Optional versus Standard Features

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ABSTRACT

Competing brands differ in the extent to which they offer a feature as standard or optional in their product line. In this paper, we study the competitive basis for this difference in brands' product line strategies. Specifically, we analyze the relationship between a brand's quality image and its propensity to offer a more differentiated, wider product line, starting from a relatively stripped-down base model to a more feature-rich model. We consider a duopoly model with two vertically differentiated firms, and show that a low-quality firm would offer the feature as optional, i.e., offer a feature-added product as well as a stripped-down base product, if it chooses to add the feature to its product. On the other hand, a high-quality firm would offer the feature as a standard component unless the cost of the feature is high. We test this asymmetry in the propensity of high- and low-quality firms to offer stripped-down versions of the product with data from the US passenger car market and find empirical support for our model.

Key words: Product Line Strategy; Product Feature Design; Game Theory; Probit Model; Automobile Market.

1. INTRODUCTION

When choosing among competing brands of a product such as automobiles, customers consider inherent quality of the brands as well as available features (Purohit 1992, Sullivan 1998). Typically, a brand may offer several variants with differing levels of features in its product line to appeal to different segments. For example, the 2014 Toyota Avalon is offered in the U.S. in four models (or trim levels), XLE, XLE Premium, XLE Touring and Limited that offer an increasingly richer set of features at higher prices starting from the XLE model. Although consumers can customize each model to a minor extent (such as adding a remote engine starter), a consumer desiring additional features typically needs to upgrade to a more expensive model. For example, a consumer desiring ventilated front seats has to choose the highest Limited model, since this feature is not available on the other models. On the other hand, a consumer, who does not value the steering wheel mounted audio control, cannot purchase a model without this feature because it is standard on all models.

In general, competing brands differ in the extent to which they offer a feature selectively on their product variants versus making the feature standard on all variants of their product lines. For example, heated seats are a standard feature on all 2014 Avalon models. In contrast, its American competitors in the large sedan category Chrysler 300 and Dodge Charger offer heated seats only on their most expensive, feature-rich models. Because of such standard features, Toyota Avalon appears to have offered a less differentiated, narrower product line than Chrysler 300 and Dodge Charger.[1]

In this paper, we study the competitive basis for such differences in brands' product line strategies. Specifically, we analyze the relationship between a brand's quality image and its propensity to offer a more differentiated, wider product line, starting from a relatively stripped-down base model to a more feature-rich model. For example, does Toyota's stronger quality image in comparison to Dodge make it more likely that Toyota offers a narrower product line loaded with standard features? More generally, we investigate whether and why high-quality brands offer less differentiated product lines in comparison to low-quality brands.

We answer the above research questions using a game-theoretic model in which two vertically differentiated firms, whose base products have different inherent qualities, have the

[1] While 2014 Toyota Avalon comes in only four trim levels, 2014 Chrysler 300 and Dodge Charger have six and seven trim levels, respectively (Cars.com 2015).

ability to add a feature to their base products. Inherent quality is determined by a brand's reputation and includes components of perceived quality that are hard to change in the short run such as its driving performance and expected reliability. Consumers also consider physical features of the product such as steering wheel mounted audio controls or heated seats. While firms cannot change the inherent quality in our model, they can decide on the products' features to influence consumers' purchase decision.[2] Each of the two competing firms has three product line alternatives: (i) sell the base product only; (ii) offer the feature as optional (i.e. sell two products: the base product and the base product with the feature); (iii) or sell the base product with the feature as standard (i.e. sell only one product that includes the feature).

Our equilibrium results show that the high-quality firm offers the feature as a standard component of its product except when the cost of the feature is high, when it makes the feature optional. On the other hand, the low-quality firm offers the feature only as an optional component, and it does so only when the cost of the feature is low. In other words, the low-quality firm also offers the base product whenever it offers the feature-added product. This asymmetry in the behavior of the firms is because of the quality positioning of the firms. By offering the base product as an alternative to the feature-added product, the low-quality firm avoids pricing low-valuation consumers out of the market. In contrast, if the high-quality firm adds the base product to its offering of the feature-added product, price competition is intensified as the differentiation between the firms reduces. Therefore, the high-quality firm avoids doing so except when the feature cost is high. These differing incentives of the two firms imply that the propensity to offer the base product as part of its product line, either as an option or as a stand-alone product, is higher for the low-quality firm. An empirical analysis of the US passenger car market is consistent with this prediction, thus offering support for the theoretical model.

Our model and analysis build on the literature on vertical competition (e.g., Shaked and Sutton 1982; Moorthy 1988). In contrast to this literature, we allow each competing brand to offer a line of products differentiated in "overall quality," where a product's overall quality consists of two components: the brand's inherent quality and the optional feature. By assuming that a firm's inherent quality cannot be changed while firms can choose to offer optional or standard features with their base products, we study short-run competition on product features

[2] In other words, in our model, while inherent quality is exogenous, features are decided by firms, and therefore are endogenous.

while allowing for firms to offer a quality-differentiated product line. When firms can offer a product line differentiated in quality, we find that firms consider both the price competition effect of product differentiation identified in Shaked and Sutton (1982) and the benefit of market segmentation as in Mussa and Rosen (1978). Unlike Shaked and Sutton (1982), we find that the differentiation between firms' products decreases when firms compete on product features and have the option of offering a product line.

Our work is also related to the literature on product line competition. In this literature, Champsaur and Rochet (1989) also identify price competition and market segmentation as important forces in their study of competing firms' product line choices. Their objective is to study this problem in general terms and they show that the quality ranges offered by the firms do not overlap in equilibrium. Katz (1984) and Gilbert and Matutes (1993) reach a similar conclusion in finding that competing firms may not offer full product lines. Other research on product-line competition has focused on the nature of quality discrimination in equilibrium. Desai (2001) considers product line competition between firms for discrete consumer segments with heterogeneity in taste preferences. He identifies the conditions under which the consumer segments get their efficient quality levels. Schmidt-Mohr and Villas-Boas (2008) investigate product line competition when there are quality constraints. They show that each firm offers a single product for the top and bottom portion of the customer types, and a different product for each customer type in the middle portion. In contrast to the above literature on product line competition, our paper focuses on firms' decisions on whether to offer optional or standard features with their base products.[3]

The remainder of the paper is organized as follows. Section 2 presents the theoretical model that is analyzed in the following Section 3. Section 4 tests the model's predictions using data from the U. S. passenger car market and Section 5 concludes. Proofs and additional details of the analysis are presented in an online Technical Appendix.

2. MODEL

Consider a market in which there are two firms, firm L and firm H, differentiated in the inherent quality of their products. Firm H's inherent quality (m_h) is higher than firm L's (m_l)

[3] There is also a considerable literature that addresses product line design by a monopoly firm when consumers differ in their valuation for quality (e.g., Mussa and Rosen 1978, Moorthy 1984, Villas-Boas 2004).

with $m_h - m_l = d > 0$. The inherent quality represents the quality of a basic product offered by a firm. We assume that firms are endowed with their products' intrinsic qualities and that these qualities cannot be changed in the short run. In making their purchase decisions, consumers may use brand names in assessing products' inherent qualities. (Sullivan 1998). For example, an intrinsic quality of BMW cars is its driving performance, which has been a characteristic of its cars for a long time. To focus on demand effects of quality differentiation, we assume that both firms have the same marginal cost for their respective basic product and we normalize this common marginal cost to zero for simplicity. Each firm, however, has the ability to add a feature to its basic product. In what follows, we let lb and hb denote the base or basic products, and *lf* and *hf* denote the feature-added products of firms *L* and *H* respectively.

We assume that addition of a feature enhances the perceived quality of the base product of either firm by k. Thus, the quality of a base product incorporating the feature from firm *H* and firm L becomes $m_h + k$ and $m_l + k$ respectively. The assumption that the feature increases the perceived qualities of the base products of both firms by the same amount is parsimonious, while being general enough to allow the feature to be valued differently by customers of the two firms. For example, a feature may be an "eco" setting for a car that improves gas mileage of a car by 5 miles per gallon. In this example, k refers to the objective improvement in the gas mileage of each firm's product from the feature, and will consequently be identical. However, in equilibrium, the high-quality firm would serve consumers whose value for a marginal unit quality would be higher, effectively making the value of the feature higher when offered on the high-quality product.[4] We re-parameterize $k = \alpha d$, where α represents relative value of the feature with respect to the quality difference between the two base products. We assume that $0 < \alpha < 1$, and therefore $k < d$. In other words, this assumption implies that the quality enhancement from the incorporation of the feature is smaller than the inherent quality differences between the products. Such an assumption appears reasonable for new features introduced in many durable product markets as many of the new features represent incremental innovation. Without loss of generality, we set the quality of firm L to be 1 (i.e. $m_l = 1$). We assume that incorporating the feature would increase the marginal cost of the basic product of either firm by

[4] An alternative assumption is to make the objective value of the feature increase with the quality of the base product. A model formulation that the feature adds $m_i k$ to the quality of firm *i*'s base product would be consistent with such an assumption. However, this alternative assumption would not change the key insights from our analysis.

the same amount, which we denote by c. This assumption of a common marginal cost of the feature for both firms enables us to focus on the demand effects of adding a feature to the basic product.

There is a unit mass of consumers who demand at most one unit of the product. Consumers differ in their value, x, for a unit of quality with x being uniformly distributed in [0, 1]. Consumers purchase the product that offers the highest net surplus, provided the surplus is non-negative, where net surplus is measured by the value of the product minus its price. Thus, given the prices p_i of the products in the market, a consumer with a value of x per unit of quality derives the following utility from purchasing product i or from not purchasing as follows:

$$U_i(x) = \begin{cases} (m_h + k)x - p_i & \text{if } i = hf \\ m_h x - p_i & \text{if } i = hb \\ (m_l + k)x - p_i & \text{if } i = lf \\ m_l x - p_i & \text{if } i = lb \\ 0 & \text{otherwise} \end{cases}$$

In the paper, we focus our analysis on the interesting case where $c < k$, or equivalently, $c < \alpha d$. In other words, the interesting case occurs when at least the highest valuation consumer in the market values the feature more than its cost. The sequence of decisions in the game is as follows. First, firms decide through their product line strategies whether they will give flexibility to consumers in choosing between a base product and a product that combines the base product with a feature. In other words, each firm has three alternatives: (1) Sell only the base product (strategy *B*); (2) Make a feature optional thereby giving flexibility to consumers in choosing between two products, the base product and the feature-added product (strategy *BF*); (3) Make a feature standard on its product thereby selling only the feature-added product (strategy *F*). In the second stage, firms announce prices for individual products in the product lines. We assume prices are chosen after the product line decisions because prices can be more easily changed than the product line. Our assumption about the valuation distribution of consumers implies that the market is not covered in equilibrium. The lack of complete market coverage, i.e., a market where not everyone purchases the product, is likely a more appropriate assumption for durable good markets. Given the three product line strategies for each firm, there are nine possible subgames at the end of the first stage, as shown in Table 1. We solve for the subgame perfect equilibrium of the game.

3. ANALYSIS

3.1 Benchmark Case

We first analyze a simpler version of the main model to serve as a benchmark for our main analysis. In the benchmark case, firms can only offer one product, which could be either a base product or a feature-added product (i.e. feature is offered as standard). The consumer segments in such a market can be represented as in Figure 1, where x_1 and x_2 represent respectively the consumers who are indifferent between firm *H* and firm *L*, and between firm *L* and no purchase. This benchmark analysis helps us to understand how the cost of a feature interacts with the demand effects from adding the feature while restricting the product line length to one. Proposition 1 presents the results of the benchmark model.

Proposition 1: *When firms offer just one product, the equilibrium strategies are as follows:*

a. *F-F when* $0 < c < min(\chi_1^{BM}, \chi_2^{BM})$.
b. *B-F when* $\chi_2^{BM} < c < \chi_3^{BM}$.
c. *B-B when* $\chi_3^{BM} < c$.

