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ABSTRACT

The Introduction of New Product Qualities by Incumbent Firms: Market Proliferation versus Cannibalization

by Ralph Siebert*

This study analyzes the optimal provision of goods in a market characterized by vertical product differentiation. We consider a duopoly model in which incumbents may introduce a new product with certain quality, and decide whether to keep or to withdraw the existing product from the market. We find that the strategic and cannibalization effects dominate, such that no room is left for discrimination among consumers. The innovator always withdraws the existing product from the market, in order to reduce price competition and to avoid cannibalizing its new product demand. In contrast to horizontally differentiated markets, firms are better off not to offer a range or interval of product qualities in vertically differentiated markets. Hence, firms fare better, despite offering a smaller variety of goods.

Keywords: Asymmetric Firms, Cannibalization, Market Proliferation, New Product Introduction, Product Innovation, Vertical Product Differentiation.

JEL Classification: L11, L13, O31, O32

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ZUSAMMENFASSUNG

Die Einfuehrung neuer Qualitaetsprodukte von Unternehmen: Marktnischenbesetzung versus Kannibalisierung der Nachfrage

Diese Studie analysiert das optimale Angebot von Guetern, die sich in der Qualitaet unterscheiden. Wir betrachten ein Modell, in dem zwei insaessige Unternehmen neue Produkte mit unterschiedlicher Qualitaet in den Markt einfuehren koennen. Zudem koennen die Innovatoren entscheiden, ob ihre existierenden Produkte weiterhin im Markt angeboten oder abgezogen werden sollen. Wir zeigen, dass strategische Effekte und Kannibalisierungseffekte keine Diskriminierung zwischen den Konsumenten zulassen. Der Innovator zieht das existierende Produkt immer aus dem Markt, um einen erhoehten Preiswettbewerb und eine Kannibilisierung der eigenen Nachfrage zu vermeiden. Im Gegensatz zu horizontal differenzierten Maerkten, stellen sich Unternehmen in vertikal differenzierten Maerkten besser, eine geringere Produktvielfalt anzubieten.

1 Introduction

Many industries are characterized by oligopolistic competition with differentiated products. Technological progress motivates firms to introduce new products with different characteristics. Consumers' valuation of those product characteristics distinguish horizontal from vertical product differentiation settings. In horizontally differentiated markets, we frequently observe that incumbent firms introduce improved goods of higher quality level and keep their existing product in the market.[1] Prominent examples, characterized by a high degree of market coverage, are the automobile industry, insurance markets, and the food industry. In these industries, firms' optimal product provision might be determined by proliferating the product space in order to discriminate among consumers for gaining on demand (see, e.g., Champsaur and Rochet (1989), Shaked and Sutton (1990), Anderson and de Palma (1988) plus Anderson, de Palma, and Thisse (1992)).

In vertically differentiated markets, however, incumbents often introduce new products of higher quality and withdraw their existing products from the market.[2] A prominent example is the electronics and telecommunications industry: new PCs or laptops with faster processors, new cellular phones with longer 'stand by time', new computer screens with higher resolutions, and new software with improved applications enter the markets, and existing products are withdrawn. In these industries, firms may have less of an incentive to proliferate the product space while keeping the existing products in the market, see, e.g., Moorthy and Png (1992).

The aim of this study is to explain firms' incentives to proliferate the product space in vertically differentiated product markets.[3] We analyze which effects determine the innovator's decision to keep or to withdraw existing products from the market.[4]

This study presents a duopoly model in which incumbents may introduce a new product with certain quality. The innovator may keep or withdraw the existing product from the market and firms set prices in the product market. As solving for product qualities in closed form is rather difficult, we implicitly derive the effects

[1]In horizontal product differentiation models consumers' preferences are distributed over a spectrum of products in which each consumer chooses the closest product. Dixit and Stiglitz (1977), Salop (1979), and Brander and Eaton (1984) are some pioneering studies in this field.

[2]In models characterized by vertical product differentiation all consumers rank qualities in the same order, but differ in their income. Mussa and Rosen (1978), Gabszewicz and Thisse (1979 and 1980) and Shaked and Sutton (1982) are the first studies in this area. Choi and Shin (1992) modify the vertical differentiation model by Shaked and Sutton (1982) allowing for an uncoverd market. Caplin and Nalebuff (1991) provide a short overview of different approaches on discrete choice models. For more recent contributions in the area of vertical product differentiation, see Hoppe and Lee (2003), Hoppe and Lehmann-Grube (2001), and Lehmann-Grube (1997) and the cited literature therein.

[3]There is a large body of recent empirical work focusing on the introduction of new products. Prominent examples are Berry, Levinsohn and Pakes (1993), Berry and Waldvogel (1999), Davis (2002), Hausman (1997), and Petrin (2002), among many others.

[4]For further information regarding the distinction between horizontal and (*pure*) vertical differentiation, see also Cremer and Thisse (1991), Champsaur and Rochet (1989), and Constantatos and Perrakis (1997).

impacting the innovators decision on their optimal provision of goods.

