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A Model of Two-Sided Costly Communication for Building New Product Category Demand

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Abstract. When a firm introduces a radical innovation, consumers are unaware of the product's uses and benefits. Moreover, consumers are unsure of whether they even need the product. In this situation, we consider the role of marketing communication as generating consumers' need recognition and thus market demand for a novel product. In particular, we model marketing communication as a two-sided process that involves both firms' and consumers' costly efforts to transmit and assimilate a novel product concept. When the marketing communication takes on a two-sided process, we study a firm's different information disclosure strategies for its radical innovation. We find that sharing innovation, instead of extracting a higher rent by keeping the idea secret, can be optimal. A firm may benefit from the presence of a competitor and its communication effort. The innovator can share its innovation so that competitors can also benefit, which encourages rivals to enter the market. The presence of such competition guarantees a higher surplus for consumers, which can induce greater consumer effort in a two-sided communication process. Moreover, the increased consumer effort, in turn, prompts complementarity in the communication process and lessens the potential free-riding effect in communication between firms. Additionally, it encourages the rival firm to exert more effort, especially when the role of consumers becomes more important. Sharing innovation with a rival serves as a mechanism to induce more efforts in a two-sided communication process.

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1. Introduction

In 2014, within four years of its initial public offering, Tesla Motors had already achieved a market value half that of Ford's (Lane 2014). That same year, the company announced a surprising decision to share all of its patents with other car manufacturing companies, opening its vault to expand the long-range electric car market category (Ramsey 2014). This controversial move was not entirely uncommon. Google, which launched its ambitious hardware phone Pixel in October 2016, still allows its Android phone competitors to download, install, modify, and distribute its source code for free. For some products in the high-tech market, firms often preannounce an innovation by revealing the details and marketing plans for the product well in advance of its release, practically inviting competitors to participate in the category. In fact, publicly releasing innovative technology has become a routine practice in high-tech markets, with many companies following similar practices.

The act of releasing key information on a new technology or product into the public domain is curious, given that this type of information is usually considered a trade secret that serves as a key competitive advantage against potential competitors. When companies share a technological breakthrough, they risk prematurely disclosing a potentially disruptive innovation, resulting in greater competition and weak appropriability in the product market. For this reason, firms sometimes opt for great secrecy about new products to surprise the market (e.g., Apple's iPhone).

In this research, we focus on the introduction of revolutionary new products and firms' marketing strategies for such products. Specifically, we try to explain the puzzling differences in information disclosure strategies among innovating firms: Why and when it is optimal for a firm to share an innovative idea with competitors, as opposed to keeping the innovation secret? If a firm decides to share, how much of the innovation does it reveal? We base our explanation on the persuasion motive of firms in communication and the strategic role that consumers play in the communication process.

When a firm introduces a novel product concept for which the category does not even exist, consumers do not understand the product's uses and benefits. They are unclear as to whether they even need the product. In this context of radical innovation,[1] the role of marketing communication is crucial for educating consumers and encouraging them to deliberate their potential needs, thereby increasing product acceptance (Teo et al. 2015). In contrast to incremental innovations, about which consumers generally know the benefits from the category and can passively become aware of the values of the new features from advertisements, consumers need to bear relatively high costs to learn about the potential benefits of revolutionary new products. Therefore, a key challenge to market a radical product involves persuading consumers to expend substantial efforts in paying attention to the advertising content, assimilating the new idea, and deliberating their needs by examining an unproven product category.[2] Without consumers on board, the firm's effort alone is insufficient in conveying the new idea and convincing consumers that they need the product.

In this paper, we recognize that it takes the efforts of both parties (i.e., firms and consumers) for communication to succeed in the context of a radical product. Thus, we model marketing communication for such a product as two-sided costly communication, a process involving both firms' and consumers' efforts to transmit and assimilate information (Wernerfelt 1996, Dewatripont and Tirole 2005).[3] Through this two-way communication process, consumers then can understand a product's uses and benefits and can become potential buyers. Therefore, successful marketing communication is a critical process whereby a firm creates a market for a novel product.

In such situations, the innovator's incentive to disclose its innovation to competitors or to keep it secret depends on the trade-off between the two effects. On one hand, by disclosing its innovation to competitors, the innovator can invite the competitors to share costly communication efforts and thus expand the total market size through cooperation in the communication stage. Nevertheless, this demand-enhancing effect does not necessarily arise because of the free-riding incentive of firms—that is, firms may not expend costly efforts to increase the total demand and may instead simply free ride on the other firm's effort.[4] However, we show that strategic consumers alleviate the potential free-riding problem. By inviting the competitor, the innovator can credibly commit to providing consumers with a greater surplus, which increases the incentives for consumers to expend more costly efforts in deliberating on the new innovation. In turn, this increased consumer effort encourages firms further to put more efforts into the communication process. This complementarity in communication between firms and consumers through consumers' strategic decisions mitigates the potential free-riding problem. On the other hand, the innovator can achieve competitive advantage and greater market share in the subsequent product market by keeping the innovation secret. Even though the innovating firm will bear all costs for communication and market creation, it can then enjoy a monopoly situation in the product market.

These two effects are related to the fundamental issue of "co-opetition" (Brandenburger and Nalebuff 1996)—whether firms should cooperate with competitors to increase the total market size (which can be achieved by sharing their innovation with competitors) or compete against competitors to maximize their market share (which can be achieved by keeping the innovation secret).

The remainder of this paper proceeds as follows. In Section 2, we relate our paper to the existing literature in marketing and economics. Section 3 presents the model, and Section 4 provides our main results and analysis. In Section 5, we extend our model. Finally, Section 6 concludes.

2. Literature Review

This paper is related to several streams of research. First, it contributes to the literature on a firm's communication strategy by highlighting the two-sided costly efforts in the communication process. Marketing communication is typically viewed as one-sided costly communication, in which firms typically bear all communication costs. In these models, consumers become informed effortlessly and recognize their needs once they are exposed to a firm's advertising. Different from this one-sided perspective, our approach recognizes that the success of communication requires both firms' persuasion effort (Shin 2005) and consumers' learning or elaboration effort. Wernerfelt (1996) is the first paper that considers marketing communication as teamwork between firms and consumers, and he suggests that an efficient communication plan can induce the efficient division of labor between the two parties. Dewatripont and Tirole (2005) formalize this perspective and develop a model of communication, in which the acts of formulating and absorbing the content of communication are privately costly, and successful communication depends on the efforts of both the sender and receiver together. Furthermore, they suggest that communication efforts are strategic complements; that is, one side will try harder if the other side also tries harder. By contrast, Mayzlin and Shin (2011) consider firms' and consumers' efforts in communication as strategic substitutes. They show that inducing consumers' effort in the communication is sometimes more efficient for firms to communicate their quality information.[5] We follow and expand the framework of Dewatripont and Tirole (2005) by incorporating competition between firms. Thus, the communication in our model is characterized not only by strategic complementarity between the consumers' effort and the firms' aggregate effort but also by strategic substitutability between each firm's individual effort. Our model explores several interesting trade-offs between these two key strategic effects in the communication process and the implications on secrecy within an innovative firm.

A second stream of literature examines the impact of consumers' costs of learning and deliberation. Shugan (1980) is among the earliest to highlight the importance of incorporating consumers' cost of thinking, and several subsequent papers investigate its implications for a firm's strategy (Wathieu and Bertini 2007, Villas-Boas 2009, Kuksov and Villas-Boas 2010, Guo and Zhang 2012, Guo 2016). Wathieu and Bertini (2007) explore the firm's pricing strategy to spur deeper thinking among consumers about the personal relevance of product benefits; others (Villas-Boas 2009, Kuksov and Villas-Boas 2010, Guo and Zhang 2012) explore the firm's optimal product line decisions when consumers need to incur costly deliberation efforts to evaluate the product. Guo (2016) studies the phenomenon that consumers' costly deliberation is context dependent, and he explores the implication on preference construction. We also explore the implications of consumers' costly efforts to evaluate a new product, but our focus is on the consumers' active role in marketing communication.

Third, the current work also relates to the literature on a firm's strategies of managing business secrets and information sharing. One area focuses on a firm's choice between patenting and secrecy. Patents protect but publicize the firm's proprietary knowledge, which enables competitors to imitate and create differentiated products. Thus, firms may sometimes forgo patenting and keep secrets internally. Horstmann et al. (1985), Anton and Yao (2004), Denicolò and Franzoni (2004), and Kultti et al. (2007) examine the conditions of when to disclose secrets for patent protection and when to retain trade secrets internally. Another area deals with the information-sharing decision in the context of the research and development (R&D) process—whether or not a firm discloses its interim R&D results to the public. If the appropriability of innovation is strong (e.g., in "winner-take-all" R&D contests), firms disclose pessimistic or no information to discourage a rival's investment (Hendricks and Kovenock 1989, Gill 2008). If the appropriability of innovation is weak, the free-riding incentive arises and leads firms to disclose positive information about their interim R&D results to further encourage rivals' R&D investment (De Fraja 1993, Jansen 2010). In those papers, the appropriability of innovation is exogenously given. By contrast, the appropriability in our model is endogenously determined by the degree of information disclosure; more importantly, we further analyze how this endogenous appropriability affects firms' incentive to invest in communication efforts in equilibrium.

Fourth, broadly speaking, our research deals with a firm's strategies of cooperating and competing with competitors (which is often referred as "co-opetition" by Brandenburger and Nalebuff 1996). A large body of literature examines various forms of co-opetition, such as strategic alliances among competing firms (e.g., Bucklin and Sengupta 1993, Harbison and Pekar 1998, Amaldoss et al. 2000, Luo et al. 2007),[6] collaboration with a rival firm through licensing (e.g., Inkpen 1996, Steensma 1996), and the impacts of these actions on innovation (e.g., Hamel et al. 1989, Bonaccorsi and Lipparini 1994, Nieto and Santamaría 2007, Tsai 2009). Our paper contributes to this literature by providing another new microfoundation for co-opetition based on the firm's communication motives.

Similar to ours, several papers suggest that second sourcing, voluntarily inviting competition by sharing information (Farrell and Gallini 1988), can serve as a mechanism to guarantee a higher future consumer surplus and thus increase the total market demand (Shepard 1987, Farrell and Gallini 1988, Wernerfelt 1994, Choi and Davidson 2004). More specifically, inviting competitors can serve as a credible commitment to lower future prices (Farrell and Gallini 1988, Wernerfelt 1994) or higher future quality (Shepard 1987). Both mechanisms guarantee a higher *future* consumer surplus that would not be credible in a monopoly case. Our paper captures a similar insight but differs in two major respects. First, the focus of our model is on the role of the two-sided costly process of communication, and we provide a micro model for *how* and *when* a higher future consumer surplus (generated by inviting competition) can lead to greater market demand based on the communication mechanism. By contrast, the existing second-sourcing models treat the market expansion mechanism in a reduced-form way, such that more competition always leads to greater market demand. Second, our analysis provides more nuanced conditions under which second sourcing can generate higher total market demand by recognizing the potential free-riding problem in the process of market demand creation. We find that the intended market expansion can arise only when consumers play a significant role in communication, which alleviates the potential free-riding effect. Thus, the interaction between the two countervailing effects of strategic substitutability (between firms) and strategic complementarity (between consumers and firms) is at the core of our primary results.

Finally, there is a large body of marketing literature on a firm's preannouncement strategy. The common premise of the literature in this area is that the firm's motive is to deter the entry of competitors, and preannouncements can be used to achieve this end through communication with competitors (Bayus et al. 2001, Haan 2003, Ofek and Turut 2013) or consumers

(Farrell and Saloner 1986, Gerlach 2004, Choi et al. 2005). Our paper primarily differs from these papers in that we provide another strategic motive of preannouncements: to invite the competitor to enhance the potential market demand through joint communication with consumers.[7] In Section 5.3, we further investigate when inviting competition (through disclosing information or preannouncements) can serve as an entry deterrence or an entry invitation.

3. Model Setup

The market consists of two firms, firm 1 and firm 2, and a continuum of consumers with a mass of 1. Firm 1 is an innovator that discovers a radical innovation, and firm 2 is a follower. Once firm 1 discovers a new idea, it chooses a level of secrecy by deciding the amount of information to publicly disclose about its novel product idea. We denote by d the amount of information that firm 1 discloses, and thus $1 - d$ represents the level of secrecy.[8] The degree of disclosure is a continuous variable, $d \in [0,1]$, where $d = 0$ means no disclosure (i.e., complete secrecy) and $d = 1$ means full disclosure (i.e., no secrecy). Then, as long as $d > 0$, the follower makes a decision about whether to enter the market by following that new idea and developing a similar product in the same product category, $\chi = \{0,1\}$.[9] If the follower decides not to enter ($\chi = 0$), the product market will be a monopoly. If the follower decides to enter ($\chi = 1$), the market will becomes a duopoly.

Prior to competition in the product market, firms can engage in communication with consumers about the new product idea. We model this marketing communication as a two-sided costly process that involves both firms' and consumers' efforts. Successful communication endogenously generates consumers' need recognition and thus market demand for the novel product.

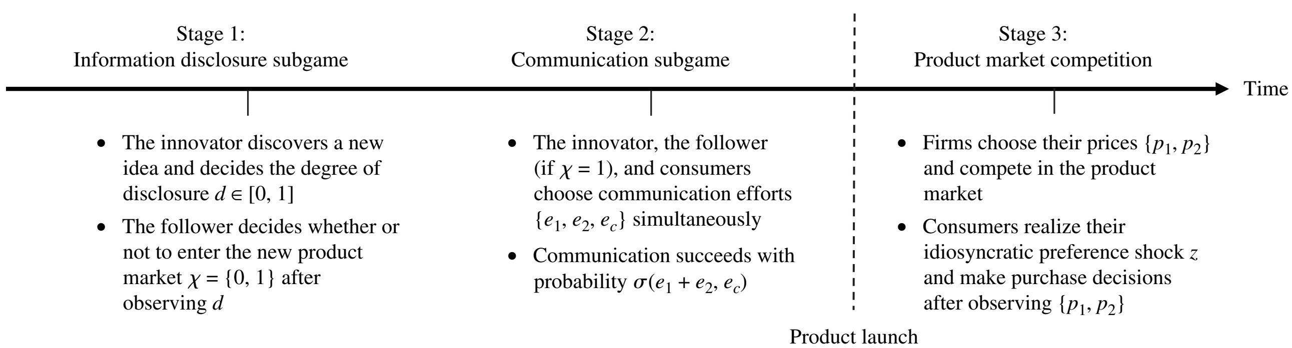
Finally, once the innovator and the follower (if $\chi = 1$) develop the idea into differentiated final products, they engage in Bertrand competition and set prices $\{p_1, p_2\}$. If $\chi = 0$, firm 1 monopolizes the market and offers its product at p_1.