χ_1^{BM}, χ_2^{BM}, and χ_3^{BM} *are given in the proof. The equilibrium profits, prices and quantities are given in Table 2.*

Proposition 1 shows that when the marginal cost, *c*, of adding a feature is sufficiently small, both firms make the feature standard (*F-F*) in equilibrium, while neither firm offers the feature when *c* is large. In the intermediate range of *c*, only firm *H* offers the feature-added product. Note that this result is different from the standard result such as Shaked and Sutton (1982) in which the only equilibrium pair with some firm offering the feature can be *B-F*, as such an equilibrium would lead to maximal differentiation between the firms. This difference arises because we assume that the market is not covered unlike Shaked and Sutton (1982) and similar to Moorthy (1988). As noted earlier, a lack of complete market coverage may be an appropriate assumption for durable good markets.

The interesting insight from Proposition 1 is that there cannot be an *F-B* equilibrium in which only the low-quality firm offers the feature in the product. In particular, the result that the high-quality firm could offer the feature either as the only firm doing so, or along with the low-quality firm, suggests a bias in favor of the high-quality firm in offering the feature. The intuition for this bias is the difference in the strategic effects on price competition when firm *H* offers the feature versus when firm *L* offers it. Specifically, when firm *L* offers the feature, the price competition intensifies as the quality differentiation between the firms reduces. This increase in price competition reduces the potential profits to firm L from adding the feature. However, when firm H offers the feature, the quality differentiation between the firms increases, relaxing the price competition between the firms and increasing the profit from adding the feature. This difference in the strategic effects for the two firms implies that if firm L finds it profitable to add the feature in spite of the accompanying intensification of price competition, firm H would certainly find it profitable to do the same, because its offer of the feature would have the added benefit of reducing competition. On the other hand, it is possible that firm H finds it profitable to offer the feature while firm L does not. Thus, there is a bias in favor of firm H offering the feature.

3.2 Main Analysis

We now analyze our main model in which firms may offer more than one product, i.e. a product with the feature and one without. The equilibrium results for the various product-line subgames (see Table 1) are presented in Tables 3. Lemma 1 below identifies the product-line strategy combinations that cannot constitute an equilibrium.

LEMMA 1: *B-B, BF-B, F-B, F-BF, and F-F cannot be an equilibrium.*

Lemma 1 suggests that equilibrium cannot entail firm L offering the feature-added product without offering the base product. Likewise, firm H would not offer the base product without offering the feature-added product in equilibrium. The intuition is a market segmentation argument. Consider, for example, why *F-B* cannot be an equilibrium. In the case of an *F-B* equilibrium, the market is segmented as in Figure 1 with consumers between x_1 and x_2 buying the featured-added product (*lf*) of firm L while consumers between x_1 and 1 buy the base product (*hb*) offered by firm H. If firm L were to offer a base product (*lb*) as well in its product line, the market segmentation in the resulting *BF-B* equilibrium would be as in Figure 2, with the segment to the left of x_2 being split into two segments: those buying firm L's base product (*lb*) and those opting to not buying any product. As a result of such segmentation, firm L serves with its base product some consumers who were previously priced out of the market and did not buy any product. Thus, firm L's market share increases in the *BF-B* equilibrium in comparison to the *F-B* equilibrium (see Table 3. In addition, firm L's addition of the base product to its product line does not increase the intensity of price competition, as evident from the unchanged equilibrium price of its feature-added product between the *F-B* and *BF-B* equilibria (see Table 3). The rationale is that the marginal consumer choosing between firm *L*'s products and firm *H*'s product in both equilibria (consumer at x_1 in Figures 1 and 2) is choosing between the feature-added product of firm *L* and the base product of firm *H* in either equilibrium. Thus, when firm *L* adds a base product to move from an *F-B* equilibrium to a *BF-B* equilibrium, it increases its market share through better market segmentation without affecting the intensity of price competition, thus increasing its profit. Therefore, firm *L* always deviates from an *F-B* equilibrium causing the latter to not exist as seen in Lemma 1. For the same reason, *F-F* and *F-BF* cannot be equilibrium strategies.

An analogous situation obtains when firm *H* extends its product line by offering a feature-added product (*hf*) in addition to its base product (*hb*). In this case, the consumers between x_1 and 1 are split into two segments as shown in Figure 3 for the *B-BF* equilibrium: those buying product *hf* and those buying product *hb*. Note from Figure 3 that product *hf* appeals to consumers with the highest valuation for quality and therefore it is firm *H*'s base product, *hb*, that competes directly with firm *L* for the marginal consumer at x_1. Thus, the addition of the feature-added product as a second product helps firm *H* discriminate between high valuation consumers without intensifying price competition, thereby increasing profit.[5] Therefore, firm *H* finds it profitable to deviate from equilibria such as *BF-B*, *F-B*, and *B-B* by adding the feature-added product to its product line, making such equilibria non-existent as given in Lemma 1.

Given the strategy combinations ruled out as equilibrium by Lemma 1, we now characterize the conditions under which the remaining strategy combinations, which are *B-BF*, *B-F*, *BF-BF*, and *BF-F*, can each be an equilibrium. Because the conditions for equilibrium are quite complex for general d, we assume d =1 for the rest of the analysis. While the intuition for the results described below also holds for general d, the main difference in the general case is that *BF-BF* can be an equilibrium for d sufficiently greater than 1, while it fails to be an equilibrium when d = 1. The rationale is that the four products offered by the two firms in a *BF-BF* equilibrium (see Figure 2) are sufficiently differentiated and profitable to sustain the equilibrium, only when the difference between firms' intrinsic quality is sufficiently large (i.e., large d).[6] Proposition 2 characterizes the equilibrium for the main model assuming d = 1.

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[5] Consistent with a lack of intensification of price competition, the price of firm *H*'s base product, *hb*, stays the same between the *B-B* and *B-BF* equilibrium as seen in Table 3.

[6] This result is similar to that in Gibert and Matutes (1993), who show that both firms may offer a full product line when the level of differentiation between firms is sufficiently large.

PROPOSITION 2: *When firms can offer a product line with the feature being optional or standard, the equilibrium strategies are as follows:*

a. *BF-F when* $0 < c < \chi_1$.
b. *B-F when* $\chi_1 < c < \chi_2$.
c. *B-BF when* $\chi_2 < c < \alpha$.

χ_1 *and* χ_2 *are given in the Technical Appendix. The equilibrium profits, prices and quantities are given in Table 3.*

Proposition 2 shows that the low-quality firm always offers its base product, but does not offer the feature-added product except when the cost is low. Even in this case of low marginal cost for the feature, the feature-added product is offered as an option in firm *L*'s product line. In contrast, the high-quality firm always offers the feature-added product. Further, the feature is included as a standard part of its product except when the cost is high when the feature is offered as an option in firm *H*'s product line. This asymmetry in the equilibrium strategies of the high- and low-quality firm is a result of the previously discussed strategic effect of product offerings on price competition and the benefits of market segmentation. Thus, firm *L* always offers the base product because this product minimizes the intensity of price competition when firm *L* offers only one product in its line. Further, in the event that firm *L* offers the feature-added product, the addition of the base product to the product line provides market segmentation benefits without intensifying price competition (see our discussion after Lemma 1 for the intuition). Similarly, firm *H* always offers the feature-added product because this is the product that would minimize price competition when firm *H* offers a single product in its line. However, even if firm *H* offers the base product, the addition of the feature-added product would increase profit due to market segmentation without increasing price competition. This bias of the high-quality firm towards offering the feature-added product is similar to that in the benchmark case except that the intuition for this bias relies both on price competition and market segmentation considerations in the main model.

Thus, the remaining question concerns the issues of when firm *L* chooses to add the feature-added product to its product line and when firm *H* chooses to add the base product to its product line. As Proposition 2 shows, when the cost of the feature is sufficiently low, firm *L* finds that the profit from a feature-added product is sufficiently attractive to offset the increased price competition that will result from adding this product to its line. On the other hand, the low cost of the feature makes the segmentation benefits to firm *H* from adding a lower-cost base product smaller than the negative effects of increased price competition that such a move would engender. Thus, firm *H* prefers not to add a base product when the cost of the feature is low, and we have a *BF-F* or a *B-F* equilibrium. However, when the cost of the feature is sufficiently high, firm *H* realizes less profit from the feature-added product and therefore finds that the segmentation benefits from offering a lower-cost base product dwarfs the negative effects of higher price competition. On the other hand, adding the feature-added product is not attractive to firm *L* when the cost is high as noted above. Thus, we have a *B-BF* equilibrium when the cost of the feature is sufficiently high. For intermediate cost levels, both firms are content to offer a single product and minimize price competition, and we have a *B-F* equilibrium. Note also that the above discussion implies that consumers would have more products to choose from when the cost of a feature is either sufficiently low or high. In other words, consumers' product choice in the market would be limited when the cost of a feature is in the intermediate cost levels.

We now present some interesting characteristics of the equilibrium in the main model in Result 1 below.

Result 1: (i) The minimum cost, χ_2, of the feature needed to induce firm *H* to offer the base product increases with α, the quality of the feature.

(ii) The maximum cost, χ_1, of the feature at which firm *L* would offer the feature-added product increases with α, the quality of the feature.

As the relative value, α, of the feature increases, firm *H* finds it worthwhile to introduce a base product (at the expense of higher price competition) only at a higher cost threshold, because the higher α makes the feature-added product more profitable. Likewise, firm *L* finds it profitable to offer the feature-added product even at higher cost levels when α is higher, because of this product's greater profitability. Next, we compare the equilibrium results in the main model with those in the benchmark case to draw some interesting implications for how the length of the product line affects firms' product strategies.

Result 2: In comparison to the benchmark case,

(i) Firm *H* offers the feature-added product at comparatively higher cost levels, because firm *H* does not offer the feature-added product in the benchmark case when $\chi_3^{BM} < c < \alpha$.

(ii) The minimum cost at which firm *H* offers the base product in its product line decreases, because $\chi_2 < \chi_3^{BM}$.

(iii) The maximum cost at which firm L offers the feature-added product increases because $min(\chi_1^{BM}, \chi_2^{BM}) < \chi_1$.

(iv) The intermediate interval of cost values at which firms' products are maximally differentiated in quality, i.e. where the equilibrium is *B-F*, is smaller.

In the benchmark case, where the firm is restricted to selling only one product, firm *H* prefers offering the base product to the feature-added product, when the cost of the feature becomes sufficiently high. However, when firm *H* has the option of offering a product line, it chooses to offer the feature-added product in its product line even when the feature cost is so high that it offers the base product. The rationale is to take advantage of the benefits of market segmentation as discussed earlier. This intuition explains part (i) of Result 2. The rationale for part (ii) begins with the understanding that firm *H* persists with the feature-added product in the benchmark case even at high costs in order to avoid the higher price competition from offering the base product alone. However, when offering a product line of *hb-hf* in the main model, firm *H* can attract additional consumers by offering the base product, thus increasing its market share. Although the base product induces greater price competition, resulting in a lower price of its feature-added product, the higher overall market share offsets the loss from the price decrease of the feature-added product. Thus, firm *H* offers the base product at lower cost levels in the main model explaining part (ii) of Result 2. As for part (iii), consider first the benchmark case. In this case, as cost increases, firm *L* finds that the price of the feature-added product prices many low-valuation consumers out of the market. Consequently, it switches to offering the base product, which also reduces price competition. In contrast, in the main model, firm *L* can continue to offer the feature-added product at higher costs of the feature, because the base product brings in the low-valuation consumers. Lastly, part (iv) of Result 2 follows directly from parts (ii) and (iii). Note that maximal differentiation between the firms occurs in the *B-F* equilibrium. In comparison to the benchmark case, because firm *H* offers the base model at lower cost values (by part (ii)), and firm *L* offers the feature-added product at higher cost values (by part (iii)), the cost interval where products are maximally differentiated shrinks in the main model. Thus, interestingly, when firms can offer a product line with optional features, they may not choose to be maximally differentiated unlike Shaked and Sutton (1982).

Result 3: In comparison with the benchmark case, if a firm offers a wider product line, its profit is higher, while the profit of the competing firm may be lower.

The result that a firm that expands its product line in comparison to the benchmark case, gains in profit, is intuitive as otherwise, the firm would gain by rolling back its product line. This product line expansion, however, hurts the competing firm whenever it reduces the differentiation between firms' products, because of more intense price competition. Specifically, firms *H* and *L* respectively enjoy lower profits than in the benchmark in the *BF-F* and *B-BF* equilibria because of the wider product line of their competitor.

