencies in demand into models of product line competition.

Abstracting away from competition results in a further restriction that the comparisons among the products of the same firm are the only ones that define the context. The reference point can be extended to account for competitors' products without any directional changes to the presented results, as long as the internal reference point is assumed to be important enough such that the composite reference point lies in the convex hull of the product under consideration. This implies, for example, that the firm's lowest-quality product will always be perceived to be in the loss domain for quality when consumers make comparisons within the larger choice set. This will happen if the effect of the competitors' products on the reference point is relatively low. Otherwise, the gain and loss domains for the firm's products will be determined by the competitors' products, and domains have to be specified before product line design is undertaken. More strategic placement recommendations can be derived for the particular domain in which the competitors' products place the firm's products.

Another approach to capturing the evidence on context effects is to model the behavioral reasoning behind them. Unfortunately, very different explanations for different context effects have been proposed, ranging from a perceptual-based explanation by Dhar and Glazer (1996), which posits that the existence of other products changes the judgements of similarity between options, to Wernerfelt (1995) and Kamenica (2008), which reconciles evidence on the compromise

effect with an explanation based on an asymmetric information setup in which consumers can infer the product that is most suitable for them on the basis of what the firm offers. Alternatively, Prelec et al. (1997) show that the compromise effect can be explained only in part by what the consumers infer from the product line about what a suitable product is. I consider the dependencies between products beyond those induced by informational value of the product line. In focusing only on the existence of comparative valuations, I completely abstract from potential signalling aspects of the product line such as the positive signal of a scarce product (Stock and Balachander 2005), the negative signal of a product-line extension in terms of the quality of products offered (Randall and Reibstein 1998), or the negative quality signal of targeted price points rather than a single price (Anderson and Simester 2001).

6. Conclusion

I present a model of optimal product line strategies based on a psychologically richer model of consumer behavior that accounts for how preferences may change across choice sets. The model provides evidence that choice set-dependent preferences can lead to marketplace outcomes that are distinct. It demonstrates the importance of accounting for such preferences rather than projecting local trade-offs in attributes to other regions of gain and loss. The decisions of how to position products and which segments to serve involve trade-offs between discrimination motives and the strength of context management incentives for each segment. Therefore, the model can produce surprising results such as the dominance of spillovers that aim to increase gains over those that aim to decrease losses on the market quality provisions, even when all consumers care about losses more than gains. By providing insights into the specific forces at play in the equilibrium outcome of number of products and their positions, the model offers a useful decision tool for managers facing particular market conditions.

It is my hope that this paper creates more thought on incorporating the evidence on consumer behavior into the strategic reasoning of firms to develop more accurate models to analyze welfare effects of market outcomes and provide better managerial recommendations.

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Appendix

A.1. Capturing Documented Local Context Effects

The reference point will be picked as the centroid for consistency across the demonstrations below. The preference reversals arise from the directional change in the reference point as we focus in on these demonstrations. However, the extent and magnitude of such effects may depend on the position of the reference point. In further empirical studies, the formation of the reference point can be addressed.

A.1.a. Asymmetric Dominance and Asymmetric Advantage. Figure A.1 depicts asymmetric dominance and advantage effects. The fact that option **B** fares better in the choice set of {**A**, **B**, **D**} than in the choice set of {**A**, **B**} is an example of *asymmetric dominance* effect. The way that the presented framework captures this effect is through modeling how the addition of **D** changes the reference point, depicted as from R1 to R2 and allowing for loss aversion. Option **B** fares better compared to R2 than compared to R1, and this valuation increase is more favorable than the change to the valuation of option **A** as a result of the same change. Therefore, the relative share of option **B** increases.

On the other hand, the fact that option **A** fares better in the choice set of {**A**, **B**, **E**} than in the choice set of {**A**, **B**} is an example of *asymmetric advantage* effect. Similarly, the addition of **E** changes the reference point as depicted from R1 to R2. This reduces the perceived losses in attribute x associated with the purchase of **A** and increases the perceived losses in attribute y associated with purchasing **B**, leading to a preference reversal.