This paper confirms that the basic result established by Champsaur and Rochet (1989) for horizontal differentiation also holds in a *pure* vertical differentiation setting with uniformly distributed preferences. The Chamberlinian incentive (*strategic effect*) to isolate oneself from other firms' products is so strong that an innovator differentiates its products from those of its competitors in order to soften price competition. Therefore, in innovation cases, in which the innovator's existing product is adjacent to the rival's product, it better withdraws. However, in contrast to horizontal models, the innovators incentives to differentiate their products is not limited towards rivals' products, but also holds among its own goods. Moreover, innovators withdraw their existing products close to their own goods, in order to avoid cannibalizing their own product demand and to soften price competition towards their own products. We show that the *strategic* and *cannibalization effects* are so strong, that no room is left for discrimination (*demand effect*) among consumers; they earn higher profits despite a smaller variety of goods. Consequently, in contrast to horizontally differentiated markets, firms are worse off to offer a range or interval of product qualities in vertically differentiated product markets.

It is well established that models characterized by horizontal differentiation may provide different results than vertical differentiation settings. For instance, Shaked and Sutton (1983) show that in vertical product differentiation models an upper bound on the number of firms exists, in contrast to the horizontal models in which the market can support an arbitrarily large number of firms. Hence, the distinction between horizontal and vertical product differentiation might be crucial as well, regarding the optimal provision of products in the market.

We may expect that an innovator's choice to keep or to withdraw the existing product is determined by the *demand effect.* An innovator may prefer to proliferate the product space in order to discriminate among consumers which attracts more consumers and increases sales. Up to this point, the existing literature on product proliferation with the purpose of discrimination among consumers is mostly characterized by a monopolist who decides on a product range offered in the market, see, e.g., Mussa and Rosen (1978). They show that a protected monopolist may decide to leave parts of the market unserved and does not engage in complete market coverage.

A further aspect, the innovator may account for, is given by keeping the existing product in the market which increases price competition (*strategic effect*). The principle of 'maximal product differentiation' by Shaked and Sutton (1982) illustrates that the benefit to firms by moving product qualities apart from each other in order to soften price competition (*strategic effect*), outweighs the market share gained through discriminating among consumers and proliferating the product space through moving qualities closer to each other (*demand effect*). This trade off is also highlighted in Champsaur and Rochet (1989). In a general horizontal product differentiation model they analyze the incentives of multiproduct duopolists' to offer different intervals (ranges) of product qualities. The authors show that both firms will differentiate their product lines from those of their competitors according to the principle of 'maximal product differentiation'. Therefore, the Chamberlinian incentive, or the *strategic effect* dominates the *demand effect* for intermediate qualities which induces a gap between both firms' product lines. For the purpose of generality, they exclude the case of *pure* vertical differentiation, as originated by Gabszewicz and Thisse (1979) and Shaked and Sutton (1982). Therefore, we analyze to what extent this result also applies to a pure vertical differentiation setting.

Finally, an innovator's decision on existing products depends on the impact on its new product demand when keeping the existing product in the market, e.g., the *cannibalization effect.* The *cannibalization effect* indicates that some consumers will switch to buy from one of the innovator's products to another of their products. For literature covering the aspect of cannibalization, see, e.g., Aron and Lazear (1990) and Moorthy and Png (1992). However, it is still unclear whether the *cannibalization effect* is restricted towards cases in which own products are direct neighbors, or if it also applies for nonneighboring products, e.g., in case the innovator leapfrogs the other firms' product quality. Moreover, we may also expect these effects to impact firms differently.

The remainder of this paper is organized as follows. Section 2 describes our model of new product introduction in a vertical differentiation setting. In Section 3, we provide a detailed analysis when the high-quality firm may introduce a new product. Section 4 investigates when the low-quality firm is the innovator. We conclude in section 5.

2 The Model

We consider an outset in which two firms ($i = 1, 2$) offer each one product with quality $\underline{s}, \overline{s} \in \Re^+$ and $\underline{s} < \overline{s}$ in the market.[5] Thus, firm 1 is the low-quality and firm 2 is the high-quality provider. Since innovations frequently follow from inventions made by the firm in related business fields, we assume that there is one firm which benefits from a technological progress. The technological progress improves the firm's production technology and enables it to introduce a new product into the market. Hence, we distinguish between two scenarios depending on which firm is subject to technological progress: the high-quality firm may introduce a new product, and the low-quality firm may introduce a new product. We assume the new product quality to be higher than its existing product, $s_i > \underline{s}$ or $\overline{s}$, if $i = 1$ or 2, respectively. We would like to stress that the assumption of introducing a new product only of higher quality, is imposed without loss of generality.[6] We can distinguish between two quality areas: a low-quality area ($\underline{s} < s_i < \overline{s}$), and a high-quality area ($s_i > \overline{s}$).

We model a two-stage duopoly game.[7] In the *first stage*, the innovator (firm i)

[5]The outset is based on the model by Choi and Shin (1992) which is a modification of Shaked and Sutton (1982) in which the version of Tirole (1992) is used. The results are shown in Appendix 1.

[6]The assumption simplifies the analysis, as it rules out several innovation cases which will not be part of the set of candidate equilibria. In general, the analysis holds for any new product with quality $s_i \in [0, \infty)$.