4. EMPIRICAL ANALYSIS

4.1 Hypothesis and Data

Proposition 2 suggests that the low-quality firm offers the base model under all conditions. In contrast, the high-quality firm does not offer the base model unless the cost of the feature, c, is high in relation to its value, α. This result suggests the following hypotheses:

H_1: As the inherent quality of a firm increases, its propensity to offer a base product as part of its product line decreases.

H_2: As the cost of a feature decreases, the propensity to offer a base product without the feature decreases more for products with higher inherent quality.

We investigate if these predictions of our theoretical model are supported by data from the US passenger car market for the period 2001-2010. We obtain data on technical specification of cars sold in the US passenger car market during this period as reported by Ward's Automotive Yearbook. For a particular year and car model, the specifications are available for each variant represented by the trim level of the car and its body style. For example, in 2001, specification data for the car model, Ford Focus, is available for each of its trim levels such as LX, SE and ZTS and for each available body style such as a 2-door hatchback or a 4-door sedan. Available specifications include car characteristics such as weight, engine horsepower and gas mileage as well as whether two features, anti-lock (ABS) brakes and traction control, were each offered as optional equipment or as standard equipment for that car model variant. Our empirical analysis tests the propensity of these features to be offered as optional or standard features by car models. In particular, if a car model offers both of these features as optional equipment, we infer that this car model offers a base product.

As a measure of inherent quality of the car models, we use APEAL[7] ratings of a car model's "performance" as provided by J.D. Power and Associates. Derived from surveys of new vehicle owners, the APEAL ratings range from 1 to 5 for each car model, with a rating of 5 indicating the best score on the attribute. Further, according to J. D. Power, the APEAL ratings of a car model's performance is "based on owner satisfaction with the vehicle's powertrain and suspension systems, including acceleration, fuel economy, handling stability, braking performance, and shift quality." From a mechanical standpoint, the optional car features of anti-lock brakes and traction control in our study should be strongly related to handling stability and braking performance that are part of the APEAL performance ratings. Therefore, we use these ratings as our measure of inherent quality to be consistent with our analytical model in which consumer valuations of inherent quality and the optional feature are perfectly correlated. A regression of performance ratings against car characteristics and the availability of anti-lock brakes and traction control as standard or optional features confirms that these features are positively related to a car model's performance ratings (see Table 4). Table 4 shows that the availability of traction control as a standard or optional equipment (TRACT_standard or TRACT_optional) is associated with a statistically significant increase in the performance rating of a car model, with the standard equipment increasing ratings higher. In the case of ABS, offering this feature as standard (but not optional) equipment is associated with an increase in performance ratings of a car model. Further, we find that ABS and traction control account for only 25.4% of the variation in performance ratings of car models. Therefore, offering of these features is unlikely to drastically change perceived performance of a car model consistent with the assumption of our theoretical analysis that $k < d$.

We exclude hybrid cars from our analysis, leaving us with a sample of 150 distinct car models over the two-year period. To test hypothesis H_1, we analyze the propensity for firms to offer optional or standard features for a car variant as represented by a car model and body style, with the body style classified into four kinds: 2-door sedan, 3-door hatchback, 4-door sedan, and 4-door wagon. We use such a variant as the unit of analysis because consumers may have sufficiently strong preferences for a body style to induce them to confine their purchases to cars with their preferred body styles. Between 2001 and 2010, the annual number of variants representing combinations of car models and body styles ranged from 146 to 183 with an

[7] APEAL stands for Automotive Performance, Execution and Layout.

average of 168.1 for the time period. Of the 1681 car models/body styles offered over this period, Table 5 shows that 27.2 % offer a stripped-down product without both ABS and traction control. In contrast, the proportions of car models/body styles that offer a less stripped-down product such as one without traction control (but with ABS being standard) or without ABS (but with traction control standard) are 22.2% and 0% respectively. The remaining 50.6% of car models/body styles offer both traction control and ABS as standard features.

4.2 Empirical Model and Dependent Variable

To test the hypotheses, we estimate two models with slightly different dependent variables. The first model is a probit model in which for car model *i* and body-style *b* in year *t*, the dependent variable, $y_{ibt} = 1$ if a fully stripped down base product with no traction control and no ABS is offered, with $y_{ibt} = 0$ otherwise. Note that this formulation of the dependent variable makes no distinction between a car variant that offers a partially stripped down product without one of the two features, and a car variant in which both features are standard equipment, setting $y_{ibt} = 0$ in both cases. We therefore estimate an alternative ordered probit model in which for car model *i* and body-style *b* in year *t*, y_{ibt} is defined as follows: $y_{ibt} = 1$ if both ABS and traction control are offered as standard features; $y_{ibt} = 2$ if ABS is a standard feature but a product variant without traction control is offered; and $y_{ibt} = 3$ if a base product without ABS or traction control is offered. Note that we do not have a value for y_{ibt} in the case of a car variant that offers traction control as a standard feature but without ABS because we observe no such car variants in our data (see Table 5). Further, note that an ordered probit model is appropriate for this formulation of y_{ibt} because the degree to which the base product is stripped down increases as y_{ibt} increases discretely from 1 to 3. For both the probit and ordered probit models, the empirical model is specified as follows.

$$y^*_{ibt} = \beta X_{ibt} + \varepsilon_{ibt} \tag{0}$$

In the above equation, X_{ibt} is a vector of explanatory variables, β is a parameter vector, and ε_{ibt} is an error term distributed as $N(0,1)$. y^*_{ibt} is a latent variable whose value determines the observed variable, y_{ibt}, as follows. For the probit model, $y_{ibt} = 1$, if $y^*_{ibt} > 0$, and $y_{ibt} = 0$ otherwise. In the case of the ordered probit model, $y_{ibt} = k$ if $\mu_{k-1} < y^*_{ibt} \leq \mu_k$, for $k = 1, 2, 3$, where $\mu_0 = -\infty$, $\mu_3 = \infty$, and μ_k, for $k = 1, 2$, are parameters to be estimated. Given that we estimate μ_1 and μ_2, we do not use an intercept term in the ordered probit model, as this term cannot be separately identified. We estimate both models using maximum likelihood methods. (See Greene, 2008 for details.)

4.3 Key Explanatory Variables in the Empirical Model

We use two sets of models, each with different key explanatory variables, to test hypothesis H_1 and H_2 respectively. We describe the key explanatory variables for each hypothesis below. The models for testing both hypotheses however use the same control variables, which are described subsequently.

Hypothesis H_1

A key explanatory variable that we include in the model is PERFORMANCE, which is the car model's APEAL performance rating. As discussed above, we use this variable as a measure of the inherent quality of a model as considered in our theoretical analysis. Note that the performance ratings of cars in the APEAL survey reflect the performance attributable to the inherent quality of the car as well as that due to the optional features of ABS and traction control. In other words, the measured performance ratings reflect $m+k$ rather than m in our analytical model. However, if H_1 is true, the measured performance of car models with higher inherent quality would be higher, because such car models are less likely to offer a base product without the performance-enhancing features. Therefore, H_1 would imply that the propensity to offer a base product is also negatively related to the average values of $m+k$ (measured performance) for the cars offered in equilibrium. Thus, we hypothesize that the estimated coefficient of PERFORMANCE is negative.

Hypothesis H_2

We do not have access to annual cost data on ABS and traction control systems for cars. However, Kahane and Dang (2009) suggest that costs for these features decline over time. These authors note that the cost of an ABS system declined from \$670 around 1989 to about \$382 in 2006 (both prices are in 2006 dollars). Therefore, we use time as a proxy variable for cost of the ABS and traction-control features, with the assumption that costs decline with time. Figure 4 shows that the propensity to offer a base model declines more rapidly over time for car variants with higher performance (intrinsic quality) ratings, thus offering tentative support for Hypothesis

H_2.[8] However, the extent of the decline in propensity with time does not appear to be related to performance in linear fashion. Therefore, we create six dummy variables, PERF1 through PERF6 to represent APEAL performance ratings in the ranges, 2.0-2.5, 2.5-3.0, 3.0-3.5, 3.5-4.0, 4.0-4.5 and 4.5-5.0. We include PERF2 through PERF6 as explanatory variables in the empirical model and interact these performance dummy variables with the variable, TIME, where TIME is the number of years since 2001. Because we consider TIME to be a proxy for cost of the features, we expect, consistent with hypothesis, H_2, that the coefficients of the interaction terms would be negative for car models with higher performance ratings.

4.4 Control Variables in the Empirical Model

In the models to test both hypotheses, we include the following additional explanatory variables to control for other factors that may influence a car model's propensity to offer a base product.

Car Segment: We expect that a car model's offer of a base product would depend on the product-market segment it competes in. For example, car models in the high-end luxury segment may not find it optimal to offer products devoid of ABS or traction control irrespective of the inherent qualities of the car models, because these features are essential for any consumer to purchase in this segment. We use a classification of cars into segments provided by Ward's Automotive yearbook to control for segment-related effects on the propensity to offer a base product. Specifically, Ward's classifies car models into one of twelve segments: lower small, upper small, small specialty, lower middle, upper middle, middle specialty, large, lower luxury, middle luxury, upper luxury, luxury specialty, and luxury sport. We combine the lower small and upper small into one segment called 'small' because of lack of variation in the product offerings in terms of optional features in one of these individual segments. For the same reason, we combine the middle luxury and upper luxury segments into one segment called 'upper luxury.' We include nine dummy variables to capture a car's membership in one of the resulting ten segments, with the luxury sport segment acting as the baseline.

Own and Competitive Offerings: We expect that a car model's offer of a base product would be influenced by the number of other models offered by the same company in the same

[8] Note that our performance measures, strictly speaking, capture the average values of the total quality, m+k, for a car model. However, hypothesis H_2 would suggest that brands with higher total quality would be associated with a greater decline in the propensity to offer a base product as the cost of the feature decreases.

car segment and body style. For example, the propensity of Ford to offer a base product for the Ford Mustang in the middle specialty car segment may be reduced because it offers a base product for its other car model, Ford Probe, in the same car segment. Thus, we include a variable, OWNMODEL for any given car model and body style to capture the number of other car models with the same body style that the firm offers in the same segment. We expect the coefficient of OWNMODEL to be negative. Similarly, we may expect that a car model's offer of a base product to be influenced by the number of competitive models, COMPMODEL, in the same car segment and body style. For example, Kotler (2000, p. 402) notes that a firm may offer additional products so as to plug holes in its product line and keep competitors out. This suggests that we may expect the coefficient of the explanatory variable, COMPMODEL to be positive.

Other variables: We include dummy variables, TWODR, HATCH and WAGON, to indicate the body styles of a 2-door sedan, a 3-door hatchback and a 4-door wagon respectively. A car model variant for which the above dummy variables are all zero would be a 4-door sedan. These body style variables control for potential effects of the markets for cars with these body styles on a car model's propensity to offer a base product in these styles. For example, the small size of the market for a wagon body style may limit the number of variants that a model may offer in this style.

Table 6 provides descriptive statistics of the variables in the model. We checked the correlations between variables and found none of them to be high enough to raise concerns about multicollinearity.

4.4 Estimation Results

Hypothesis H_1

Table 7 presents the parameter estimates of the probit model and the ordered probit model for our empirical test of hypothesis H_1. For both models, the likelihood ratio test rejects the null hypothesis that the coefficients of the explanatory variables are zero ($p < 0.0001$). The coefficient of PERFORMANCE is negative and significant ($p < 0.001$) in both models. This result is consistent with hypothesis H_1, lending support to our theoretical finding that propensity to offer a base product is negatively related to the inherent brand or firm quality. The similar results with the alternative empirical models of probit and ordered probit indicate robustness of this finding. We also estimated alternative models in which the propensity to introduce a base product was measured at the brand or company level rather than at the car model level. Such an analysis may capture the notion that brands or firms may consider their decision to offer a base product in the context of their entire portfolio of products. These analyses yielded similar results.