We analyze strategic interactions, not only among the competing firms but also between the firms and consumers. As we can see in Figure 1, the entire game involves three players (two competing firms and consumers), and each makes several distinctive decisions at different stages. In stage 1, the innovator discovers a new idea and decides the amount of information to disclose, $d \in [0,1]$. Then, the follower makes a decision whether to enter the market after observing the innovator's disclosure decision. In stage 2, firms and consumers decide on their optimal levels of communication efforts to transfer and assimilate the idea. Finally, in stage 3, firms compete with each other in the product market and decide on prices while consumers observe their idiosyncratic match with each firm and make purchase decisions.

It is important to note that these decisions are interlinked. First, when the innovator decides on the information disclosure in stage 1, it fully takes into account the effects of disclosure (1) on the follower's decision regarding whether to enter the market (stage 1: information disclosure subgame), (2) on the equilibrium outcomes of the communication game between the firms and consumers (stage 2: communication subgame), and (3) on the equilibrium outcomes of the pricing game in the product market played by the firms (stage 3: product market competition subgame). In addition, the communication efforts by the firms and consumers endogenously determine the potential market demand, which clearly affects the equilibrium payoffs in the product market in stage 3. When the players choose their optimal effort levels for communication, they fully internalize the future payoffs from the product market. Furthermore, these considerations affect the follower's decision regarding whether to enter the market in stage 1. We now discuss each of these decisions in detail.

Information Disclosure. Managing secrecy of an innovative idea has strategic implications for the innovator's competitive advantage. The more innovation the innovator keeps secret (or equivalently, the less the innovator discloses), the more technological leadership

Figure 1. Sequence of the Game



it can possess, and thus, the innovator can have a greater competitive advantage over the competitor when the product idea is fully developed and launched in the product market. We model the decision of the innovator's information disclosure as a continuous variable, $d \in [0,1]$.[10] Here, we impose a truth-telling assumption: revealed information is truthful. An innovator can disclose a piece of proprietary information to its competitor through different strategic endeavors; for example, it can do so through licensing contracts or open source, which can directly affect the relative competitive advantage of the innovator (e.g., Tesla and Google Android). In the licensing scenario, d can be interpreted as the amount of innovation disclosed (no innovation disclosure as $d = 0$ and full innovation disclosure as $d = 1$). Alternatively, an innovator can release information about its upcoming product well in advance of the actual market availability through preannouncements. By making preannouncements, firms can deliver information on a product while it is still under development. In the preannouncement cases, d can be interpreted as the length of time prior to the actual launch of the product or the actual maturity of an innovative idea upon market announcement; for example, one can think of $d = 0$ as keeping the innovation completely secret and announcing the product at the same time as the product release or $d = 1$ as disclosing its premature idea so early that the follower can fully catch up with the innovator, and there is no clear competitive disadvantage upon the launch of the actual product.

We capture the influence of information disclosure on the innovator's competitive advantage through cost advantage.[11] We assume that the innovator can retain its cost advantage stemming from its technical breakthrough if the firm keeps it secret.[12] First, we fix the innovator's marginal production cost as $m_1 = 0$ and assume the follower's marginal production cost as $m_2(d)$, which is a decreasing function of d: $m_2(d) = (1 - d) \cdot \bar{m}$. The formulation implies that when $d = 1$, the technical innovation is shared with the competitor perfectly, and the innovator has no relative cost advantage (i.e., $m_2(1) = 0$), while the competitive advantage is maximized when $d = 0$ (i.e., $m_2(0) = \bar{m} > 0$).

Note that the credibility of the announcement is an important issue, and preannouncements can be pure cheap talk (Bayus et al. 2001, Choi et al. 2005, Ofek and Turut 2013). However, this cheap talk analysis is beyond the scope of this paper, and we treat the preannouncement as truthful information sharing. By doing so, we can focus on the effects of information disclosure on marketing communication and market competition, and we can analyze the strategic motives for a firm to convey its private information about a new innovation to change other parties' behaviors in a way that is beneficial to the firm.

Communication Technology. We consider a communication technology where both the firms and consumers simultaneously exert elaboration and learning efforts to transfer and assimilate an idea. In Section 5.1, we allow the firms' and consumers' effort choices to be sequential and show the robustness of our results. The probability that the idea is properly communicated to and accepted by consumers is

$$\sigma(e_f, e_c) = e_f^k \cdot e_c^{1-k}, \tag{1}$$

where $e_f \in [0,1]$ is the aggregate effort that the firms exert to transmit an idea and persuade consumers to accept it, and $e_c \in [0,1]$ is consumers' efforts to pay attention, deliberate, and assess this message.[13] In a monopoly situation ($\chi = 0$), the total firm-side effort is $e_f = e_1$; in a duopoly situation ($\chi = 1$), $e_f = e_1 + e_2$. Here, consumers are ex ante homogeneous, and they all spend the same amount of effort. Then, the communication succeeds with probability $\sigma(e_f, e_c)$; therefore, some consumers realize the value of the innovation, and they become ex post heterogeneous.[14]

The primary role of firms' communication efforts (such as advertisements) in our context is about generating the total category demand. When a radical new product category is first introduced in the market, the market demand is unknown, and firms need to expand their efforts to stimulate greater demand by providing more sales service (Shin 2005) or showing advertisements that mainly promote the benefits and advantages of the new product concepts without touting brand-specific features (Bass et al. 2005, Lu 2018). For example, when satellite radio was first introduced, both Sirius and XM allocated significant portions of their advertising budgets for generic advertising to inform and educate consumers about their products' uses and benefits so as to enhance consumer acceptance of the product concepts (Beardi 2001).[15] One can think of these advertising activities as firms' communication efforts, $e_f = e_1 + e_2$.

On the other hand, when consumers face these new radical product categories, which are often technically complicated or conceptually unprecedented, they are uncertain about the values or benefits of the products because they have no prior experience with them (Jing 2016, Li et al. 2017). Consumers need to expend significant costs in thinking (Shugan 1980) to deliberate the potential benefits or uses of new products. Furthermore, consumers who have not experienced these products would find it difficult to assess the exact value of a new feature or benefit. Thus, consumers' efforts to resolve such uncertainty surrounding new innovations are substantial. The efforts can consist of search cost for all relevant information, cost of thinking or evaluation, opportunity cost, and even minor costs, such as reading the ingredients (Hauser and Wernerfelt 1990).

We capture consumers' costs of learning and deliberation to evaluate the new product idea as e_c, which is time consuming and leads to the depletion of cognitive resources (Shugan 1980, Guo and Zhang 2012, Guo 2016). Thus, communication efforts involve private costs $C(e)$ for both the firms and consumers. We assume these costs are increasing and convex such that $C(e) = e^2/2$.

Moreover, $k \in [0, 1]$ captures the relative importance of the efforts in communication. For example, Tesla's Model S and Toyota's 11th generation of Corolla (E160) were introduced to the market around the same time in 2012.[16] Even though consumers were aware of Tesla, the marketing communication could not succeed if consumers who were only familiar with gasoline-fueled cars did not spend efforts in learning about the alternative new technology and deliberating their potential need for it. The Tesla Model S represents a case where k is small, and consumers play a critical role in marketing communication. By contrast, since the Corolla E160 is the 11th generation of this series, consumers had prior experience in driving gasoline cars and had seen different generations on the street. As long as they were merely aware of the introduction of the 11th generation, they might consider this car. This case corresponds to the case where k is large.

The communication technology exhibits several important properties. First, $\sigma(e_f, e_c) = 0$ when $e_f = 0$ or $e_c = 0$. This captures the key characteristic that communication requires two-sided efforts, and the communication can never succeed without both sides exerting efforts. Second, this communication technology assumes complementarity between the firms and consumers: $\sigma_{fc} = \partial^2\sigma(e_f, e_c)/\partial e_f \partial e_c \geq 0$. That is, each side is willing to exert more effort if the other side also exerts more effort, and "the return from expending effort increases when the other party explains better or listens better" Dewatripont and Tirole (2005, p. 1224).[17] Finally, another key characteristic of our communication technology is that the efforts of the two firms are strategic substitutes: $\sigma_{12} = \partial^2\sigma(e_f, e_c)/\partial e_1 \partial e_2 \leq 0$. Because communication involves private costs, firms have incentives to reduce their efforts and free ride on the other side's communication effort. Furthermore, we assume that the two firms are symmetric in terms of their influences on the effectiveness of communication; that is, $\sigma_1 = \partial\sigma(e_f, e_c)/\partial e_1 = \partial\sigma(e_f, e_c)/\partial e_2 = \sigma_2$.[18]

Given the aforementioned communication technology, the communication of an idea can fail (with probability $1 - \sigma$). In this case, consumers cannot be aware of the potential benefits for the new idea (e.g., consumers might think that the new innovation, such as the Tesla, is only for tech-savvy geeks, not them). Thus, they will not even consider purchasing the new product. On the other hand, if the idea is successfully communicated (with probability σ), consumers become educated about the radical innovation; they understand the potential benefits and accept the new product idea. Those who become educated about the radical innovation are the potential buyers, and they will consider purchasing the product when it becomes available in the market. Thus, the size of potential buyers is $\sigma^T = \sigma(e_f, e_c)$. Marketing communication efforts endogenously create and expand the expected demand (i.e., total market size) for the new product category.

Competition in the Product Market. Product market competition is captured through Salop's circular city model (1979). The innovator, firm 1, can be located at any place on the circle. In a monopoly case, firm 1 chooses the center of the circle and sets the monopoly price, p_1. When the market is a duopoly, the two firms are located as far apart as possible on the circle.[19] They compete in prices by charging p_1 and p_2, respectively.

If potential buyers (with a size of σ^T) purchase a product, they receive a positive base consumption utility v. Besides v, they receive an idiosyncratic match in terms of their location. Their locations are uniformly distributed on a circle with a perimeter equal to 1. For any potential buyer j, we then denote her distance from firm 1 as z_j. Because the maximum distance is half of the circumference, $z_j \sim \mathrm{U}[0, \frac{1}{2}]$. Accordingly, her distance from firm 2 is $\frac{1}{2} - z_j$ in a duopoly case. Potential buyer j obtains utility $u_{1j} = v - tz_j - p_1$ if purchasing from firm 1 and utility $u_{2j} = v - t(\frac{1}{2} - z_j) - p_2$ if purchasing from firm 2, where the travel cost t captures the extent of product differentiation between the two products. After observing their preferences and the prices, potential buyers make their purchase decisions, and the firms receive their payoffs. We assume that v is sufficiently large ($v > 3t/2$) so that all potential buyers purchase from one of the two firms in equilibrium.

4. Analysis

The game consists of three distinct stages: innovation disclosure, communication, and product market competition.[20] We begin our analysis using backward induction to solve the game.[21] All proofs are presented in the appendix.

4.1. Stage 3: Product Market Competition

We first solve the final stage of the game—product market competition. We denote firm 1's disclosure level as d and the firms' aggregate communication effort and consumers' effort as $\{e_f, e_c\}$, which will be endogenously determined in equilibrium. For now, we take them as given. There are two different cases we need to consider, depending on whether the follower (firm 2) decides to enter the market or not (which again will be endogenously determined in equilibrium).

Duopoly ($\chi = 1$). As we can see later, there always exists firm 1's minimal level of information disclosure $\underline{d}$ such that for all $d \geq \underline{d}$, firm 2 chooses to follow firm 1's idea and enter the market with a fixed cost f, and thus, the market is a duopoly in stage 3. For simplicity, we assume that the fixed cost $f = 0$.[22] Given any level of $d \geq \underline{d}$ and subsequent communication efforts $e_f(d) = e_1(d) + e_2(d)$ and $e_c(d)$, the total number of potential buyers is determined at the communication stage as $\sigma^T = \sigma(e_f, e_c)$. These are the consumers who are convinced of the need for the new product innovation through successful communication (which happens with probability σ^T). The potential buyers make purchase decisions once they observe the prices and their preferences. Potential buyer j purchases from firm 1 if $u_{1j} = v - tz_j - p_1 \geq v - t(\frac{1}{2} - z_j) - p_2 = u_{2j} \Leftrightarrow z_j \leq \frac{1}{4} - (p_1 - p_2)/2t \equiv z^*$. Thus, firm 1's demand is $D_1(p_1, p_2) = \sigma^T \cdot 2z^*$, and firm 2's demand is $D_2(p_1, p_2) = \sigma^T \cdot (1 - 2z^*)$. Here, we can consider σ^T to be the total category demand, while $2z^*$ and $1 - 2z^*$ define the selective demand share for each firm within the category. The two firms choose their product prices $\{p_1, p_2\}$ that maximize their retail profits $\{R_1, R_2\}$

$$\begin{aligned} p_1^D &= \arg\max_{p_1} R_1(p_1; p_2^D) := \sigma^T (p_1 - m_1)\left(\frac{1}{2} - \frac{p_1 - p_2^D}{t}\right), \\ p_2^D &= \arg\max_{p_2} R_2(p_2; p_1^D) := \sigma^T (p_2 - m_2)\left(\frac{1}{2} - \frac{p_2 - p_1^D}{t}\right), \end{aligned} \tag{2}$$

where firm 1's marginal cost is $m_1 = 0$, and firm 2's marginal cost is $m_2 = (1 - d)\bar{m}$.

Then, we have the equilibrium duopoly prices $p_1^D = t/2 + (1 - d)\bar{m}/3$, $p_2^D = t/2 + 2(1 - d)\bar{m}/3$. Because firm 2's marginal production cost should be low enough to enable it to make a positive profit in the product market $p_2^D \geq m_2$, we obtain that $d \geq \underline{d} = 1 - 3t/(2\bar{m})$.[23]

Also, the equilibrium duopoly retail profits are

$$\begin{aligned} R_1^D &= \sigma^T \cdot \frac{(3t + 2(1 - d)\bar{m})^2}{36t} = \sigma^T \cdot \pi_1^D, \\ R_2^D &= \sigma^T \cdot \frac{(3t - 2(1 - d)\bar{m})^2}{36t} = \sigma^T \cdot \pi_2^D, \end{aligned} \tag{3}$$

where $\pi_1^D = (3t + 2(1 - d)\bar{m})^2/(36t)$ and $\pi_2^D = (3t - 2 \cdot (1 - d)\bar{m})^2/(36t)$ are the average profits that firm 1 and firm 2 make in the duopoly product market per customer, respectively. Note that the average profit π_i is independent of the total market size and only captures the marginal benefit to the firm from an increase in the total category demand σ^T. The average profit will play an important role in determining σ^T in later analysis.

Therefore, as long as firm 1 discloses sufficient information ($d \geq \underline{d} = 1 - 3t/(2\bar{m})$), firm 2 will make a nonnegative profit by entering the market. Also, for a given σ^T, firm 1's profit decreases as it discloses more information (i.e., d increases), whereas firm 2's profit increases in d. Next, we analyze the retail market if firm 1 becomes the monopolist (i.e., $d < \underline{d}$).