[7]Since we want to emphasize on the number of products offered in the market, but not on the

decides whether to keep or to withdraw its existing product from the market, having introduced a new product with certain quality s_i. The innovator keeps the existing product in the market, if

$$\pi_i^k\left(\underline{s}, \overline{s}, s_i\right) - \pi_i^w\left(s, s_i\right) > 0 \qquad (1)$$

applies, with $i = 1, 2$ and $s = \overline{s}$ or $\underline{s}$, if $i = 1$ or 2; π_i^k and π_i^w denote firm i's profits, when it keeps or withdraws the existing product, respectively. In terms of the number of products offered in the market, the following cases may occur: the innovator keeps the existing product in the market and three products are offered; the innovator withdraws the existing product from the market and two products are offered in the market.

In the *second stage*, firms maximize profits by simultaneously choosing prices in the product market having observed the qualities and the number of products offered in the market. We distinguish between R&D costs depending on quality, and production costs being independent of quality. No entry is assumed to occur. Figure 1 shows the different innovation cases.

Case a	**Product Locations**	**Case** b	**Case** c
s_2	high-quality area		s_1
$\overline{s}$	existing high-quality product	$\overline{s}$	$\overline{s}$
	low-quality area	s_1	
$\underline{s}$	existing low-quality product	$\underline{s}$	$\underline{s}$
New Product Introduction by the High-Quality Firm		New Product Introduction by the Low-Quality Firm	

Figure 1: The Innovation Cases

Consumers' preferences are given by $U = \theta s - p$ if they buy a good and zero, otherwise. Each consumer has the same ranking of qualities and prefers higher quality for a given price p. Consumers differ in their income. Their income parameter θ is uniformly distributed over the interval $[0, 1]$.[8] The assumption on the income parameter implies that the market is not covered which means that some consumers do not buy any one of these products. Every consumer is allowed to buy at most one of the products. We look for pure strategies and solve the game by applying backward induction for every innovation case.

properties of the R&D cost functions, we abstract (without loss of generality) from endogenizing quality.

[8] Another common assumption is the bimodular distribution. The uniform distribution is an appropriate assumption for the electronics and telecommunications market. Otherwise, it might be difficult to explain very low preference for intermediate quality goods for the industries under consideration.

3 New Product Introduction by the High-Quality Firm (Case a)

In what follows, when the high-quality firm is the innovator, we investigate the product market competition (stage 2) in section 3.1 and derive prices, demand, and profits. Section 3.2 investigates the innovator's choice to keep or withdraw the existing product (stage 1).

3.1 Product Market Competition - Stage 2

When the high-quality firm introduces a new product in the high-quality area, three products with qualities $s_2 > \overline{s} > \underline{s}$ are offered. Consequently, there are three indifferent consumers prevalent in the market. One of them is indifferent between buying the product with highest quality s_2 or with second highest quality $\overline{s}$ from the high-quality firm. The income parameter of this consumer is given by $\theta_2 = \frac{(p_2 - \overline{p})}{(s_2 - \overline{s})}$. The consumer who is indifferent between buying the high-quality firm's existing product with quality $\overline{s}$ and the low-quality firm's product with quality $\underline{s}$ is described by the income parameter $\overline{\theta} = \frac{(\overline{p} - \underline{p})}{(\overline{s} - \underline{s})}$, whereas the income parameter $\underline{\theta} = \frac{\underline{p}}{\underline{s}}$ represents the consumer who is indifferent between buying the product with lowest quality from the low-quality firm and not buying at all. For the demand functions, we get

$$D_2\left(\overline{p}, p_2, \overline{s}, s_2\right) = \int_{\theta_2}^{\theta=1} f(\theta)\, d\theta = 1 - \frac{(p_2 - \overline{p})}{(s_2 - \overline{s})}, \tag{2}$$

$$\overline{D}\left(\underline{p}, \overline{p}, p_2, \underline{s}, \overline{s}, s_2\right) = \int_{\overline{\theta}}^{\theta_2} f(\theta)\, d\theta = \frac{(p_2 - \overline{p})}{(s_2 - \overline{s})} - \frac{\left(\overline{p} - \underline{p}\right)}{\left(\overline{s} - \underline{s}\right)}, \tag{3}$$

and

$$\underline{D}\left(\underline{p}, \overline{p}, \underline{s}, \overline{s}\right) = \int_{\underline{\theta}}^{\overline{\theta}} f(\theta)\, d\theta = \frac{\left(\overline{p} - \underline{p}\right)}{\left(\overline{s} - \underline{s}\right)} - \frac{\underline{p}}{\underline{s}}. \tag{4}$$

Firms' profit functions in stage 2 are given by

$$\underline{\pi}(\underline{p}, \underline{D}) = \underline{p}\underline{D}(\cdot), \text{ and}$$

$$\pi_2^k\left(\overline{p}, \overline{D}, p_2, D_2\right) = \overline{p}\overline{D}(\cdot) + p_2 D_2(\cdot).$$

Each firm maximizes its profits with respect to its own product price. The first order condition for the low-quality firm, is given by

$$\frac{\partial \underline{\pi}(\underline{p}, \underline{D})}{\partial \underline{p}} \equiv 0 \Longrightarrow \underline{p}(\overline{p}) = \frac{\overline{p}\underline{s}}{2\overline{s}}.$$

The first order condition for the high-quality firm with respect to the price of the high-quality product, is as follows

$$\frac{\partial \pi_2^k(\overline{p}, \overline{D}, p_2, D_2)}{\partial p_2} \equiv 0 \Longrightarrow p_2\left(\overline{p}\right) = \frac{2\overline{p} - \overline{s} + s_2}{2},$$

and with respect to the price of its existing product, is given by

$$\frac{\partial \pi_2^k(\overline{p}, \overline{D}, p_2, D_2)}{\partial \overline{p}} \equiv 0 \Longrightarrow \overline{p}\left(\underline{p}\right) = \frac{\underline{p} - \underline{s} + \overline{s}}{2}.$$