Reviewing the other parameter estimates in the probit model, we find that the offer of a base product for a car model/body style is negatively related to the number of other models a firm offers in the same car segment and body style (OWNMODEL). This relationship is statistically significant in the probit model ($p < 0.01$) but not in the ordered probit model. However, the effect of the number of competitive models in the same segment and body style on the propensity to offer a base product is not statistically significant. These results are similar in the ordered probit model as well. We find that the body styles offered by a model such as wagon, two-door or hatchbacks are less likely to offer a base product in comparison to a 4-door sedan. The rationale for this result may be that the lower volumes sold of the wagon, two-door sedan or hatchbacks may not justify offering a broader product line (that includes a base product) for these body styles. [9] Note that the coefficients of the car segment dummies in Table 7 measure the difference with respect to the luxury-sport segment. In general, the segment dummies show that the propensity to offer a base product varies across car segments, with car models in the luxury segments less likely to offer a base product.

Hypothesis H_2

Table 8 presents the parameter estimates of the probit model and the ordered probit model for our empirical test of hypothesis H_2. For both models, the likelihood ratio test rejects the null hypothesis that the coefficients of the explanatory variables are zero ($p < 0.0001$). Note that the baseline results, when all performance dummies, PERF2 through PERF6 and their related interaction terms are zero, applies to the car variants whose APEAL performance ratings fall in the lowest (2.0 to 2.5) range. The coefficient of TIME applies to this lowest performance range, and is negative and significant in both models, suggesting that even for car model variants with the lowest inherent quality, there is a time trend towards not offering a base product, perhaps because of greater standardization due to lower costs of the features. Note that we consider TIME to be a proxy for the costs of the features of ABS and traction control. Consistent with hypothesis H_2, the decline in the propensity of a car model variant to offer a base product with TIME is more pronounced with higher performance ratings of a car model, as indicated by the negative interaction terms of PERF2 through PERF6 with TIME (except for the interaction

[9] Note that our theoretical model does not assume costs that vary with volume.

term of PERF6 with TIME in the probit model that is not statistically significant). However, the negative interaction terms are not significant for the highest performance rating categories (PERF4, PERF5 and PERF6) perhaps because car model variants in these categories have a propensity to offer a base product that is close to zero even at the beginning of our data window (see Figure 4). As in the case of hypothesis H_1, the results on the interaction terms remains robust in alternative models, wherein the propensity to introduce a base product is measured at the brand or company level rather than at the car model level. The signs of the coefficients of the control variables in Table 8 are quite consistent with those found in Table 7.

5. CONCLUSIONS AND MANAGERIAL IMPLICATIONS

In this paper, we study how firms that differ in their brand image or intrinsic quality of their products include additional product features in their base products. Specifically, should firms offer additional product features as an optional component or as a standard component in their base products? Our model results show that a low-quality firm would offer the feature as optional, i.e. offer a feature-added product as well as a base product, if it chooses to add the feature to its product. On the other hand, a high-quality firm would offer the feature as a standard component unless the cost of the feature is high. These results point to an asymmetry in the propensity of high- and low-quality firms to offer stripped-down versions (i.e. the base product without the added feature) of the product, in that a low-quality firm generally prefers to offer a stripped-down product in its product line. Further, a high-quality firm becomes less likely to offer a stripped-down product in its product line as the cost of the feature decreases. We test these last two predictions using data from the US passenger car market. Specifically, we look at the propensity of car brands with different overall performance ratings (as measured by J. D. Power) to offer stripped-down car models without anti-lock brakes and traction or stability control. Our analysis shows that the propensity to offer stripped-down models decreases for high-performing brands, and this decline in propensity for high-performing brands to offer stripped-down models is more precipitous when the cost of added features decline. These results are consistent with the predictions of our theoretical model and offer support for our model.

The managerial implications of our research are as follows. If a firm's product is perceived to be of a higher quality than those of its competitors, then unless the cost of added features is very high, such a firm should refrain from offering stripped down versions of its product in order not to aggravate price competition in the market. On the other hand, if the cost of added features is high, a high-quality firm may offer a stripped-down product for cost reasons. However, while doing so, this firm should also offer a fully loaded product with added features in its product line to appeal to high-end customers, thus profiting from market segmentation. Conversely, if a firm's product is perceived to be of a lower quality than those of its competitors, such a firm should generally offer a stripped down version of its product to appeal to price-sensitive users who are unwilling to pay much for higher quality. However, if such a firm were to also offer a more fully featured product in its product line, it should be cautious about going head-to-head on the added features with high-quality brands, because doing so may lead to increased price competition and lower profits. Nevertheless, if the variable cost of the added features is low, a low-quality firm might find it profitable to add a fully loaded product to its product line, as the low cost of the features may offset the effect of lower prices that result from higher price competition.

As in any study, our work is not without limitations. Our theoretical model only considers vertically differentiated firms and features (i.e., quality differentiation). It is possible that consumers may have different tastes for firms' base products and features. As a result, it may be interesting to extend our model to study product line decisions with horizontally differentiated firms and features. Our empirical analysis is based on the US passenger car market. It may be useful to test our model's predictions in other markets such as household appliances to strengthen our understanding of this problem.

REFERENCES

Champsaur, P., J. Rochet. 1989. Multiproduct Duopolists. *Econometrica* **57**(3) 533-557.

Cars.com 2015, Available from: <http://www.cars.com/>. [May 4, 2015].

Desai, P. 2001. Quality segmentation in spatial markets: When does cannibalization affect product line design? *Marketing Sci.* **20**(3) 265-283.

Gilbert, R., C. Matutes. 1993. Product Line Rivalry with Brand Differentiation. *The Journal of Industrial Economics*. **41** (3), 223-240.

Greene, W. H. 2008. *Econometric Analysis*. Pearson Prentice-Hall, Upper Saddle River, NJ.

Kahane, C. J. and J. N. Dang. 2009.The Long-Term Effect of ABS in Passenger Cars and LTVs. *NHTSA Technical Report, DOT HS 811 182*. Washington, DC: National Highway Traffic Safety Administration.

Katz, M. 1984. Firm specific differentiation and competition among multiproduct firms. *J. Bus.* **57**(1) 149-166.

Kotler, P. 2000. *Marketing Management, The Millennium Edition*. Prentice Hall, Upper Saddle River, NJ.

Moorthy, S. 1984. Market segmentation, self-selection, and product line design. *Marketing Sci.* **3**(4) 288-307

Moorthy, S. 1988. Product and price competition in a duopoly. *Marketing Sci.* **7**(2) 141-168.

Mussa, M., S. Rossen. 1978. Monopoly and product quality. *J. Econom. Theory* **18** 301-317.

Purohit, D. 1992. Exploring the relationships between the markets for new and used durable goods: The case of automobiles. *Marketing Sci*. **11**(2) 154-167.

Shaked, A., J. Sutton. 1982. Relaxing price competition through product differentiation. *Rev. Econom. Stud.* **49**(1) 3-13.

Schmidt-Mohr, U., J. M. Villas-Boas. 2008. Competitive product lines with quality constraints. *Quant. Marketing Econom.* **6**, 1-16**.**

Sullivan, M. W. 1998. How brand names affect the demand for twin automobiles. *J. Marketing Res.* **35**(2) 154-165.

Villas-Boas, J. M. 2004. Communication strategies and product line design. *Marketing Sci.* **23**(3) 156-159.

Table 1: Subgames after Stage 1

		Firm *H*'s Product Line Strategy (Product Line in brackets)		
		B {*hb*}	***BF*** {*hb*,*hf*}	***F*** {*hf*}
Firm *L's* Product Line Strategy (Product Line in brackets)	***B*** {*lb*}	*B-B*	*B-BF*	*B-F*
	BF {*lb*,*lf*}	*BF-B*	*BF-BF*	*BF-F*
	F {*lf*}	*F-B*	*F-BF*	*F-F*

Table 2: Equilibrium Prices, Quantities and Profits in the Benchmark Case

		Firm *H*	
Firm *L*		*B*	*F*
	B	$p_{lb} = \frac{d}{3+4d}$ $p_{hb} = \frac{2d(1+d)}{3+4d}$ $q_{lb} = \frac{1+d}{3+4d}$ $q_{hb} = \frac{2(1+d)}{3+4d}$ $\pi_L = \frac{d\,(1+d)}{(3+4d)^2}$ $\pi_H = \frac{4d(1+d)^2}{(3+4d)^2}$	$p_{lb} = \frac{c+d+\alpha d}{3+4(1+\alpha)d}$ $p_{hf} = \frac{2(1+d+\alpha d)(c+d+\alpha d)}{3+4(1+\alpha)d}$ $q_{lb} = \frac{(1+d+\alpha d)(c+d+\alpha d)}{(1+\alpha)d(3+4(1+\alpha)d)}$ $q_{hf} = 1 - \frac{(c+d+\alpha d)(1+2(1+\alpha)d)}{(1+\alpha)d(3+4(1+\alpha)d)}$ $\pi_L = \frac{(1+d+\alpha d)(c+d+\alpha d)^2}{(1+\alpha)d(3+4(1+\alpha)d)^2}$ $\pi_H = \frac{(c+2(1+\alpha)cd-2(1+\alpha)d(1+d+\alpha d))^2}{(1+\alpha)d(3+4(1+\alpha)d)^2}$
	F	$p_{lf} = \frac{2c(1+d)+(1-\alpha)d(1+\alpha d)}{3+(4-\alpha)d}$ $p_{hb} = \frac{(1+d)(c+2(1-\alpha)d)}{3+(4-\alpha)d}$ $q_{lf} =$ $\frac{(1+d)((1-\alpha)d(1+\alpha d)-c(1+(2-\alpha)d))}{(1-\alpha)d(3+(4-\alpha)d)(1+\alpha d)}$ $q_{hb} = \frac{(1+d)(c+2(1-\alpha)d)}{(1-\alpha)d(3+(4-\alpha)d)}$ $\pi_L =$ $\frac{(1+d)(c+(2-\alpha)cd-(1-\alpha)d(1+\alpha d))^2}{(1-\alpha)d(-3+(-4+\alpha)d)^2(1+\alpha d)}$	$p_{lf} = \frac{3c+d+d((2+3\alpha)c+\alpha d)}{3+(4+3\alpha)d}$ $p_{hf} = \frac{(3c+2d)(1+d+\alpha d)}{3+(4+3\alpha)d}$ $q_{lf} = \frac{(1-2c+\alpha d)(1+d+\alpha d)}{(1+\alpha d)(3+(4+3\alpha)d)}$ $q_{hf} = 1 - \frac{1+c+(2+\alpha)d}{3+(4+3\alpha)d}$ $\pi_L = \frac{d(1-2c+\alpha d)^2(1+d+\alpha d)}{(1+\alpha d)(3+(4+3\alpha)d)^2}$ $\pi_H = \frac{d(c-2(1+d+\alpha d))^2}{(3+(4+3\alpha)d)^2}$

