Who is the Winner in an Industry of Innovation

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Abstract

This paper offers insight as to why the average profitability of firms in categories characterized by innovation is high and a rationale for empirical evidence that firms with basic products in innovative categories often exhibit higher profitability than the leading innovator. The analysis is built on the simple fact that not all consumers in a market are willing to pay more for an innovation when it is introduced. Our model reflects price competition between an innovating firm that chooses an optimal level of innovation and a competitor that offers a basic product. The price equilibrium establishes that the innovator confers a significant positive externality on its competitor by innovating. This increases the profitability of both firms. Findings from our model demonstrate that the profitability of the innovator is affected by the cost of innovation, the fraction of consumers who are willing to pay more for the innovation and changes in the cost of producing the improved product. The model identifies market conditions that lead the non-innovating competitor to benefit as much or more than the innovator who invests to develop the innovation. We believe that these dynamics are pivotal in explaining high overall profitability in categories characterized by innovation. The analysis also provides important prescriptions for the management of firms in innovative categories.

Keywords: innovation, price competition, segmentation, externalities, mixed-strategy equilibrium.

1 Introduction

It is difficult to argue with the observation that categories characterized by big innovations exhibit high levels of profitability. Of the world's 10 most profitable companies, 6 are in categories characterized by innovation, 3 are banks and 1 is in the resource sector.[1] Not surprisingly, salaries and rewards for employees are also the highest at companies that operate in innovation-rich sectors. It is important to note that multiple companies in these categories are profitable, not just the innovators. The Booz Allen Hamilton Inc.'s 2005 – 2018 annual "Global Innovation 1000" reports provide lists of "high-leverage innovators" representing companies that outperformed peers within the same industry on key measures of financial success (e.g. sales, revenue, gross margin, profitability, market capitalization) while at the same time spending less on R&D. Examples from the list include companies such as Fiat Chrysler whose product technology is considered lagging that of Mercedez-Benz or Tesla in automobiles and Embraer whose products are a step behind Boeing and Airbus in aerospace.[2] Another persistent finding in the reports is the lack of a significant statistical relationship between R&D spending and the primary measures of financial or corporate success. These empirical findings challenge the conventional wisdom of viewing "R&D as a predictable black box that automatically translates today's innovation investments into tomorrow's profits," (Jaruzelski, Dehoff and Bordia 2006).

In this paper, we build an analytical model to study competition between an innovating firm offering a new improved product and a non-innovating firm that sells a basic product. The purpose of this setup is to provide a close representation of today's market reality. Within many industries, there is typically just one company (or few) that has the R&D capability to create highly innovative products.[3] For example, Xerox through its Palo Alto Research Centre developed many breakthrough inventions including the Windows-based GUI, the mouse and laser printing. Clearly, the ability of Xerox to innovate was by orders of magnitude higher than its key competitors. Most firms within an industry are "copycats" or "laggards" who provide products after the innovation or break-through technology has been introduced by the innovator. This cycle of innovation by one firm and imitation by others continues over time. Our model analysis reflects the nature of price competition between the two types of firms within the same industry (innovator versus non-

[1] Please see http://fortune.com/2016/06/08/fortune-500-most-profitable-companies-2016/. Incidentally, it can be argued that banking is a sector that has been transformed by innovations as much as any.

[2] Please see https://www.fastcompany.com/3041642/the-worlds-top-10-most-innovative-companies-of-2015-in-automo and https://newengineer.com/insight/top-9-aerospace-companies-1113357.

[3] Another persistent finding from the annual Global Innovation 1000 reports is that R&D spending is highly concentrated. For example, in 2018, the top 20 largest R&D spenders account for about 28 percent of the Global Innovation 1000's total R&D spending, while the Global Innovation 1000 account for about 85 percent of total global corporate R&D spending (see p.5 of 2018 report).

innovator) and identifies market conditions under which the non-innovating firm is more profitable than the innovator. The key intuition behind this counter-intuitive result is a positive externality conferred on the non-innovating firm by the innovator through price competition for demand from two distinct consumer segments. Below we discuss three assumptions based on which our model is constructed.

The first is that as categories mature, the offerings in those categories become similar and this leads to commoditization (Gatignon and Soberman 2002). From a technological perspective, standards develop and this reduces the ability of firms to distinguish their products. As a result, markets become price sensitive and this leads to intense competition and declining profits.[4] For example, Campbell and Hopenhayn (1999) find that mature retail markets are associated with lower margins and more customers per establishment. It is this dynamic that provides the incentive for at least one firm to innovate.

The second assumption is that as markets mature, they go through a process of consolidation. The basic drive is to maintain or grow market share.[5] Moreover, many fragmented suppliers consolidate. In fact, as noted in Kotler and Keller (2006), the issue facing a company in a mature market is "whether to struggle to become one of the big 2 or 3 or to pursue a niching strategy."

The third assumption speaks to the fundamental theory of marketing which is based on market segmentation. When an innovation is introduced, we consider a context in which not all consumers are willing to pay an additional increment for the new product. A water-proof watch (or camera) would appear as very valuable to consumers that are actively engaged in water-related sports activities, yet would not bring extra value to consumers who are not active in water-related activities. Similarly, many product review sites praise the Fitbit Charge 3 as an improvement over its predecessors (and competitors) due to the fact that it is swim-proof. Nevertheless, responses by many potential consumers claim that they have no use for that feature and are unwilling to pay for it.[6] Heterogeneity in the response to innovation is endemic to the marketing context (Smith 1956; Wind 1978; Hauser and Shugan 1983) and it explains why innovations take time to diffuse across a population (Bass 1969).

These assumptions and the economic need that firms have to "break out" of markets characterized by Bertrand competition (due to product homogenization) are sufficient to generate the finding that a non-innovating firm is often the key beneficiary of the innovative activity of a competitor.

[4] Note that spatial models also suggest that products become more substitutable as the number of product variants increases (Salop 1979).

[5] This definition is paraphrased from Kotler and Keller's (2006) treatment of the subject (pages 321-334).

[6] See for example pcmag.com/review. Similarly, Adaptive Cruise Control, introduced by General Motors in the 1990s, would have little value for people that rarely drive on highways.

Our analysis indicates that the positive externality conferred on a non-innovating firm results from the endogenously determined optimal level of innovation combined with the nature of price competition between the two firms (innovator versus non-innovator). When an innovator chooses to offer a product with a *big* innovation, the price equilibrium entails the innovating firm offering the improved product at a relatively high price and only selling to customers that are willing to pay more for it. In contrast, the non-innovating firm prices aggressively such that it captures business not only from the segment that is unwilling to pay for the innovation, but also from the segment targeted by the innovator. When offering a product of *medium* or *small* innovation, the innovator prices aggressively and captures demand not just from the segment willing to pay more for the innovation but also from consumers who do not see value in the innovation. Here, the non-innovating firm defends its turf by pricing aggressively and only captures demand from customers who are not willing to pay more for the innovation. Despite this dynamic, equilibrium prices still lead to positive profits for both firms. As a result, industry profit increases compared to the pre-innovation market. In addition, our analysis identifies conditions in terms of the innovation strategy, segment size, innovation and production costs under which the non-innovating firm (offering the basic product) enjoys higher profit than the innovator. These findings have useful managerial implications regarding how firms should manage market selection, new product development and pricing when consumers are heterogeneous in their acceptance of new technology.

The remainder of the paper is organized as follows: Section 2 discusses the relevant literatures and highlights the contribution of this paper. Section 3 presents the setup of the model. Sections 4 and 5 derive the analytical results for the main model and its extension. We present a concise empirical validation in Section 6 as further support for our analytical findings. Section 7 summarizes the managerial implications from our study and Section 8 concludes with a discussion of future research directions.

2 Related Literature

Our study stands at the intersection of three streams of marketing literature. Substantively, it is related to the literature on product innovation. Second, it is related to work in economics that studies the impact of differentiation in vertically differentiated markets. Finally, the study builds on literature that employs mixed-strategy equilibria to characterize price competition when pure strategy equilibria do not exist.

First, there is a large body of research on product innovation in a marketing context (for a detailed review see Hauser, Tellis and Griffin 2006). Our analysis combines demand-side consumer

heterogeneity and supply-side product development to examine how the magnitude of an innovation influences the profitability of firms in a market. On the demand side, we know that consumers respond heterogeneously to innovation (e.g. Hirschman 1980). To facilitate the analysis, we model attitudes towards an innovative product in discrete terms (Farrell and Saloner 1985). To be specific, one segment of consumers is assumed to appreciate the innovative product (and is willing to pay more for it). In contrast, the second consumer segment is indifferent towards the innovation and is not willing to pay anything beyond the basic product price for the innovation. On the supply side, we study a firm's decision about the level of product innovation to choose (Garcia and Calantone 2002). In particular, we examine how an innovative firm decides on the level of innovation to provide when existing products are similar. To be specific, the innovator develops a product that provides an improvement over the existing product (e.g. sequential generation as in Weitzman et al. 1981 or a set of performance features as in Leifer et al. 2000).

Our paper is also related to work that examines competition between firms where one product is of higher quality than another, i.e., the market is vertically differentiated (e.g. Shaked and Sutton 1982, Moorthy 1988, Vandenbosch and Weinberg 1995). Shaked and Sutton (1982) study competition between firms that decide sequentially on market entry, product quality and pricing. They find that in equilibrium two firms will enter the market and offer distinctive product qualities in order to relax the intensity of price competition. Our study is related to Shaked and Sutton in that we highlight how differences in product quality between competitors relax the intensity of price competition. However, there are two factors that distinguish our work from Shaked and Sutton (1982). The first factor is that our objective is not to examine firms' market entry decisions and the associated product choices. The focus of our paper is on a fundamentally different research question: How the level of innovation (quality improvement) chosen by an existing firm affects competition with another firm within the same industry that does not have the capability to innovate. This structure is representative of many industries where only one firm (or a limited number) has the R&D capability to create innovative products.