The reaction functions are strictly monotone. Solving the first order conditions yields the corresponding prices[9]

$$\underline{p}(\underline{s}, \overline{s}) = \frac{\underline{s}\left(\overline{s} - \underline{s}\right)}{4\overline{s} - \underline{s}},\ \overline{p}(\underline{s}, \overline{s}) = \frac{2\overline{s}\left(\overline{s} - \underline{s}\right)}{4\overline{s} - \underline{s}},\ \text{and}$$

$$p_2(\underline{s}, \overline{s}, s_2) = \frac{4\overline{s}s_2 - \underline{s}\left(s_2 + 3\overline{s}\right)}{2\left(4\overline{s} - \underline{s}\right)}.$$

Substituting these into equations (2), (3), and (4) gives us the equivalent demand

$$\underline{D}(\underline{s}, \overline{s}) = \frac{\overline{s}}{4\overline{s} - \underline{s}},\ \overline{D}(\underline{s}, \overline{s}) = \frac{\underline{s}}{2\left(4\overline{s} - \underline{s}\right)},\ \text{and } D_2 = \frac{1}{2}.$$

Similarly, firms' profits in the product market are

$$\underline{\pi}(\underline{s}, \overline{s}) = \frac{\underline{s}\overline{s}\left(\overline{s} - \underline{s}\right)}{\left(4\overline{s} - \underline{s}\right)^2},\ \text{and}$$

$$\pi_2^k(\underline{s}, \overline{s}, s_2) = \frac{\underline{s}\overline{s}\left(\overline{s} - \underline{s}\right)}{\left(4\overline{s} - \underline{s}\right)^2} + \frac{4\overline{s}s_2 - \underline{s}\left(3\overline{s} + s_2\right)}{4\left(4\overline{s} - \underline{s}\right)}. \tag{5}$$

Equation (5) shows that firms' profits depend on the product qualities and the number of products in the market. Note, in case the innovator withdraws its existing product each firm offers one product and the results are similar to the outset adjusted for the corresponding product quality $s_2 = \overline{s}$, see Appendix 1.

[9] See also Caplin and Nalebuff (1991) regarding the existence and uniqueness of Nash equilibria in this setting.

3.2 Keep or Withdraw - Stage 1

The innovator's decision to keep or withdraw the existing product is analyzed, as per equation (1). The main problem is given by the difficulty to explicitly solve for quality, as the terms are often characterized by polynomials of high degrees. Consequently, we are not able to compare the high-quality firm's profits when it keeps its product, as shown by equation (5), with the case when it withdraws, as shown in Appendix 1, equation (10), adjusted for $\overline{s} = s_2$. Therefore, we implicitly solve the system by parceling out the total effects in several parts which makes the analysis computationally tractable. We implicitly analyze the innovator's decision to keep or withdraw the existing product from its marginal profits with respect to its existing product quality $\overline{s}$. For illustrative purposes, we decompose the total derivative of the reduced-form profit function into several effects.[10] The derivative of the high-quality firm's second-stage profit function with respect to its existing product quality $\overline{s}$, is given by[11]

$$\begin{aligned}
\frac{d\pi_2^k}{d\overline{s}} &= \underbrace{\overbrace{\frac{\partial \pi_2^k}{\partial \overline{D}}}^{+}\overbrace{\frac{\partial \overline{D}}{\partial \underline{p}}}^{+}\overbrace{\frac{d\underline{p}}{d\overline{s}}}^{+}}_{\text{strategic effect}} + \underbrace{\overbrace{\frac{\partial \pi_2^k}{\partial \overline{D}}}^{+}\overbrace{\frac{\partial \overline{D}}{\partial \overline{s}}}^{+}}_{\text{demand effect}} + \underbrace{\overbrace{\frac{\partial \pi_2^k}{\partial D_2}}^{+}\overbrace{\frac{\partial D_2}{\partial \overline{s}}}^{-}}_{\text{cannibalization effect}} \qquad (6) \\
&= \underbrace{\frac{6\underline{s}^2\overline{s}}{(4\overline{s}-\underline{s})^3}}_{\text{strategic effect}} + \underbrace{\frac{\overline{s}\left(\underline{s}^2 - 3\underline{s}\overline{s} - 2\underline{s}s_2 + 4\overline{s}s_2\right)}{(s_2-\overline{s})\left(\underline{s}-4\overline{s}\right)^2}}_{\text{demand effect}} \\
&\quad + \underbrace{\frac{\left(\underline{s}\left(3\overline{s}+s_2\right) - 4\overline{s}s_2\right)}{4\left(\underline{s}-4\overline{s}\right)\left(\overline{s}-s_2\right)}}_{\text{cannibalization effect}} > 0 \,.
\end{aligned}$$

The incentive for the high-quality firm to withdraw its existing product with quality $\overline{s}$, is determined by three *effects*.[12] The *strategic effect* indicates that decreasing the existing product quality toughens price competition in the market. The *demand effect* refers to the fact that increasing the high-quality firm's existing product quality increases its profits through gaining on demand. The *cannibalization effect* indicates that keeping the existing product cannibalizes the new product's demand which lowers the innovator's profits. Some consumers will switch to buy the existing product instead of purchasing the new product. Since the *cannibalization effect* dominates the *demand effect* the existing product attracts less consumers than it *cannibalizes* its new product's demand. Therefore, keeping the existing product in the market

[10] Decomposing the marginal profits into several effects will be necessary in later scenarios in order to show the sign of the derivative.