		$\pi_H = \frac{4d(1+d)^2}{(1-\alpha)d(3+(4-\alpha)d)^2}$	

Table 3(a). Equilibrium Profits in the Main Analysis

		Firm H		
L		*B*	*BF*	*F*
	B	$\pi_L = \frac{d\,(1+d)}{(3+4d)^2}$ $\pi_H = \frac{4d(1+d)^2}{(3+4d)^2}$	$\pi_L^{B-BF} = \frac{d(1+d)}{(3+4d)^2}$ $\pi_H^{B-BF} =$ $\frac{1}{16}(-8c + \frac{4c^2}{\alpha d} + \frac{4d(16(1+d)^2+\alpha(3+4d)^2)}{(3+4d)^2})$	$\pi_L^{B-F} = \frac{(1+d+\alpha d)(c+d+\alpha d)^2}{(1+\alpha)d(3+4(1+\alpha)d)^2}$ $\pi_H^{B-F} =$ $\frac{(c+2(1+\alpha)cd-2(1+\alpha)d(1+d+\alpha d))^2}{(1+\alpha)d(3+4(1+\alpha)d)^2}$
	BF	$\pi_L^{BF-B} = \frac{1}{6}(\frac{3c(c+2d-2\alpha d)}{\alpha d(6+8d-2\alpha d)} +$ $\frac{((d-\alpha d)(1+\alpha d)+c(-1-2d+\alpha d))(-\frac{3c}{\alpha d}+\frac{2c}{-d+\alpha d}+\frac{c-6(1+d)}{-3-4d+\alpha d}}{3+4d-\alpha d}$ $\pi_H^{BF-B} = \frac{(d\,(c-2\,(1+d+\alpha\,d))2)}{(3+(4+3\,\alpha)\,d)2}$	$\pi_L^{BF-BF} =$ $\frac{1}{6}(\frac{3c(c+2d-2\alpha d)}{\alpha d(6+8d-2\alpha d)} +$ $\frac{((d-\alpha d)(1+\alpha d)+c(-1-2d+\alpha d))(-\frac{3c}{\alpha d}+\frac{2c}{-d+\alpha d}+\frac{c-6(1+d)}{-3-4d+\alpha d})}{3+4d-\alpha d})$ $\pi_H^{BF-BF} =$ $\frac{(-c+\alpha d)\left(\alpha d+\alpha^2 d^2-4d(1+d)+c(1+2d-\alpha d)\right)}{4\alpha d(-3-4d+\alpha d)}$ $+\frac{(1+d)(c+2d-2\alpha d)(1+\alpha d)}{2(-3-4d+\alpha d)^2}$ $+\frac{\mathrm{c}(1+d)(c+2d-2\alpha d)\left(4d^2-3d(-1+\alpha d)+\alpha d(-1+\alpha d)\right)}{2\alpha(1-\alpha)d^2(-3-4d+\alpha d)^2}$	$\pi_L^{BF-F} = \frac{d(1+\alpha)(1+d+\alpha)}{(3+4d+3\alpha)^2} +$ $\frac{c^2((3+4d)^2+(9+16d)\alpha)}{4\alpha(3+4d+3\alpha)^2} - \frac{4cd(1+d+\alpha)}{(3+4d+3\alpha)^2}$ $\pi_H^{BF-F} = \frac{\mathrm{d}\,(\mathrm{c}-2\,(1+\mathrm{d}+\alpha\,\mathrm{d}))2}{(3+(4+3\,\alpha)\,\mathrm{d})2}$
	F	$\pi_L^{F-B} = \frac{(1+d)(c+(2-\alpha)cd-(1-\alpha)d(1+\alpha d))^2}{(1-\alpha)d(-3+(-4+\alpha)d)^2(1+\alpha d)}$ $\pi_H^{F-B} = \frac{4d(1+d)^2}{(1-\alpha)d(3+(4-\alpha)d)^2}$	$\pi_L^{F-BF} = \frac{(1+d)(c+(2-\alpha)cd-(1-\alpha)d(1+\alpha d))^2}{(1-\alpha)d(-3+(-4+\alpha)d)^2(1+\alpha d)}$ $\pi_H^{F-BF} = \frac{d\left(\alpha^3 d^2+16(1+d)^2-2\alpha^2 d(3+4d)-\alpha(7+8d)\right)}{4(-3+(-4+\alpha)d)^2}$ $-\frac{c\left[1+(8-6\alpha)d+\left(8-8\alpha+\alpha^2\right)d^2\right]}{2(-3+(-4+\alpha)d)^2}$ $-\frac{c^2[\alpha^3 d^2-3\alpha^2 d(2+3d)-(3+4d)^2+\alpha\left(5+22d+20d^2\right)]}{4(1-\alpha)\alpha d(-3+(-4+\alpha)d)^2}$	$\pi_L^{F\_F} = \frac{d(1-2c+\alpha d)^2(1+d+\alpha d)}{(1+\alpha d)(3+(4+3\alpha)d)^2}$ $\pi_H^{F-F} = \frac{d(c-2(1+d+\alpha d))^2}{(3+(4+3\alpha)d)^2}$

Table 3(b). Equilibrium Prices in the Main Analysis

	H			
L		*B*	*BF*	*F*
	B	$p_{lb} = \frac{d}{3+4d}$ $p_{hb} = \frac{2d(1+d)}{3+4d}$	$p_{lb} = \frac{d}{3+4d}$ $p_{hf} = \frac{c(3+4d)+d(4+3a+4(1+a)d)}{6+8d}$ $p_{hb} = \frac{2d(1+d)}{3+4d}$	$p_{lb} = \frac{c+d+\alpha d}{3+4(1+\alpha)d}$ $p_{hf} = \frac{2(1+d+\alpha d)(c+d+\alpha d)}{3+4(1+\alpha)d}$
	BF	$p_{lf} = \frac{2c(1+d)+(1-\alpha)d(1+\alpha d)}{3+(4-\alpha)d}$ $p_{lb} = \frac{c+2(1-\alpha)d}{6+2(4-\alpha)d}$ $p_{hb} = \frac{(1+d)(c+2(1-\alpha)d)}{3+(4-\alpha)d}$	$p_{lf} = \frac{2c(1+d)+(1-\alpha)d(1+\alpha d)}{3+(4-\alpha)d}$ $p_{lb} = \frac{c+2(1-\alpha)d}{6+2(4-\alpha)d}$ $p_{hf} = \frac{5c+(4-\alpha)d+d((6-\alpha)c+(4-\alpha^2)d)}{6+2(4-\alpha)d}$ $p_{hb} = \frac{(1+d)(c+2(1-\alpha)d)}{3+(4-\alpha)d}$	$p_{lf} = \frac{3c+d+d((2+3\alpha)c+\alpha d)}{3+(4+3\alpha)d}$ $p_{lb} = \frac{3c+2d}{6+2(4+3\alpha)d}$ $p_{hf} = \frac{(3c+2d)(1+d+\alpha d)}{3+(4+3\alpha)d}$
	F	$p_{lf} = \frac{2c(1+d)+(1-\alpha)d(1+\alpha d)}{3+(4-\alpha)d}$ $p_{hb} = \frac{(1+d)(c+2(1-\alpha)d)}{3+(4-\alpha)d}$	$p_{lf} = \frac{2c(1+d)+(1-\alpha)d(1+\alpha d)}{3+(4-\alpha)d}$ $p_{hf} = \frac{c(5+(6-\alpha)d)+d(4-\alpha+(4-\alpha^2)d)}{6+2(4-\alpha)d}$ $p_{hb} = \frac{(1+d)(c+2(1-\alpha)d)}{3+(4-\alpha)d}$	$p_{lf} = \frac{3c+d+d((2+3\alpha)c+\alpha d)}{3+(4+3\alpha)d}$ $p_{hf} = \frac{(3c+2d)(1+d+\alpha d)}{3+(4+3\alpha)d}$

Table 3(c). Equilibrium Quantities in the Main Analysis

	H			
L		B	BF	F
	B	$q_{lb} = \frac{1+d}{3+4d}$ $q_{hb} = \frac{2(1+d)}{3+4d}$	$q_{lb} = \frac{1+d}{3+4d}$ $q_{hf} = \frac{1}{2} - \frac{c}{2\alpha d}$ $q_{hb} = \frac{3c+\alpha d+4cd}{6\alpha d+8\alpha d^2}$	$q_{lb} = \frac{(1+d+\alpha d)(c+d+\alpha d)}{(1+\alpha)d(3+4(1+\alpha)d)}$ $q_{hf} = 1 - \frac{(c+d+\alpha d)(1+2(1+\alpha)d)}{(1+\alpha)d(3+4(1+\alpha)d)}$
	BF	$q_{lf} = \frac{2(1-\alpha)\alpha d(1+d)-c(3-\alpha+2(2-\alpha)d)}{2(1-\alpha)\alpha d(3+(4-\alpha)d)}$ $q_{lb} = \frac{c}{2\alpha d}$ $q_{hb} = \frac{(1+d)(c+2(1-\alpha)d)}{(1-\alpha)d(3+(4-\alpha)d)}$	$q_{lf} = \frac{2(1-\alpha)\alpha d(1+d)-c(3-\alpha+2(2-\alpha)d)}{2(1-\alpha)\alpha d(3+(4-\alpha)d)}$ $q_{lb} = \frac{c}{2\alpha d}$ $q_{hf} = \frac{1}{2} - \frac{c}{2\alpha d}$ $q_{hb} = \frac{1}{2}\left(1 + \frac{c}{\alpha d} + \frac{2\left(c(1+d)-(1-\alpha)d(1+(2-\alpha)d)\right)}{(1-\alpha)d(3+(4-\alpha)d)}\right)$	$q_{lf} = \frac{2\alpha d(1+d+\alpha d)-c(3+4(1+\alpha)d)}{2\alpha d(3+(4+3\alpha)d)}$ $q_{lb} = \frac{c}{2\alpha d}$ $q_{hf} = 1 - \frac{1+c+(2+\alpha)d}{3+(4+3\alpha)d}$
	F	$q_{lf} = \frac{(1+d)((1-\alpha)d(1+\alpha d)-c(1+(2-\alpha)d))}{(1-\alpha)d(3+(4-\alpha)d)(1+\alpha d)}$ $q_{hb} = \frac{(1+d)(c+2(1-\alpha)d)}{(1-\alpha)d(3+(4-\alpha)d)}$	$q_{lf} = \frac{-(1+d)(c(1+(2-\alpha)d)+(1-\alpha)d(1+\alpha d))}{(1-\alpha)d(3+(4-\alpha)d)(1+\alpha d)}$ $q_{hf} = \frac{1}{2} - \frac{c}{2\alpha d}$ $q_{hb} = \frac{1}{2}\left(1 + \frac{c}{\alpha d} + \frac{2\left(c(1+d)-(1-\alpha)d(1+(2-\alpha)d)\right)}{(1-\alpha)d(3+(4-\alpha)d)}\right)$	$q_{lf} = \frac{(1-2c+\alpha d)(1+d+\alpha d)}{(1+\alpha d)(3+(4+3\alpha)d)}$ $q_{hf} = 1 - \frac{1+c+(2+\alpha)d}{3+(4+3\alpha)d}$

Table 4. Regression of Performance Rating on Car Characteristics

Variable	Estimate	Standard Error	t -Stat	p-value
Intercept	1.638	0.167	9.78	<.0001
Miles per gallon	0.010	0.004	2.4	0.016
Horsepower/Weight (lb.)	13.607	0.929	14.64	<.0001
ABS_Standard	0.507	0.087	5.83	<.0001
ABS_Optional	0.009	0.086	0.11	0.914
TRACT_Optional	0.362	0.048	7.54	<.0001
TRACT_Standard	0.872	0.050	17.51	<.0001
R^2	0.544			

Table 5. Offer of Base Product Without Features Among Car Models/Body Styles

Frequency **%** **Row %** **Column %**		**Offer Car Variant Without Traction Control?**		**Total**
		No	**Yes**	
Offer Car Variant Without ABS?	**No**	850 50.6% 69.5% 100.0%	373 22.2% 30.5% 44.9%	1223 72.8%
	Yes	0 0% 0% 0%	134 27.2% 100.0% 55.1%	458 27.2%
	Total	850 50.6%	831 49.4%	1681 100%

Table 6. Descriptive Statistics of Model Variables

Variable	Mean	Std. Dev	Minimum	Maximum
y_{ibt} (Probit Model)	0.271	0.445	0	1
y_{ibt} (Ordered Probit Model)	1.766	0.850	1	3
PERFORMANCE	3.729	0.944	2	5
Small	0.227	0.419	0	1
Small Special	0.025	0.156	0	1
Lower Middle	0.056	0.230	0	1
Upper Middle	0.142	0.349	0	1
Middle Specialty	0.076	0.264	0	1
Large	0.036	0.187	0	1
Lower Luxury	0.145	0.352	0	1
Upper Luxury	0.151	0.358	0	1
Luxury Specialty	0.039	0.193	0	1
Luxury Sport	0.104	0.305	0	1
WAGON	0.161	0.367	0	1
TWODR	0.286	0.452	0	1
HATCH	0.049	0.217	0	1
OWNMODEL	4.888	4.286	0	24
COMPMODEL	24.669	17.215	0	76
TIME	4.369	2.861	0	9
PERF1	0.086	0.281	0	1
PERF2	0.093	0.290	0	1
PERF3	0.148	0.355	0	1
PERF4	0.202	0.401	0	1
PERF5	0.130	0.337	0	1
PERF6	0.156	0.363	0	1