A.1.b. Extremeness Aversion. Simonson and Tversky (1992) label the finding that middle options fare better than extreme options as extremeness aversion. If both attributes exhibit extremeness aversion, then this effect is called *compromise effect*. If only one attribute exhibits extremeness aversion, then the phenomenon is called *polarization*. The proposed framework can incorporate both effects, respectively, when both attributes exhibit loss aversion or when only one does. In fact, this framework can capture a continuum of relative importance of loss and gain sensitivities for the two attributes. Figure A.2 demonstrates an example of compromise effect, where option **L** is preferred to option **M** when the choice set is {**K**, **L**, **M**} and option **M** is preferred to option **L** when the choice set is {**L**, **M**, **N**}. The reference point can be anywhere within the convex hull of the alternatives, which is the line represented by options {**K**, **L**, **M**} in the first choice set and the line represented by options {**L**, **M**, **N**} in the second choice set. For simplicity, R1 and R2

Figure A.1 Asymmetric Dominance and Asymmetric Advantage

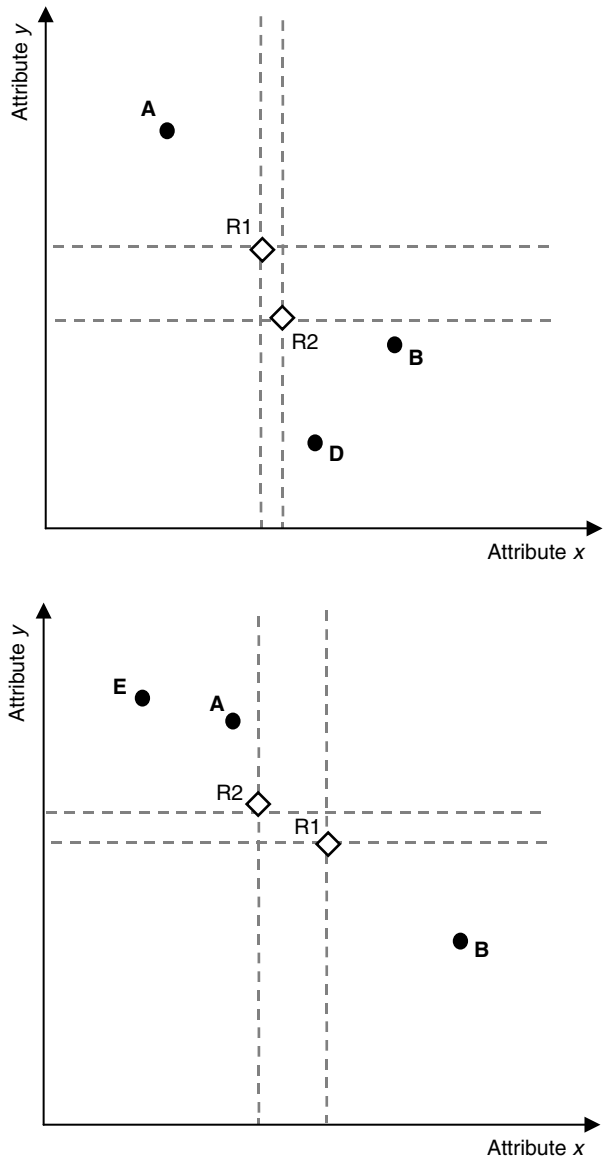
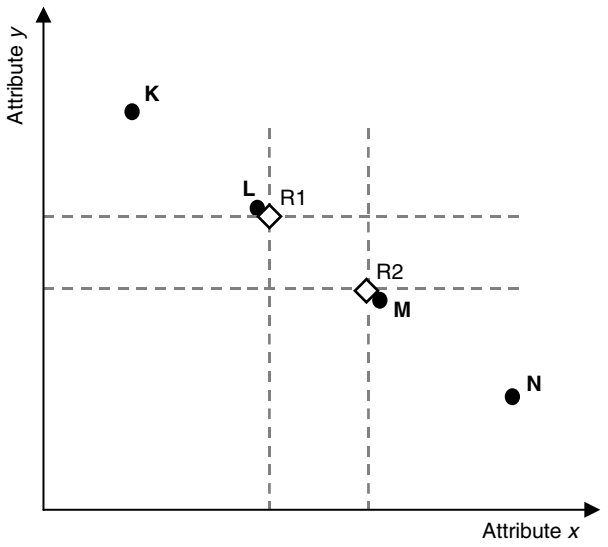