The second differentiating factor is that models such as Shaked and Sutton (1982) consider the impact of vertical product differentiation on competition in markets where consumer preferences for quality are continuously distributed.[7] From a marketing perspective, the missing element in a model where consumers are continuously distributed is distinct segments. As noted in the introduction, the fundamental theory of marketing is based on segmentation, targeting and positioning. Our paper adopts the simplest two-segment setup to study the myriad effects of innovation on competition

[7] This means that any increase in quality causes all consumers to value the product at a higher (albeit different) level.

and firm profitability where a fraction of consumers in the market appreciate the innovation and the rest do not. Consider the hypothetical example from the Canadian chocolate bar market where Nestle has dominant share in the sub-category of wafer-based chocolate bars with the Coffee Crisp® chocolate bar. Suppose Nestle develops an improved version of Coffee Crisp® which is gluten-free (i.e., the new version is identical to the original product in every respect plus it is also gluten-free). New Coffee Crisp® is a product for which consumers with gluten sensitivity would be willing to pay more. However, consumers who are not gluten sensitive would not be willing to pay more for New Coffee Crisp®.[8] Today, disparity in the value provided by an innovation seems to be the rule not the exception. Our model contributes to the study of innovation by showing how the existence of discrete segments (and the resulting lumpiness of demand) affects an innovator's incentive to invest in innovation, the nature of price competition between innovative and basic product (from previous standard) and the comparative profitability of an innovator versus a firm that sells basic product. These insights do not emerge from a standard model of vertical differentiation such as Shaked and Sutton (1982).

Building on the work of Shilony (1977), we use mixed pricing strategies to characterize competition between an innovator and a non-innovator. Today, mixed pricing strategies are broadly applied in economics and marketing to represent markets where two competitors sell a single product to satisfy the demand of a heterogeneous consumer base. Typically, each firm has a loyal customer segment and competes for a price-sensitive switching segment (e.g. Varian 1980, Narasimhan 1988). In contrast, we model price competition between a non-innovating firm that offers a basic product and an innovator that develops an improved product in a market without a loyal segment for either firm. The market in our model consists of two segments: one segment is willing to pay more for the innovation and the other is not. The analysis reveals that by offering a product with a substantial innovation, the innovator only captures demand from the segment that is willing to pay more for the innovation. In contrast, the non-innovating firm sells to consumers who do not value the innovation and sometimes prices low enough to attract consumers that do value it.

Finally, our study is related to research that examines how various marketing levers can target specific market segments. Literature in this vein considers targeted product modifications, targeted pricing and targeted advertising (e.g. Iyer and Soberman 2000; Chen, Narasimhan and Zhang 2001; Iyer, Soberman and Villas-Boas 2005). In our model, an innovative product represents an offer targeted to a consumer segment that appreciates the innovation and is willing to pay more for it. Our interest is to learn how the application of this strategy affects the performance of both the

[8] "What Are My Options for Gluten-Free Candy?" https://www.healthline.com/health/food-nutrition/gluten-free-candy

innovator and a firm that faces this as a competitive strategy.

3 Model Setup

On the supply side, we assume that two firms offer products in the same category. Firm 1 offers an innovative product which represents an improvement compared to the basic product of Firm 2. Without loss of generality, we normalize Firm 2's cost of producing the basic product to zero and assume that Firm 1 incurs a marginal cost of c to produce the improved product.

On the demand side, we assume that the total mass of consumers in the market equals 1 without loss of generality. The consumer market can be divided into 2 segments: Segment 1 of size β and Segment 2 of size $1 - \beta$, where $0 < \beta < 1$. Both segments of consumers have the same maximum willingness to pay $V > 0$ for the basic product. What distinguishes the two segments is their valuation of the innovative product developed by Firm 1.

The improvement provided by the innovation over the existing product is d. Consumers in Segment 1 appreciate the innovation of Firm 1's product and hence, will pay a maximum of $V + d$ for it. Conversely, consumers in Segment 2 are not willing to pay extra for it. As a result, they will pay a maximum of V for Firm 1's product. This follows the third assumption outlined in the introduction section: a fraction of consumers in the market do not understand/appreciate the innovation and are unwilling to pay more for it. Every consumer purchases the product that provides the highest surplus. We further assume that when both products provide equal surplus, consumers choose randomly between the two firms.[9]

Finally, we assume that the cost of innovation is a convex function of the value created. Economists have long emphasized the profit incentives of innovation and its relation to the size of the target market. In his seminal work Schmookler (1966) argued that "...invention is governed by the extent of the market." Loosely paraphrasing marketing guru Seth Godin, "marketers know that you can always find one person that will like something but trying to find something that everyone likes is significantly more difficult" (Godin 2018). In technologically-driven durable product categories (the main focus of this paper), it is often more costly to develop innovations that appeal to a large fraction of a potential market.[10] To incorporate this into our model, we assume that Firm 1's innovation cost is a function of the fraction of consumers in the market to whom it appeals (β).

[9] We want to point out that even though a tie-breaking rule needs to be specified before solving the game, it does not come into play in the equilibrium (as shown in the later analysis) where the probability of equal surplus from two products is zero.

[10] In some categories such as phamarceuticals, the cost of developing new treatments (e.g. a new medicine for cancer) may not be directly related to the patient (segment) base. However in many cases the cost of developing treatements is related to the prevalence or gravity of the disease.

Hence, for Firm 1 to develop an innovation where a fraction β of the market is willing to pay d beyond valuation of the basic product, it incurs a fixed cost $\frac{\gamma}{2}\beta(d)^2$,where $\gamma > 0$. This reflects the idea that it is proportionally more challenging to develop an innovation that appeals to a large segment versus a small segment (e.g. Acemoglu and Linn 2004).[11]

We model a two-stage innovation-pricing game. In the first stage, Firm 1 determines the level of product innovation to be offered to the market. In the second stage, Firm 1 and 2 simultaneously set prices and compete for demand from the market. After observing the product and price information from both firms, the consumers make purchase decisions, and profits are realized. We use backward induction to solve for the Subgame-Perfect Nash equilibrium. That is, we first identify the equilibrium in pricing between the two firms, conditional upon Firm 1's choice of a specific innovation level d. Returning to the first stage, Firm 1's optimal innovation strategy is determined as a function of the corresponding price competition that occurs in the second stage.

4 Main Model

In this section, we analyze the case where the two consumer segments are of equal size (i.e., $\beta = \frac{1}{2}$). Firm 1 moves first by choosing a level of innovation, d. Both firms then compete in terms of price to maximize profits. The analysis reveals that the innovation level, d, falls into three distinct zones, each of which leads to different mixed pricing strategy outcomes. We label the three zones as big, medium, and small and the zones are defined by $d > V$, $\frac{V}{2} \leq d \leq V$, and $d < \frac{V}{2}$ respectively. We present the analysis for the three zones of innovation levels separately. We then combine the findings from the three innovation levels to generate a summary of Firm 1's optimal innovation decision under different market and cost conditions. We also compare the equilibrium profits of the innovator (Firm 1) and the non-innovator (Firm 2). To begin, we normalize the marginal production cost of the innovative product to zero ($c = 0$). This reflects innovations that are related to design and not the use of more expensive manufacturing or raw materials. Later in this section, we relax this assumption to assess the robustness of our findings.

When Firm 1 invests to introduce of product with a big innovation ($d > V$), we present a complete analysis for the equilibrium pricing, optimal innovation level and profits. Results for the medium and small innovation levels follow the analysis for big innovation and the analysis is presented more concisely. Complete details are provided in the Online Supplement.

[11] With this model, the qualitative results are similar when the cost of innovation is independent of segment size.

4.1 Equilibrium as a Function of Firm 1's Innovation Decision: Big, Medium or Small

Proposition 1 summarizes the equilibrium in mixed pricing strategies for Firm 1 (that introduces a big innovation) and Firm 2 (that continues to sell the basic product). The proofs of all lemmas and propositions are provided in the Appendix.

Proposition 1 *When $d > V$, the price equilibrium is that Firm 1 employs a mixed strategy in prices over the interval $\left(\frac{V}{2}+d, V+d\right)$ with expected profit of $E\pi_1 = \frac{1}{2}\left(\frac{V}{2}+d\right)$. The cumulative distribution function (CDF) for Firm 1's prices is given by:*

$$F_1(p_1) = \begin{cases} 0 & \text{if} \quad p_1 < \frac{V}{2}+d \\ 2-\frac{V}{p_1-d} & \text{if} \quad p_1 \in \left(\frac{V}{2}+d, V+d\right) \\ 1 & \text{if} \quad p_1 \geq V+d \end{cases}$$

Firm 2 chooses a mixed strategy in prices over the interval $\left(\frac{V}{2}, V\right)$ with expected profit of $E\pi_2 = \frac{V}{2}$. The cumulative distribution function (CDF) for Firm 2's prices is:

$$F_2(p_2) = \begin{cases} 0 & \text{if} \quad p_2 < \frac{V}{2} \\ 1-\frac{V+2d}{2(p_2+d)} & \text{if} \quad p_2 \in \left(\frac{V}{2}, V\right) \\ 1 & \text{if} \quad p_2 \geq V \end{cases}$$

To illustrate the pricing equilibrium, we show the CDFs for Firms 1 and 2 using numerical values of $V = 10$ and $d = 14$ in Figure 1. The figure shows that when $d > V$, the CDF of Firm 1 (the provider of the innovative product) is continuous, while the CDF of Firm 2 (the provider of a basic product) has a mass point at $p_2 = V$ with a probability mass of $\frac{V+2d}{2(V+d)} \in [0,1]$, illustrated by the circled-line in Figure 1. In other words, there is a jump in the CDF of Firm 2 when Firm 1 develops a big innovation ($d > V$). Proposition 1 implies that with the introduction of a highly innovative product, Firm 1 sources all of its demand from Segment 1: consumers that are willing to pay a premium $(V + d)$ for the innovation. However, consumers from this segment are sometimes attracted to the basic product of Firm 2 due to its low price. This happens when Firm 2's price advantage over Firm 1 exceeds the benefit d associated with Firm 1's product. Conversely, Firm 2 always serves consumers from Segment 2 (those who are not willing to pay a premium for Firm 1's innovation).

With the introduction of the innovative product, Firm 1 sets prices much higher than that of Firm 2. As shown in the Appendix, Firm 1's equilibrium price support is $\left(\frac{V}{2}+d, V+d\right)$ and Firm 2's equilibrium price support is $\left(\frac{V}{2}, V\right)$. The reason that Firm 1 sets such high prices is to capture the benefit of its innovation d as well as the surplus V associated with the basic product. When Firm 1 does this, it becomes vulnerable to aggressive pricing by Firm 2. The mixed strategy equilibrium

reported in Proposition 1 reflects a context where the firms compete with price promotion after the new product is introduced. The innovator (Firm 1) wishes to set a high price but is forced to discount from time to time to make its offer more attractive to innovative consumers. Innovative consumers (Segment 1) being wily only buy the innovative product if the incremental benefit d exceeds the price difference that they pay to trade up to the better product.