Table 7. Probit and Ordered Probit Models of Propensity to Offer Base Product

Parameter	Probit Model		Ordered Probit Model	
	Estimate	Standard Error	Estimate	Standard Error
PERFORMANCE	-0.763**	0.070	-0.747**	0.052
OWNMODEL	-0.033**	0.012	-0.017	0.009
COMPMODEL	0.002	0.004	-0.001	0.003
Small	2.332**	0.483	1.152**	0.156
Small Special	1.179*	0.563	0.473*	0.219
Lower Middle	1.744**	0.504	0.299	0.187
Upper Middle	1.744**	0.486	0.437**	0.155
Middle Specialty	2.370**	0.488	1.242**	0.157
Large	1.237*	0.533	0.225	0.218
Lower Luxury	0.802	0.514	-0.431**	0.160
Upper Luxury	0.624	0.542	-0.734**	0.184
Luxury Specialty	1.271*	0.619	-0.529	0.285
WAGON	-0.301*	0.147	-0.286*	0.119
TWODR	-0.287*	0.142	-0.219*	0.107
HATCH	-0.421	0.224	-0.529**	0.183
Intercept	0.566	0.543	-	-
μ_1			-2.766	0.275
μ_2	-	-	-1.701	0.271
Log Likelihood	-565.9		-1126.9	
Likelihood Ratio	833.3**		1220.5**	
ρ^2	0.424		0.351	

**: significant at p = 0.01

*: significant at p = 0.05

Table 8. Probit and Ordered Probit Models of Propensity to Offer Base Product Over Time

Parameter	Probit Model		Ordered Probit Model	
	Estimate	Standard Error	Estimate	Standard Error
TIME	-0.079*	0.034	-0.117**	0.026
PERF2	0.812**	0.285	1.123**	0.246
PERF3	0.313	0.241	0.491*	0.200
PERF4	-0.133	0.231	0.320	0.180
PERF5	-0.348	0.267	0.052	0.193
PERF6	-1.104*	0.548	-0.203	0.233
PERF2*TIME	-0.185**	0.057	-0.109*	0.046
PERF3*TIME	-0.114*	0.048	-0.042	0.039
PERF4*TIME	-0.051	0.045	-0.029	0.035
PERF5*TIME	-0.077	0.055	-0.026	0.040
PERF6*TIME	0.033	0.090	-0.019	0.044
OWNMODEL	-0.023	0.013	-0.014	0.009
COMPMODEL	0.002	0.004	0.000	0.003
Small	3.005**	0.403	2.093**	0.147
Small Special	1.526**	0.485	0.902**	0.220
Lower Middle	1.990**	0.431	0.796**	0.189
Upper Middle	1.924**	0.411	0.827**	0.155
Middle Specialty	2.694**	0.412	1.740**	0.160
Large	1.467**	0.464	0.661**	0.218
Lower Luxury	0.695	0.432	-0.364*	0.162
Upper Luxury	0.100	0.462	-0.808**	0.181
Luxury Specialty	0.792	0.539	-0.609*	0.283
WAGON	-0.349*	0.148	-0.277*	0.118
TWODR	-0.485**	0.143	-0.366**	0.106
HATCH	-0.748**	0.223	-0.809**	0.180
Intercept	-1.655**	0.445	-	-
μ_1	-	-	-0.058	0.214
μ_2	-	-	1.011	0.216
Log Likelihood	-553.9		-1131.1	
Likelihood Ratio	857.4**		1212.0**	
ρ^2	0.436		0.349	

**: significant at p = 0.01; *: significant at p = 0.05

Figure 1: Consumer Segments in the Benchmark Model

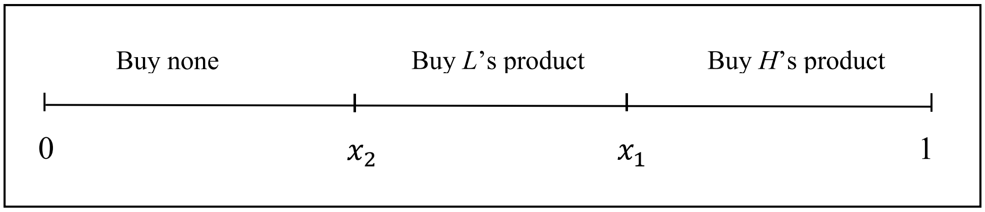


Figure 2: Consumer Segments in a BF-B Equilibrium

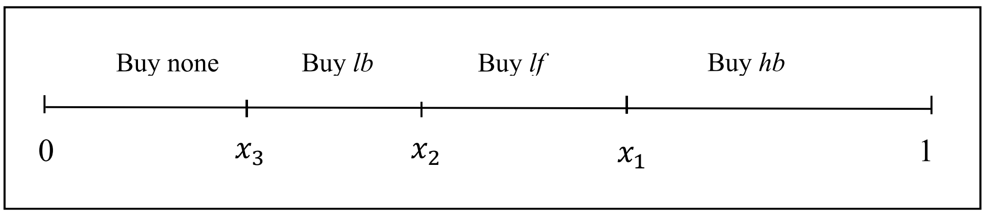


Figure 3: Consumer Segments in a B-BF Equilibrium

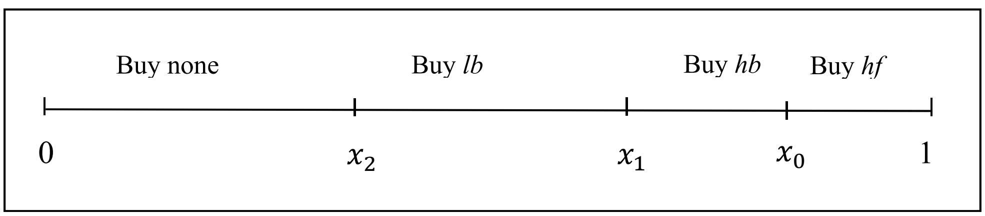
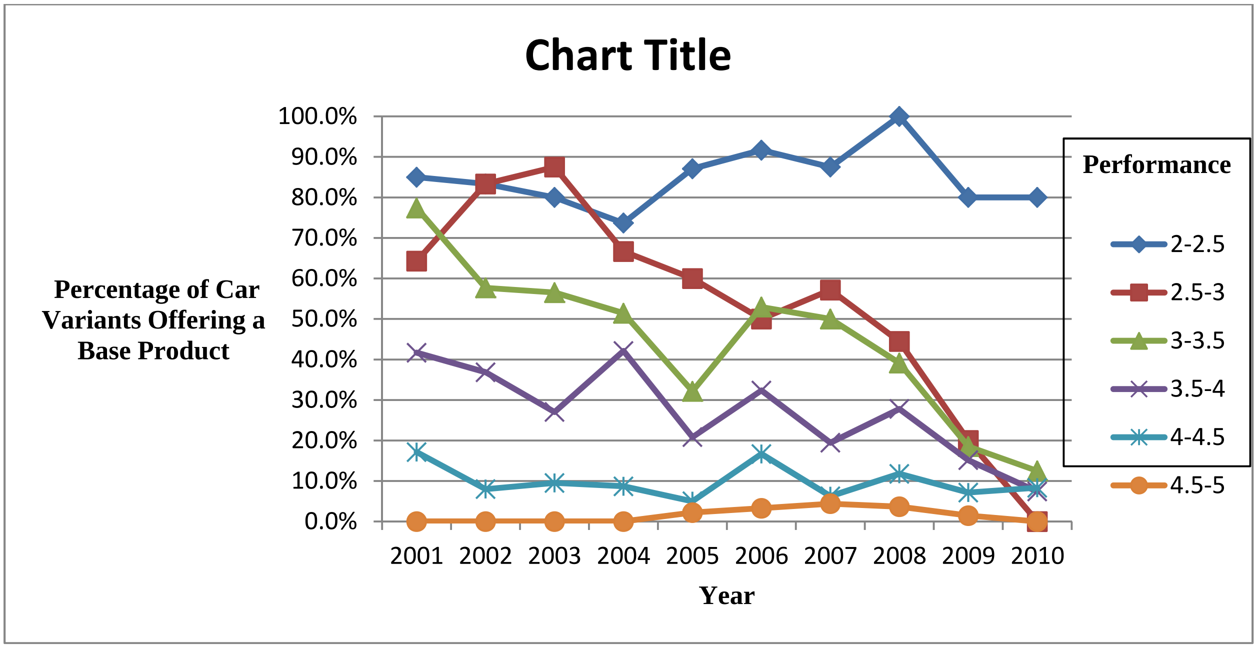


Figure 4. Propensity to Offer a Base Product over Time for Performance Categories



ONLINE TECHNICAL APPENDIX

Proof of Proposition 1

First, we derive the firms' profits in the subgames for the benchmark case. Table 2 shows the resulting profits, prices and quantities. Below, we derive the profits in the *B-B* subgame for expositional purposes. The profits in the other subgames are derived in the same manner.

In the *B-B* subgame, two products are available in the market, since both firms offer the base product only. This implies there exist at most three potential consumer segments. The segment $[x_1, 1]$ buys the highest quality product, which is the base product of firm *H*, (m_h), the segment $[x_2, x_1)$ buys the lowest quality product (m_l), and the segment $[0, x_2)$ buys nothing. The threshold consumers x_1 and x_2 are indifferent between adjacent quality levels, thus satisfying the equations:

$$(m_h)x_1 - p_{hb} = (m_l)x_1 - p_{lb} \text{ and } (m_l)x_2 - p_{lb} = 0 \tag{A.1}$$

Hence, $x_1 = \frac{p_{hb} - p_{lb}}{d}$ and $x_2 = \frac{p_{lb}}{m_l}$. The quantities sold by the firms are: $q_{hb} = 1 - x_1$ and $q_{lb} = x_1 - x_2$; and the objective functions of the firms can be expressed as follows:

$$Max_{p_{hb}} \pi_H^{B-B} = p_h \left(1 - \frac{p_{hb} - p_{lb}}{d}\right) \tag{A.2}$$

$$Max_{p_{lb}} \pi_L^{B-B} = p_l \left(\frac{p_{hb} - p_{lb}}{d} - \frac{p_{lb}}{m_l}\right) \tag{A.3}$$

Differentiating (A.2) with respect to p_h and (A.3) with respect to p_l and setting the derivatives equal to zero yields the following solution for equilibrium prices:

$$p_{hb} = \frac{2d(1+d)}{3+4d} \text{ and } p_{lb} = \frac{d}{3+4d}. \tag{A.4}$$

(Note that the second order conditions for the maximizations in (A.2) and (A.3) are satisfied because $\frac{\partial^2 \pi_H^{B-B}}{\partial p_{hb}^2} = -\frac{2}{d} < 0$, $\frac{\partial^2 \pi_L^{B-B}}{\partial p_{lb}^2} = -2 - \frac{2}{d} < 0$.)

Substituting the equilibrium prices into the expressions derived for x_1 and x_2, allows us to solve for the quantities sold of each type of product as follows:

$$q_{hb} = \frac{2(1+d)}{3+4d}, q_{lb} = \frac{1+d}{3+4d}. \tag{A.5}$$

Substituting the equilibrium prices and quantities in the profit functions given in (A.2) and (A.3) yields the equilibrium profits, $\boldsymbol{\pi_H^{B-B}} = \frac{\boldsymbol{4d(1+d)^2}}{\boldsymbol{(3+4d)^2}}$ and $\boldsymbol{\pi_L^{B-B}} = \frac{\boldsymbol{4d(1+d)^2}}{\boldsymbol{(3+4d)^2}}$. Similarly, we derive the profits of firm *H* and *L* in all other subgames.

The assumptions to ensure a positive amount of sales for all products in the benchmark equilibrium are as follows. In the *B-F* equilibrium, $c < \frac{2(1+\alpha)(1+(1+\alpha)d)d}{1+2(1+\alpha)d}$; in the *F-B* equilibrium, $c < \frac{(1-\alpha)(1+\alpha d)d}{1+(2-\alpha)d}$; and in the *F-F* equilibrium, $c < \frac{1+\alpha d}{2}$.

We now establish the equilibrium conditions for the strategy combinations.