Monopoly ($\chi = 0$). As long as firm 1 keeps a sufficient degree of secrecy ($d < \underline{d}$), firm 2 cannot make a positive profit by entering the market. Therefore, firm 2 chooses not to work on a similar idea ($\chi = 0$), and firm 1 becomes the monopolist in the product market. Similar to the duopoly case, potential buyer j purchases the product if the utility $v - tz_j - p_1 \geq 0 \Leftrightarrow z_j \leq (v - p_1)/t$. Thus, the market demand for firm 1's product is $D_1(v, p_1) = \sigma^T \cdot \max\{2 \cdot (v - p_1)/t, 1\}$. Under the market coverage condition ($v > 3t/2$), the equilibrium price is $p_1^M = v - t/2$, and the market demand is $D_1 = \sigma^T$.[24] Firm 1's monopoly retail profit is

$$R_1^M = \sigma^T \cdot \pi_1^M = \sigma^T \cdot \left(v - \frac{t}{2}\right), \tag{4}$$

where $\pi_1^M = v - t/2$ is firm 1's average profit per customer as the monopolist.

Clearly, the innovator enjoys a greater average profit in the monopoly situation; $\pi_1^M > \pi_1^D$. Moreover, we find that even the total firm-side average profit in the duopoly case is always smaller than in the monopoly case: $\pi_1^D(d) + \pi_2^D(d) = t/2 + 2(1 - d)^2\bar{m}^2/(9t) < t/2 + 2(1 - \underline{d})^2\bar{m}^2/(9t) = t < v - t/2 = \pi_1^M$, where $\underline{d} = 1 - 3t/(2\bar{m})$.

Lemma 1. *The total firm-side average profit is greater under the monopoly than under the duopoly market structure*: $\pi_1^D(d) + \pi_2^D(d) < \pi_1^M$, *for all* $d \in [\underline{d}, 1]$.

4.2. Stage 2: Communication Game

The market size $\sigma^T = \sigma(e_f, e_c)$ is the outcome of a two-sided marketing communication. All players who are involved in the marketing communication are strategic and forward looking. That is, for a given d (firm 1's choice in the first stage), players decide on their communication efforts, anticipating the equilibrium product market outcomes in stage 3.

Since consumers have not yet observed the idiosyncratic preferences ($z_j \sim \mathrm{U}[0, \frac{1}{2}]$), they form expectations on the consumption utility, taking into account the equilibrium price(s) in the product market in stage 3

$$Eu = \tilde{u} = \begin{cases} \tilde{u}^M = \int_z 2\max\{v - tz - p_1^M, 0\}\, dz, & \text{(Monopoly case)} \\ \tilde{u}^D = \int_z 2\max\left\{v - tz - p_1^D, v - t\left(\frac{1}{2} - z\right) - p_2^D\right\} dz. & \text{(Duopoly case)} \end{cases} \tag{5}$$

It is immediate to have Lemma 2 from Equation (5).

Lemma 2. *Consumers' expected utility from purchasing the product is higher under the duopoly than the monopoly market structure*: $\tilde{u}^D > \tilde{u}^M$.

Thus, competition can serve as a credible commitment to guarantee a higher consumer surplus.

Strategic Complementarity and Substitutability. When $d < \underline{d}$, the follower chooses not to follow the innovator's idea ($\chi = 0$), and the innovator engages in marketing communication by itself. Therefore, firm 1 and consumers choose the optimal communication efforts $\{e_1, e_c\}$ that maximize their total expected payoffs

$$E\Pi_1 = (e_1^k \cdot e_c^{1-k})\pi_1^M - \frac{e_1^2}{2}, \quad EU = (e_1^k \cdot e_c^{1-k})\tilde{u}^M - \frac{e_c^2}{2}. \tag{6}$$

Here, the single-firm communication simply displays strategic complementarity between a firm's and consumers' efforts

$$\frac{\partial^2 E\Pi_1}{\partial e_1 \partial e_c} = k(1-k)e_1^{k-1}e_c^{-k}\pi_1^M \geq 0, \quad \frac{\partial^2 EU}{\partial e_1 \partial e_c} = k(1-k)e_1^{k-1}e_c^{-k}\tilde{u}^M \geq 0. \tag{7}$$

Because of this strategic complementarity effect, increasing effort from one side leads to a higher response from the other side. Thus, the equilibrium efforts are determined by the following best-response functions:

$$e_1^M = (k\pi_1^M(e_c)^{1-k})^{1/(2-k)}, \quad e_c^M = ((1-k)\tilde{u}^M(e_1)^k)^{1/(1+k)}. \tag{8}$$

The best replies $e_1^M(e_c)$ and $e_c^M(e_1)$ are increasing in the other side's effort e_c and e_1, and their own expected average payoffs from the product market π_1^M and $\tilde{u}^M$, respectively.

Next, when $d \geq \underline{d}$, both firms engage in collective marketing communication. Thus, firm 1, firm 2, and consumers choose the optimal communication efforts $\{e_1, e_2, e_c\}$ that maximize the following payoff functions:

$$E\Pi_i = (e_f^k \cdot e_c^{1-k})\pi_i^D - \frac{e_i^2}{2}, \quad EU = (e_f^k \cdot e_c^{1-k})\tilde{u}^D - \frac{e_c^2}{2}, \tag{9}$$

where $i \in \{1,2\}$, and $e_f = e_1 + e_2$ is the firm-side total effort.

Similar to the monopoly market case ($\chi = 0$), there exists strategic complementarity between a firm's and consumers' efforts

$$\frac{\partial^2 E\Pi_i}{\partial e_i \partial e_c} = k(1-k)e_f^{k-1}e_c^{-k}\pi_i^D \geq 0, \quad \frac{\partial^2 EU}{\partial e_i \partial e_c} = k(1-k)e_f^{k-1}e_c^{-k}\tilde{u}^D \geq 0, \quad \text{for all } i \in \{1,2\}. \tag{10}$$

The equilibrium efforts for firm $i \in \{1,2\}$ and consumers are implicitly given by the first-order conditions:
$e_i^D = k\pi_i^D(e_c^D)^{1-k}(e_f^D)^{k-1}$ and $e_c^D = ((1-k)\cdot\tilde{u}^D(e_f^D)^k)^{1/(k+1)}$.
Similar to the monopoly case, the optimal effort of firm i (e_i^D) is increasing in the consumer-side effort e_c^D, and its own expected average profit π_i^D.[25] However, different from the monopoly case, firm i's effort is now affected by the other firm $-i$'s effort. The communication game shows strategic substitutability between each firm's individual effort

$$\frac{\partial^2 E\Pi_i}{\partial e_i \partial e_{-i}} = -k(1-k)e_f^{k-2}e_c^{1-k}\pi_i^D \leq 0. \tag{11}$$

This strategic substitutability between each firm's individual effort leads to a free-riding problem in communication. The success of communication benefits both firms, but efforts are costly. Therefore, each firm has an incentive to free ride on the other firm's costly effort and lower its effort in response to an increased effort by the other firm.[26]

Because of the existence of both strategic complementarity and strategic substitutability in communication, the total effect of an increase in the rival firm's effort on the focal firm's own effort is ambiguous. There are two (direct and indirect) effects. On one hand, firm i's best response to an increase in the rival's effort is to decrease its own because of the free-riding effect (Equation (11)). On the other hand, because of the strategic complementarity effect between e_c and e_i (Equation (10)), consumers' effort e_c increases with firm $-i$'s effort, and furthermore, this increased consumer-side effort incentivizes firm i to raise its effort level. The indirect effect of firm $-i$'s effort on firm i's effort is through consumers' strategic response. We explore the interaction between these countervailing effects next.

Communication Incentives and Optimal Efforts. The equilibrium communication efforts are characterized in the following proposition.

Proposition 1. (1) *Each player's equilibrium effort in communication increases in its own expected payoff from the product market*: $\partial e_1^M/\partial \pi_1^M \geq 0$, $\partial e_i^D/\partial \pi_i^D \geq 0$ (*for* $i \in \{1,2\}$), *and* $\partial e_c/\partial \tilde{u} \geq 0$.

(2) *Moreover, in the duopoly case* ($\chi = 1$), *the ratio of the efforts between the two rival firms* (e_1^D/e_2^D) *is equal to the ratio of their expected average profits from the product market*: $e_1^D/e_2^D = \pi_1^D/\pi_2^D$.

The incentives for all players to exert efforts increase in their expected future payoffs from the product market in stage 3. Also, in the duopoly case, the relative efforts between the two firms are determined by only the split of the total product market profits, regardless of the amount of consumer effort. Hence, to induce the competitor to shoulder more communication costs and expand the total market size, the innovator may disclose more information to increase the competitor's average profit. Nevertheless, the exact levels of the firms' efforts are affected by consumer effort, which is again influenced by consumers' expected payoff from the product market.

Furthermore, we already know that consumer's expected utility is higher under a duopoly than under a monopoly market ($\tilde{u}^D > \tilde{u}^M$) from Lemma 2. Thus, we reach the following corollary.

Corollary 1. *Consumers exert more efforts under the duopoly than the monopoly market structure*: $e_c^D \geq e_c^M$, *for all* $k \in [0, 1]$.

The presence of a competitor serves as a commitment device to assure consumers that they will receive higher utility later in the product market (Lemma 2), which, in turn, increases the incentive for consumers to expend more efforts in deliberating the new idea at the communication stage.

Communication Outcome and Market Size. Next, we compare the equilibrium market size. Under both monopoly and duopoly cases, the total market sizes are given by

$$\sigma^T = (k\pi_f)^k((1-k)\tilde{u})^{1-k}, \tag{12}$$

where π_f denotes the aggregate average retail profits. If the market is a monopoly, $\pi_f^M = \pi_1^M$; if the market is a duopoly, $\pi_f^D = \pi_1^D + \pi_2^D$.[27]

The direct comparison of the total market size σ^T under a duopoly and under a monopoly (Equation (12)) allows us to identify the exact condition under which the market expands with the presence of the competitor.

Proposition 2. *For any given* $d \in [\underline{d}, 1]$, *there always exists a threshold* $\bar{k}(d) \equiv [1 + \ln(\pi_1^M/(\pi_1^D + \pi_2^D))/\ln(\tilde{u}^D/\tilde{u}^M)]^{-1}$ *such that for all* $k \leq \bar{k}(d)$, *the total market size is greater under the duopoly than the monopoly market structure*: $\sigma^{TD}(d) \geq \sigma^{TM}$.

The proposition suggests that whether or not the market expands under a duopoly depends on consumers' expected utility $\tilde{u}$ and the firms' aggregate average retail profits π_f. More importantly, as consumers play an increasingly critical role (i.e., $k \leq \bar{k}$), the market tends to expand under a duopoly. Thus, the innovator is more likely to disclose its idea to invite competition.

When the competitor's communication effort increases, the innovator has an incentive to lower its effort because of the free-riding effect. At the same time, inviting the competitor allows the innovator to commit to providing a greater surplus to consumers, which increases the consumers' efforts in deliberating on the new innovation. The increased effort by consumers (e_c), in turn, increases the firms' efforts through complementarity ($\partial e_i/\partial e_c \geq 0$, for all $i \in \{1, 2\}$). Moreover, as the role of consumers becomes more significant ($k \leq \bar{k}$), the indirect effect of increased effort from complementarity through consumers outweighs the direct effect of reduced effort from the free-riding effect, and thus, the market expands under a duopoly. Therefore, the complementarity in communication between the firms and consumers through consumers' strategic behavior is the key to mitigating the potential free-riding incentive between the firms.

The next subsection highlights this insight by investigating a benchmark case where consumers do not play a role in communication (i.e., $k = 1$).

Benchmark Case: One-Side Communication. Here, we look at a benchmark where marketing communication is purely one-sided. That corresponds to the extreme case of $k = 1$, where only firm-side effort e_f matters, whereas consumer-side effort e_c does not affect the communication outcome. Consumers can effortlessly become aware of the benefits of the product through firms' efforts, such as advertising.

First, when $d < \underline{d}$, firm 1 is the monopolist and engages in marketing communication alone. Firm 1 chooses an effort level that maximizes $E\Pi_1 = e_1\pi_1^M - e_1^2/2$, which is $e_1^M = \pi_1^M = v - t/2$. Then, firm 1's expected payoff as the monopolist is $E\Pi_1^M = \frac{1}{2}\cdot(\pi_1^M)^2 = \frac{1}{2}(v - t/2)^2$.

Next, when $d \geq \underline{d}$, the market becomes a duopoly. Both firms contribute to the communication efforts. In a one-sided marketing communication, there only exists the free-riding effect between the two firms. Firm 1's and firm 2's efforts, e_1 and e_2, maximize $E\Pi_1^D = (e_1 + e_2)\cdot\pi_1^D - e_1^2/2$ and $E\Pi_2^D = (e_1 + e_2)\pi_2^D - e_2^2/2$, respectively. Then, the optimal efforts are $e_i^D = \pi_i^D$, $i \in \{1, 2\}$, and the total firm-side effort is $e_f^D = \pi_1^D + \pi_2^D = t/2 + 2(1-d)^2\bar{m}^2/(9t)$. Hence, we can get their expected payoffs: $E\Pi_1^D = (\pi_1^D)^2/2 + \pi_1^D\cdot\pi_2^D$ and $E\Pi_2^D = (\pi_2^D)^2/2 + \pi_1^D\cdot\pi_2^D$, where $\pi_1^D = (3t + 2(1-d)\bar{m})^2/(36t)$ and $\pi_2^D = (3t - 2(1-d)\bar{m})^2/(36t)$.

It is immediate that $e_1^M = \pi_1^M > \pi_1^D + \pi_2^D = e_f^D$ from Lemma 1. Since the market size is only determined by the firm-side effort, $e_f^M > e_f^D$ also indicates $\sigma^{TM} > \sigma^{TD}$.

Lemma 3. *When the marketing communication is one-sided, the firm-side aggregate effort is always greater under the monopoly market structure, and so is the total market size*: $e_f^M > e_f^D$ *and* $\sigma^{TM} > \sigma^{TD}$.

The above findings are in stark contrast to the two-sided communication case, where the aggregate firm-side effort, as well as the total market size, expands under the duopoly. Moreover, the innovator has no incentive to disclose the innovation or invite competition.

Proposition 3. *When the marketing communication is one-sided, the innovator never discloses its innovation and prefers to become the monopolist in the product market.*

Without the complementarity effect between the two sides, the potential benefit from disclosing information, such as the cost-sharing effect in communication (in the next subsection, we discuss these potential effects of information disclosure in more detail), does not compensate for the innovator's profit loss in the product market.

4.3. Stage 1: Innovation Disclosure

In the first stage, the innovator decides on the degree of innovation disclosure ($d \in [0,1]$), taking into full consideration the effects of disclosure on (1) the follower's entry decision ($\chi \in \{0,1\}$), (2) the equilibrium outcomes of the communication game between firms and consumers (e_1, e_2 if $\chi = 1$, and e_c), and (3) the equilibrium average profit from the product competition (π_1). Firm 2 follows the idea and enters the market ($\chi = 1$) if $d \geq \underline{d}$, and does not enter the market ($\chi = 0$) if $d < \underline{d}$. Both firms correctly anticipate the equilibrium outcomes in the communication and product market competition stages, given the actions $\{d, \chi\}$ they choose.