(Put Figure 1 about here)

The mixed-strategy pricing distributions reported in Proposition 1 raise two interesting issues. First, the two firms' price supports are of the same length $\frac{V}{2}$: the innovative Firm 1's price support is simply an upward shift of Firm 2's price support $\left(\frac{V}{2}, V\right)$ by the innovation value d. Second, the expected profit for the basic product offered by Firm 2 $\left(\frac{V}{2}\right)$ does not depend on the innovation value d. Mathematically, this obtains because every price generates the same profit in Firm 2's price support in a mixed-strategy equilibrium. When Firm 2 prices at the bottom of its support $\left(\frac{V}{2}\right)$, it captures the entire market implying that its profit is independent of the size of the innovation (d). Conversely, Firm 1's price support is the same as Firm 2's support shifted upwards by d: when Firm 1 prices at the bottom of its support $\left(\frac{V}{2} + d\right)$, it captures all of Segment 1 leading to expected profit that depends on the innovation value d.[12] Intuitively, Firm 1 knows that its competitor (with a basic product) prices aggressively to attract customers. In response, Firm 1 lowers its price to retain customers. But Firm 1 does not price as aggressively as Firm 2 because it wishes to extract profit (with high prices) from the consumer segment that appreciates the innovation. Because Firm 1 is incentivized to price high to capture profit from Segment 1, this creates a positive externality for Firm 2 in the form of less intense price competition: effectively, the firms segment the market with Firm 1 catering to Segment 1 and Firm 2 catering to Segment 2. Furthermore, the innovating Firm 1 never captures demand from consumers in Segment 2 whereas Firm 2 captures demand from consumers that value the innovation (Segment 1) from time to time. Despite these positive externalities for Firm 2, the big innovator (Firm 1) has higher expected sub-game profit than Firm 2 as confirmed in Proposition 1. However, Firm 1 funds the development of the innovation (in Stage 1 of the game) while Firm 2 enjoys the positive externality at no cost. Lemma 1 shows that when choosing the optimal level of innovation given the expected outcomes of price competition in Stage 2, Firm 1 earns higher net profit than Firm 2 unless the innovation cost exceeds a threshold.

[12] In Section 5, we show that when the two consumer segments are of different sizes, Firm 2's equilibrium price support depends on the segment size parameter β. Even there, Firm 2's price support is unaffacted by the innovation value d.

Lemma 1 *Anticipating the price competition with Firm 2, Firm 1 will choose an optimal level of big innovation* $d_b^* = \frac{1}{\gamma}$*, with* $\gamma < \frac{1}{V}$*, the net profit of Firm 1 is* $\pi_{1b}^* = \frac{\gamma V+1}{4\gamma}$ *which is greater than Firm 2's net profit of* $\pi_{2b}^* = \frac{V}{2}$*. Otherwise when* $\gamma \geq \frac{1}{V}$*, Firm 1's optimal level of innovation is* $d_{bc}^* = V$*, the net profit of Firm 1 is* $\pi_{1c}^* = \frac{V(3-\gamma V)}{4}$ *which is less than Firm 2's net profit of* $\pi_{2b}^* = \frac{V}{2}$*.*

As noted in the introduction, a key assumption of our model is "commoditization": as categories mature, competing offerings in the market become similar leading to intense price competition and low profits. This provides incentive for at least one firm to innovate. The analysis of this subsection implies that Firm 1's decision to innovate increases profit for both firms (compared to the outcome of Bertrand type competition): innovation is a path for the industry to escape intense competition. When the size of the two consumer segments are equal, the big innovator generally enjoys higher profit than its rival even though it shoulders all R&D costs.[13]

As noted earlier, two other innovation investment regions are available to Firm 1. She can invest less and develop a "medium" innovation or a lot less and develop a "small" innovation. Accordingly, we solve the pricing sub-game equilibrium when Firm 1 develops a new product of "medium" ($\frac{V}{2} \leq d \leq V$) or "small" ($d < \frac{V}{2}$) level of innovation. The derivation of the equilibrium price strategy for these scenarios is similar to the approach used to solve the pricing subgame for "big" innovations. To simplify our exposition here, we only report the equilibrium price supports and expected sub-game profits of the mixed-strategy equilibrium. Further details are provided in the Online Supplement.

Proposition 2 *1) When* $d < \frac{V}{2}$*, the price equilibrium is that Firm 1 and Firm 2 employ mixed strategies in prices over the interval* $(d, 2d)$ *with expected profits of* $E\pi_1 = d$*,* $E\pi_2 = \frac{d}{2}$*.*

2) When $\frac{V}{2} \leq d \leq V$*, the price equilibrium is that Firm 1 employs a mixed strategy in prices over the interval* $(d, V) \cup \left(\frac{V}{2} + d, 2d\right)$ *with an expected profit of* $E\pi_1 = \frac{1}{2}\left(\frac{V}{2} + d\right)$*. Firm 2 employs a mixed strategy in prices over the interval* $\left(\frac{V}{2}, V\right)$ *with an expected profit of* $E\pi_2 = \frac{d}{2}$*.*

We follow a similar process to that was employed to derive Lemma 1 to identify the optimal level of innovation (for each region) and the resulting net profits for both firms. These outcomes are summarized in Table 1.

(Put Table 1 about here)

[13] In a model where the innovation cost function is independent of segment size (i.e.$c(d) = \frac{\gamma}{2}d^2$), qualitatively similar results to Lemma 1 with rescaled parameter conditions are generated.

4.2 Firm 1's Optimal Innovation Strategy when Segment Sizes are Equal

Lemma 1 shows that when the cost of innovation is high ($\gamma \geq \frac{1}{V}$), the net profit of Firm 1 when it introduces a big innovation is less than that of Firm 2. However, Table 1 indicates that introducing a big innovation is not the best choice for Firm 1 when $\gamma \geq \frac{1}{V}$. For example, Firm 1 can choose a medium level of innovation in Stage 1 which leads to a higher net profit. Proposition 3 summarizes the full result of main model: Firm 1's optimal innovation strategy and the resulting net profits of the two firms when half of the market appreciates innovation. For ease of comparison, this is reported as a function of the innovation cost parameter (γ).

Proposition 3 *The optimal strategy for Firm 1 when:*

1) $\gamma < \frac{1}{V}$*, is to introduce a product of big innovation with* $d_b^* = \frac{1}{\gamma}$*. The net profit of Firm 1 is* $\pi_{1b}^* = \frac{\gamma V+1}{4\gamma}$ *which is greater than Firm 2's net profit* $\pi_{2b}^* = \frac{V}{2}$*;*

2) $\frac{1}{V} \leq \gamma \leq \frac{2}{V}$*, is to introduce a product of medium innovation with* $d_m^* = \frac{1}{\gamma}$*. The net profit of Firm 1 is* $\pi_{1m}^* = \frac{\gamma V+1}{4\gamma}$ *which is greater than Firm 2's net profit* $\pi_{2m}^* = \frac{1}{2\gamma}$*;*

3) $\frac{2}{V} < \gamma \leq \frac{4}{V}$*, is to introduce an innovative product with* $d_{mc}^* = \frac{V}{2}$*. The net profit of Firm 1 is* $\pi_{1mc}^* = \frac{V(8-\gamma V)}{16}$ *which is greater than Firm 2's net profit* $\pi_{2mc}^* = \frac{V}{4}$*;*

4) $\gamma > \frac{4}{V}$*, is to introduce a product of small innovation with* $d_s^* = \frac{2}{\gamma}$*. The net profit of Firm 1 is* $\pi_{1s}^* = \frac{1}{\gamma}$ *which is equal to Firm 2's net profit* $\pi_{2s}^* = \frac{1}{\gamma}$*.*

When half of the market is willing to pay more for innovation, it is optimal for Firm 1 to choose a drastically innovative product ($d^* > V$) when the cost of innovation is small. Aggressive pricing by Firm 2 means that sometimes the consumers who value innovation buy Firm 2's basic product. Nevertheless, Firm 1 captures significant surplus from the big innovation by charging a high price to the consumers who buy it. As a result, Firm 1 earns higher net profit than Firm 2. As the cost of innovation increases, Firm 1 adopts a milder innovation strategy with a reduced level of d^* and correspondingly lower prices. When the innovation cost exceeds a threshold, Firm 1 develops a product with a small innovation. Here, Firm 1 captures demand from the segment who values the innovation and occasional sales from consumers who do not value the innovation. Moreover, independent of Firm 1's innovation strategy, Firm 2 enjoys positive profit through the "positive externality" detailed in Section 4.1.

For $V = 10$, Figure 2 numerically illustrates Firm 1's optimal level of innovation (d^*) as a function of the full range of innovation cost parameter (γ) reported in Proposition 3. Papers

including Shaked and Sutton (1982) find that firms seek maximum differentiation in quality and that quality differentiation increases when the innovation cost is reduced. An important insight from our main model is that the optimal innovation strategy (and the associated profit) for an innovator (Firm 1 in our model) is not driven purely by costs. For intermediate cost levels, in our example when $\gamma \in (0.2, 0.4)$, the optimal innovation level is constant implying that the optimal level of differentiation (between Firm 1's innovative product and Firm 2's basic product) does not always decrease in the cost of innovation. This happens because the innovator strategically chooses the quality level of the new product to manage price competition with non-innovating firm. The innovator balances the potential for higher innovation (feasible due to lower cost) with the loss of sales from an entire segment that does not value the innovation. The lumpiness of demand due to the existence of market segments leads to a range of innovation costs for which increasing the innovation level is not profitable.

Figure 3 further illustrates the net profits for both firms based on Proposition 3. When half of the market is willing to pay a premium for a new product with a certain innovation level, the innovating Firm 1's net profit is always greater than that of Firm 2 unless the innovation cost is sufficiently high ($\gamma > \frac{4}{V}$). Even when the innovation cost is high, Firm 1 still benefits from innovation, but Firm 2 benefits as much as Firm 1. For example, when $\gamma > 0.4$, the two profit curves on Figure 3 coincide. Cost plays a role here because innovation needs to be financed. However, we emphasize that it is the benefit of innovation relative to the cost that drives the profitability of the innovator, while it is the relaxation of Bertrand-type price competition that drives the profit of the non-innovating firm.

(Put Figures 2 and 3 about here)

4.3 The Impact of Production Cost

In this section, we assess the generality of the findings in Proposition 3 and Figure 3 by extending the model to study the situation where Firm 1 incurs an increase in marginal cost $c > 0$ to produce the innovative product. We focus on "big" innovations ($d > V$) in order to contrast our findings with the results of Section 4.1 (where the assumption is $c = 0$).