B-B

We examine firms' incentive to deviate from the *B-B* subgame. First, considering firm H's deviation from *B-B* to *B-F* by examining $\pi_H^{B-B} - \pi_H^{B-F}$,

$$\pi_H^{B-B} - \pi_H^{B-F} = \frac{1}{144}[72c - 36\alpha d - \frac{27}{(3+4d)^2} - \frac{45}{3+4d} - \frac{16c^2}{d+\alpha d} + \frac{3(3-4c)^2}{(3+4(1+\alpha)d)^2} + \frac{45-80c^2}{3+4(1+\alpha)d}] \tag{A.6}$$

The right-hand side of (A.6) is positive for $c > \chi_3^{BM}$, where $\chi_3^{BM} = \frac{1}{2} + (1+\alpha)d - \frac{1}{2+4(1+\alpha)d} - \frac{2d(1+d)(3+4(1+\alpha)d)\sqrt{1+\alpha}}{(3+4d)}$. Considering firm *L*'s deviation, we have

$$\pi_L^{B-B} - \pi_L^{F-B} = \frac{d(1+d)}{(3+4d)^2} - \frac{(1+d)(c+(2-\alpha)cd-(1-\alpha)d(1+\alpha d))^2}{(1-\alpha)d(3+(4-\alpha)d)^2(1+\alpha d)} \tag{A.7}$$

The right-hand side of (A.7) is positive for $c > \chi_4^{BM}$, where $\chi_4^{BM} = \frac{(1-\alpha)(1+\alpha d)d}{1+(2-\alpha)d} - \frac{d(1+d)(3+(4-\alpha)d)\sqrt{(1-\alpha)(1+\alpha d)}}{(3+4d)(1+(2-\alpha)d)}$. Note that $\chi_4^{BM} < \chi_3^{BM}$. Thus, *B-B* is an equilibrium when $c > \chi_3^{BM}$.[10]

B-F

Similar to above, we consider firms' potential deviation from *B-F* equilibrium. First, (A.6) shows that firm *H* chooses *B*-F over *B-B* for $c < \chi_3^{BM}$. Considering firm *L* deviation from *B-F* to *F-F*,

$$\pi_L^{B-F} - \pi_L^{F-F} = \frac{1+(1+\alpha)d}{d}[\frac{(c+(1+\alpha)d)^2}{(1+\alpha)(3+4(1+\alpha)d)^2} - \frac{d^2(1+\alpha d-2c)^2}{(1+\alpha d)(3+(4+3\alpha)d)^2}] \tag{A.8}$$

The right-hand side of (A.8) is positive if $c > \chi_2^{BM}$, where $\chi_2^{BM} = \frac{(1+\alpha)(1+\alpha d)[9+(42+18\alpha+64d+9(8+\alpha)\alpha d+32(1+\alpha)^2d^2)d]d-(3+4(1+\alpha)d)(1+(2+3\alpha)d)(3+(4+3\alpha)d)d\sqrt{(1+\alpha)(1+\alpha d)}}{[64(1+\alpha)^3d^3+(96+(176+9(8-\alpha)\alpha)\alpha)d^2-4(6-5d)-27\alpha-3\alpha(4+9\alpha)d]d-9}$. Further, the technical condition to guarantee $q_{hf} > 0$ is $c < \frac{2(1+\alpha)(1+(1+\alpha)d)d}{1+2(1+\alpha)d}$. Comparing it with

[10]Note that the technical conditions for positive sales are always satisfied.

χ_3^{BM}, we have $\chi_3^{BM} - \frac{2(1+\alpha)(1+(1+\alpha)d)d}{1+2(1+\alpha)d} = -2\sqrt{\frac{(1+\alpha)(1+d)^2(3+4(1+\alpha)d)^2d^2}{(3+4d)^2(1+2(1+\alpha)d)^2}} < 0$. Thus, *B-F* is an equilibrium when $\chi_2^{BM} < c < \chi_3^{BM}$.

F-B

(A.7) shows that firm *L* chooses *F-B* over *B-B* for $c < \chi_4^{BM}$. Considering firm *H*'s potential deviation from *F-B* to *F-F*,

$$\pi_H^{F-B} - \pi_H^{F-F} = \frac{4(2(1-\alpha)+c)^2}{(7-\alpha)^2(1-\alpha)} - \frac{(2(2+\alpha)-c)^2}{(7+3\alpha)^2} \qquad \text{(A.9)}$$

The right-hand side of (A.9) is positive when $c > \chi_1^{BM}$, where $\chi_1^{BM}=2d[\frac{(1+d)(1+2d)(3+(4-\alpha)d)(3+(4+3\alpha)d)\sqrt{1-\alpha}}{9+(32(2+d)d+3\alpha^2d(3+4d)+3(3+4d)(2+(5+4d)d)\alpha+42+\alpha^3d^3)d} - \frac{(1-\alpha)(9+(51+18\alpha+(106+9(7+\alpha)\alpha)d+(4+\alpha)(24+13\alpha)d^2+(32+(32+(2+\alpha)\alpha)\alpha)d^3)d)}{9+(32(2+d)d+3\alpha^2d(3+4d)+3(3+4d)(2+(5+4d)d)\alpha+42+\alpha^3d^3)d}]$. Note that $\chi_1^{BM} > \chi_4^{BM}$. Thus, *F-B* cannot arise as equilibrium.

F-F

(A.9) shows that firm *H* chooses *F-F* over *F-B* for $c < \chi_1^{BM}$, and (A.8) shows that firm *L* chooses *F-F* over *B-F* for $c < \chi_2^{BM}$. The technical condition to guarantee positive sales for both products is $c < \frac{1+\alpha d}{2}$. Comparing it with χ_1^{BM} and χ_2^{BM}, we have $\frac{1+\alpha d}{2} > \chi_1^{BM}$ and $\frac{1+\alpha d}{2} > \chi_2^{BM}$. Therefore, *F-F* is an equilibrium for $c < \min(\chi_1^{BM}, \chi_2^{BM})$. To show the existence of the equilibria in Proposition 1, consider an example with $d = 1$ and $\alpha = 0.5$. Then, we have $\chi_1^{BM} = 0.2769, \chi_2^{BM} = 0.0283$ and $\chi_3^{BM} = 0.3008$, showing existence of the equilibria for appropriate values of *c*. For this example, the technical condition required for positive sales of both firms in all equilibria is $c < 0.75$, which holds because c < α = 0.5, by assumption.

Proof of Lemma 1

First, we derive the profits in the nine subgames listed in Table 1. We present below the analysis of the *B-BF* subgame. The derivations for the other subgames are similar and are omitted.

In *B-BF*, three products are available in the market; firm *L* offers a base product only, and firm *H* offers both a base product and a feature-added one. Thus, there exist at most four consumer segments. The segment $[x_0, 1]$ buys the highest quality product, which is the product with feature of firm *H* $(m_h + \alpha d)$, the segment $[x_1, x_0)$ buys the intermediate quality product, the base product of firm *H* (m_h), the segment $[x_2, x_1)$ buys the lowest quality product, the base product of firm *L*

(m_h) and the segment $[0, x_2)$ nothing. The threshold consumers, x_0, x_1 and x_2, are indifferent between adjacent quality levels, thus satisfying the equations:

$(m_h + \alpha d)x_1 - p_{hf} = (m_h)x_1 - p_{hb}$, $(m_h)x_2 - p_{hb} = (m_l)x_2 - p_{lb}$ and $(m_l)x_3 - p_{lb} = 0$ (A.10)

Solving, we get $x_0 = \frac{p_{hf}-p_{hb}}{\alpha d}$, $x_1 = \frac{p_{hb}-p_{lb}}{d}$, and $x_2 = \frac{p_{lb}}{m_l}$. The quantities sold by the firms are: $q_{hf} = 1 - x_0$, $q_{hb} = x_0 - x_1$ and $q_{lb} = x_1 - x_2$; and the objective functions of the firms can be expressed as follows:

$$Max_{p_{hf},p_{hb}} \pi_H^{B-BF} = \left(p_{hf} - c\right)\left(1 - \frac{p_{hf}-p_{hb}}{\alpha d}\right) + (p_{hb})\left(\frac{p_{hf}-p_{hb}}{\alpha d} - \frac{p_{hb}-p_{lb}}{d}\right), \quad \text{(A.11)}$$

$$Max_{p_{lb}} \pi_L^{B-BF} = (p_{lb})\left(\frac{p_{hb}-p_{lb}}{d} - \frac{p_{lb}}{m_l}\right) \quad \text{(A.12)}$$

Differentiating (A.11) with respect to p_{hf}, p_{hb} and (A.12) with respect to p_{lb} and setting the derivatives equal to zero, yields the following solution for equilibrium prices:

$$p_{hf} = \frac{c(3+4d)+d(4+3a+4(1+a)d)}{6+8d}, p_{hb} = \frac{2d(1+d)}{3+4d}, \text{ and } p_{lb} = \frac{d}{3+4d}. \quad \text{(A.13)}$$

Note that the second order conditions for the maximizations in (A.11) and (A.12) are satisfied because $\frac{\partial^2 \pi_H^{B-BF}}{\partial p_{hf}^2} = -\frac{2}{\alpha d} < 0$, $\frac{\partial^2 \pi_H^{B-BF}}{\partial p_{hb}^2} = -\frac{2}{d} - \frac{2}{\alpha d} < 0$, $\frac{\partial^2 \pi_L^{B-BF}}{\partial p_{lb}^2} = -2 - \frac{2}{d} < 0$, $\frac{\partial^2 \pi_H^{B-BF}}{\partial p_{hf}^2} \frac{\partial^2 \pi_H^{B-BF}}{\partial p_{hb}^2} - \left(\frac{\partial^2 \pi_H^{B-BF}}{\partial p_{hf}\, \partial p_{hb}}\right)^2 = \frac{4}{\alpha d^2} > 0$.

Substituting the equilibrium prices into the expressions derived for x_1, x_2 and x_3 allows us to solve for the quantities sold of each type of product as follows:

$$q_{hf} = \frac{1}{2} - \frac{c}{2\alpha d}, q_{hb} = \frac{3c+\alpha d+4cd}{6\alpha d+8\alpha d^2}, q_{lb} = \frac{1+d}{3+4d}. \quad \text{(A.14)}$$

Substituting the equilibrium prices and quantities back into the objectives (A.11) and (A.12) yields the equilibrium profits, $\pi_H^{B-BF} = \frac{1}{16}\left[\frac{4c^2}{\alpha d} + \frac{4d\left(16(1+d)^2+\alpha(3+4d)^2\right)}{(3+4d)^2} - 8c\right]$ and $\pi_L^{B-BF} = \frac{d(1+d)}{(3+4d)^2}$.

Table 3 summarizes the equilibrium profits, prices and quantities for all subgames. We now determine which subgames fail to become an equilibrium by comparing the profits. First, for the *B-B* subgame, we examine if firm *H* has any incentive to deviate from its strategy.

$$\pi_H^{B-B} - \pi_H^{B-BF} = -\frac{(c-\alpha d)^2}{4\alpha d} \quad \text{(A.15)}$$

The right-hand side of (A.15) is negative. Thus, *B-B* fails to become equilibrium. Likewise, for the subgames *BF-B* and *F-B*, we examine firm *H'*s potential deviation.

$$\pi_H^{BF-B} - \pi_H^{BF-BF} = -\frac{(c-\alpha d)^2}{4\alpha d} < 0 \tag{A.16}$$

$$\pi_H^{F-B} - \pi_H^{F-BF} = -\frac{(c-\alpha d)^2}{4\alpha d} < 0 \tag{A.17}$$

(A.16) and (A.17) show that both *BF-F* and *F-B* cannot become equilibrium. For the subgames *F-BF* and *F-F*, we examine firm *L*'s potential deviation.

$$\pi_L^{F-BF} - \pi_L^{BF-BF} = -\frac{c^2}{4\alpha d+4\alpha^2 d^2} < 0 \tag{A.18}$$

$$\pi_L^{F-F} - \pi_L^{BF-F} = -\frac{c^2}{4\alpha d+4\alpha^2 d^2} < 0 \tag{A.19}$$

Thus, *F-BF* and *F-F* cannot arise as equilibrium.

Proof of Proposition 2

Given the equilibrium profits in Table 3, we establish the equilibrium regions for the assuming $d = 1$.