First, we analyze firm 1's optimal disclosure level when $d \geq \underline{d}$. Firm 1 chooses a disclosure level d that maximizes its expected payoff:

$$\begin{aligned} E\Pi_1(d) &= \sigma^{TD}(d)\pi_1^D(d) - C(e_1^D(d)) \\ &= \sigma^{TD}(d)\pi_1^D(d) - \tfrac{1}{2}(e_1^D(d))^2. \end{aligned} \tag{13}$$

Therefore, firm 1 solves the following optimality condition:

$$\begin{aligned} \frac{\partial E\Pi_1}{\partial d} &= \underbrace{\frac{\partial E\Pi_1}{\partial \sigma}\cdot\frac{\partial \sigma^{TD}}{\partial d}}_{\text{potential market expansion}} + \underbrace{\frac{\partial E\Pi_1}{\partial \pi_1}\cdot\frac{\partial \pi_1^D}{\partial d}}_{\text{retail profit loss}} \\ &\quad - \underbrace{\frac{\partial E\Pi_1}{\partial C}\cdot\frac{\partial C(e_1^D)}{\partial d}}_{\text{reducing comm. cost}} \\ &= \pi_1^D\left(\frac{\partial \sigma^{TD}}{\partial e_c}\frac{\partial e_c^D}{\partial d} + \frac{\partial \sigma^{TD}}{\partial e_2}\frac{\partial e_2^D}{\partial d} + \frac{\partial \sigma^{TD}}{\partial e_1}\frac{\partial e_1^D}{\partial d}\right) \\ &\quad + \sigma^{TD}\frac{\partial \pi_1^D}{\partial d} - C'(e_1^D)\frac{\partial e_1^D}{\partial d}. \end{aligned} \tag{14}$$

The above equation demonstrates that there are three effects of disclosure at play: (1) the market expansion effect through successful marketing communication ($\partial E\Pi_1/\partial\sigma \cdot \partial\sigma^{TD}/\partial d$), (2) the cost-saving effect from the sharing of communication costs with the competitor ($-\partial E\Pi_1/\partial C \cdot \partial C(e_1^D)/\partial d$), and (3) the retail profit loss from forgoing the competitive advantage ($\partial E\Pi_1/\partial \pi_1 \cdot \partial \pi_1^D/\partial d$).[28] When the innovator discloses more information about its innovation, its average profit decreases as a result of increased competition ($\partial E\Pi_1/\partial \pi_1 \cdot \partial \pi_1^D/\partial d \leq 0$), and its savings in communication costs can be larger ($-\partial E\Pi_1/\partial C \cdot \partial C(e_1^D)/\partial d \geq 0$). However, without market expansion, the cost-saving effect alone cannot fully compensate for the profit loss in the product market. Hence, the key for firm 1 to share its innovation with the competitor depends on the extent of the market expansion effect. Only when the market expansion effect is sufficiently large such that it can outweigh the net loss in the product market (i.e., retail profit loss minus the cost-saving benefit) will the innovator disclose information.

Proposition 4. *There exists a threshold*

$$k^* = \left(\ln\frac{\tilde{u}^D(\underline{d})}{\tilde{u}^M} - \ln\frac{\pi_1^M}{\pi_1^D(\underline{d})}\right)\bigg/\left(\ln\frac{\tilde{u}^D(\underline{d})}{\tilde{u}^M} + \ln\frac{\pi_1^M}{\pi_1^D(\underline{d})}\right)$$

such that the following holds:

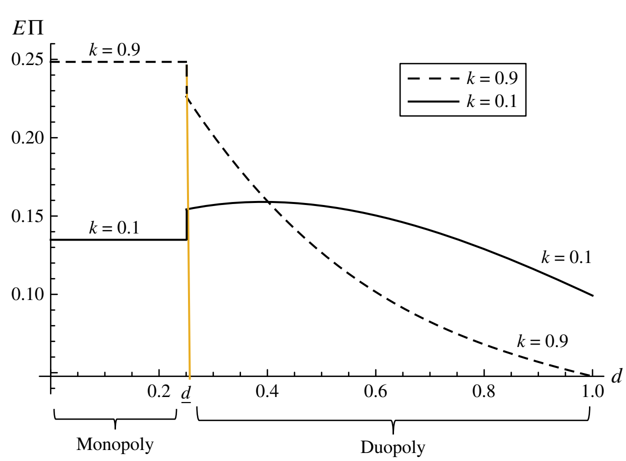
(1) *When $k > k^*$, the optimal strategy for the innovator is not to disclose any information $d^e = 0$, and the market becomes a monopoly.*[29]

(2) *When $k \leq k^*$, the optimal strategy for the innovator is to disclose sufficient information $d^e \in [\underline{d}, 1]$, where $\underline{d} = 1 - 3t/(2\bar{m})$, such that the follower decides to enter the market ($\chi = 1$) and the market becomes a duopoly.*

When the consumers' role in communication is sufficiently important (or k is sufficiently low), the market expansion effect ($\partial E\Pi_1/\partial\sigma \cdot \partial\sigma^{TD}/\partial d$) can compensate for the net loss in the product market, and an innovator can be better off inviting its competitor through sharing its innovation. By disclosing sufficient information to the competitor, a firm can encourage the entry of the competitor into the market. The presence of competition can serve as a credible mechanism to guarantee a greater surplus for consumers, which generates higher consumer effort in communication. Only when consumers play an important role in communication will this increased consumer-side effort lead to a higher market demand σ^{TD}. Otherwise (i.e., $k > k^*$), inviting competition does not increase the market demand because of the free-riding effect between the two rival firms, and therefore, the innovator prefers to maintain its competitive advantage by keeping its innovation secret.[30]

Figure 2 demonstrates the trade-offs in the innovator's disclosure decision under two different cases ($k = 0.1$ versus $k = 0.9$).[31] When the importance of consumers in communication is low ($k = 0.9$), the innovator's expected monopoly payoff is greater than the expected duopoly payoff. Thus, the firm is better off

Figure 2. (Color online) Firm 1's Expected Payoff When $k = 0.1$ and $k = 0.9$



avoiding competition by keeping its innovation secret. In comparison, when the importance of consumers is high ($k = 0.1$), the innovator's expected payoff under the duopoly market structure can be greater due to the market expansion effect. Hence, the firm can benefit from inviting competition by disclosing sufficient innovation to the competitor ($d^e \geq \underline{d}$).

Next, we examine the role of the market expansion effect for information sharing. Note that $\underline{d} = 1 - 3t/(2\bar{m})$ is the minimum level of information disclosure at which the innovator can induce the follower to enter the market. Also, $\bar{k}(d)$ denotes the threshold level below which the duopoly market size exceeds the monopoly market size (Proposition 2). We can find the following relationship between $\bar{k}(\underline{d})$ and the threshold k^* below which the innovator shares an innovation (Proposition 4).

Corollary 2. *The threshold $k^* \leq \bar{k}(\underline{d})$ always holds for $\bar{k}(\underline{d}) \in [0,1]$.*

This relationship ($k^* \leq \bar{k}(\underline{d})$) suggests that market expansion is a necessary condition for information sharing. For example, when $k^* \leq k \leq \bar{k}(\underline{d})$, the market size can be larger with a competitor, but the innovator still finds it optimal not to disclose any innovation. Only when the role of consumers becomes much greater (i.e., $k < k^*$) does firm 1 find it optimal to disclose innovation.

Interestingly, the innovator sometimes finds it optimal to share more than the minimum level $\underline{d}$ when the role of consumers becomes even more critical in generating the success of communication.

Proposition 5. *When k becomes even smaller such that $k < \underline{k} = (4v - 7t)/(3t - 4v)$, where $\underline{k} < k^*$, the innovator discloses information $d^e > \underline{d}$, so that the follower makes a positive profit and exerts a positive communication effort. Furthermore, this threshold $\underline{k} > 0$ exists only when $t > 4v/7$.*

As the consumer-side effort becomes more important in determining the success of marketing communication, the innovator may disclose more information than necessary to invite competition ($d^e > \underline{d}$). In particular, this can occur only when the horizontal differentiation becomes sufficiently large ($t > 4v/7$). As t increases, consumers have a lower expected utility from product consumption and therefore less incentive to incur up-front learning costs. In this case, firm 1 has to incentivize consumers to exert efforts by committing to even more intense competition and lower prices. Disclosing more information to the competitor can serve as a commitment device for that purpose.

On the other hand, when horizontal differentiation is not large enough ($t \leq 4v/7$), even if firm 1 prefers to invite the competitor to the market, firm 1 keeps the maximal secrecy $d^e = \underline{d}$ (since there does not exist $\underline{k} > 0$). In this case, firm 2 does not exert any communication effort (since $\underline{d}$ is the level of information disclosure that gives firm 2 a zero profit by entering the market). Given a low t, the expected utility of consumers is already sufficiently high such that the existence of competition itself is sufficient to convince consumers to expend learning efforts in communication. The purpose of information disclosure is not to use competitors to expand the market together; rather, competition serves as a commitment not to hold up consumers in the product market.

In summary, there are two key mechanisms through which a firm may benefit from revealing information to its competitor in equilibrium: First, there is a direct effect on the competitor's entry decision and communication effort. Information disclosure increases the follower's profit, which facilitates entry and incentivizes the follower to engage more in the communication. Second, there is an indirect effect of information disclosure on consumers' effort: the existence of competition (triggered by the information disclosure) can serve as a commitment mechanism for higher consumer surplus, which accelerates consumer learning in communication. Increased consumer effort contributes to market expansion through complementarity between firms and consumers in communication.[32]

5. Extensions

5.1. Sequential Two-Sided Communication

In our main model, we consider a case where firms and consumers simultaneously decide on their communication efforts without observing the decisions of the others. In our first extension, we relax this assumption and study a case where communication decisions are sequential such that consumers adjust their learning effort after observing firms' marketing efforts.[33] We find that the complementarity effect amplifies in the sequential communication case, which results in a higher equilibrium level of communication effort, and therefore, the innovator is more likely to disclose its information in this case than in the simultaneous communication case.

The last stage of retail competition remains the same as the simultaneous communication case. However, in the communication stage, the sequentiality would affect the equilibrium results. Consumers maximize their expected utility, $EU = (e_f^k \cdot e_c^{1-k})\tilde{u} - e_c^2/2$, after observing a given effort e_f. Hence, the best reply function for consumers is still the same as in the simultaneous case, which is $e_c^{BR} = ((1-k)\tilde{u}{e_f}^k)^{1/(1+k)}$. However, the firms are now Stackelberg leaders. Anticipating the consumers' best response e_c, firm i, for all $i \in \{1,2\}$, solves the following maximization problem: $\max_{e_i} E\Pi_i = (e_f^k \cdot (e_c^{BR})^{1-k}) \cdot \pi_i - e_i^2/2$, where $e_f = e_1 + e_2$ when $\chi = 1$, whereas $e_f = e_1$ when $\chi = 0$. Subsequently, we know that the total firm-side effort is implicitly given by

$$\left(\frac{\partial \sigma}{\partial e_f} + \frac{\partial \sigma}{\partial e_c} \cdot \frac{\partial e_c^{BR}}{\partial e_f}\right)\pi_f = e_f. \tag{15}$$

Compared with the simultaneous communication case, there is an additional incentive for the firm(s) to exert effort; that is, $\partial\sigma/\partial e_c \cdot \partial e_c^{BR}/\partial e_f > 0$. Consequently, the firm-side effort expands in the sequential communication case, which in turn, leads to a greater effort from consumers. More specifically, in equilibrium, both the consumer-side effort and the total firm-side effort can be understood as the product of the equilibrium effort in the simultaneous case and a multiplier effect in terms of k (see the proof of Proposition 6 for the derivation)

$$\begin{aligned} e_f &= \underbrace{\left(\frac{2}{1+k}\right)^{(1+k)/2}}_{\text{sequential multiplier}} \times \underbrace{(k\pi_f)^{(1+k)/2}((1-k)\tilde{u})^{(1-k)/2}}_{\text{equilibrium effort in the simultaneous case}}, \\ e_c &= \underbrace{\left(\frac{2}{1+k}\right)^{k/2}}_{\text{sequential multiplier}} \times \underbrace{(k\pi_f)^{k/2}((1-k)\tilde{u})^{1-k/2}}_{\text{equilibrium effort in the simultaneous case}}. \end{aligned} \tag{16}$$

In the first stage, firm 1 chooses the optimal disclosure level $d_{\text{seq}}^e \in [0,1]$. Similar to the simultaneous case, the innovating firm prefers to share information only when the role of consumers in communication becomes critical (i.e., $k \le k_{\text{seq}}^*$). Moreover, both the firms and consumers incur more communication efforts, and therefore, the market expansion effect through communication gets amplified, which increases firm 1's incentive to disclose information.

Proposition 6. 1. *When $k \le k_{\text{seq}}^*$, firm 1 has an incentive to invite the competitor. Moreover, it is more likely for firm 1 to invite the competitor under sequential communication than under simultaneous communication.*

2. *Also, the total communication efforts are higher in the sequential case.*

5.2. Myopic Consumers and Bounded Rationality

Next, we relax one of our key assumptions about consumers' perfect foresight.[34] In our model, consumers are forward looking; when they decide on their effort level in the communication stage, they take into account their expected future utility from the product market in stage 3. One may question the validity of this assumption, especially in the context of novel products where consumers do not usually know much about the radical innovation yet. Our main results, however, rely on the assumption of forward-looking consumers, which is critical to trigger complementarity in communication. Forward-looking consumers expect a greater surplus under a duopoly and therefore exert more communication efforts. The key insight in our main model lies in that the increased consumer effort prompts complementarity in the communication and lessens the potential free-riding effect between the firms (especially when the role of consumers becomes more important).

However, if consumers are completely myopic, inviting competition would not affect the level of their communication efforts because their expected future utility remains the same, irrespective of the market structure. Furthermore, the total firm-side profit is smaller in the duopoly case compared with the monopoly case (Lemma 1), which leads to a considerably lower effort from the firm side. Therefore, either the firms or consumers would not initiate higher communication efforts. The desired effect of complementarity in communication would not ensue by inviting competition, and thus, our main results do not hold.

Proposition 7. *When consumers are myopic, the innovator never shares information with its rival.*

Although consumers may not calculate a sophisticated game theory problem in a perfectly rational manner, one could argue the case of the bounded rationality of consumers' decision making (see Ellison 2006, Ho et al. 2006, Goldfarb et al. 2012, and Rabin 2013 for an extensive review on this issue in marketing). In other words, consumers can still expect higher utility from lower prices, due to severe competition or greater product valuation, as a result of a wider variety of products in a more competitive market from their past experience or rules of thumb (Ellison 2006). Consumers may have some incentives to exert more efforts in a duopoly market, which can be sufficient enough to elicit complementarity in the communication process, and thus, the innovator may find it optimal to invite competition by sharing information.