Our derivation indicates that the equilibrium price distribution of Firm 1 is unaffected by the production cost, however, its profit is lowered. In contrast, Firm 2's equilibrium price distribution is affected by Firm 1's production cost, c, but its profit is not. Details are reported in the following Proposition 4.

Proposition 4 *When $d > V$, and $0 < c < \frac{V}{2} + d$, the price equilibrium is that Firm 1 employs a mixed strategy in prices over the interval $\left(\frac{V}{2} + d, V + d\right)$ with expected profit $E\pi_1 = \frac{1}{2}\left(\frac{V}{2} + d - c\right)$. The cumulative distribution function (CDF) for Firm 1's prices is:*

$$F_1(p_1) = \begin{cases} 0 & \text{if} \quad p_1 < \frac{V}{2} + d \\ 2 - \frac{V}{p_1 - d} & \text{if} \quad p_1 \in (\frac{V}{2} + d, V + d) \\ 1 & \text{if} \quad p_1 \geq V + d \end{cases}$$

Firm 2 chooses a mixed strategy in prices over the interval $\left(\frac{V}{2}, V\right)$ with expected profit of $E\pi_2 = \frac{V}{2}$. The cumulative distribution function (CDF) for Firm 2's prices is:

$$F_2(p_2) = \begin{cases} 0 & \text{if} \quad p_2 < \frac{V}{2} \\ 1 - \frac{V+2d-2c}{2(p_2+d-c)} & \text{if} \quad p_2 \in (\frac{V}{2}, V) \\ 1 & \text{if} \quad p_2 \geq V \end{cases}$$

Results from Proposition 4 show that Firm 1 needs to absorb both the cost of innovating (γ) and a higher marginal cost (c) of production to make the new product available. When the marginal cost of producing the innovative product is sufficiently high, the innovating firm may have lower profit than its rival assuming the level of innovation is chosen optimally. However, even when c is relatively small, Firm 2's aggressive pricing may result in higher net profit than Firm 1, as reported in Lemma 2.

Lemma 2 *Anticipating price competition with Firm 2, Firm 1 chooses the optimal level of big innovation, $d^* = \frac{1}{\gamma}$, when $\gamma < \frac{1}{V}$. The net profit of Firm 1 is $\pi_1^* = \frac{V\gamma - 2c\gamma + 1}{4\gamma}$, which is greater than $\pi_2^* = \frac{V}{2}$ when $\gamma < \frac{1}{V+2c}$; otherwise when $\frac{1}{V+2c} \leq \gamma < \frac{1}{V}$, $\pi_1^* < \pi_2^*$.*

Figure 4 illustrates with a numerical value $V = 10$, the net profits of the two firms when the innovation cost (γ) is such that it is optimal for Firm 1 to develop a big innovation. However here, the innovation also implies an increase in marginal production cost for Firm 1. As illustrated by Figure 4, with a value of $c = 4$, when the cost parameter (γ) is sufficiently high, Firm 2's net profit is higher than Firm 1's. This reinforces the idea that a non-innovating firm is often the main beneficiary of innovative activity by a competitor aiming to escape Bertrand competition.

(Put Figure 4 about here)

In Corollary 1, we summarize our finding with regards to which firm is the profit "winner" from innovation within the industry.

Corollary 1 *When half of the market is willing to pay extra for the innovative product (beyond the valuation of basic product) and Firm 1 chooses its optimal level of innovation, Firm 1's net profit is greater than or equal to that of Firm 2 unless the production cost of the innovative product (c) exceeds a threshold.*

In general, when the market is evenly split between consumers who value innovation and those who do not, the innovating firm is the winner in terms of increased profit. Despite having to finance the R&D and having to defend against aggressive pricing by the firm with the basic product, the innovator increases profit and outperforms the competitor. However, when the innovative product costs more to produce than the basic product, the non-innovating firm may be an even bigger beneficiary of Firm 1's R&D investment than Firm 1 itself.

5 Extensions

We now extend the model of Section 4 to a general case where the consumer segments are not of equal size, i.e., when $\beta \neq \frac{1}{2}$. To start, we focus on the case of $\beta < \frac{1}{2}$: when there are less consumers in the market who are willing to pay an increment for Firm 1's innovative product. Here, we investigate Firm 1's optimal innovation strategy and the profit comparison between the innovator and the firm offering basic product. For illustration purposes, we follow the same sequence of presentation as in Section 4. First, we report the details of the equilibrium when Firm 1 chooses a "big" level of innovation ($d > V$). The results for "medium" and "small" innovations are provided with reduced technical content. For further detail, readers are directed to the Online Supplement.

5.1 Equilibrium when Firm 1 Adopts Big Innovation ($\beta < \frac{1}{2}$)

Proposition 5 characterizes the equilibrium pricing when Firm 1 chooses a big innovation and the marginal cost of innovative product is normalized to zero ($c = 0$).

Proposition 5 *When $d > V$ and $\frac{V}{V+d} \leq \beta < \frac{1}{2}$, the price equilibrium is that Firm 1 employs a mixed strategy in prices over the interval $((1-\beta)V + d, V + d)$ with expected profit of $E\pi_1 = \beta((1-\beta)V + d)$. The cumulative distribution function (CDF) for Firm 1's prices is:*

$$F_1(p_1) = \begin{cases} 0 & \text{if} \quad p_1 < (1-\beta)V + d \\ \frac{1}{\beta} - \frac{(1-\beta)V}{\beta(p_1 - d)} & \text{if} \quad p_1 \in ((1-\beta)V + d, V + d) \\ 1 & \text{if} \quad p_1 \geq V + d \end{cases}$$

Firm 2 chooses a mixed strategy in prices over the interval $((1-\beta)V, V)$ with expected profit of

$E\pi_2 = (1-\beta)V$. *The cumulative distribution function (CDF) for Firm 2's prices is:*

$$F_2(p_2) = \begin{cases} 0 & \text{if} \quad p_2 < (1-\beta)V \\ \frac{p_2-(1-\beta)V}{(p_2+d)} & \text{if} \quad p_2 \in ((1-\beta)V, V) \\ 1 & \text{if} \quad p_2 \geq V \end{cases}$$

Similar to the main model (Proposition 1), the support of the price distribution for Firm 1 is that of Firm 2 shifted upwards by d. Firm 1's expected sub-game profit (given the level of big innovation d) is always higher than that of Firm 2. We now derive Firm 1's optimal level of big innovation and compare Firm 1's net profit with that of Firm 2. The findings are reported in Lemma 3.

Lemma 3 *When $\frac{\gamma V}{\gamma V+1} \leq \beta < \frac{1}{2}$, Firm 1 chooses the optimal level of big innovation to be $d_b^* = \frac{1}{\gamma}$ when $\gamma < \frac{1}{V}$, the net profit of Firm 1 is $\pi_{1b}^* = \frac{(2V(1-\beta)\gamma+1)\beta}{2\gamma}$, which is less than Firm 2's net profit $\pi_2^* = (1-\beta)V$ when $\frac{\beta}{2(1-\beta)^2 V} < \gamma < \frac{1}{V}$. Otherwise, when $\gamma \geq \frac{1}{V}$, Firm 1's optimal level of innovation is a corner solution of $d_{bc}^* = V$, the net profit of Firm 1 is $\pi_{1bc}^* = \frac{V\beta(4-2\beta-\gamma V)}{2}$, which is greater than Firm 2's net profit.*

It is straightforward to show that $\frac{\partial}{\partial\gamma}\left(\frac{\gamma V}{\gamma V+1}\right) > 0$. This implies that the lower end of the region for β where Firm 1 implements a big innovation (Lemma 3) is positively related to the innovation cost. Therefore, if the innovation cost (γ) is sufficiently low, Firm 1 will develop a "big" innovation even if there is a small fraction of consumers who are willing to pay extra for the innovation. It can also be shown that $\frac{\partial}{\partial\beta}\left(\frac{\beta}{2(1-\beta)^2 V}\right) > 0$. This implies that as the fraction of consumers who value innovation increases, it is less likely that Firm 1's net profit is less than that of Firm 2. The intuition for this finding is that it is the benefit of big innovation relative to the cost that drives the profitability of Firm 1. Again, the qualitative result in Lemma 3 is unaffected if the cost of innovation is assumed independent of segment size (β). The only change is that the parameter condition, $\frac{\beta}{2(1-\beta)^2 V} < \gamma < \frac{1}{V}$, of Lemma 3 becomes $\frac{\beta^2}{2V(1-\beta)^2} < \gamma < \frac{\beta}{V}$.

5.2 Firm 1's Optimal Innovation Strategy when $\beta < \frac{1}{2}$

Even though "big" innovation is feasible for Firm 1 when there are less consumers in the market who are willing to pay for the innovation than those who are not, the question remains as to whether this strategy is optimal. To answer this, we follow the same approach as in Section 4 and derive the equilibrium of price competition and Firm 1's optimal level of innovation under "medium" and "small" innovations. We summarize the results in Table 2. All details are provided in the Online Supplement.

(Put Table 2 about here)

Table 2 provides intermediate results which allow us to derive the optimal innovation strategy for Firm 1 when $\beta < \frac{1}{2}$, which is summarized in Proposition 6.

Proposition 6 *To compete with Firm 2's basic product,*

1) *When $\gamma < \gamma_1^*$, it is optimal for Firm 1 to introduce a product of big innovation at the level of $d_b^* = \frac{1}{\gamma}$;*

2) *When $\gamma_1^* \leq \gamma < \gamma_2^*$, it is optimal for Firm 1 to introduce a product of medium innovation at the level of $d_m^* = \frac{1}{\gamma}$;*

3) *When $\gamma_2^* \leq \gamma \leq \gamma_3^*$, it is optimal for Firm 1 to introduce an innovative product at the level of $d_{sc}^* = \frac{V}{2}$;*

4) *Otherwise when $\gamma > \gamma_3^*$, it is optimal for Firm 1 to introduce a product of small innovation at the level of $d_s^* = \frac{1}{\beta\gamma}$.*
where $\gamma_1^* = \frac{1}{V}$, $\gamma_2^* = \frac{\left(2-4\beta(1-\beta)-2\sqrt{(1-\beta)(1-2\beta)(1-\beta+2\beta^2)}\right)}{\beta V}$, $\gamma_3^* = \frac{2}{\beta V}$.