Figure A.2 Compromise Effect



depict the reference points for choice sets {**K**, **L**, **M**} and {**L**, **M**, **N**}, respectively. The addition of **N** and the deletion of **K** makes the reference point move closer to option **M** and away from option **L**. If loss aversion is relatively similar on both attributes, we see a preference reversal as the consumer prefers to incur a very small loss (or none at all) in one dimension and a very small gain in another around the reference point R1 rather than incurring a large loss and a large gain compared to reference point R2. When extremeness aversion is exhibited toward only one attribute, this effect is called polarization and can be captured by allowing the loss aversion parameters to be attribute specific. The way that the model captures the extremeness aversion findings is similar to the loss aversion model that Kivetz et al. (2004) propose.

A.1.c. Enhancement and Detraction. Figure A.3 depicts enhancement and detraction effects. The fact that the comparison of **F** to **A** and **B** is more favorable when both **A** and **B** exist versus a comparison to either one of them is called the enhancement effect. How the model captures this effect follows the same logic as that of the compromise effect. The losses for option **F** are smaller or are not existent or revert to gains when compared with the reference point R generated by the choice set {**A**, **B**, **F**}. However, in binary comparisons, both options have losses in one attribute and gains in another, as comparisons of **F** to R1 and R2 illustrate. That **F** fares better in {**A**, **B**, **F**} than in both binary comparisons suggests that consumers exhibit some loss aversion in each attribute. Similar to compromise effect, enhancement can be captured by the proposed model, which accounts for comparative valuations and loss aversion in such comparisons.

Detraction effect is observed when the option **G** fares better in binary comparisons rather than in the full set {**A**, **B**, **G**}. If the reference point in the full set is the centroid R as illustrated, option **G** is dominated by the reference point, bearing losses in both dimensions. Whereas in binary comparisons with **A** or **B**, it bears losses in one dimension and gains in the other, as comparisons to R1 and R2 highlight. The detraction effect occurs when losses on both dimensions cause greater disutility than in the case of a larger loss in one and a gain in the other. This effect will be more prominent if a diminishing sensitivity to gains or losses is incorporated in the comparative valuation function $f_k(\,)$, as suggested by Tversky and Kahneman (1991).

A.2. IC Constraint for the Low Type Is Slack

We need to show that

$$\theta_l[(1+\lambda_q)q_l - \lambda_q q_r] - p_l + \gamma_p(p_r - p_l) > \theta_l[(1+\gamma_q)q_h - \gamma_q q_r] - p_h - \lambda_p(p_h - p_r).$$

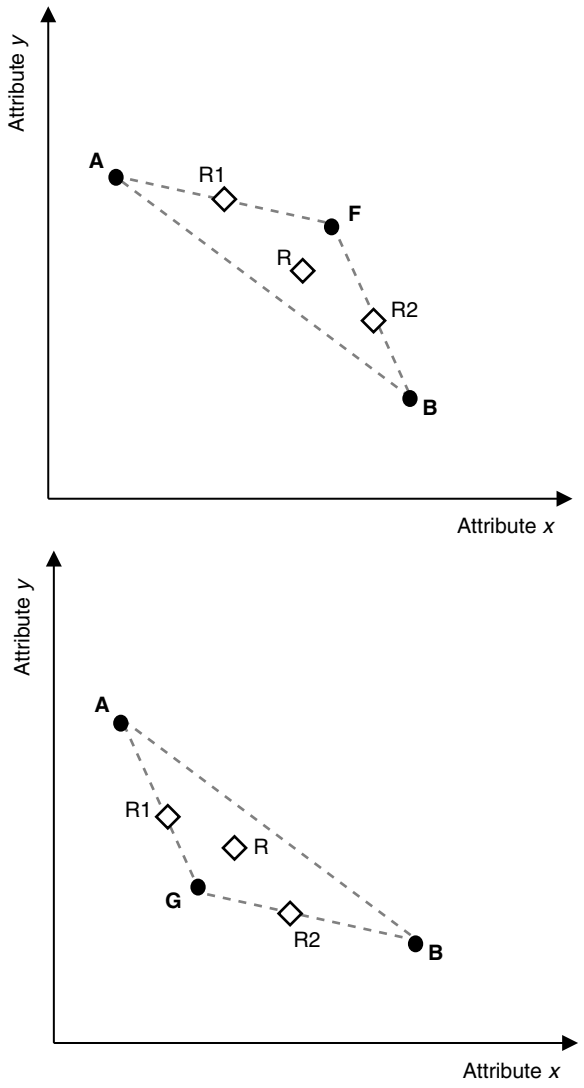
Because of IR constraint binding for the low type, we know that