[11] Second-stage optimization, implies $\frac{\partial \pi_2^k}{\partial p_2} = 0$ and $\frac{\partial \pi_2^k}{\partial \overline{p}} = 0$. Thus, the effect of $\overline{s}$ on π_2^k through the high quality firm's price change can be ignored by applying the envelope theorem.

[12] A *strategic effect* towards the innovator's new product price does not appear since the innovator internalizes price competition towards its own high quality product.

cannibalizes the new product's demand to a higher extent than the existing product's ability to attract customers. Moreover, as the *strategic effect* dominates the *cannibalization effect*, the high-quality firm earns higher profits through relaxing price competition and approaching the existing product quality towards the new product with quality s_2. The total derivative of the high-quality firm is positive, indicating that its profits continuously increase in the quality of the existing product. The extreme case when both product qualities are identical, is equivalent to withdrawing the existing product from the market.

In other words, the high-quality firm is better off withdrawing its existing product from the market in order to avoid cannibalization and to soften price competition. In this case, two products are offered in the market: the low-quality firm's existing product with quality $\underline{s}$ and the high-quality firm's new product with quality s_2. The same results as in Appendix 1, setting $s_2 = \overline{s}$, apply. In case the high-quality firm is the innovator, we obtain the following result.

Proposition 1 *The high-quality firm always withdraws the existing product from the market, after introducing a new product in the high-quality area.*

In the next section, we investigate the innovation cases *b* and *c* when the low-quality firm is the innovator.

4 New Product Introduction by the Low-Quality Firm

In the following, we first analyze the case, when the low-quality firm may introduce a new product in the low-quality are (case *b*), before we turn to the case, when the high-quality firm may introduce a new product in the high-quality area (case *c*).

4.1 Low-Quality Innovation by the Low-Quality Firm

The results for the product market competition (stage 2) are shown in Appendix 2. We proceed with investigating the low-quality firm's choice to keep or withdraw the existing product (stage 1).

4.1.1 Keep or Withdraw - Stage 1

In order to determine the low-quality firm's decision to keep or withdraw the existing product from the market, according to equation (1), we implicitly solve the system by parceling out the total effects in several parts. The total derivative of the low-quality firm's profit function with respect its product with quality $\underline{s}$, given by

$$\frac{d\pi_1^k}{d\underline{s}} = \underbrace{\overbrace{\frac{\partial \pi_1^k}{\partial \underline{D}}}^{+}\overbrace{\frac{\partial \underline{D}}{\partial \underline{s}}}^{+}}_{demand\ effect} + \underbrace{\overbrace{\frac{\partial \pi_1^k}{\partial D_1}}^{+}\overbrace{\frac{\partial D_1}{\partial \underline{s}}}^{-}}_{cannibalization\ effect} \tag{7}$$

$$= \underbrace{\frac{s_1\left(\overline{s}-s_1\right)^2}{\left(s_1-\underline{s}\right)\left(4\overline{s}-s_1\right)^2}}_{\textit{demand effect}} + \underbrace{\frac{s_1\left(\overline{s}-s_1\right)^2}{\left(\underline{s}-s_1\right)\left(4\overline{s}-s_1\right)^2}}_{\textit{cannibalization effect}} . \tag{8}$$

As we see in equation (7), marginal profits are determined by a *demand* and a *cannibalization effect*. The *demand effect* shows that increasing the existing product quality attracts more consumers. The *cannibalization effect* shows that some consumers will switch to buy the existing product instead of purchasing the new product. As we see in equation (8), the *cannibalization* and the *demand effect* are balancing each other. However, the low-quality firm internalizes the *strategic effect* towards its own product by pricing the low-quality product relatively high, such that no consumer will buy the existing product with lower quality, see equation (16) in Appendix 2. Therefore, the low-quality firm's decision is equivalent to withdrawing the existing product from the market. Two products will be offered in the market. The same results as in Appendix 1 , with $s_1 = \underline{s}$ apply.

4.2 High-Quality Innovation by the Low-Quality Firm

The results for the product market competition (stage 2) are shown in Appendix 3. In the following, we concentrate on the innovator's choice to keep or withdraw the existing product (stage 1).