The net profits of the firms in Parts 1-4 of Proposition 6 are provided in Table 2. Note that when $\beta = \frac{1}{2}$, γ_2^* and γ_3^* in the above Proposition 6 converge to the corresponding parameter values under equal segment case (Proposition 3). This implies that Firm 1's optimal innovation strategy follows a consistent pattern even when the fraction of consumers who are willing to pay for innovative product is smaller. When the cost of innovation is sufficiently small, Firm 1 develops a big innovation and the consumers who value the innovation are willing to pay significantly more for the new product ($d^* > V$). As the cost of innovation increases, Firm 1 reduces the level of innovation it chooses: first, towards a medium innovation and finally developing a small innovation. Proposition 6 shows that the optimal level under small innovation (d_s^*) changes with respect to target consumer segment (β). For big and medium innovations, this is not the case. The intuition obtains by examining equilibrium pricing when Firm 1 competes with Firm 2 under different levels of innovation (see the Online Supplement). When Firm 1 competes using a small innovation, it needs to price more aggressively in order to secure demand from both the segment (β) that is willing to pay for the innovation and also those who do not value the innovation ($1-\beta$). Here, the benefit of the innovation is small and the ability of Firm 1 to capitalize on its product advantage is handicapped.

Figure 5 illustrates the net profits of the two firms using the numerical values $V = 10, \beta = 0.48$. Different from the equal segment case (Section 4, Figure 3), Firm 2's net profit is above Firm 1's approaching the right-tail of Figure 5. This means that when there are less consumers in the market

that value innovation ($\beta < \frac{1}{2}$), Firm 2 is the profit winner when the innovation cost is sufficiently high. We summarize this finding in Corollary 2.

Corollary 2 *when $\gamma > \gamma_3^*$ (as defined in the above Proposition 6), Firm 1's net profit from adopting the optimal small innovation is less than the net profit of Firm 2.*

(Put Figure 5 about here)

5.3 Equilibrium Analysis when $\beta > \frac{1}{2}$

For the purpose of completeness, we extend the main model to study the scenario where there are more consumers in the market who are willing to pay extra for innovation, i.e., when $\beta > \frac{1}{2}$. We focus on a situation where the size of Segment 1 is somewhat bigger. To facilitate comparison with the main model, we report the equilibrium in pricing between Firm 1 and Firm 2 when Firm 1 offers a product of big innovation ($d > V$).

Proposition 7 *When $d > V$ and $\frac{1}{2} < \beta \leq \frac{d}{V+d}$, the price equilibrium is that Firm 1 employs a mixed strategy in prices over the interval $((1-\beta)V + d, V + d)$ with expected profit of $E\pi_1 = \beta((1-\beta)V + d)$. Firm 2 chooses a mixed strategy in prices over the interval $((1-\beta)V, V)$ with expected profit of $E\pi_2 = (1-\beta)V$.*

The equilibrium price supports and expected sub-game profits of the two firms reported in Proposition 7 echo the results found when the size of Segment 1 is slightly less than Segment 2 (as in Proposition 5). Both are continuous extensions from the equal segment size case (Proposition 1). Firm 1's optimal level of innovation and the net profit comparison with Firm 2 are reported in Lemma 4.

Lemma 4 *When $\frac{1}{2} < \beta \leq \frac{1}{\gamma V+1}$, anticipating the price competition with Firm 2, Firm 1 will offer a new product of big innovation at the level of $\tilde{d_b} = \frac{1}{\gamma}$, which is greater than V when $\gamma > \frac{1}{V}$. The net profit of Firm 1 is $\tilde{\pi_{1b}} = \frac{(2V(1-\beta)\gamma+1)\beta}{2\gamma}$ which is greater than Firm 2's net profit of $\tilde{\pi_2} = (1-\beta)V$.*

In the Online Supplement, we outline the analysis for "medium" and "small" innovation when there are more consumers in the market who are willing to pay extra for innovation ($\beta > \frac{1}{2}$). The patterns of the price equilibrium, optimal innovation strategy and firm profits are similar to the cases of equal segment size ($\beta = \frac{1}{2}$) and when there are less consumers in the market who are willing to pay extra for innovation ($\beta < \frac{1}{2}$). We omit the full details of the analysis for the case of

$\beta > \frac{1}{2}$; however, the analysis shows that Firm 1 is always the "winner" in terms of net profit when there is no increase in the marginal cost of the new product.[14]

6 Empirical Validation

In this section, we present additional facts and analysis to support the findings generated by our model. We conduct an empirical estimation using data from the 2018 "Global Innovation 1000" report generated by Booz Allen Hamilton, Inc.[15] The raw data set is available on the company's website and it contains 2017 and 2018 dollar amounts, as well as average 3-yr, 5-yr percentage changes in R&D spending and revenue at a company level. After eliminating missing observations, we are left with 902 companies belonging to 10 industry sectors based on the Bloomberg Industry Classification (Table 3).

(Put Table 3 about here)

About 82% of companies in the data set belong to industrial, consumer discretionary, information technology or health sectors. Figure 6 plots the 3-year industry average R&D spending growth versus the rate of revenue growth during the same period.

(Put Figure 6 about here)

Figure 6 demonstrates a trend of an increasing monotonic relationship between R&D spending growth and revenue at the industry level. It aligns with the findings of our model which show that even one firm's innovation is sufficient to help an industry "break out" of Bertrand competition and increase industry profitability.

At the individual level, a company j from the data set is classified as "revenue winner" (coded by variable $revW_j = 1$) if its 2018 revenue is above median industry level, otherwise $revW_j = 0$. Similarly a company j is classified as "big innovator" (coded by dummy variable $BigRD17_j = 1$) if its 2017 R&D spending is greater than median industry level, otherwise $BigRD17_j = 0$. We estimate a binary Probit model (Wooldridge 2010) with the dependent variable being $revW_j$ and the explanatory variables including $BigRD17_j$ and sector dummies accounting for structure differences

[14] Similar to the earlier cases, when the marginal cost is positive and exceeds a threshold, Firm 2 will be more profitable than Firm 1.

[15] Now a subsidiary of PricewaterhouseCoopers (PwC).

across major industries. The estimated coefficient of $BigRD17_j$ is negative which suggests that investment in R&D might be negatively related to firm revenue. Full results of estimation are reported in Table 4.

(Put Table 4 about here)

A second binary Probit model is estimated using a company j's 2017-18 percentage of change in R&D spending as explanatory variable along with industry dummies. The estimated coefficient and standard error suggest that R&D spending increases have an insignificant effect on the probability of a company being the revenue winner in 2018. Estimation results from models using alternative measures of R&D versus revenue levels generate findings that are qualitatively consistent with our analytical model. Sometimes R&D spending leads to higher than average firm revenues and sometimes to lower than average. We believe this short empirical study generates findings that are consistent with the predictions of our model and how innovation affects industry sectors.

7 Managerial Implications

This paper studies a firm's incentive to invest in R&D when the market is characterized by price competition for essentially homogenous products. We investigate the impact of innovation on the profits of all the firms in the industry including both the innovator and a competitor that offers the basic product. Our study suggests that in order to assess the expected profitability of an industry, marketers need to account for the degree of innovative activity in the industry. Although it is common that only one firm (or very limited number of firms) in an industry has the R&D capacity to create highly innovative products, all it takes is one innovator's new product to drive up total profitability of the entire industry. Our model also generates four normative implications that are important for managers.

First, strong R&D capability for a firm is typically seen as a blessing because it enables the development of innovative products that outperform competitive offerings based on current technology. Yet our findings caution that innovation (and its ultimate impact on differentiation as suggested in the literature, e.g. Shaked and Sutton 1982) should not be blindly adopted as a path to profitability. When an innovative firm considers the introduction of a new product, an important step of business planning is to assess the fraction of the market that will value the innovation. If there are enough consumers in the market (e.g. close to 50% or more) who value innovation, the innovative firm typically enjoys greater profit than the competitor (this advantage dimishes,

the more costly it is to develop the innovation). However, when a minority of consumers in the market value the innovation, there are often conditions where the introduction of the innovation leads to the competitor benefitting more from the innovation than the innovator. This serves as an important forewarning to innovative firms. Innovation may free up resources for a competitor to attack the innovative firm aggressively when marketing and/or access to market is a challenge within the sector.

Second, it is important for an innovative firm to recognize that the magnitude of the innovation it develops determines the mix of consumers it ultimately serves. When an innovative firm introduces an innovation, conventional wisdom suggests the market should segment: the innovative firm will serve consumers who value the innovation and the competitor will serve consumers that do not. Our analysis demonstrates that segmentation does occur but it is fuzzy at best. One of the two firms will serve two segments and the other firm will serve only one segment. Most importantly, the identity of the firm selling to two segments depends on the level of innovation introduced by the innovator. When the level of innovation is big, competition leads to the innovating firm selling only to the segment that is willing to pay more for the innovation. Here, the innovative firm can coordinate its supply chain and marketing communication accordingly. However, when the level of innovation is medium or small, the innovator will serve a mix of consumers: some are willing to pay more for the innovation and some are not. In this case the innovative firm needs to make sure that its supply chain and marketing communication is designed to serve both consumer segments. A study conducted by Christensen, Cook and Hall (2005) found that 90% of 30,000 new product launches in America failed because of errors in segmentation. Our paper thus highlights the practical significance of a marketing model which incorporates the existence of distinct consumer segments into the decision framework.

Third, our paper underlines how important it is for managers of innovation to understand all the sources of benefit created by innovation. When a firm introduces an innovation, part of the benefit is from the value it creates for a specific-segment of consumers. But another part of the benefit comes from relaxing the intensity of price competition with the competitor. In our model, it is straightforward to show that if the innovator continues to sell the basic product along with the innovative product, competition with the rival drives the price of basic product to the lowest possible level (marginal cost). This eliminates a key source of the competition-relaxing impact that the innovation provides. While the innovative firm will sell more units under such a scenario, ultimately it leads to lower profit. Accordingly, in order for an innovative firm to realize the full benefit of its innovation, it needs to discontinue the marketing of its old product as quickly as

possible.[16]

Finally, our paper also provides managerial guidance to firms in an industry that lack R&D capability, i.e., the non-innovators. Recommendations from the extant marketing literature (e.g., the "Defender Model' proposed by Hauser and Shugan 1983) suggest deploying myriad strategies to prevent an innovator from making a focal firm's product obsolete. Examples include market foreclosure, lobbying activity before the innovation can be introduced and criticizing the new product in the press and social media. Contrary to conventional wisdom, "big" innovations do not always lead to higher market share for the innovator. They sometimes lead to the opposite and the market share of the non-innovating firm can increase. However, higher market share is not the only benefit that is sometimes enjoyed by the firm selling the basic product. There are market conditions under which a non-innovating firm is the big winner in terms of profit. Said differently, there are conditions where the innovator's ability to capitalize on its innovation is handicapped. Despite a technology disadvantage, a non-innovating firm facing competition from an innovator, improves its profitability by implementing a mixed pricing strategy that captures consumers from the segment who do not value innovation while from time to time enticing those consumers who value innovation to instead buy the basic product at a low price. In summary, a non-innovative firm often has as much incentive to support the competitor's innovation efforts as does the innovator itself.