$$\theta_l[(1+\lambda_q)q_l - \lambda_q q_r] = p_l - \gamma_p(p_r - p_l).$$

Equivalently, we need to show that

$$\theta_l[(1+\gamma_q)q_h - \gamma_q q_r] - p_h - \lambda_p(p_h - p_r) < 0,$$

Figure A.3 Enhancement and Detraction



and because IC constraint is binding for the high type,

$$\theta_h[(1+\gamma_q)q_h-\gamma_q q_r]-p_h-\lambda_p(p_h-p_r)$$
$$=\theta_h[(1+\lambda_q)q_l-\lambda_q q_r]-p_l+\gamma_p(p_r-p_l).$$

Combining with the IR constraint, we have

$$\theta_h[(1+\gamma_q)q_h-\gamma_q q_r]-p_h-\lambda_p(p_h-p_r)$$
$$=(\theta_h-\theta_l)[(1+\lambda_q)q_l-\lambda_q q_r],$$

and therefore,

$$\theta_h[(1+\gamma_q)q_h-\gamma_q q_r]-(\theta_h-\theta_l)[(1+\lambda_q)q_l-\lambda_q q_r]$$
$$=p_h+\lambda_p(p_h-p_r).$$

Then,

$$\theta_l[(1+\gamma_q)q_h-\gamma_q q_r]-p_h-\lambda_p(p_h-p_r)$$
$$=(\theta_l-\theta_h)[(1+\gamma_q)q_h-\gamma_q q_r]+(\theta_h-\theta_l)[(1+\lambda_q)q_l-\lambda_q q_r]$$
$$=(\theta_l-\theta_h)[q_h-q_l+\gamma_q(q_h-q_r)+\lambda_q(q_r-q_l)].$$

If the consumers can be ordered in their relative valuations of quality versus money in the same way across products and domains of gain and loss, then the optimal quality provisions are increasing in these valuations. Thus, in equilibrium, when both segments are served with distinct products, $q_l < q_h$, and therefore, by construction, $q_l < q_r < q_h$. Therefore, we have,

$$(\theta_l-\theta_h)[q_h-q_l+\gamma_q(q_h-q_r)+\lambda_q(q_r-q_l)]<0.$$

A.3. IR Constraint for the High Type Is Slack

Information rent is positive.

A.4. Solving for the Equilibrium Prices and Quantities

The firm will charge the following prices in equilibrium:

$$p_l=\frac{\theta_l[q_l-\lambda_q(q_r^l-q_l)]+\gamma_p p_r^l}{1+\gamma_p},$$

$$p_h=\frac{\theta_h(q_h+\gamma_q(q_h-q_r^h))-(\theta_h-\theta_l)(q_l-\lambda_q(q_r^l-q_l))+\lambda_p p_r^h}{1+\lambda_p}.$$