4.2.1 Keep or Withdraw - Stage 1

When the low-quality firm introduces a new product in the high-quality area, its choice to keep or withdraw the existing product from the market is given by equation (1). We analyze the total derivative of its profit function with respect to its existing product quality $\underline{s}$, given by

$$\begin{aligned}
\frac{d\pi_1^k}{d\underline{s}} &= \underbrace{\overbrace{\frac{\partial \pi_1^k}{\partial \underline{D}}}^{+}\overbrace{\frac{\partial \underline{D}}{\partial \overline{p}}}^{+}\overbrace{\frac{d\overline{p}}{d\underline{s}}}^{-}}_{\textit{first strategic effect}} + \underbrace{\overbrace{\frac{\partial \pi_1^k}{\partial D_1}}^{+}\overbrace{\frac{\partial D_1}{\partial \overline{p}}}^{+}\overbrace{\frac{d\overline{p}}{d\underline{s}}}^{-}}_{\textit{second strategic effect}} + \underbrace{\overbrace{\frac{\partial \pi_1^k}{\partial \underline{D}}}^{+}\overbrace{\frac{\partial \underline{D}}{\partial \underline{s}}}^{+}}_{\textit{demand effect}} \\
&= \underbrace{\frac{3\underline{s}\overline{s}^2\left(s_1-\overline{s}\right)^3}{2\Psi^3}}_{\textit{first strategic effect}} + \underbrace{\frac{3\overline{s}^2\left(s_1-\overline{s}\right)^2\left(4\overline{s}s_1-\underline{s}\left(3\overline{s}+s_1\right)\right)}{2\Psi^3}}_{\textit{second strategic effect}} + \\
&\quad + \underbrace{\frac{\overline{s}^2\left(s_1-\overline{s}\right)^2}{4\left(\overline{s}\left(\overline{s}-4s_1\right)+\underline{s}\left(2\overline{s}+s_1\right)\right)^2}}_{\textit{demand effect}} < 0
\end{aligned} \tag{9}$$

with $\Psi = 2\underline{s}\overline{s} + \overline{s}^2 + \underline{s}s_1 - 4\overline{s}s_1$. Two negative *strategic effects* and one positive *demand effect* determine the low-quality firm's marginal profits. Both *strategic effects* indicate that price competition is softened towards the rival's price by decreasing the quality of the existing product. The relaxed price competition has a positive impact on both the low-quality firm's product demands. The *demand effect* shows that increasing the existing product quality attracts more consumers. No *cannibalization* occurs in this scenario because the new product does not directly impact the demand of its own existing product; only neighboring products do so. As shown in equation (9), both *strategic effects* dominate the *demand effect* resulting in a total negative effect.

The low-quality firm earns higher profits by withdrawing the existing product from the market in order to soften price competition, instead of keeping the existing product and gaining on demand. As a result, two products are offered in the market and the same results as in Appendix 1 apply, setting $s_1 = \overline{s}$ and $\overline{s} = \underline{s}$. When the low-quality firm introduces a new product into the market (cases b and c) we obtain the following result.

Proposition 2 *The low-quality firm always withdraws the existing product after introducing a new product in the low or high-quality area.*

Taking all innovation cases together, we have shown that innovators withdraw their existing product from the market in order to avoid *cannibalizing* its own product demand or to soften price competition (*strategic effect*) in the market.

5 Conclusion

In the context of a vertical product differentiation model with uniformly distributed preferences, we explain firms' optimal provision of products in the market. We analyze if innovators better keep the existing product in the market in order to discriminate among consumers, or if they rather withdraw their existing products in order to avoid cannibalization and to soften price competition.

We can confirm that the basic result by Champsaur and Rochet (1989) also holds, to some extent, in a *pure* vertical differentiation setting. As shown, the innovator differentiates its products from those of its competitor in order to soften price competition. However, we also show that innovators withdraw their existing products close to its own goods in order to avoid cannibalizing their own product demand and to soften price competition among its own products. We show that the *strategic* and *cannibalization effects* are so strong, that no room is left for discrimination (*demand effect*). An innovator always withdraws the existing product from the market and earns higher profits despite a smaller variety of goods. Therefore, the gap between the products is not limited towards intermediate qualities or rivals' products as in horizontal models, but also holds among its own products. Consequently, in contrast to horizontally differentiated markets, firms are worse off to offer a range or interval of product qualities in vertically differentiated product markets.

It is interesting to note that our results also contributes to the literature on 'damaged goods', as we can conclude that the distribution of quality preferences plays an important role in determining firms' decision to either keep or withdraw the existing product. Prominent examples are Deneckere and McAfee (1996) and Johnson and

Myatt (2002). The literature on 'damaged goods', often based on a bimodal distribution of preferences for quality, suggests firms to keep their existing product in the market. Our model which is based on the assumption of a uniform distribution of preferences for quality is consistent with firms withdrawing the existing product from the market.

Some industries, e.g., the Dynamic Random Access Memory industry, are characterized by adjacent product generations simultaneously offered in the market. For further research it might be interesting to empirically investigate by how much firms' profits increase when they withdraw their existing product generation, after they introduced a new product generation. Moreover, it might be interesting to investigate by how much their product qualities and their prices will change, due to their higher profits earned in the product market.

6 APPENDIX

Appendix 1: The Outset

The outset is based on the model by Choi and Shin (1992) which is a modification of Shaked and Sutton (1982) where we use the version of Tirole (1992). The model is a noncooperative two-stage game where two firms ($i = 1, 2$) simultaneously choose their qualities in the first stage and given their qualities, they compete in the second stage with prices in the product market.