8 Concluding Remarks

In a brief empirical section, we show that there is no significant statistical relationship between R&D spending and revenue across the major categories in the Booz Allen Global Innovation 1000 Report data set. Certainly, a key message of Global Innovation 1000 Report is that there is a weak (or no) relationship between R&D spending and the primary measures of financial or corporate success such as sales, gross margin, profits, and market capitalization. Nevertheless, the industry categories included in this data set are the world's most profitable. This suggests that the benefits of R&D investments are real but they are distributed across many firms in a category not just by those that invest. This dynamic is precisely the message demonstrated by our model. To further test the predictions from our theoretical model, a comprehensive empirical project is needed.

Several potential extensions follow from our analysis. The consumer market we present is stylized and can be extended to capture consumer heterogeneity in a more complete sense by

[16] This provides an interesting perspective on why innovators in many technology categories (e.g. Apple) only sell the "previous" version of a new model until inventories run out.

including more than two distinct consumer segments with different valuations for the innovation. Such a setup on the demand side leads to the investigation of a related yet different research question: when should an innovative firm consider offering a product line? Consider, for example, a market that consists of three distinct consumer segments: consumers in two segments value the innovation to a different degree (e.g., $\theta_i d$, $i = 1, 2$) where $\theta_1 = 1$ and $\theta_2 < 1$ while the third segment does not value the innovation at all. Here, the innovative firm has an incentive to develop two different levels of innovation and depending on how expensive it is to develop two innovative products (versus one), a rationale for a quality differentiated product line emerges similar to Mussa and Rosen (1978). However, even in this context, there is no incentive for the innovative firm to continue selling the basic product (in its product line). To capture the full competition-relaxing benefit of innovation (even in the context of a product line), the innovative firm needs to discontinue the marketing of its old product as quickly as possible. Another avenue for potential research is to compare alternative R&D strategies for an innovative firm. In particular, assessing the attractiveness of targeted drastic innovations compared to broad-based innovations of smaller magnitude might provide insight about how innovative industries are likely to evolve.

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Figure 1: Equilibrium CDFs ($d > V$)

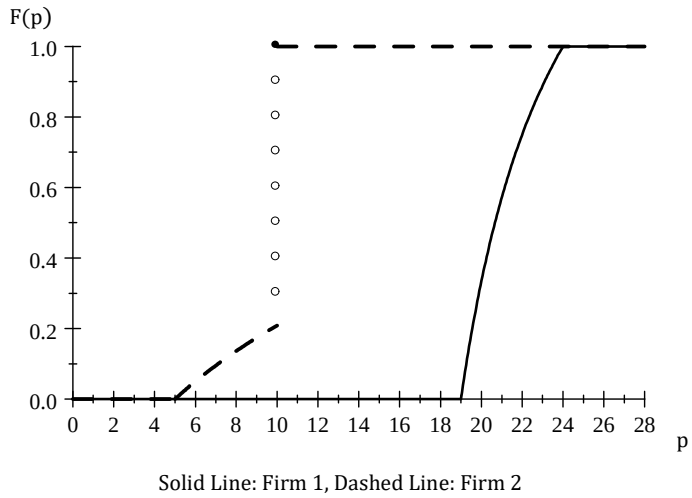


Figure 2: Firm 1's Optimal Level of Innovation

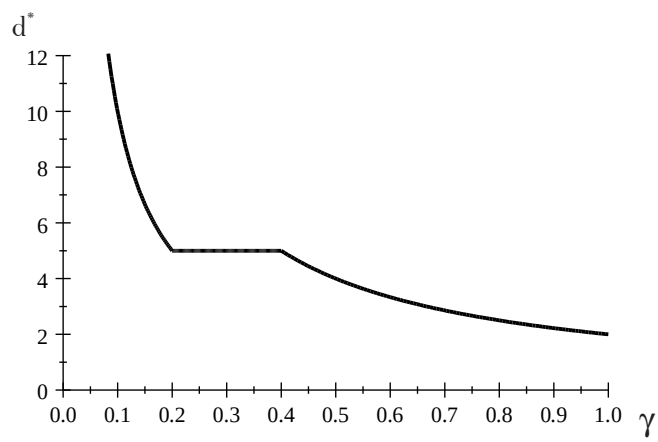
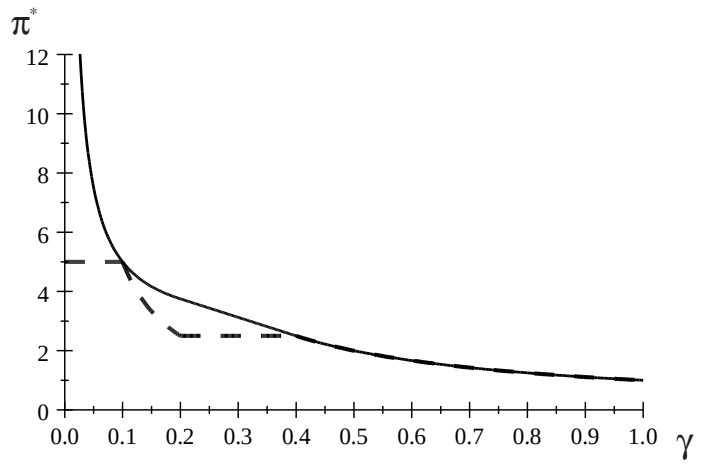


Table 1: Firm 1's Optimal Level of Innovation (d^*) and Two Firms' Net Profits ($\pi_j^*, j = 1, 2$)

Innovation	Optimal Level (d^*)	Innovation Cost (γ)	π_1^*	π_2^*
Small	$\frac{V}{2}$	$\gamma \leq \frac{4}{V}$	$\frac{V(8-\gamma V)}{16}$	$\frac{V}{4}$
	$\frac{2}{\gamma}$	$\gamma > \frac{4}{V}$	$\frac{1}{\gamma}$	$\frac{1}{\gamma}$
Medium	V	$\gamma < \frac{1}{V}$	$\frac{V(3-\gamma V)}{4}$	$\frac{V}{2}$
	$\frac{1}{\gamma}$	$\frac{1}{V} \leq \gamma \leq \frac{2}{V}$	$\frac{\gamma V+1}{4\gamma}$	$\frac{1}{2\gamma}$
	$\frac{V}{2}$	$\gamma > \frac{2}{V}$	$\frac{V(8-\gamma V)}{16}$	$\frac{V}{4}$
Big	$\frac{1}{\gamma}$	$\gamma < \frac{1}{V}$	$\frac{\gamma V+1}{4\gamma}$	$\frac{V}{2}$
	V	$\gamma \geq \frac{1}{V}$	$\frac{V(3-\gamma V)}{4}$	$\frac{V}{2}$

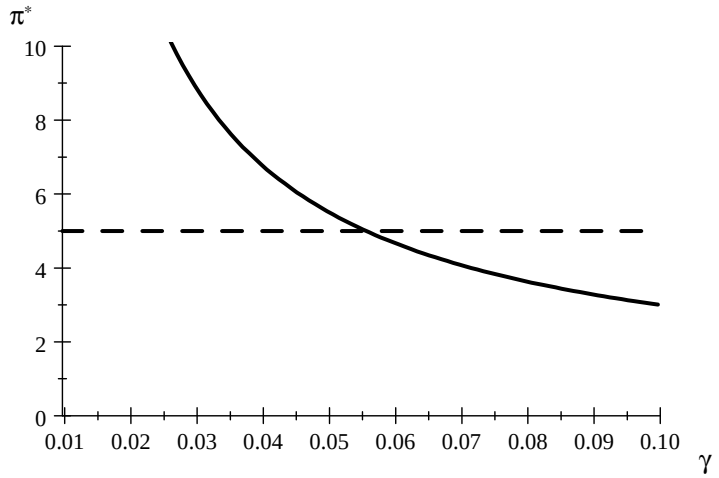
Table 2: Firm 1's Optimal Level of Innovation (d^*) and Two Firms' Net Profits ($\pi_j^*, j = 1, 2$)

Figure 3: Net Profits of the Two Firms



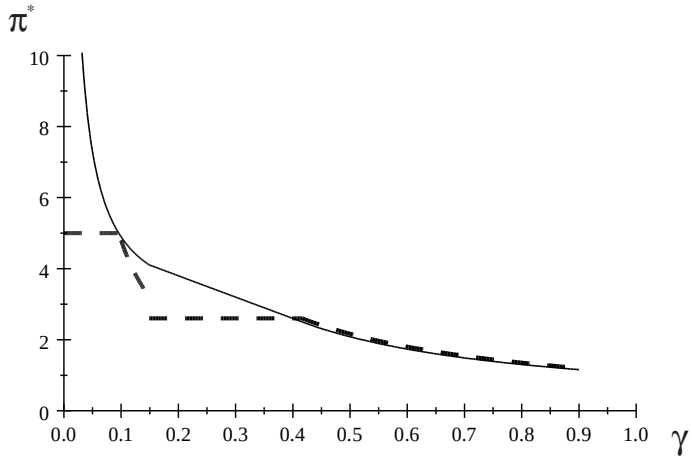
Solid line: Firm 1; Dashed line: Firm 2

Figure 4: Net Profits of the two Firms ($c > 0$)



Solid Line: Firm 1, Dashed Line: Firm 2

Figure 5: Net Profits of the Two Firms ($\beta < \frac{1}{2}$)