Because choice set dependency posits that the reference prices are affected by other products in the product line, each price is in fact a function of the other. The equilibrium quality provisions are solutions to the following maximization problem by the firm:

$$\max_{q_l,\,q_h}[\alpha_l(p_l-c(q_l))+\alpha_h(p_h-c(q_h))].$$

Therefore, the firm chooses optimal qualities such that

$$\frac{d\pi}{dq_h}=\alpha_h\left(\frac{dp_h}{dq_h}-\frac{dc(q_h)}{dq_h}\right)+\alpha_l\frac{dp_l}{dq_h}=0,$$
$$\frac{d\pi}{dq_l}=\alpha_l\left(\frac{dp_l}{dq_l}-\frac{dc(q_l)}{dq_l}\right)+\alpha_h\frac{dp_h}{dq_l}=0,$$

where

$$\frac{dp_h}{dq_h}=\frac{\partial p_h}{\partial q_h}+\underbrace{\frac{\partial p_h}{\partial q_r^l}\frac{\partial q_r^l}{\partial q_h}}_{IC/comparison}+\underbrace{\frac{\partial p_h}{\partial p_r^h}\frac{\partial p_r^h}{\partial p_l}}_{comparison}\left(\underbrace{\frac{\partial p_l}{\partial q_r^l}\frac{\partial q_r^l}{\partial q_h}}_{comparison}+\underbrace{\frac{\partial p_l}{\partial p_r^l}\frac{\partial p_r^l}{\partial p_h}\frac{dp_h}{dq_h}}_{indirect/comparison}\right),$$

$$\frac{dp_l}{dq_h}=\underbrace{\frac{\partial p_l}{\partial q_r^l}\frac{\partial q_r^l}{\partial q_h}}_{comparison}+\underbrace{\frac{\partial p_l}{\partial p_r^l}\frac{\partial p_r^l}{\partial p_h}\frac{dp_h}{dq_h}}_{indirect/comparison},$$

$$\frac{dp_l}{dq_l}=\frac{\partial p_l}{\partial q_l}+\underbrace{\frac{\partial p_l}{\partial p_r^l}\frac{\partial p_r^l}{\partial p_h}}_{comparison}\left(\underbrace{\frac{\partial p_h}{\partial q_l}}_{IC}+\underbrace{\frac{\partial p_h}{\partial q_r^h}\frac{\partial q_r^h}{\partial q_l}}_{comparison}+\underbrace{\frac{\partial p_h}{\partial p_r^h}\frac{\partial p_r^h}{\partial p_l}\frac{dp_l}{dq_l}}_{indirect/comparison}\right),$$

$$\frac{dp_h}{dq_l}=\underbrace{\frac{\partial p_h}{\partial q_l}}_{IC}+\underbrace{\frac{\partial p_h}{\partial q_r^h}\frac{\partial q_r^h}{\partial q_l}}_{comparison}+\underbrace{\frac{\partial p_h}{\partial p_r^h}\frac{\partial p_r^h}{\partial p_l}\frac{dp_l}{dq_l}}_{indirect/comparison}.$$

The resulting equilibrium quality provisions are

$$c'(q_h)=\frac{1}{(1+\gamma_p)(1+\lambda_p)-\gamma_p\eta_h\lambda_p\eta_l}$$
$$\cdot\left\{\theta_h(1+\gamma_q)\left(1+\gamma_p+\frac{\alpha_l}{\alpha_h}\gamma_p\eta_h\right)\right.$$
$$-\lambda_q\mu_h\left[\theta_l\left(\frac{\alpha_l}{\alpha_h}(1+\lambda_p)+\lambda_p\eta_l\right)\right.$$
$$\left.\left.-(\theta_h-\theta_l)\left(1+\gamma_p+\frac{\alpha_l}{\alpha_h}\gamma_p\eta_h\right)\right]\right\},$$

$$c'(q_l) = \frac{1}{(1+\gamma_p)(1+\lambda_p) - \gamma_p\eta_h\lambda_p\eta_l} \cdot \left\{(1+\lambda_q)\theta_l\left((1+\lambda_p)+\frac{\alpha_h}{\alpha_l}\lambda_p\eta_l\right) - \left(\frac{\alpha_h}{\alpha_l}(1+\gamma_p)+\gamma_p\eta_h\right) \cdot [(\theta_h-\theta_l)(1+\lambda_q)+\theta_h\gamma_q\mu_l]\right\}.$$