Product qualities $\underline{s}, \overline{s}$ with $\underline{s} < \overline{s}$ are chosen from the following set of qualities, defined as $[0, \widetilde{s}]$ where $\widetilde{s}$ is any finite number. Firm 1 is supposed to be the low-quality provider and firm 2 is the high-quality provider. We focus on pure strategies. Consumers' preferences are described in the model section above. After deriving the corresponding demand functions, we get for the corresponding prices[13]

$$\underline{p}\left(\underline{s}, \overline{s}\right) = \frac{\underline{s}\left(\overline{s} - \underline{s}\right)}{4\overline{s} - \underline{s}}, \text{ and } \overline{p}\left(\underline{s}, \overline{s}\right) = \frac{2\overline{s}\left(\overline{s} - \underline{s}\right)}{4\overline{s} - \underline{s}}.$$

For demand, we get

$$\underline{D}\left(\underline{s}, \overline{s}\right) = \frac{\overline{s}}{4\overline{s} - \underline{s}}, \text{ and } \overline{D}\left(\underline{s}, \overline{s}\right) = \frac{2\overline{s}}{4\overline{s} - \underline{s}}.$$

Profits are

$$\underline{\pi}\left(\underline{s}, \overline{s}\right) = \frac{\underline{s}\overline{s}\left(\overline{s} - \underline{s}\right)}{\left(4\overline{s} - \underline{s}\right)^2}, \text{ and } \overline{\pi}\left(\underline{s}, \overline{s}\right) = \frac{4\overline{s}^2\left(\overline{s} - \underline{s}\right)}{\left(4\overline{s} - \underline{s}\right)^2}. \tag{10}$$

Reduced-form profit functions are continuous and differentiable, given by

$$\frac{\partial \underline{\pi}\left(\underline{s}, \overline{s}\right)}{\partial \underline{s}} = \frac{\overline{s}^2\left(4\overline{s} - 7\underline{s}\right)}{\left(4\overline{s} - \underline{s}\right)^3} \gtreqless 0 \text{ for } \underline{s} \lesseqgtr \frac{4}{7}\overline{s}, \text{ and} \tag{11}$$

$$\frac{\partial \overline{\pi}\left(\underline{s}, \overline{s}\right)}{\partial \overline{s}} = \frac{4\overline{s}\left(4\overline{s}^2 + 2\underline{s}^2 - 3\underline{s}\overline{s}\right)}{\left(4\overline{s} - \underline{s}\right)^3} > 0. \tag{12}$$

$$\frac{\partial \underline{\pi}\left(\underline{s}, \overline{s}\right)}{\partial \overline{s}} = \frac{\underline{s}^2\left(\underline{s} + 2\overline{s}\right)}{\left(4\overline{s} - \underline{s}\right)^3} > 0, \text{ and} \tag{13}$$

$$\frac{\partial \overline{\pi}\left(\underline{s}, \overline{s}\right)}{\partial \underline{s}} = \frac{4\overline{s}^2\left(\underline{s} + 2\overline{s}\right)}{\left(\underline{s} - 4\overline{s}\right)^3} < 0. \tag{14}$$

$$\frac{\partial^2 \underline{\pi}\left(\underline{s}, \overline{s}\right)}{\partial \underline{s}^2} < 0, \text{ and } \frac{\partial^2 \overline{\pi}\left(\underline{s}, \overline{s}\right)}{\partial \overline{s}^2} < 0. \tag{15}$$

[13] See also Caplin and Nalebuff (1991) regarding the existence and uniqueness of Nash equilibria in this setting.

From equation (11), we see that the low-quality firm's profits first increase in quality since more consumers buy the new product (*demand effect*). But the closer the product quality is moved towards the competitor's product the higher is the price competition (*strategic effect*) which decreases the low-quality firm's profits. When both product qualities are identical Bertrand competition drives firms' profits to zero. The low-quality provider's optimal distance to the high-quality product is given by the point where the *demand effect* and the *strategic effect* are balancing each other. The high-quality firm increases profits by offering a higher product quality. We get the result of 'maximal product differentiation' where in equilibrium firms maximally differentiate their products. The low-quality firm offers the lowest feasible product quality and the high-quality firm offers the highest feasible product quality.

Appendix 2: Low-Quality Innovation by the Low-Quality Firm (Case b)

In case b, the low-quality firm introduces a new product in the low-quality area $\overline{s} > s_1$ and keeps the existing product in the market. Firms' profit functions are given by

$$\pi_1^k\left(\underline{p}, \underline{D}, p_1, D_1\right) = \underline{p}\underline{D}\left(\cdot\right) + p_1 D_1\left(\cdot\right),$$

$$\overline{\pi}(\overline{p}, \overline{D}) = \overline{p}\overline{D}\left(\cdot\right).$$

Each firm maximizes its profit function with respect to its own product price. The first order condition for the low-quality firm, with respect to its existing product price is given by

$$\frac{\partial \pi_1^k(\underline{p}, \underline{D}, p_1, D_1)}{\partial \underline{p}} \equiv 0 \Longrightarrow \underline{p}\left(p_1\right) = \frac{p_1 \underline{s}}{s_1}$$

and with respect to its new product price, internalizing the price effect of its new product price on its existing product price is given by

$$\frac{\partial \pi_1^k(\underline{p}, \underline{D}, p_1, D_1)}{\partial p_1} \equiv 0 \Longrightarrow p_1\left(\overline{p}\right) = \frac{\overline{p} s_1}{2\overline{s}}.$$

The first order condition for the high-quality firm, is

$$\frac{\partial \overline{\pi}(\overline{p}, \overline{D})}{\partial \overline{p}} \equiv 0 \Longrightarrow \overline{p}\left(p_1\right) = \frac{p_1 - s_1 + \overline{s}}{2}.$$