Solid line: Firm 1; Dashed line: Firm 2

when $\beta < \frac{1}{2}$

Innovation	Optimal Level (d^*)	Innovation Cost (γ)	π_1^*	π_2^*
Small	$\frac{V}{2}$	$\gamma \leq \frac{2}{\beta V}$	$\frac{V(4-\gamma\beta V)}{8}$	$\frac{V(1-\beta)}{2}$
$\left(d < \frac{V}{2}\right)$	$\frac{1}{\beta\gamma}$	$\gamma > \frac{2}{\beta V}$	$\frac{1}{2\beta\gamma}$	$\frac{1-\beta}{\beta\gamma}$
Medium	V	$\gamma < \frac{1}{V}$	$\frac{V\beta(4-2\beta-\gamma V)}{2}$	βV
$\left(d \in [\frac{V}{2}, V]\right)$	$\frac{1}{\gamma}$	$\frac{1}{V} \leq \gamma < \frac{\beta}{(1-\beta)^2 V}$	$\frac{(2V(1-\beta)\gamma+1)\beta}{2\gamma}$	$\frac{\beta}{\gamma}$
	$\frac{(1-\beta)^2 V}{\beta}$	$\gamma \geq \frac{\beta}{(1-\beta)^2 V}$	$\frac{V(1-\beta)\left(2\beta-V\gamma\left(1-\beta^3\right)+3V\beta(1-\beta)\gamma\right)}{2\beta}$	$(1-\beta)^2 V$
Big	$\frac{1}{\gamma}$	$\gamma < \frac{1}{V}$	$\frac{(2V(1-\beta)\gamma+1)\beta}{2\gamma}$	$(1-\beta) V$
$(d > V)$	V	$\gamma \geq \frac{1}{V}$	$\frac{V\beta(4-2\beta-\gamma V)}{2}$	$(1-\beta) V$

Table 3: 2018 "Global Innovation 1000" Company Distribution

Bloomberg Industry Classification	*Company Observation*	*Percentage in the Data set*
Consumer Discretionary	139	15.4%
Consumer Staples	36	4%
Energy	21	2.3%
Financial	7	0.8%
Health	163	18.1%
Industrial	159	17.6%
Information Technology	277	30.7%
Material	77	8.5%
Tele Communication	15	1.7%
Utility	8	0.9%

Figure 6: 2015-2017 Industry Average R&D Spending versus Revenue Growth

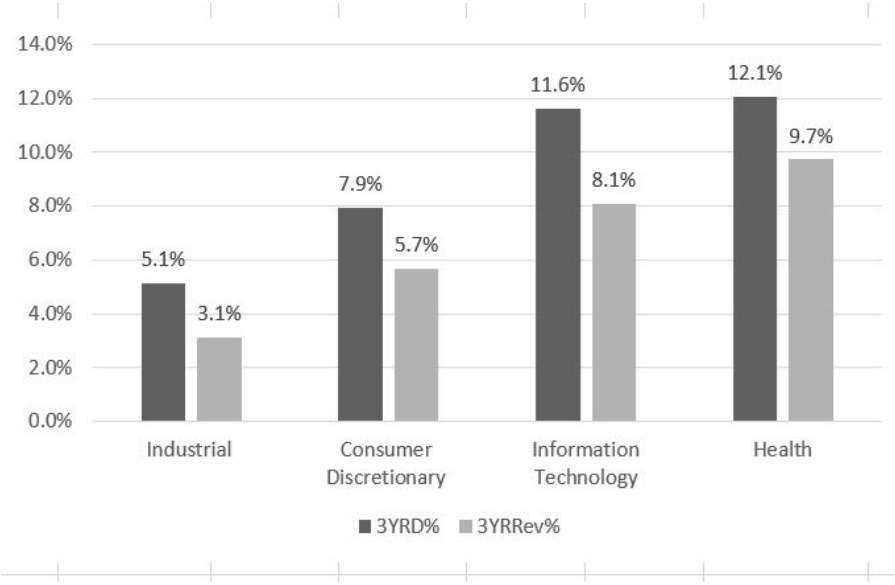


Table 4: Results of Binary Probit Estimation

Parameter	*Est Coefficient*	*Std. Error*	*P-Value*
Intercept	0.7970	0.2018	0.000*
Consumer Discretionary	−0.040	0.2296	0.863
Consumer Staples	−0.045	0.2957	0.879
Health	−0.040	0.2259	0.858
Industrial	−0.039	0.2258	0.858
Information Technology	−0.042	0.2137	0.843
Material	−0.036	0.2501	0.886
BigRD17	−1.503	0.0926	0.000*

(* statistically significant at 95% level of confidence)

Appendix

Proof for Proposition 1

We proceed in three steps. First we derive the two firms' best response functions. Next we define a "reduced" pricing game after sequentially eliminating dominated strategies of each firm. As a result, the strategies of the two firms in the "reduced" pricing game consist of only their respectively non-dominated strategies. Finally the equilibrium of the reduced game is constructed by using the condition that expected profits must be equal from all strategies which are being played with positive probability.

A consumer from Segment 1 has utility of $V + d - p_1$ from buying Firm 1's product; $V - p_2$ from buying Firm 2's product. A consumer from Segment 2 has utility of $V - p_1$ from buying Firm 1's product; $V - p_2$ from buying Firm 2's product. The two firms' best responses can be defined as :

$$BR_1(p_2) = \begin{cases} p_2 + d & \text{if} \quad p_2 < V \\ V + d & \text{if} \quad p_2 \geq V \end{cases}$$

$$BR_2(p_1) = \begin{cases} p_1 & \text{if} \quad p_1 < V \\ V & \text{if} \quad V \leq p_1 < \frac{V}{2} + d \\ p_1 - d & \text{if} \quad \frac{V}{2} + d \leq p_1 < V + d \\ V & \text{if} \quad p_1 \geq V + d \end{cases}$$

Figure A1 illustrates the two best response curves above using numerical values $V = 10, d = 14$.

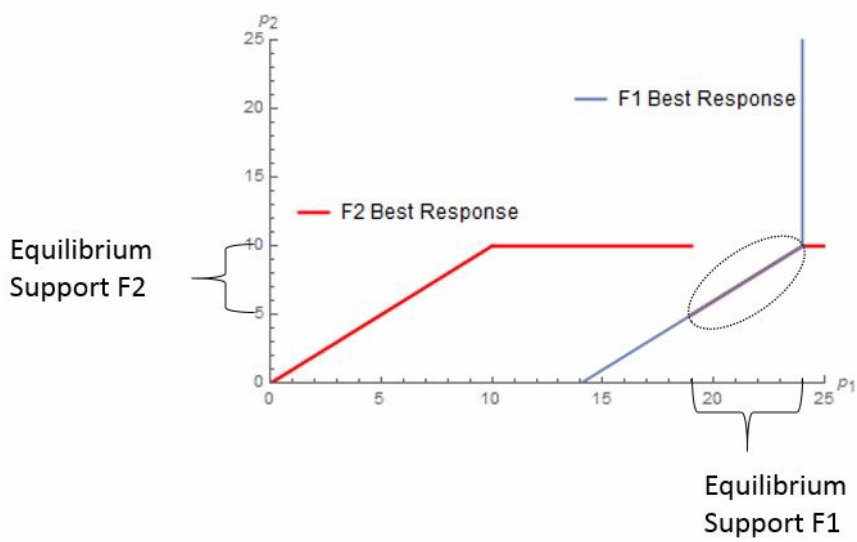


Figure A1: Two Firms' Best Response Curves

Through elimination of dominated strategies, we found that the final price supports for the two firms in the "reduced" game are: Firm 1 $\left(\frac{V}{2} + d, V + d\right)$, Firm 2 $\left(\frac{V}{2}, V\right)$ as highlighted on Figure

A1. To derive the cumulative distribution functions for each firm, we assume there is a mass point for Firm 2 at the top of its price support ($p_2 = V$) with probability m.

For Firm 1, if it chooses a price marginally less than $\frac{V}{2} + d$ it captures demand from Segment 1 but not Segment 2, the expected gross profit $E\pi_1 = \frac{1}{2}\left(\frac{V}{2} + d\right)$ in the limit. If Firm 1 prices marginally less than $V + d$, it will not get Segment 2, and will get Segment 1 if Firm 2 prices at V (with probability m), in this case $E\pi_1 = \frac{1}{2}(V + d)\, m$. We can solve m by equating $\frac{1}{2}(V + d)\, m = \frac{1}{2}\left(\frac{V}{2} + d\right)$, which yields $m = \frac{V+2d}{2(V+d)}$.

For Firm 2, if it prices slightly below $\frac{V}{2}$, it captures demand from both segments, $E\pi_2 = \frac{V}{2}$ in the limit. If Firm 2 prices at V (mass point), it will get Segment 2 for sure, but not Segment 1. Again $E\pi_2 = \frac{V}{2}$.

Denote $F_1(.)$ to be Firm 1's CDF in equilibrium,

$$E\pi_2(p_2) = p_2\left(\frac{1}{2} + \frac{1}{2}(1 - F_1(p_2 + d))\right) = \frac{V}{2} \tag{A1}$$

Denote $F_2(.)$ to be Firm 2's CDF in equilibrium,

$$E\pi_1(p_1) = p_1(\frac{1}{2}(1 - F_2(p_1 - d)) = \frac{1}{2}\left(\frac{V}{2} + d\right) \tag{A2}$$

Solving Equations (A1) and (A2) yields the expressions of $F_1(.)$, $F_2(.)$ as reported in Proposition 1. This completes the proof.

Proof for Lemma 1

Anticipating the equilibrium outcome from the price competition with Firm 2 of basic product, Firm 1 chooses his level of big innovation by maximizing $\pi_1 = \frac{1}{2}\left(\frac{V}{2} + d\right) - \frac{\gamma}{2}\beta d^2 = \frac{1}{2}\left(\frac{V}{2} + d\right) - \frac{\gamma}{4}d^2$ (with $\beta = \frac{1}{2}$). The optimal d_b^*, π_{1b}^* reported in Lemma 1 result from taking first order partial derivative of π_1 with respect to d and checking the negativeness of second order condition. Notice that $d_b^* > V$ as long as $\gamma < \frac{1}{V}$, under which condition $\pi_{1b}^* > \pi_{2b}^*(= \frac{V}{2}$ according to Proposition 1). If $\gamma \geq \frac{1}{V}$, the optimization will be a corner solution ($d_{bc}^* = V$). This completes the proof.