To show this, we first define Δ_u as the log difference between the expected utilities under the two market structures

$$\Delta_u \equiv \log \frac{\tilde{u}^D}{\tilde{u}^M} = \log \tilde{u}^D - \log \tilde{u}^M. \tag{17}$$

When consumers are completely myopic, $\tilde{u}^{mD} = \tilde{u}^{mM}$, and thus, $\Delta_u^m = 0$. However, under bounded rationality, consumers have rules of thumb that lead them to believe that they may have higher utility under the duopoly market structure such that $\Delta_u^b > 0$.

Proposition 8. *When consumers are bounded rational such that $\Delta_u^b > 0$, the innovator may choose to share the information when k becomes smaller.*

As long as consumers expect a higher utility in the duopoly case, our main result still holds: when consumers play a more important role in two-sided communication, the innovator may find it more profitable to share an innovation with the rival to encourage its entry into the market.

5.3. Disclosure as Entry Deterrence

Finally, we incorporate another possible role of information disclosure.[35] In our main model, the innovator is the only party that possesses verifiable information about the innovation. The purpose of information disclosure is to invite the competitor to enter the market. Without disclosure, the follower cannot enter the market, and thus, no disclosure is de facto entry deterrence. However, one can argue that even truthful information can sometimes serve the opposite role of discouraging potential entrants from entering the market.[36]

To pursue this possibility and accommodate both roles of information disclosure as an entry invitation and an entry deterrence, we change our basic model slightly. First, we allow that firm 2 can independently develop a similar idea, even without the disclosure from the innovator. However, the marginal production cost m_2 will be either $\underline{m}$ or $\bar{m}$ with equal probability $\frac{1}{2}$, where $\underline{m} \leq 3t/2 < \bar{m}$. This assumption implies that in the low-cost state $\underline{m}$, firm 2 can compete with the innovator and can make a positive profit without further information sharing from the innovator. On the other hand, when $m_2 = \bar{m}$, it can make a positive profit only if firm 1 discloses a sufficient amount of information.

Also, we assume that the innovator can disclose two types of verifiable information: (1) the existence of a new technology ($\phi \in \{0,1\}$) and (2) the amount of key information concerning the new technology that reduces the relative competitive advantage ($d \in [0,1]$).[37] Our main model focuses on the second type, which obviously implies the existence of the new idea when $d > 0$. Moreover, we impose one more assumption that there is uncertainty whether the innovator truly holds a new idea ($I \in \{0,1\}$): firm 1 succeeds in discovering an innovation ($I = 1$) with probability μ and fails ($I = 0$) with probability $1 - \mu$. Here, we assume that $\mu < \bar{\mu}$ (where $\bar{\mu} < 1$) so that the ex ante expected profit of entering the market for firm 2 is positive, and therefore firm 2 always finds it optimal to enter the market with prior belief μ, irrespective of the realization of the cost. Thus, it creates an incentive for firm 1 to disclose information to deter competition.

Firm 1's strategy of disclosing the existence of an innovative idea is ϕ: $I \in \{0,1\} \to \{0,1\}$. If firm 1 fails to discover an idea ($I = 0$), it cannot disclose anything (i.e., $\phi = 0$), given the nature of the verifiability of information. If firm 1 succeeds in discovering an idea ($I = 1$), it chooses whether or not to disclose the existence of its product idea, $\phi \in \{0,1\}$. Contingent on $\phi = 1$, firm 1 decides on its second piece of information: how much to share its key information $d \in [0,1]$. Clearly, if firm 1 chooses not to disclose the existence of an innovation ($\phi = 0$), it does not disclose any key information ($d = 0$).

In this modified setting, we examine whether information disclosure per se can deter a competitor's entry. The disclosure has a real entry deterrence effect when (1) the follower would have entered the market if the innovator had not disclosed any information, and (2) both firms can benefit from the absence of the follower in the market if the innovator discloses the product's existence.

The timeline of the game differs from the main model to reflect these modeling changes. Here, before the game starts (in stage 0), the innovator tries to develop a new innovation. It may succeed ($I = 1$) with probability μ, or it may fail ($I = 0$) with probability $1 - \mu$. Once firm 1 successfully discovers an idea, it can produce a product at a marginal cost of $m_1 \equiv 0$, which is common knowledge. Firm 2 is endowed with a similar idea with a marginal production cost of $m_2 \in \{\underline{m}, \bar{m}\}$.[38]

In stage 1 of the information disclosure game, the innovator decides on its disclosure strategy for (1) the existence of the idea $\phi \in \{0,1\}$ and (2) the amount of key information $d \in [0,1]$. After observing firm 1's disclosure decisions $\{\phi, d\}$, the follower rationally updates its posterior belief about firm 1's success in discovering an idea, $\mu_2(I \mid \phi, d)$. Then, it decides whether to enter the market $\chi \in \{0,1\}$. At the end of stage 1, firm 2's marginal cost becomes public. Such a timing assumption enables us to apply the existing results of stage 2 (the communication subgame) and stage 3 (the product market competition subgame) from the main model with minor modifications to avoid unnecessary complexity. We use the perfect Bayesian equilibrium as our solution concept, in which $\{\phi, d\}$ are sequentially rational given $\mu_2(I \mid \phi, d)$, and $\mu_2(I \mid \phi, d)$ is consistent with $\{\phi, d\}$.

We present a sketch of the model analysis here and provide a full analysis in our online appendix. The analysis of the last two stages is very similar to the main model, except for the fact that there is one more possible market scenario such that firm 2 becomes a monopoly. This scenario can arise when firm 1 fails to discover ($I = 0$) but firm 2 enters the market ($\chi = 1$).

There exist two types of pure strategy equilibrium in the disclosure subgame: (1) the separating equilibrium, where firm 1 truthfully discloses the existence of an idea only when it discovers one, $\phi^e(I) = I$, and firm 2 correctly updates its posterior belief about the existence of firm 1's new innovation, $\mu_2^e(I = 1 \mid \phi^e) = \phi^e$ and $\mu_2^e(I = 0 \mid \phi^e) = 1 - \phi^e$; and (2) the pooling equilibrium, where firm 1 does not disclose the existence of an idea in any case, $\phi^e(I) = 0$, and firm 2's posterior belief remains as the prior belief, $\mu_2^e(I = 1 \mid \phi^e) = \mu$ and $\mu_2^e(I = 0 \mid \phi^e) = 1 - \mu$.[39]

More importantly, in the separating equilibrium, depending on firm 1's strategic disclosure of key information d, firm 1's disclosure of the existence of an idea ϕ can serve two opposite purposes, either entry deterrence or entry invitation. If firm 1 only discloses the idea existence ($\phi = 1$) but does not reveal any key information ($d = 0$), firm 1's incentive to disclose is to discourage the competitor from entering the market. On the other hand, if firm 1 discloses not only the existence of the idea ($\phi = 1$) but also the key information ($d \geq \underline{d}$), disclosure serves as an invitation to encourage firm 2's entry. In both cases, firm 1's disclosure can successfully deter or invite firm 2's entry when firm 2's marginal cost is high $m_2 = \bar{m}$.

Note that the pooling equilibrium cannot arise in the main model because the innovator always has the idea ($I = 1$). Furthermore, the separating equilibrium where disclosure works as an entry deterrence does not arise either, because the follower cannot have a similar idea without the disclosure from the innovator in the main model.

Proposition 9 (Equilibrium). 1. *If k is sufficiently small or large, the innovator discloses the product existence truthfully when it discovers an innovation ("separating equilibrium").*[40] *In particular,*

(a) *When k is sufficiently small, disclosure serves as an entry invitation. Firm 1 reveals a sufficient amount of key information ($d^e \geq \underline{d}$) to encourage firm 2 to enter the market.*

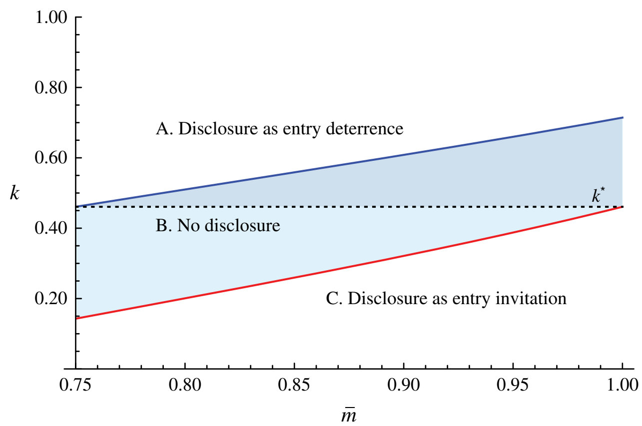
(b) *When k is sufficiently large, disclosure serves as an entry deterrence. Firm 1 never reveals any key information ($d^e = 0$) so that it can deter firm 2 from entering the market when $m_2 = \bar{m}$.*

2. *If k is intermediate, the innovator does not disclose the existence of an idea, irrespective of the true state ("pooling equilibrium"). Firm 2 always enters the market.*

We show the formal proof of this proposition in the online appendix. Allowing for the potential entry deterrence role of disclosure, we find that our main result still holds. When consumers' role is relatively important (k is sufficiently small), the innovator discloses more information ($d \geq \underline{d}$) to invite the competitor to join the market (disclosure as an entry invitation). On the other hand, when the role of consumers in communication becomes less important (k is sufficiently large), it is in the best interest of the innovator to maintain the position of the market monopolist. Disclosing the existence of the innovation here can effectively discourage the competitor from entering the market (disclosure as an entry deterrence). This is so because when the competitor's cost is high ($m_2 = \bar{m}$), the competitor finds it optimal not to enter the market if it knows from the disclosure that the innovator will be in the market. On the other hand, without disclosure ($\phi = 0$), the follower would have entered the market, irrespective of the realization of its cost m_2.

What is interesting in the current setting is the existence of the pooling equilibrium when k is in the intermediate range. In this range, the innovator prefers $\phi(I = 1) = 0$ to $\phi(I = 1) = 1$ so that it does not prevent the entry of the competitor even when the competitor's cost is $m_2 = \bar{m}$. The innovator can still benefit from

Figure 3. (Color online) Disclosure as Entry Deterrence vs. Entry Invitation



the presence of the competitor because of consumers' higher incentive to engage in communication, but the benefit is not large enough such that the innovator will not sacrifice its competitive advantage by sharing its key information. Thus, the innovator chooses not to reveal the existence of the idea. We illustrate these equilibrium outcomes in Figure 3.[41]

6. Conclusion

In this research, we study a firm's information disclosure strategy for introducing a revolutionary product and try to offer a rationale about whether and how much a firm should share an innovation with competitors or whether it should be kept secret. We base our explanation on the persuasion motive of firms and the complementary role of consumers in marketing communication. Specifically, we model marketing communication as a two-sided costly process in which both firms and consumers need to incur efforts and consider such a process as the key determinant of the market demand for a novel product. During the communication process, not only does a firm need to exert costly effort, but consumers also have to expend efforts in assimilating the idea and deliberating their needs. Hence, a key challenge for a firm to market a revolutionary product is to persuade consumers to spend substantial communication efforts in assimilating a new idea, examining an unproven product category, and deliberating their needs.

Our analysis shows a few interesting trade-offs that innovating firms face when they choose information disclosure strategy. Publicly disclosing an innovation, instead of extracting a higher rent by keeping the idea secret, increases the rival's profit in the product market. Information disclosure not only encourages the rival's entry into the market but also incentivizes it to engage in communication. Thus, the innovating firm can benefit from disclosure because the presence of the competitor can help expand the market through cooperation in the communication stage. However, this desired cooperation may not necessarily arise because of a potential free-riding problem. Only when consumers play an important role in communication can an innovating firm benefit from sharing an innovation; the presence of competition, which is induced by innovation sharing, can serve as a commitment to guarantee a greater surplus for consumers so that firms can convince consumers to expend more communication efforts. Furthermore, an increased consumer effort can result in market expansion through the complementarity effect between firms and consumers in a two-sided communication process. Thus, without consumers playing a complementary role in marketing communication, a free-riding problem that arises from strategic substitutability between the two firms' efforts leads to a shrinking market size under a duopoly market structure.

In essence, the fundamental issue that any innovator faces is the basic trade-off embedded in a co-opetition situation—whether to increase the market size with competitors or to capture the market share against competitors. In this sense, we believe that our research can shed light on understanding this important issue in co-opetition by providing one micromechanism that explains when to cooperate with competitors to reach higher value creation (such as market expansion) and when to compete against rivals to achieve a larger competitive advantage.

Finally, our results depend critically on the key features of communication: strategic complementarity between consumers' effort and firms' aggregate effort and strategic substitutability between each firm's efforts. Although we believe that imposing these characteristics in marketing communication is reasonable in many situations, we do not wish to claim that marketing communication always takes on strategic complementarity between firms and consumers. In certain situations, it is possible that communication displays strategic substitutability between firms and consumers. For example, many inbound marketing firms encourage consumers to search for product information on their own instead of bearing all communication costs if it is more efficient for consumers to accomplish the communication. Mayzlin and Shin (2011) formalize this perspective by considering firms' and consumers' efforts in communication as substitutes. Nonetheless, one can better capture communication between firms and consumers through strategic complementarity in many situations such as radical innovations, in which consumers are unsure about the uses and benefits of a product, and even their innate needs. In these situations, the firm-side effort cannot fully substitute for consumers' efforts because consumers have to incur private costs in learning about the product and recognizing their needs. In this research, we highlight that the acts of formulating and absorbing the content of communication are privately costly, and we provide a new perspective on marketing communication (as a two-sided costly process) and its strategic implications.