The reaction functions are strictly monotone. Solving the first order conditions gives the corresponding prices

$$\underline{p}(\underline{s}, s_1, \overline{s}) = \frac{\underline{s}\left(\overline{s} - s_1\right)}{4\overline{s} - s_1}, \; p_1(s_1, \overline{s}) = \frac{s_1\left(\overline{s} - s_1\right)}{4\overline{s} - s_1},$$

$$\text{and } \overline{p}(s_1, \overline{s}) = \frac{2\overline{s}\left(\overline{s} - s_1\right)}{4\overline{s} - s_1}.$$

The demand is

$$\underline{D}(\cdot) = 0,\ D_1(s_1, \overline{s}) = \frac{\overline{s}}{4\overline{s} - s_1},\ \text{and}\ \overline{D} = \frac{2\overline{s}}{4\overline{s} - s_1}. \tag{16}$$

Firms' profits are as follows

$$\pi_1^k(s_1, \overline{s}) = \frac{s_1 \overline{s}(\overline{s} - s_1)}{(4\overline{s} - s_1)^2}, \text{and} \tag{17}$$

$$\overline{\pi}(s_1, \overline{s}) = \frac{4\overline{s}^2(\overline{s} - s_1)}{(4\overline{s} - s_1)^2}. \tag{18}$$

Appendix 3: High-Quality Innovation by the Low-Quality Firm (Case c)

In case c, the low-quality firm introduces a new product in the high-quality area $s_1 > \overline{s}$ and keeps the existing product in the market. Firms' profit functions are given by

$$\pi_1^k(\underline{p}, \underline{D}, p_1, D_1) = \underline{p}\underline{D}(\cdot) + p_1 D_1(\cdot) \ \text{ and}$$

$$\overline{\pi}\left(\overline{p}, \overline{D}\right) = \overline{p}\overline{D}(\cdot).$$

Each firm maximizes its profit function with respect to its own product price. The first order condition for the high-quality firm, is given by

$$\frac{\partial \overline{\pi}(\overline{p}, \overline{D})}{\partial \overline{p}} \equiv 0 \Longrightarrow \overline{p}\left(\underline{p}\right) = \frac{p_1(\overline{s} - \underline{s}) + \underline{p}(s_1 - \overline{s})}{2(s_1 - \underline{s})}.$$

The first order condition for the low-quality firm with respect to its existing product price

$$\frac{\partial \pi_1^k\left(\underline{p}, \underline{D}, p_1, D_1\right)}{\partial \underline{p}} \equiv 0 \Longrightarrow \underline{p}(\overline{p}) = \frac{\overline{p}\underline{s}}{2\overline{s}},$$

and with respect to its new product price,

$$\frac{\partial \pi_1^k\left(\underline{p}, \underline{D}, p_1, D_1\right)}{\partial p_1} \equiv 0 \Longrightarrow p_1(\overline{p}) = \frac{\overline{p} + s_1 - \overline{s}}{2}.$$

The reaction functions are strictly monotone. Solving the first order conditions yields the corresponding prices

$$\underline{p}(\underline{s}, \overline{s}, s_1) = \frac{\underline{s}(\overline{s} - \underline{s})(\overline{s} - s_1)}{2\Psi},\ \overline{p}(\underline{s}, \overline{s}, s_1) = \frac{\overline{s}(\overline{s} - \underline{s})(\overline{s} - s_1)}{\Psi},$$

$$p_1(\underline{s}, \overline{s}, s_1) = \frac{(s_1 - \overline{s})}{2\left(1 + \frac{\overline{s}(\overline{s} - \underline{s})}{3\underline{s}\overline{s} + \underline{s}s_1 - 4\overline{s}s_1}\right)},$$

with $\Psi = 2\underline{s}\overline{s} + \overline{s}^2 + \underline{s}s_1 - 4\overline{s}s_1$. Substituting these gives us the equivalent demand

$$\underline{D}(\underline{s}, \overline{s}, s_1) = \frac{\overline{s}\left(\overline{s} - s_1\right)}{2\Psi}, \ \overline{D}(\underline{s}, \overline{s}, s_1) = \frac{\overline{s}\left(\underline{s} - s_1\right)}{\Psi}, \text{and}$$

$$D_1(\underline{s}, \overline{s}, s_1) = \frac{\left(\underline{s}\left(3\overline{s} + s_1\right) - 4\overline{s}s_1\right)}{2\Psi}.$$

Similarly, firms' profits in the product market are

$$\pi_1^k(\underline{s}, \overline{s}, s_1) = \frac{\underline{s}(\overline{s}-\underline{s})\overline{s}(\overline{s}-s_1)^2}{4\Psi^2} + \frac{(s_1-\overline{s})(\underline{s}(3\overline{s}+s_1)-4\overline{s}s_1)}{4\Psi\left(1+\frac{\overline{s}(\overline{s}-\underline{s})}{(3\underline{s}\overline{s}+\underline{s}s_1-4\overline{s}s_1)}\right)}, \text{ and}$$

$$\overline{\pi}(\underline{s}, \overline{s}, s_1) = \frac{\overline{s}^2\left(\overline{s} - \underline{s}\right)\left(\underline{s} - s_1\right)\left(\overline{s} - s_1\right)}{\Psi^2}. \tag{19}$$

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