A.5. Compression and Pooling Effects

$$c'(q_h) = \frac{1}{(1+\gamma_p)(1+\lambda_p) - \gamma_p\eta_h\lambda_p\eta_l} \cdot \left\{\theta_h(1+\gamma_q)\left(1+\gamma_p+\frac{\alpha_l}{\alpha_h}\gamma_p\eta_h\right) - \lambda_q\mu_h\left[\theta_l\left(\frac{\alpha_l}{\alpha_h}(1+\lambda_p)+\lambda_p\eta_l\right) - (\theta_h-\theta_l)\left(1+\gamma_p+\frac{\alpha_l}{\alpha_h}\gamma_p\eta_h\right)\right]\right\},$$

$$c'(q_l) = \frac{1}{(1+\gamma_p)(1+\lambda_p) - \gamma_p\eta_h\lambda_p\eta_l} \cdot \left\{(1+\lambda_q)\theta_l\left((1+\lambda_p)+\frac{\alpha_h}{\alpha_l}\lambda_p\eta_l\right) - \left(\frac{\alpha_h}{\alpha_l}(1+\gamma_p)+\gamma_p\eta_h\right) \cdot [(\theta_h-\theta_l)(1+\lambda_q)+\theta_h\gamma_q\mu_l]\right\},$$

$$\begin{aligned}((1+\gamma_p)(1+\lambda_p) - \gamma_p\eta_h\lambda_p\eta_l)[c'(q_h)-c'(q_l)] &= \theta_h(1+\gamma_q)(1+\gamma_p) - \theta_l(1+\lambda_q)(1+\lambda_p) \\ &+ \frac{\alpha_h}{\alpha_l}(\theta_h-\theta_l)(1+\gamma_p)(1+\lambda_q) + \frac{\alpha_l}{\alpha_h}\gamma_p\eta_h\theta_h(1+\gamma_q) \\ &+ \gamma_p\eta_h[(\theta_h-\theta_l)(1+\lambda_q)+\theta_h\gamma_q\mu_l] + \theta_h\gamma_q\mu_l\frac{\alpha_h}{\alpha_l}(1+\gamma_p) \\ &- \lambda_q\mu_h\left[\theta_l\left(\frac{\alpha_l}{\alpha_h}(1+\lambda_p)+\lambda_p\eta_l\right) - (\theta_h-\theta_l)\left(1+\gamma_p+\frac{\alpha_l}{\alpha_h}\gamma_p\eta_h\right)\right] - \frac{\alpha_h}{\alpha_l}\lambda_p\eta_l(1+\lambda_q)\theta_l.\end{aligned}$$

If only comparisons in the quality dimension matter to consumers, comparisons in the quality dimension lead to a compression of quality provision if

$$\frac{\lambda_q\mu_h}{\gamma_q\mu_l} > \frac{\theta_h\alpha_h^2}{\alpha_l(\theta_l-\alpha_h\theta_h)}.$$

If only comparisons in the price dimension matter, then $c'(q_h)-c'(q_l)$ is proportional to

$$\theta_h(1+\gamma_p) - \theta_l(1+\lambda_p) + \frac{\alpha_h}{\alpha_l}(\theta_h-\theta_l)(1+\gamma_p) + \gamma_p\eta_h\left[\frac{\alpha_l}{\alpha_h}\theta_h+(\theta_h-\theta_l)\right] - \frac{\alpha_h}{\alpha_l}\lambda_p\eta_l\theta_l$$

and will be smaller than its baseline counterpart if

$$\frac{\lambda_p\eta_l}{\gamma_p\eta_h} > \frac{\alpha_l(\theta_h-\alpha_h\theta_l)}{\theta_l\alpha_h^2}.$$

The firm will serve both types with the same product if

$$\lambda_q(\mu_h\alpha_l+\alpha_h)[\theta_l(b+w)-\theta_h w] - \gamma_q(\alpha_h\mu_l+\alpha_l)\theta_h w > \theta_h w - \alpha_h\theta_l(b+w),$$

$$w = \alpha_h + \alpha_h\gamma_p + \alpha_l\gamma_p\eta_h,$$

$$b = \alpha_l + \alpha_l\lambda_p + \alpha_h\lambda_p\eta_l.$$

Pooling will never be profitable if only comparisons in the price dimension are made, because of the sorting condition, $\theta_l(1+\lambda_q)(1+\lambda_p) < \theta_h(1+\gamma_q)(1+\gamma_p)$.

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