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Appendix

Proof of Lemma 2

Proof. Under a monopoly, all consumers purchase the product at the monopoly price $p_1^M = v - t/2$. Thus, we have $\tilde{u}^M = \int_0^{1/2} 2(v - t\cdot z - v + t/2)\,dz = t/4$. Under a duopoly, consumers with $z_j \le z^*$ purchase from firm 1, and the rest purchase from firm 2 at $\{p_1^D,\, p_2^D\} = \{t/2 + \bar{m}(1-d)/3,\; t/2 + 2\bar{m}(1-d)/3\}$, where $z^* = \frac{1}{4} - (p_1^D - p_2^D)/(2t)$. Thus, $\tilde{u}^D = \int_0^{1/2} 2\max\{v - tz - p_1^D,\, v - t(\frac{1}{2} - z) - p_2^D\}\,dz = \int_0^{z^*} 2(v - tz - p_1^D)\,dz + \int_{z^*}^{1/2} 2(v - t(\frac{1}{2} - z) - p_2^D)\,dz = (4((1-d)\bar{m})^2 - 36(1-d)\bar{m}t + 9t(8v - 5t))/(72t)$. When $v > 2t$, $\tilde{u}^D > \tilde{u}^M$ for all $d \in [\underline{d}, 1]$ and $\underline{d} = 1 - 3t/(2\bar{m})$. When $v \le 2t$, $\tilde{u}^D \ge \tilde{u}^M$ if $d \le d_1 = 1 - (1/\bar{m})(\frac{9}{2}t + 3\sqrt{2t(2t - v)})$ or $d \ge d_2 = 1 - (1/\bar{m})(\frac{9}{2}t - 3\sqrt{2t(2t - v)})$. Here, we note that the market is a duopoly only when $d \ge \underline{d}$, and $\underline{d} > d_2$ because $v > \frac{3}{2}t$. □

Proof of Proposition 1

Proof. (1) Consumers' equilibrium effort is $e_c = ((1-k)\tilde{u})^{1-k/2} \cdot (k\pi_f)^{k/2}$, where $\tilde{u} = \tilde{u}^M$ and $\pi_f = \pi_1^M$ in a monopoly case; $\tilde{u} = \tilde{u}^D$ and $\pi_f = \pi_1^D + \pi_2^D$ in a duopoly case. Let $\partial e_c/\partial \tilde{u} = (1-k)(1-k/2)((1-k)\tilde{u})^{-k/2}(k\pi_f)^{k/2} \ge 0$. Next, we check the firms' efforts. In a monopoly case, firm 1's equilibrium effort is $e_1^M = ((1-k)\tilde{u}^M)^{(1-k)/2}(k\pi_1^M)^{(1+k)/2}$. So $\partial e_1^M/\partial \pi_1^M = ((1-k)\tilde{u}^M)^{(1-k)/2} k((1+k)/2)(k\pi_1^M)^{(k-1)/2} \ge 0$. In a duopoly case, the equilibrium effort of firm i, $i \in \{1,2\}$, is $e_i^D = ((1-k)\cdot \tilde{u}^D)^{(1-k)/2}(k(\pi_1^D + \pi_2^D))^{(1+k)/2}(\pi_i^D/(\pi_1^D + \pi_2^D))$. So

$$\frac{\partial e_i^D}{\partial \pi_i^D} = ((1-k)\tilde{u}^D)^{(1-k)/2} \cdot (k(\pi_1^D + \pi_2^D))^{(1+k)/2} \cdot \frac{(1+k)\,\pi_i^D + 2\pi_j^D}{2\left(\pi_1^D + \pi_2^D\right)^2} \ge 0.$$

(2) It is straightforward from $e_i^D = k\pi_i^D (e_c^D)^{1-k}(e_f^D)^{k-1}$ that

$$\frac{e_1^D}{e_2^D} = \frac{k\pi_1^D (e_c^D)^{1-k}(e_f^D)^{k-1}}{k\pi_2^D (e_c^D)^{1-k}(e_f^D)^{k-1}} = \frac{\pi_1^D}{\pi_2^D}. \quad \square$$

Proof of Corollary 1

Proof. First, when $k = 1$, consumers' effort does not affect the communication outcome, and thus, consumers do not exert any costly effort, hence $e_c^D = e_c^M = 0$. Next, when $k \in [0,1)$, we show the inequality $e_c^D > e_c^M$. Consumers' equilibrium effort is given by $e_c = ((1-k)\tilde{u})^{1-k/2}(k\pi_f)^{k/2}$, so $e_c^D > e_c^M$ when $e_c^D/e_c^M = (\tilde{u}^D/\tilde{u}^M)^{1-k/2}((\pi_1^D+\pi_2^D)/\pi_1^M)^{k/2} > 1$. Since e_c^D and e_c^M are positive for $k \in [0,1)$, we take the logarithm of both sides of the aforementioned inequality and obtain the equivalent condition $\ln(\tilde{u}^D/\tilde{u}^M) - (k/2)[\ln(\pi_1^M/(\pi_1^D+\pi_2^D)) + \ln(\tilde{u}^D/\tilde{u}^M)] > 0$. Thus, $e_c^D > e_c^M$ if and only if $\ln(\tilde{u}^D/\tilde{u}^M) - (k/2)[\ln(\tilde{u}^D/\tilde{u}^M) + \ln(\pi_1^M/(\pi_1^D+\pi_2^D))] > 0$. Here, we observe that both terms inside the bracket are positive: for all $d \in [\underline{d}, 1]$, $\tilde{u}^D(d)/\tilde{u}^M > 0$ (by Lemma 2) and $\pi_1^M/(\pi_1^D(d)+\pi_2^D(d)) > 0$ (from Lemma 1). Then, we can show the following relationship: for all $k \in [0,1)$,

$$\begin{aligned}&\ln\frac{\tilde{u}^D}{\tilde{u}^M} - \frac{k}{2}\left(\ln\frac{\tilde{u}^D}{\tilde{u}^M} + \ln\frac{\pi_1^M}{\pi_1^D+\pi_2^D}\right)\\ &\quad > \ln\frac{\tilde{u}^D}{\tilde{u}^M} - \frac{1}{2}\left(\ln\frac{\tilde{u}^D}{\tilde{u}^M} + \ln\frac{\pi_1^M}{\pi_1^D+\pi_2^D}\right) = \frac{1}{2}\left(\ln\frac{\tilde{u}^D}{\tilde{u}^M} - \ln\frac{\pi_1^M}{\pi_1^D+\pi_2^D}\right).\end{aligned}$$

Therefore, as long as $\ln(\tilde{u}^D/\tilde{u}^M) > \ln(\pi_1^M/(\pi_1^D+\pi_2^D))$, $\ln(\tilde{u}^D/\tilde{u}^M) - (k/2)(\ln(\pi_1^M/(\pi_1^D+\pi_2^D)) + \ln(\tilde{u}^D/\tilde{u}^M)) > 0$, and thus, $e_c^D > e_c^M$. Then, we only need to show $\ln(\tilde{u}^D/\tilde{u}^M) > \ln(\pi_1^M/(\pi_1^D+\pi_2^D))$, which is indeed true because for all $v > \frac{3}{2}t$ and $d \in [\underline{d}, 1]$,

$$\begin{aligned}\frac{\tilde{u}^D(d)}{\tilde{u}^M} &= \left(\frac{1}{18t}((1-d)\bar{m})^2 - \frac{1}{2}(1-d)\bar{m} + v - \frac{5}{8}t\right)\bigg/\left(\frac{t}{4}\right)\\ &> \left(v - \frac{t}{2}\right)\bigg/\left(\frac{t}{2} + \frac{2(1-d)^2\bar{m}^2}{9t}\right) = \frac{\pi_1^M}{\pi_1^D(d)+\pi_2^D(d)}.\end{aligned}$$

This proves that for all $k \in [0,1]$, $e_c^D \geq e_c^M$. □

Proof of Proposition 2

Proof. The relative market size $\sigma^{TD}/\sigma^{TM} = ((1-k)^{1-k}k^k \cdot (\tilde{u}^D)^{1-k}(\pi_1^D+\pi_2^D)^k)/((1-k)^{1-k}k^k(\tilde{u}^M)^{1-k}(\pi_1^M)^k) = (\tilde{u}^D/\tilde{u}^M)^{1-k} \cdot ((\pi_1^D+\pi_2^D)/\pi_1^M)^k$, where $\tilde{u}^D$ and $\pi_1^D+\pi_2^D$ are functions of d. Hence, $\sigma^{TD} \geq \sigma^{TM}$ if and only if $(\tilde{u}^D/\tilde{u}^M)^{1-k}((\pi_1^D+\pi_2^D)/\pi_1^M)^k \geq 1 \Leftrightarrow (1-k)\ln(\tilde{u}^D/\tilde{u}^M) + k\ln((\pi_1^D+\pi_2^D)/\pi_1^M) \geq 0$. Since $\ln(\pi_1^M/(\pi_1^D+\pi_2^D)) > 0$ and $\ln(\tilde{u}^D/\tilde{u}^M) > 0$ (from the proof of Corollary 1), this inequality leads to $k \leq 1/(1+\ln(\pi_1^M/(\pi_1^D+\pi_2^D))/\ln(\tilde{u}^D/\tilde{u}^M)) \equiv \bar{k}(d)$. Moreover, $\ln(\pi_1^M/(\pi_1^D+\pi_2^D))/\ln(\tilde{u}^D/\tilde{u}^M)$ is also positive, and therefore, $1/(1+\ln(\pi_1^M/(\pi_1^D+\pi_2^D))/\ln(\tilde{u}^D/\tilde{u}^M)) \equiv \bar{k}(d) \in (0,1)$. □

Proof of Proposition 3

Proof. In the monopoly case, $E\Pi_1^M = \frac{1}{2}(\pi_1^M)^2$, whereas in the duopoly case, $E\Pi_1^D = \frac{1}{2}(\pi_1^D)^2 + \pi_1^D\pi_2^D$. Because $\pi_1^D + \pi_2^D < \pi_1^M$, the following inequality should hold: $E\Pi_1^M = \frac{1}{2}(\pi_1^M)^2 > \frac{1}{2}(\pi_1^D+\pi_2^D)^2 = E\Pi_1^D + \frac{1}{2}(\pi_2^D)^2 > E\Pi_1^D$. □

Proof of Proposition 4

Proof. We start with a lemma, and the proof can be found in the online appendix.

Lemma 4. *The expected payoff $E\Pi_1^D(d)$ is monotonically decreasing in $d \in [\underline{d}, 1]$ when $k > k^*$.*

From this lemma, when $k > k^*$, it is immediate that $\underline{d}$ is the optimal disclosure level in the duopoly case. We note that the expected payoff under a duopoly is $E\Pi_1^D(d) = \sigma^{TD}(d)\pi_1^D(d) - \frac{1}{2}(e_1^D(d))^2 = (k(\pi_1^D(d)+\pi_2^D(d)))^k \cdot ((1-k)\tilde{u}^D(d))^{1-k}\pi_1^D(d)(1-(k/2)(\pi_1^D(d)/(\pi_1^D(d)+\pi_2^D(d))))$, where $\sigma^{TD}(d) = (k(\pi_1^D(d)+\pi_2^D(d)))^k \times ((1-k)\tilde{u}^D(d))^{1-k}$ and $e_1^D(d) = (k(\pi_1^D(d)+\pi_2^D(d)))^{(1+k)/2}((1-k)\tilde{u}^D(d))^{(1-k)/2} \times \pi_1^D(d)/(\pi_1^D(d)+\pi_2^D(d))$. At $\underline{d}$, firm 1 does not leave any surplus to firm 2 (i.e., $\pi_2^D(\underline{d}) = 0$). Thus $E\Pi_1^D(\underline{d})$ can be simplified as $E\Pi_1^D(\underline{d}) = (k\pi_1^D(\underline{d}))^k((1-k)\tilde{u}^D(\underline{d}))^{1-k}\pi_1^D(\underline{d})(1-k/2)$. Similarly, we calculate firm 1's expected payoff under a monopoly, $E\Pi_1^M = (k\pi_1^M)^k((1-k)\tilde{u}^M)^{1-k}\pi_1^M(1-k/2)$.

Together, we have the following: $E\Pi_1^M > E\Pi_1^D(\underline{d}) \Leftrightarrow E\Pi_1^M/E\Pi_1^D(\underline{d}) = (\tilde{u}^M/\tilde{u}^D(\underline{d}))^{1-k}(\pi_1^M/\pi_1^D(\underline{d}))^{1+k} > 1$. Taking the logarithm of both sides of the above inequality, we get the equivalence $(1-k)\ln(\tilde{u}^M/\tilde{u}^D(\underline{d})) + (1+k)\ln(\pi_1^M/\pi_1^D(\underline{d})) > 0 \Leftrightarrow k(\ln(\tilde{u}^D(\underline{d})/\tilde{u}^M) + \ln(\pi_1^M/\pi_1^D(\underline{d}))) > \ln(\tilde{u}^D(\underline{d})/\tilde{u}^M) - \ln(\pi_1^M/\pi_1^D(\underline{d}))$. Since both $\ln(\tilde{u}^D(\underline{d})/\tilde{u}^M) + \ln(\pi_1^M/\pi_1^D(\underline{d})) > 0$ and $\ln(\tilde{u}^D(\underline{d})/\tilde{u}^M) - \ln(\pi_1^M/\pi_1^D(\underline{d})) > 0$ (from the proof of Corollary 1), we can restate the condition in terms of k:

$$k > \left(\ln\frac{\tilde{u}^D(\underline{d})}{\tilde{u}^M} - \ln\frac{\pi_1^M}{\pi_1^D(\underline{d})}\right)\bigg/\left(\ln\frac{\tilde{u}^D(\underline{d})}{\tilde{u}^M} + \ln\frac{\pi_1^M}{\pi_1^D(\underline{d})}\right) \equiv k^* \in (0,1).$$

Therefore, when $k > k^*$, $E\Pi_1^M > E\Pi_1^D(\underline{d})$, and thus, the optimal strategy for the innovator is not to disclose any information; that is, $d^e = 0$.

Conversely, when $k \leq k^*$, we at least know that $E\Pi_1^M \leq E\Pi_1^D(\underline{d})$, which implies that not disclosing any information is a dominated strategy. □

Proof of Corollary 2

Proof. Note that

$$\bar{k}(\underline{d}) = \left[1 + \frac{\ln(\pi_1^M/\pi_1^D(\underline{d}))}{\ln(\tilde{u}^D(\underline{d})/\tilde{u}^M)}\right]^{-1} \Rightarrow \frac{\ln(\pi_1^M/\pi_1^D(\underline{d}))}{\ln(\tilde{u}^D(\underline{d})/\tilde{u}^M)} = \frac{1}{\bar{k}(\underline{d})} - 1.$$

Also,

$$\begin{aligned}k^* &= \left(\ln\frac{\tilde{u}^D(\underline{d})}{\tilde{u}^M} - \ln\frac{\pi_1^M}{\pi_1^D(\underline{d})}\right)\bigg/\left(\ln\frac{\pi_1^M}{\pi_1^D(\underline{d})} + \ln\frac{\tilde{u}^D(\underline{d})}{\tilde{u}^M}\right)\\ &= \left(1 - \frac{\ln(\pi_1^M/\pi_1^D(\underline{d}))}{\ln(\tilde{u}^D(\underline{d})/\tilde{u}^M)}\right)\bigg/\left(1 + \frac{\ln(\pi_1^M/\pi_1^D(\underline{d}))}{\ln(\tilde{u}^D(\underline{d})/\tilde{u}^M)}\right)\\ &= \left(2 - \frac{1}{\bar{k}(\underline{d})}\right)\bigg/\left(\frac{1}{\bar{k}(\underline{d})}\right) = 2\bar{k}(\underline{d}) - 1.\end{aligned}$$

Thus, $k^* = 2\bar{k}(\underline{d}) - 1 \leq \bar{k}(\underline{d})$ for all $\bar{k}(\underline{d}) \in [0,1]$. □

Proof of Proposition 5

Proof. Note that the exact disclosure level d^e solves the equation $\partial E\Pi_1/\partial d = 0$, which is equivalent to solving

$$\begin{aligned}\frac{\partial \log E\Pi_1^D}{\partial d} &= \frac{(1-k)}{\tilde{u}^D}\frac{\partial \tilde{u}^D}{\partial d} + \frac{k}{\pi_1^D+\pi_2^D}\frac{\partial(\pi_1^D+\pi_2^D)}{\partial d} + \frac{1}{\pi_1^D}\frac{\partial \pi_1^D}{\partial d}\\ &\quad + \frac{k/2}{1-(k/2)(\pi_1^D/(\pi_1^D+\pi_2^D))}\frac{\partial}{\partial d}\left(-\frac{\pi_1^D}{\pi_1^D+\pi_2^D}\right) = 0.\end{aligned}$$

We further reduce the above formula to $\partial \log E\Pi_1^D/\partial d = \Psi \cdot G(k,d)$, where $\tilde{m} = (1-d)\bar{m}$ and

$$\Psi = \frac{4\tilde{m}}{\begin{bmatrix}(2\tilde{m}+3t)(4(4-k)\tilde{m}^2 - 12k\tilde{m}t + 9(4-k)t^2)\\ \times(4\tilde{m}^2+9t^2)(4\tilde{m}^2 - 36\tilde{m}t + 9t(8v-5t)),\end{bmatrix}}$$

$$G(k,d) = k^2 9t(2\tilde{m}+3t)^3(9t^2+4\tilde{m}(\tilde{m}+3t-4v)) - 32(4\tilde{m}^2+9t^2)^2(\tilde{m}^2-6\tilde{m}t+9t(v-t)) + k(2\tilde{m}+3t) \cdot \big(32\tilde{m}^2\big(2\tilde{m}^3+9t(\tfrac{5}{6}\tilde{m}^2+2\tilde{m}(2t-3v)-3t^2)\big) + 81t^3(4\tilde{m}(t-12v)-3t(25t-16v))\big).$$

From the proof of Lemma 4 in the online appendix, Ψ is positive, and the sign of $\partial \log E\Pi_1^D/\partial d$ depends on the shape of $G(k,d)$.