Proof for Proposition 3

According to Table 1, when $\gamma < \frac{1}{V}$, Firm 1's net profit in equilibrium equals $\pi_{1b}^* = \frac{\gamma V+1}{4\gamma}$ by offering a new product of big innovation $d_b^* = \frac{1}{\gamma}$ which is greater than V. Alternatively Firm 1 will have a net profit in equilibrium equals $\pi_{1m}^* = \frac{V(3-\gamma V)}{4}$by offering a new product of lower innovation $d_m^* = V$. Lastly the net profit of Firm 1 is $\pi_{1s}^* = \frac{V(8-\gamma V)}{16}$ if offering a new product of small innovation $d_s^* = \frac{V}{2}$. It is straightforward to see that:

$$\frac{\gamma V + 1}{4\gamma} - \frac{V(3 - \gamma V)}{4} = \frac{(V\gamma - 1)^2}{4\gamma} > 0 \tag{A3}$$

$$\frac{\gamma V + 1}{4\gamma} - \frac{V(8 - \gamma V)}{16} = \frac{(V\gamma - 2)^2}{16\gamma} > 0 \tag{A4}$$

Equations (A3) and (A4) together prove part 1) of Proposition 3. Part 2) - 4) can be proved following similar process.

Proof for Proposition 4

Note that in this case the two firms' best response correspondences are not affected by the existence of marginal product cost, hence the price supports are still those reported in Proposition 1. In particular, $\left(\frac{V}{2}+d, V+d\right)$ for Firm 1, $\left(\frac{V}{2}, V\right)$ for Firm 2. As in the proof of Proposition 1, assume there is a mass point for Firm 2 at the top of its price support ($p_2 = V$) with probability m_c.

For Firm 1, if it chooses a price marginally less than $\frac{V}{2}+d$ it captures demand from Segment 1 but not Segment 2, $E\pi_1 = \frac{1}{2}\left(\frac{V}{2}+d-c\right)$. If Firm 1 prices marginally less than $V+d$, it will not get Segment 2, and will get Segment 1 if Firm 2 prices at V (with probability m_c), in this case $E\pi_1 = \frac{1}{2}(V+d-c)\, m_c$. We can solve m_c by equating $\frac{1}{2}\left(\frac{V}{2}+d-c\right) = \frac{1}{2}(V+d-c)\, m_c$, which yields $m_c = \frac{\frac{V}{2}+d-c}{V+d-c} = \frac{V+2d-2c}{2(V+d-c)}$. Note that $m_c = m$ (in the Proof of Proposition 1) when $c = 0$. For Firm 2, if it prices slightly below $\frac{V}{2}$, it captures demand from both segments, $E\pi_2 = \frac{V}{2}$. If Firm 2 prices at V (mass point), it will get Segment 2 for sure, but not Segment 1. Again $E\pi_2 = \frac{V}{2}$.

Denote $F_1(.)$ to be Firm 1's CDF in equilibrium,

$$E\pi_2(p_2) = p_2\left(\frac{1}{2}+\frac{1}{2}(1-F_1(p_2+d))\right) = \frac{V}{2} \tag{A5}$$

Denote $F_2(.)$ to be Firm 2's CDF in equilibrium,

$$E\pi_1(p_1) = (p_1-c)\,(\frac{1}{2}(1-F_2(p_1-d)) = \frac{1}{2}\left(\frac{V}{2}+d-c\right) \tag{A6}$$

Solving Equations (A5) and (A6) yields the expression of $F_1(.)$, as $F_2(.)$ as reported in Proposition 4. This completes the proof.

Proof for Lemma 2

Anticipating the equilibrium outcome from the price competition with Firm 2 of basic product, Firm 1 chooses its level of big innovation by maximizing $\pi_1 = \frac{1}{2}\left(\frac{V}{2}+d-c\right) - \frac{\gamma}{2}\beta d^2 = \frac{1}{2}\left(\frac{V}{2}+d-c\right) - \frac{\gamma}{4}d^2$ (with $\beta = \frac{1}{2}$). The optimal d^*, π_1^* reported in Lemma 2 result from taking first order partial derivative of π_1 with respect to d and checking the negativeness of second order condition. Notice that $d^* > V$ as long as $\gamma < \frac{1}{V}$. Solving for $\pi_1^* - \pi_2^* < 0$ yields the parameter condition on γ reported in Lemma 2. This completes the proof.

Proof for Proposition 5

The proof follows similar steps as in the Proof for Proposition 1. When $\frac{V}{V+d} \leq \beta \leq \frac{1}{2}$ (given $d > V$), we can derive the two firms' best responses as: :

$$BR_1(p_2) = \begin{cases} p_2 + d & \text{if} \quad p_2 < V \\ V + d & \text{if} \quad p_1 \geq V \end{cases}$$

$$BR_2(p_1) = \begin{cases} p_1 & \text{if} \quad p_1 < V \\ V & \text{if} \quad V \leq p_1 < (1-\beta)V + d \\ p_1 - d & \text{if} \quad (1-\beta)V + d \leq p_1 < V + d \\ V & \text{if} \quad p_1 \geq V + d \end{cases}$$

Through the elimination of dominated strategies, we found that the final price supports for the two firms in the "reduced" game are: Firm 1 $((1-\beta)V+d, V+d)$, Firm 2 $((1-\beta)V, V)$. We assume there is a mass point for Firm 2 at the top of its price support ($p_2 = V$) with probability m_2.

For Firm 1, if it chooses a price marginally less than $(1-\beta)V+d$, it captures demand from Segment 1 but not Segment 2, $E\pi_1 = \beta((1-\beta)V+d)$ in the limit. If Firm 1 prices marginally less than $V+d$, it will not get Segment 2, and will get Segment 1 if Firm 2 prices at V (with probability m_2), in this case $E\pi_1 = \beta(V+d)m_2$. We can solve m_2 by equating $\beta(V+d)m_2 = \beta((1-\beta)V+d)$, which yields $m_2 = \frac{(1-\beta)V+d}{V+d}$.

For Firm 2, if it prices slightly below $(1-\beta)V$, it captures demand from both segments, $E\pi_2 = (1-\beta)V$ in the limit. If Firm 2 prices at V (mass point), it will get Segment 2 for sure, but not Segment 1. Again $E\pi_2 = (1-\beta)V$.

Denote $F_1(.)$ to be Firm 1's CDF in equilibrium,

$$E\pi_2(p_2) = p_2((1-\beta)+\beta(1-F_1(p_2+d))) = (1-\beta)V \tag{A7}$$

Denote $F_2(.)$ to be Firm 2's CDF in equilibrium,

$$E\pi_1(p_1) = p_1\beta(1-F_2(p_1-d)) = \beta((1-\beta)V+d) \tag{A8}$$

Solving Equations (A7) and (A8) yields the expression of $F_1(.)$, $F_2(.)$ as reported in Proposition 5. This completes the proof.

Proof for Lemma 3

Anticipating the equilibrium outcome from the price competition with Firm 2 of basic product, Firm 1 chooses his level of big innovation by maximizing $\pi_1 = \beta((1-\beta)V+d) - \frac{\gamma}{2}\beta d^2$. The optimal d_b^*, π_{1b}^* reported in Lemma 3 result from taking first order partial derivative of π_1 with respect to d and checking the negativeness of second order condition. Notice that $d_b^* > V$ as long as $\gamma < \frac{1}{V}$. Solving for $\pi_{1b}^* - \pi_2^* < 0$ yields the parameter condition on γ reported in Lemma 3. If $\gamma \geq \frac{1}{V}$, the optimization will be a corner solution ($d_{bc}^* = V$) and it can be shown through straight algebra that $\pi_1^*(d_{bc}^* = V) - \pi_2^* > 0$. This completes the proof.

Proof for Proposition 6

According to Table 2, when $\gamma < \frac{1}{V}$, Firm 1's net profit equals $\pi_{1b}^u = \frac{(2V(1-\beta)\gamma+1)\beta}{2\gamma}$ by offering a new product of big innovation $d_b = \frac{1}{\gamma}$. Alternatively Firm 1 will have a net profit equals $\pi_{1m}^u = \frac{V\beta(4-2\beta-V\gamma)}{2}$ by offering a new product of lower innovation $d_m = V$. Lastly the net profit of Firm 1 is $\pi_{1s}^u = \frac{V(4-\gamma\beta V)}{8}$ if offering a new product of small innovation $d_s = \frac{V}{2}$. Straight algebra can show that $\pi_{1b}^u > \pi_{1m}^u > \pi_{1s}^u$. The rest of Proposition 6 can be proved following the similar procedure.

Proof for Corollary 2

According to part 4) of Proposition 6 and Table 2, when $\gamma > \gamma_3^* \left(= \frac{2}{\beta V}\right)$, $\pi_1^* - \pi_2^* = \frac{1}{2\beta\gamma} - \frac{1-\beta}{\beta\gamma} = \frac{2\beta-1}{2\beta\gamma} < 0$ given $\beta < \frac{1}{2}$.

Proof for Proposition 7

The two firms' best responses as reported in the Proof for Proposition 5 above are valid for $\frac{V}{V+d} \leq \beta \leq \frac{d}{V+d}$ with $\frac{V}{V+d} < \frac{1}{2}, \frac{d}{V+d} > \frac{1}{2}$ given $d > V$. The derivation for price supports and expected profits in equilibrium thus follow the same procedure as in Proposition 5.

Proof for Lemma 4

Anticipating the equilibrium outcome in terms of prices with Firm 2 of basic product, Firm 1 chooses a level of small innovation by maximizing $\pi_1 = \beta\left(\left(1-\beta\right)V + d\right) - \frac{\gamma}{2}\beta d^2$. The optimal $\tilde{d_b}, \tilde{\pi_{1b}}, \tilde{\pi_2}$ reported in Lemma 4 result from taking first order partial derivative of π_1 with respect to d and checking the negativeness of second order condition. Substituting $\tilde{d_b}$ into $\frac{1}{2} < \beta \leq \frac{d}{V+d}$, the segment size condition becomes $\frac{1}{2} < \beta \leq \frac{1}{\gamma V+1}$, which implies:

$$\gamma \leq \frac{1-\beta}{\beta V} \tag{A9}$$

Straight algebra can show that $\tilde{\pi_{1b}} - \tilde{\pi_2} = \frac{(2V(1-\beta)\gamma+1)\beta}{2\gamma} - (1-\beta)V = \frac{\left(\beta - 2V\gamma(1-\beta)^2\right)}{2\gamma} \leq 0$ if

$$\gamma \geq \frac{\beta}{2V\left(1-\beta\right)^2} \tag{A10}$$

However $\frac{\beta}{2V(1-\beta)^2} - \frac{1-\beta}{\beta V} = \frac{(2\beta-1)\left(1+(1-\beta)^2\right)}{2V\beta(1-\beta)^2} > 0$ given $\beta > \frac{1}{2}$, which implies that (A10) conflicts with (A9), hence $\tilde{\pi_{1b}} - \tilde{\pi_2} > 0$. This completes the proof.