B-BF

By examining firm *H*'s deviation between *B-BF* and *B-F*, we have the following:

$$\pi_H^{B-BF} - \pi_H^{B-F} = \frac{16}{49} + \frac{\alpha}{4} - \frac{(4+2(3+\alpha-c)\alpha-3c)^2}{(1+\alpha)(7+4\alpha)^2} - \frac{c}{2} + \frac{c^2}{4\alpha} \tag{A.20}$$

The right-hand side of (A.20) is positive if $c > \chi_2 = \frac{1}{7}[2\sqrt{3}\sqrt{\frac{\alpha^2(1+\alpha)(7+4\alpha)^2(24+19\alpha)}{\left(49+3\alpha(23+8\alpha)\right)^2}} + \frac{7\alpha(1+\alpha)}{49+3\alpha(23+8\alpha)}]$.

Now, we examine if firm *L* has any incentive to deviate to *BF-BF* from *B-BF* when $c > \chi_2$. By comparing firm *L*'s profits in *B-BF* and *BF-BF*, we have the following:

$$\pi_L^{B-BF} - \pi_L^{BF-BF} = \frac{4(25\alpha-7)\alpha+196(3-\alpha)c}{49(7-\alpha)^2} - \frac{(49-\alpha(40-7\alpha))c^2}{4\alpha(7-\alpha)^2(1-\alpha)} \tag{A.21}$$

The right-hand side of (A.21) is positive for $c > \chi_3$, where $\chi_3 = \frac{4}{7}[\frac{14(3-\alpha)(1-\alpha)\alpha}{49-(40-7\alpha)\alpha} - \sqrt{\frac{(7-\alpha)^2(1-\alpha)\alpha^2(29-21\alpha)}{(49-(40-7\alpha)\alpha)^2}}]$. Note that $\chi_2 > \chi_3$ for $0 < \alpha < d$. Moreover, the technical condition to guarantee $q_{hf} > 0$ is $c < \alpha$. Thus, *B-BF* is an equilibrium when $c > \chi_2$.

B-F

(A.20) shows that firm *H* chooses *B-F* over *B-BF* if $c < \chi_2$. For firm *L*, examining $\pi_L^{B-F} - \pi_L^{BF-F}$ gives

$$\pi_L^{B-F} - \pi_L^{BF-F} = \frac{(2+\alpha)(1+\alpha+c)^2}{(1+\alpha)(7+4\alpha)^2} - \frac{4\alpha(1+\alpha)(2+\alpha)-16\alpha(2+\alpha)c+(49+25\alpha)c^2}{4\alpha(7+3\alpha)^2} \quad \text{(A.22)}$$

The right-hand side of (A.22) is positive if $c > \chi_1$, where $\chi_1 = \frac{2\alpha(1+\alpha)(2+\alpha)[49(6-\sqrt{29})+\alpha(308-49\sqrt{29}+82\alpha-12\sqrt{29}\alpha)]}{2401+\alpha[5978+(5621+4(586+91\alpha)\alpha)\alpha]}$. The technical condition for $q_{hf} > 0$ is $c < \frac{2(1+\alpha)(2+\alpha)}{1+2(1+\alpha)}$, which is always true by assumption of $c < \alpha$, because $\frac{2(1+\alpha)(2+\alpha)}{1+2(1+\alpha)} > \alpha$. Thus, *B-F* is an equilibrium if $\chi_1 < c < \chi_2$.

BF-F

(A.22) shows that firm *L* chooses *BF-F* over *B-F* if $c < \chi_1$. For firm *H*, we examine whether firm *H* has any incentive to deviate from *BF-F* to *BF-BF* if $c < \chi_1$.

$$\pi_H^{BF-F} - \pi_H^{BF-\mathrm{BF}} = \frac{(4+2\alpha-c)^2}{(7+3\alpha)^2} + \frac{2(17-(14-\alpha)\alpha)c-64+(15-\alpha)(1+\alpha)\alpha}{4(7-\alpha)^2} - \frac{[49-(47-(15-\alpha)\alpha)\alpha]c^2}{(4(7-\alpha)^2(1-\alpha)\alpha} \quad \text{(A.23)}$$

The right-hand side of (A.23) is positive for $c < \chi_1$. The technical condition to ensure $q_{hf}, q_{lf} > 0$ is $c < \frac{2\alpha(2+\alpha)}{7+4\alpha}$. $\frac{2\alpha(2+\alpha)}{7+4\alpha} > \chi_1$, because $\chi_1 - \frac{2\alpha(2+\alpha)}{7+4\alpha}$ is $= -2\alpha(2+\alpha)\left[\frac{1}{7+4\alpha} - \frac{(1+\alpha)(49(6-\sqrt{29})+(308-49\sqrt{29})\alpha+(82-12\sqrt{29})\alpha^2)}{2401+[5978+(5621+4(586+91\alpha)\alpha)\alpha]\alpha}\right] < 0$ for $0 < \alpha < 1$. Thus *BF-F* is an equilibrium if $c < \chi_1$.

BF-BF

(A.23) shows that firm *H* chooses *BF-BF* over *BF-F* if $c > \chi_1$, and (A.21) shows that firm *L* chooses *BF-BF* over *B-BF* if $c < \chi_3$. However, $\chi_3 < \chi_1$ if $0 < \alpha < d$. Thus, *BF-BF* cannot arise as equilibrium.

To show the existence of the equilibrium strategies, consider the example where $\alpha = 0.5$. Then, we have $\chi_1 = 0.0298$ and $\chi_2 = 0.0184$, showing that all equilibria can exist for appropriate values of *c*. The technical conditions are $c < 0.278$ for *BF-F*, $c < 1.875$ for *B-F*, and $c < 4$ for *B-BF*, which are all satisfied.

Proof of Result 1

$$\frac{\partial \chi_2}{\partial \alpha} = \frac{(7+5\alpha)(7+9\alpha)}{(49+3(23+8\alpha)\alpha)^2} + \frac{3\sqrt{3}(5488+(21021+(31387+2(11513+8(523+76\alpha)\alpha)\alpha)\alpha)\alpha)}{(49+3(23+8\alpha)\alpha)^2 7\sqrt{(1+\alpha)(24+19\alpha)}} \tag{A.24}$$

The right-hand side of (A.24) is positive.

$$\frac{\partial \chi_1}{\partial \alpha} = \frac{196(6-\sqrt{29})+4(1498-245\sqrt{29}+(2073-330\sqrt{29}+(1108-170\sqrt{29}+5(41-6\sqrt{29})\alpha)\alpha)\alpha)\alpha}{2401+(5978+(5621+4(586+91\alpha)\alpha)\alpha)\alpha} -$$

$$\frac{4(1+\alpha)(2+\alpha)\alpha(2989+(5621+4(879+182\alpha)\alpha)\alpha)[49(6-\sqrt{29})+(308-49\sqrt{29}+82\alpha-12\sqrt{29}\alpha)\alpha]}{[2401+(5978+(5621+4(586+91\alpha)\alpha)\alpha)\alpha]^2} \tag{A.25}$$

The right-hand side of (A.25) is positive for $0 < \alpha < 1$.

Proof of Result 2

Comparing the boundary values of c, we have the following.

$$\chi_2 - \chi_3^{BM} = -\frac{1}{7}\left[\frac{14(1+\alpha)(2+\alpha)-4\sqrt{1+\alpha}(7+4\alpha)}{3+2\alpha} - \frac{(7(1+\alpha)+2(7+4\alpha)\sqrt{57\alpha^2+129\alpha+72})\alpha}{49+3(23+8\alpha)\alpha}\right] \tag{A.26}$$

As the right-hand side of (A.26) is negative for $0 < \alpha < 1$, $\chi_2 < \chi_3^{BM}$. Similarly,

$$\chi_1 - \chi_2^{BM} = \frac{\alpha(1+\alpha)(7+3\alpha)(7+4\alpha)[455-84\sqrt{29}+\alpha(467+2(60-11\sqrt{29})\alpha-86\sqrt{29})]}{(21+11\alpha)[2401+(5978+(5621+4(586+91\alpha)\alpha)\alpha)\alpha]} \tag{A.27}$$

The right-hand side of (A.27) is positive, implying $\chi_1 > \min(\chi_1^{BM}, \chi_2^{BM})$.

Proof of Result 3

We first consider the case when firm *L* expands its product line (i.e., when *c* is sufficiently small). First, when $0 < c < \min(\chi_1^{BM}, \chi_2^{BM})$, we compare firm *L*'s profit in the B*F-F* equilibrium of the main model with that in the *F-F* benchmark equilibrium.

$$\pi_L^{BF-F} - \pi_L^{F-F}(\text{BM}) = \frac{c^2}{4\alpha(1+\alpha)} \tag{A.28}$$

The right-hand side of (A.28) is positive, meaning firm *L*'s profit is higher in the *BF-F* equilibrium of the main analysis. Now considering firm *H*'s profit, Tables 2 and 3 show that $\pi_H^{BF-F} = \pi_H^{F-F}(\text{BM})$.

Second, when $\min(\chi_1^{BM}, \chi_2^{BM}) < c < \chi_1$, we compare firms' profit in the *BF-F* equilibrium with that in the *B-F* benchmark equilibrium. For firm *L*,

$$\pi_L^{BF-F} - \pi_L^{B-F}(\text{BM}) = \frac{(49+25\alpha)c^2+4(1+\alpha)(2+\alpha)\alpha-16(2+\alpha)\alpha c}{4\alpha(7+3\alpha)^2} - \frac{(2+\alpha)(1+\alpha+c)^2}{(1+\alpha)(7+4\alpha)^2} \tag{A.29}$$

The right-hand side of (A.29) is positive for $c < \chi_1$, showing firm *L* has a higher profit in the *BF-F* equilibrium of the main analysis. Now, considering firm *H*'s profit, we examine $\pi_H^{BF-F} - \pi_H^{B-F}$.

$$\pi_H^{BF-F} - \pi_H^{B-F}(\text{BM}) = \frac{(4+2\alpha-c)^2}{(7+3\alpha)^2} - \frac{[4+2(3+\alpha-c)\alpha-3c]^2}{(1+\alpha)(7+4\alpha)^2} \tag{A.30}$$

The right-hand side of (A.30) is negative. Thus, firm *H*'s profit in the *BF-F* equilibrium is lower than the profit in the *B-F* benchmark equilibrium.

We now consider the case when firm *H* expands its product line (i.e., when *c* is sufficiently large). First, when $\chi_3^{BM} < c$, we compare firm *H*'s profit in the *B-BF* equilibrium of the main analysis with that in the *B-B* benchmark equilibrium.

$$\pi_H^{B-BF} - \pi_H^{B-B}(\text{BM}) = \frac{(\alpha-c)^2}{4\alpha} \tag{A.31}$$

The right-hand side of (A.31) is positive, meaning firm *H*'s profit is higher in the *B-BF* equilibrium of the main analysis. Now, considering firm *L*'s profit, Table 1 and 2 show $\pi_L^{B-BF} = \pi_L^{B-B}(\text{BM})$.

Second, when $\chi_2 < c < \chi_3^{BM}$, comparing firm *H*'s profit with that in the *B-F* benchmark equilibrium,

$$\pi_H^{B-BF} - \pi_H^{B-F}(\text{BM}) = \frac{16}{49} + \frac{\alpha}{4} + \frac{c^2}{4\alpha} - \frac{[4+2(3+\alpha-c)\alpha-3c]^2}{(1+\alpha)(7+4\alpha)^2} - \frac{c}{2} \tag{A.32}$$

The right-hand side of (A.32) is positive for $c > \chi_2$, showing firm *H* has a higher profit in the *B-BF* equilibrium of the main analysis. Considering firm *L*'s profit,

$$\pi_L^{B-BF} - \pi_L^{B-F}(\text{BM}) = \frac{d(1+d)}{(3+4d)^2} - \frac{(1+d+\alpha d)(c+d+\alpha d)^2}{(1+\alpha)d(3+4(1+\alpha)d)^2} \tag{A.33}$$

The right-hand side of (A.33) is negative. Thus, firm *L* cannot receive higher profit in the B-BF equilibrium than the B-B and B-F benchmark equilibria.