Moreover, $G(k,d)$ is a convex function of k for all $d \in [\underline{d},1]$, and there are two roots, k_1 and k_2, such that $G(k_1 \mid d) = G(k_2 \mid d) = 0$, where $k_1 < 1 < k_2$. Also, we find that $G(k,d) \le 0$ for all $d \in [\underline{d},1]$ if and only if $k \ge k_1(\underline{d}) = (7t-4v)/(v-3t) \equiv \underline{k}$, where $\underline{d} = 1-3t/(2\tilde{m})$. Then $E\Pi_1^D$ monotonically decreases in $d \in [\underline{d},1]$, and the minimal level $\underline{d}$ is the optimal disclosure level under a duopoly. Conversely, if $k < \underline{k}$, there must exist some d such that $G(k,d) > 0$ for some $d \in [\underline{d},1]$, where $\underline{k}$ exists in $(0,1)$ when $t > 4v/7$. To show that the optimal disclosure level under a duopoly d^e is greater than $\underline{d}$, we use the following lemma.

Lemma 5. *When $t > 4v/7$, $k_1(d)$ is strictly decreasing in $d \in [\underline{d},1]$. Moreover, $k_1(\underline{d}) = \underline{k} \in (0,1)$ and $k_1(1) < 0$.*

We again present the proof in the online appendix. From Lemma 5, we know that there exists $\tilde{d} \in (\underline{d},1)$, $k_1(\tilde{d}) = 0$. We define an inverse function of $k_1(d)$ as $H_1^{-1}(k)$, which is a well-behaving one-to-one mapping on the range from $[0,\underline{k}]$ to $[\underline{d},\tilde{d}]$. Then, for a given $k < \underline{k}$, there always exists a $d^e = H_1^{-1}(k) \in [\underline{d},\tilde{d}]$ such that $k_1(d^e(k)) = k$ when $t > 4v/7$. Therefore, for a given $k < \underline{k}$, $G(d^e(k) \mid k) = 0$, which implies $\partial \log E\Pi_1^D(d^e)/\partial d = 0$.

Since we have not yet analyzed how G behaves in $d \in [\underline{d},1]$ for a given k, we need to show that $d^e(k)$ is indeed optimal. Consider a lower disclosure amount $d' < d^e$. Since $k_1(d)$ strictly decreases in d, a lower level of $d' < d^e$ corresponds to a higher $k_1(d') > k_1(d^e)$ such that $G(k_1(d') \mid d') = 0$. Then $G(k_1(d^e) \mid d') > G(k_1(d') \mid d') = 0$ because of the convexity of $G(k \mid d)$. Thus, for any given $k < \underline{k}$, $G(d' \mid k) > 0$ for all $d' \in [\underline{d},d^e)$. Similarly, $G(d'' \mid k) < 0$ for any $d'' \in (d^e,\tilde{d}]$. Therefore, for any $k < \underline{k}$, we can find a unique d^e such that $G(d^e(k) \mid k) = 0$, and $G(d \mid k) \ge 0$ (i.e., $E\Pi_1^D(d)$ increases) when $d \le d^e$, whereas $G(d \mid k) \le 0$ (i.e., $E\Pi_1^D(d)$ decreases) when $d \ge d^e$. Therefore, d^e is the unique optimal disclosure amount. □

Proof of Proposition 6

Proof. (1) Denote Λ as a set that includes k under which firm 1's optimal strategy is *not to* disclose any information: $\Lambda = \{k\colon E\Pi_1^M(k) > E\Pi_1^D(d \mid k),\ \forall\, d \in [\underline{d},1]\}$. We need to show that $\Lambda_{\text{seq}} \subseteq \Lambda_{\text{sim}}$. We first define an auxiliary set $\Phi = \{k\colon E\Pi_1^M(k) > E\Pi_1^D(\underline{d})\}$. By the definition of equilibrium, $\Lambda \subseteq \Phi$. Because of Lemma 4, we already know that $\Phi_{\text{sim}} = \Lambda_{\text{sim}}$. We will show that the cutoff k^*_{seq} for the sequential case is the same as the simultaneous case, $k^*_{\text{seq}} = k^*$, and therefore, $\Phi_{\text{seq}} = \Phi_{\text{sim}} = (k^*,1]$. Then, it is immediate that $\Lambda_{\text{seq}} \subseteq \Phi_{\text{seq}} = \Phi_{\text{sim}} = \Lambda_{\text{sim}}$.

To show $\Phi_{\text{seq}} = \Phi_{\text{sim}} = (k^*,1]$, we need to solve for the optimal communication effort and specify the expected payoff functions in the sequential communication case. Following Equation (15) and knowing $e_c^{BR} = ((1-k)\tilde{u}e_f^k)^{1/(k+1)}$, we have the first-order condition for optimal effort e_f: $\pi_f k e_f^{k-1}(e_c^{BR})^{1-k} + \pi_f(1-k)e_f^k(e_c^{BR})^{-k}\cdot(k/(1+k))((1-k)\tilde{u}/e_f)^{1/(1+k)} = e_f \Leftrightarrow k\pi_f \cdot e_f^{k-1}(e_c^{BR})^{1-k}(1+((1-k)/(1+k))(e_f/e_c^{BR})((1-k)\tilde{u}/e_f)^{1/(1+k)}) = e_f$. After a few algebraic steps, we have the equilibrium firm-side effort: $e_{f,\text{seq}} = (2/(1+k))^{(1+k)/2}\cdot(k\pi_f)^{(1+k)/2}((1-k)\cdot\tilde{u})^{(1-k)/2} = (2/(1+k))^{(1+k)/2}\cdot e_{f,\text{sim}}$. And consumers' equilibrium effort is $e_{c,\text{seq}} = ((1-k)\cdot\tilde{u}(e_{f,\text{seq}})^k)^{1/(k+1)} = (2/(1+k))^{k/2}\cdot(k\pi_f)^{k/2}((1-k)\tilde{u})^{(1-k)/2} = (2/(1+k))^{k/2}\cdot e_{c,\text{sim}}$. In the duopoly case, firm i's equilibrium effort is given by $e^D_{i,\text{seq}} = (\pi_i^D/(\pi_1^D+\pi_2^D))\cdot e^D_{f,\text{seq}}$, $i=\{1,2\}$.

Then, we can compute firm 1's expected payoff in the duopoly market: $E\Pi_1^D = \sigma(e_1^D+e_2^D,e_c^D)\pi_1^D - \frac{1}{2}(e_1^D)^2 = (2/(1+k))^k\cdot(k(\pi_1^D+\pi_2^D))^k((1-k)\tilde{u}^D)^{1-k}\pi_1^D(1-(k/(1+k))(\pi_1^D/(\pi_1^D+\pi_2^D)))$. Moreover, at $\underline{d}$, $E\Pi_1^D(\underline{d}) = (2/(1+k))^k(k\pi_1^D)^k\cdot((1-k)\tilde{u}^D)^{1-k}\cdot(\pi_1^D/(1+k))$.

Similarly, we compute the equilibrium effort and firm 1's expected payoff in the monopoly case respectively as follows: $e^M_{1,\text{seq}} = (2/(1+k))^{(1+k)/2}((1-k)\tilde{u}^M)^{(1-k)/2}(k\pi_1^M)^{(k+1)/2} = (2/(1+k))^{(1+k)/2}e^M_{1,\text{sim}}$ and $E\Pi_1^M = \sigma(e_1^M,e_c^M)\pi_1^M - \frac{1}{2}(e_1^M)^2 = (2/(1+k))^k(k\pi_1^M)^k((1-k)\tilde{u}^M)^{1-k}(\pi_1^M/(1+k))$.

It is straightforward that the cutoff k^*_{seq} in the sequential setting remains the same as the simultaneous case because of the same decision rule, $E\Pi_1^M/E\Pi_1^D(\underline{d}) = (\tilde{u}^M/\tilde{u}^D(\underline{d}))^{1-k}\cdot(\pi_1^M/\pi_1^D(\underline{d}))^{1+k} = 1$, which gives the same $k^*_{\text{seq}} = k^*$. Hence, $\Phi_{\text{seq}} = \Phi_{\text{sim}} = (k^*,1]$, and therefore, $\Lambda_{\text{seq}} \subseteq \Phi_{\text{seq}} = \Phi_{\text{sim}} = \Lambda_{\text{sim}}$.

(2) Also, for $k \in [0,1]$, $e^M_{1,\text{seq}} = (2/(1+k))^{(1+k)/2}\cdot e^M_{1,\text{sim}} \ge e^M_{1,\text{sim}}$ and $e^M_{c,\text{seq}} = (2/(1+k))^{k/2}\cdot e^M_{c,\text{sim}} \ge e^M_{c,\text{sim}}$ under a monopoly situation, and $e^D_{f,\text{seq}} = (2/(1+k))^{(1+k)/2}\cdot e^D_{f,\text{sim}} \ge e^D_{2,\text{sim}}$ and $e^D_{c,\text{seq}} = (2/(1+k))^{k/2}\cdot e^D_{c,\text{sim}} \ge e^D_{c,\text{sim}}$ under a duopoly situation. Thus, the total efforts are always higher under a sequential case than a simultaneous one. □

Proof of Proposition 7

Proof. Myopic consumers expect the same $\tilde{u}$ in both monopoly and duopoly markets. They choose an optimal effort that maximizes their expected payoff, $EU = e_f^k e_c^{1-k}\tilde{u} - e_c^2/2$. Hence, myopic consumers' best reply in effort is $BR(e_f) = ((1-k)\tilde{u}(e_f)^k)^{1/(1+k)}$. From the analysis of the main model, we know that the equilibrium total firm side is implicitly determined by adding up each firm's first-order conditions: $e_1^D + e_2^D = k(\pi_1^D+\pi_2^D)(e_f^D)^{k-1}(e_c^D)^{1-k}$. Knowing the consumers' best reply, we can compute the equilibrium firm-side effort as $e_f = (k\pi_f)^{(1+k)/2}((1-k)\tilde{u})^{(1-k)/2}$, where $\pi_f = \pi_1^M$ in a monopoly case and $\pi_f = \pi_1^D + \pi_2^D$ in a duopoly case. Then, consumers' equilibrium effort is $e_c = ((1-k)\tilde{u})^{1-k/2}(k\pi_f)^{k/2}$. Also from the main analysis, we already know that $e_1^D = e_f^D\cdot\pi_1^D/\pi_f^D$ and $\sigma^T = (k\pi_f)^k((1-k)\tilde{u})^{1-k}$; therefore, we can get firm 1's expected payoffs as $E\Pi_1^M = (k\pi_1^M)^k((1-k)\tilde{u})^{1-k}\pi_1^M(1-k/2)$ and $E\Pi_1^D = (k\pi_f^D)^k((1-k)\tilde{u})^{1-k}\pi_1^D(1-(k/2)(\pi_1^D/\pi_f^D))$.

Next, we show that $E\Pi_1^D < E\Pi_1^M$ always holds. That is, $E\Pi_1^D/E\Pi_1^M < 1 \Leftrightarrow (\pi_f^D/\pi_1^M)^k\cdot\pi_1^D/\pi_1^M\cdot(1-(k/2)(\pi_1^D/\pi_f^D))/(1-k/2) < 1$, which is equivalent to $(\pi_f^D/\pi_1^M)^{1+k}\cdot\pi_1^D/\pi_f^D\cdot(1-(k/2)(\pi_1^D/\pi_f^D))/(1-k/2) < 1$. Because $\pi_f^D = \pi_1^D+\pi_2^D < \pi_1^M$, the first argument $(\pi_f^D/\pi_1^M)^{1+k} < 1$. Next, we show $(\pi_1^D/\pi_f^D)\cdot(1-(k/2)(\pi_1^D/\pi_f^D))/(1-k/2) \le 1$. The result of the retail competition tells us that $\pi_1^D/\pi_f^D \in [\frac{1}{2},1]$. Notice that $(\pi_1^D/\pi_f^D)\cdot(1-(k/2)(\pi_1^D/\pi_f^D))/(1-k/2)$ increases in $k \in [0,1]$. Thus, we only need to show that $(\pi_1^D/\pi_f^D)\cdot(1-(k/2)(\pi_1^D/\pi_f^D))/(1-k/2) \le 1$ when $k=1$. That is, $(\pi_1^D/\pi_f^D)\cdot(1-(k/2)(\pi_1^D/\pi_f^D))/$

$(1-k/2) = (\pi_1^D/\pi_f^D)(2-\pi_1^D/\pi_f^D) \le 1$ for $\pi_1^D/\pi_f^D \in [\frac{1}{2}, 1]$. Hence, $E\Pi_1^D < E\Pi_1^M$. □

Proof of Proposition 8

Proof. Note that $e_f = ((1-k)\tilde{u}^b)^{(1-k)/2}(k\pi_f)^{(1+k)/2}$ and $e_c = ((1-k)\tilde{u}^b)^{1-k/2}(k\pi_f)^{k/2}$, where $\tilde{u}^b = \tilde{u}^{bM}$ and $\pi_f = \pi_1^M$ in a monopoly case, whereas $\tilde{u}^b = \tilde{u}^{bD}$ and $\pi_f = \pi_1^D + \pi_2^D$ in a duopoly case. Firm 1's expected payoffs are $E\Pi_1^M = (k\pi_1^M)^k \cdot ((1-k)\tilde{u}^{bM})^{1-k} \cdot \pi_1^M(1-k/2)$ and $E\Pi_1^D = (k\pi_f^D)^k((1-k)\cdot \tilde{u}^{bD})^{1-k} \cdot \pi_1^D(1-(k/2)(\pi_1^D/\pi_f^D))$. Firm 1 finds it more profitable to invite competition when $E\Pi_1^D/E\Pi_1^M = (\pi_f^D/\pi_1^M)^k \cdot \pi_1^D/\pi_1^M \cdot (\tilde{u}^{bD}/\tilde{u}^{bM})^{1-k} \cdot (1-(k/2)(\pi_1^D/\pi_f^D))/(1-k/2) \ge 1 \Leftrightarrow (1-(k/2)(\pi_1^D/\pi_f^D))/(1-k/2) \ge (\pi_1^M/\pi_1^D)(\tilde{u}^{bM}/\tilde{u}^{bD})((\pi_1^M/\pi_f^D)\cdot (\tilde{u}^{bD}/\tilde{u}^{bM}))^k$. Let us define the left-hand side (LHS) of the inequality as $LHS = (1-(k/2)(\pi_1^D/\pi_f^D))/(1-k/2)$ and the right-hand side (RHS) as $RHS = (\pi_1^M/\pi_1^D)(\tilde{u}^{bM}/\tilde{u}^{bD}) \cdot ((\pi_1^M/\pi_f^D)(\tilde{u}^{bD}/\tilde{u}^{bM}))^k$. We note that the LHS monotonically increases in $k \in [0,1]$ for all $\pi_1^D/\pi_f^D \in [\frac{1}{2}, 1]$. Also, RHS monotonically increases in $k \in [0,1]$ because $(\pi_1^M/\pi_f^D)(\tilde{u}^{bD}/\tilde{u}^{bM}) > 1$. At the extreme $k=1$, $E\Pi_1^D < E\Pi_1^M$, from Proposition 3. For k^* to exist in the range of $[0,1]$, at which $E\Pi_1^D = E\Pi_1^M$, it must be the case that when $k=0$, $LHS \ge RHS \Leftrightarrow 1 \ge (\pi_1^M/\pi_1^D)(\tilde{u}^{bM}/\tilde{u}^{bD}) \Leftrightarrow \tilde{u}^{bD}/\tilde{u}^{bM} \ge \pi_1^M/\pi_1^D$. We take the logarithm of both sides, and we have the desired result that $\log \tilde{u}^{bD} - \log \tilde{u}^{bM} \ge \log \pi_1^M - \log \pi_1^D > 0$. Therefore, for k^* to exist in the range of $[0,1]$, it must be the case that $\Delta\tilde{u}^b \equiv \log \tilde{u}^{bD} - \log \tilde{u}^{bM} > 0$. □

Endnotes

[1] We follow the notion that a radical innovation is a new product that represents substantial improvements in technology or consumer benefits (Chandy and Tellis 1998), and thus, consumer preferences for such products are not yet fully formed (Christensen 1997). On the other hand, incremental innovation concerns the enhancements or upgrades on an existing product or a service. Consumers already have stable preferences for such products.

[2] Such a challenge can cause many new revolutionary products to fail. By merely being exposed to an advertisement, consumers can easily become aware of the new product idea. However, awareness of a radical product does not necessarily translate into consumers' need recognition or product acceptance, as consumers might be unwilling to incur further learning costs to assimilate the advertisement of a product that seems to target "tech geeks" but not them (Garfinkel 2014).

[3] In reality, we can observe the necessity of considering two-sided efforts in a wide variety of scenarios. For example, when a teacher tries to convey a new idea to students, if the students are not interested or do not spend effort to pay attention, they will not absorb or internalize the new knowledge, no matter how hard or clearly the teacher tries to elaborate. On the other hand, no matter how hard students try to learn, if the teacher does not explain things clearly, the idea is hardly understood or accepted by the students. Both efforts are necessary for the communication to succeed.

[4] Shin (2007) analyzes the free-riding effect of a competitor's service effort on retail competition (also known as "showrooming").

[5] See also Gardete and Guo (2015) who followed the Mayzlin and Shin (2011) consumer search mechanism for consumer inference.

[6] Harbison and Pekar (1998) find that more than 50% of strategic alliances are typically formed among competing firms within the same industry.

[7] In our model, market demand is endogenously determined by the communication between firms and consumers. There are several papers that also study the issue of endogenous market demand—in particular, market expansion by supply-side efforts, such as advertising to enhance consumer awareness or learning (Agarwal and Bayus 2002, Shen 2014, Shen and Xiao 2014).

[8] We use the terms "secrecy" and "disclosure" interchangeably throughout the paper.

[9] Here, we make a simplifying assumption that the competitor can immediately understand the value of the new concept and, therefore, can always make a similar product once a small bit of the innovation is shared ($d > 0$). Although competitors may work on the identical concept (such as long-range electric cars), the final products are differentiated because firms can have different product designs and features (e.g., Tesla's Model S versus BMW's i3).

[10] We assume there is a fixed cost $\epsilon > 0$ associated with the information disclosure. The cost ϵ is a tiebreaker: when the innovator is indifferent between disclosure and no disclosure, it chooses no disclose because of this fixed cost.

[11] Alternatively, one can model competitive advantage through demand advantage (consumers have higher willingness to pay for the innovator's product, but the sharing of innovation reduces this advantage). We explored this specification, and the qualitative results remain the same.

[12] For example, when Procter & Gamble first introduced disposable diapers in 1969, the company used a new synthetic fiber technology that helped it enjoy cost advantage over the competitors (Morrison et al. 1992).

[13] This formulation is a simplified version of a full model. In a full model, we assume that with probability α, the product is a good match, in which case the new product can provide a positive value v. With probability $1-\alpha$, the product is a bad match, and consumers attach a sufficiently large negative value to the product (e.g., $-\infty$). Thus, a successful communication reveals match information for consumers. This match uncertainty guarantees that without understanding and accepting the idea, consumers would never consider purchasing the product. Dewatripont and Tirole (2005) formally introduce this decision rule as "executive decision making." Alternatively, one can consider a sufficiently low α such that it might not be profitable for a firm to lower prices to entice consumers into buying without deliberation. This alternative formulation can still lead to the same conclusion that consumers have to be convinced before making a purchase decision. In either case, this prior belief α only affects the total demand with a constant scale, and thus, we omit it in the subsequent process for simplicity. Mayzlin and Shin (2011) provide a full analysis on all possible pricing strategies and consumer search behavior accordingly in their lemma 1.

[14] One can consider that σ is an individual-specific parameter, and firms would then integrate over all populations to obtain the total demand. This alternative specification leads to the same interpretation that σ represents the number of potential buyers in the market.

[15] This was noted by XM's vice president of sales and marketing: "XM's ads will be about continuing to 'grow the whole category pie,' rather than competing with Sirius" (Boston 2003, p. 14). Lu (2018) provides a micromechanism of how and why such unbranded advertisements can be more efficient in generating the total demand than branded advertisements.

[16] The E160 was offered only in the Japanese, Hong Kong, and Sri Lankan markets, with production starting in mid-2012; the E170 was the 11th generation of Corolla offered internationally, with production starting in mid-2013.

[17] Note that this strategic complementarity arises because σ is an endogenous outcome of the strategic choices by the firms and consumers. On the other hand, if σ is fixed and exogenously given, one side expends less effort because the other side has expended more effort.

[18] One can consider asymmetric influences: First, firms may differ in their abilities to persuade consumers. We can capture this asymmetry by setting the total firm-side effort as $e_f = \beta e_1 + e_2$. The parameter β affects the exact equilibrium effort levels, but the underlying mechanism and our main results do not change as a result of the additive form of the specification. Second, communication efforts may also affect consumers' valuation differentially (consumers may have a higher willingness to pay for the advertised brand). We can capture this asymmetric effect by allowing e_i to enhance v_i while still using $e_f = e_1 + e_2$ to capture category building. However, our focus is on a particular context of communicating new ideas and building new category demand (in which the primary role of advertising is more about generating the total demand rather than affecting the product valuation). Thus, we do not pursue this possibility and leave it for future research. We thank the editor for pointing this out to us.

[19] We can consider this supposition as the outcome of a sequential location-choice game. The innovator, firm 1, enters the market first and chooses a location on the circle. Then, firm 2 enters and picks a location accordingly. The follower is better off with maximal differentiation by picking the farthest distance location from firm 1.

[20] Note that it might be possible that the game does not reach the last stage of product market competition if none of the parties (either the firms nor consumers) exerts any effort in equilibrium. However, in this scenario, both the firms and consumers earn a zero equilibrium payoff, which is dominated by the nonzero effort equilibrium. Here, we impose Pareto dominance in equilibrium selection, and thus, a proper subgame of product market competition always exists in the last stage.

[21] It can be more realistic to assume that firms do not observe consumer effort. However, this imperfect information assumption imposes significant modeling challenges and unnecessary complications such as off-equilibrium refinements without providing more additional insights. Even under the imperfect observability of consumer effort, firms can infer the level of consumer effort correctly in equilibrium. The current approach is a simplification of the reality to make our key messages more transparent and clearer.

[22] For expositional easiness and simplicity, we impose $f = 0$; however, in reality, the firm incurs sufficient costs for entering the market such as setting up the facility for production and distribution.

[23] We assume that $\bar{m} > 3t/2$ for the existence of $\underline{d} = 1 - 3t/(2\bar{m})$. Also, $v > \frac{3}{2}t$ ensures that for any $d \geq \underline{d}$, even the marginal consumer ($z^* = \frac{1}{4} + (1-d)\bar{m}/(6t)$) receives a positive utility in equilibrium: $u^* = v - t(\frac{1}{4} + (1-d)\bar{m}/(6t)) - t/2 - (1-d)\bar{m}/3 > 0$.

[24] The optimal price from the first-order condition is given by $p_1 = \arg\max_{p_1} \sigma^T p_1(2(v - p_1)/t) = v/2$. However, even the consumer with the farthest location $z_j = \frac{1}{2}$ finds a positive utility under this price, $u_j = v - t/2 - v/2 > 0$, because $v > 3t/2$. Hence, the equilibrium price is determined by making the farthest consumer indifferent between purchasing and not purchasing, $u_j = v - t/2 - p_1 = 0 \Leftrightarrow p_1^M = v - t/2$, and the market demand is $D_1 = \sigma^T$.

[25] Also, the optimal level of effort for consumers e_c^D is again increasing in the other side's effort (the firm-side total effort e_f^D) and its own expected utility in the product market $\tilde{u}^D$.

[26] We can measure the free-riding problem more directly by evaluating the direct effect of a change in the rival firm's effort on the focal firm's effort: $\partial e_i/\partial e_{-i} = -1/(1 + (e_f^{2-k} e_c^{k-1})/((1-k)k\pi_i^D)) \leq 0$.

[27] To ensure $\sigma^T \leq 1$ holds for any $d \in [0,1]$, we restrict $t \in (0,1)$ and $v \leq 1 + t/2$. However, this restriction does not impact our results because our results only depend on the ratio v/t.

[28] The net effect of $\pi_1^D(\partial\sigma^{TD}/\partial e_1) - C'(e_1^D) = 0$ in equilibrium as a result of the first-order condition of e_1^D.

[29] Technically, without any disclosure cost, any amount of information disclosure $d \in [0, \underline{d})$ can be optimal. The overall equilibrium payoffs for both firms and consumers are independent of d because the follower does not enter the market anyway when $d < \underline{d}$ (and thus, the market is a monopoly). When the market is a monopoly, the consumers' expected utility and the optimal communication effort are the same, irrespective of $d \in [0, \underline{d})$. However, this indifference result is an artifact from the model assumption of zero cost for information disclosure. If we allow some small costs associated with information disclosure $\epsilon > 0$, the innovator is no longer indifferent to the amount of information disclosure, and the optimal strategy is not to disclose any information $d^e = 0$.

[30] Recall that we assume that the entry cost for the firm is $f = 0$ for simplicity. However, one can relax this assumption and allow a more realistic scenario that a firm needs to incur positive entry cost $f > 0$ (e.g., the costs of setting up facilities for production and distribution). In this case, we can easily see that the innovator needs to disclose more information to ensure an even greater profit for the follower to cover its entry costs. In some cases where f is large enough, the innovator chooses a full disclosure $d^e = 1$, which corresponds to the example of Tesla. However, including the fixed cost $f > 0$ makes the analysis unnecessarily complicated without providing further insight, and it makes it impossible to gain a closed-form solution. Hence, we keep the simplifying assumption of $f = 0$.

[31] We set $\bar{m} = 2t$ so that $\underline{d} = 1 - 3t/(2\bar{m}) = 0.25$, $v = 5/4$, and $t = 4/5$.

[32] One should note that our results are based on a specific communication technology that assumes strategic complementarity between firms and consumers. However, even if the communication does not necessarily display strategic complementarity, there can be other mechanisms in which the innovator could still allow for competition. This could happen, for example, if the costs to develop the technology (to reach the stage for commercialization) are very high. In this case, it may be possible that the initial innovator can disclose to induce a rival's R&D investment (De Fraja 1993, Jansen 2010). We thank the associate editor for suggesting we acknowledge this possibility.

[33] In the current extension, both firms decide on their communication efforts simultaneously once they have information, which mirrors the situation where firms advertise without knowing the competitor's action, such as the case of XM and Sirius satellite radio. However, one may also think that the innovator can advertise first and then the follower responds to the innovator's move. We analyze this case where even the two firms move sequentially in our online appendix; the main results remain the same. Only the amplified complementarity effect in communication is mitigated.

[34] We thank an anonymous referee for suggesting that we explore this interesting issue.

[35] We thank the associate editor and an anonymous reviewer for encouraging us to think about this issue.

[36] Again, the credibility of the information is beyond the scope of this paper, and we only restrict our analysis to truthful information.

[37] There can be many types of information disclosure to consider. For example, an innovator can announce a major technological advantage over competitors, which can potentially discourage competitors from entering the market.

[38] Because of the zero marginal cost $m_1 = 0$, firm 1 always enters the market upon having an idea $I = 1$. Also, depending on firm 1's disclosure of key information d, where $d \in [0,1]$, firm 2 can produce at a cost $\tilde{m}_2 = \min\{m_2, \bar{m}(1-d)\}$.

[39] More precisely, the posterior belief should be a function of both ϕ and d such that $\mu_2(I \mid \phi, d)$; however, given the fact that $d > 0$ is contingent on $\phi = 1$, we use the notation $\mu_2(I \mid \phi)$ for simplicity.

[40] In any equilibrium, when firm 2's marginal cost is low ($m_2 = \underline{m}$), firm 1's disclosure has no real effect on firm 2, and firm 2 always enters the market.

[41] Here, we set the parameter values as $v = 1$, $t = 0.5$. The graph shows the case when the optimal-level disclosure is $\underline{d}$, which demonstrates

the least favorable case. The region of disclosure as an invitation can be even larger.

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