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 even unsure whether they need the product. In this situation, we consider the role of marketing communication as generating consumers’ need recognition and thereby market demand for a novel product. In particular, we model the marketing communication process as a two-sided process that involves both firms’ and consumers’ costly efforts to transmit and assimilate the 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 an innovative idea, instead of extracting a higher rent by keeping the idea secret, can be optimal. A firm may benefit from the presence of competitors and their communication efforts. The innovator can share its innovation so that competitors can also profit, which encourages the rivals to enter the market and exert more efforts to expand the market together. Moreover, the presence of the competition guarantees a higher surplus for consumers, which can induce greater consumer efforts in a two-sided communication. The increased consumer effort, in turn, prompts complementarity in the communication process and lessens the potential free-riding effect in communication between firms, especially when the role of consumers becomes more important in a two-sided communication. Sharing innovation with a rival serves as a mechanism to induce more efforts in a two-sided communication.

Keywords: Communication, information disclosure, endogenous demand, strategic complementarity, strategic substitutability, free-riding.

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1 Introduction

In 2014, within four years of its IPO, Tesla Motors had already achieved a market value half that of Ford’s. That same year, the company decided to share all of its patents with other car manufacturing companies, opening its vault to expand the long-range electronic car market category. This controversial move wasn’t entirely unprecedented. In the semiconductor industry, for instance, it is common practice for an innovative firm – one that has developed a new generation of processor – to license its innovation to one or more competing firms. This strategy creates multiple sources of supply (Semiconductor Licensing Trends 2013) and can spur broader product demand for the next generation semiconductor (Shepard 1987).

In fact, publicly releasing innovative technology has become a routine practice in high-tech markets, with many companies following similar practices. For some products, firms pre-announce 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.

Consider Google: In April 2012, Google announced its marketing plan for the new product, “Google Glass” – a radical wearable technology. Interestingly, the product was at the conceptual stage; Google had not even finalized its prototype. Rather, the Google Glass Team posted a video about an ideal day using their (then) imagined product. The design team shared prototype ideas online. Google marketed “Glass” so early that Samsung, Microsoft, Intel, and many other technology companies quickly followed and announced they would also commercialize a product of wearable technology in the mass market. Although the project was declared a failure due to consumer concerns over privacy and social awkwardness – in January 2015, Google officially announced its plan to withdraw the product from the market – many industry experts acknowledge that Google Glass fostered a market for new wearable technologies. And in December 2015, Google revealed the new version of Glass at a second attempt. Nowadays, technology experts widely recognize wearable technology such as Apple Watch and Samsung Gear as the next big thing for consumers: in 2014, wearable technology had thus far generated $3 billion in revenue; and it is estimated to...
grow to $6 billion by 2016\textsuperscript{9} and $19 billion by 2018.\textsuperscript{10}

In the examples of Tesla and Google Glass, firms released key information on a new technology or product into the public domain. This behavior is curious since this type of information is usually considered a trade secret that serves as a key competitive advantage against potential competitors. When companies market a half-baked idea or share a technological breakthrough, they risk prematurely disclosing a potentially disruptive innovation, resulting in greater competition and weak appropriability in the product market. That is why firms sometimes opt for great secrecy around new products to maximize their competitive surprise (i.e. 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: how much do these firms choose to keep secret, and how much of their innovation do they reveal? We propose an explanation for why a firm sometimes shares an innovative idea with competitors, which might potentially undermine its dominant position in the market, and when this choice (as opposed to keeping the innovation secret) is optimal. Our explanation is based on the persuasion motive of firms in communication and the strategic role of 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 even unclear as to whether they need the product. In this context, the role of marketing communication is to educate consumers and encourage them to deliberate their potential needs, and thus increase product acceptance (Teo et al. 2015). In contrast to incremental innovations, where consumers generally know the benefits from the category, and can passively learn about the value of new features from advertising, consumers bear relatively high costs to learn about the potential benefits of revolutionary new products.\textsuperscript{11} Therefore, a key challenge to market a radical innovation is to persuade consumers to expend more effort in paying attention to the content, assimilating the new idea, and deliberating their needs by examining an unproven product category. For example, consumers can be aware of new wearable technology products like Google Glass from advertising alone. 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 for a product that seems to aim at tech geeks but not them.\textsuperscript{12} Marketers, therefore, need to not only advertise the product and its features but also create the right marketing environment in which customers are willing to invest

\textsuperscript{11}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 an existing product or service whose performance has been enhanced or upgraded. Consumers already have a stable preference for such products.
\textsuperscript{12}“Glass, Darkly for its wearable computer to be accepted, Google must convince people that the device isn’t creepy”, MIT Technology Review, http://www.technologyreview.com/review/524576/glass-darkly
in costly learning. Without consumers on board, the firm’s effort alone is sometimes insufficient to convey the new idea and convince 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 new innovation. Thus, we model marketing communication for a radical product as two-sided costly communication, a process that involves both firms’ and consumers’ efforts to transmit and assimilate information (Wernerfelt 1996, Dewatripont and Tirole 2005).13 Through this two-way communication process, consumers can come to understand product’s uses and benefits and become potential buyers. Therefore, successful marketing communication is a critical process whereby a firm creates a market for a novel product.

In the situations where two-sided costly communication plays an important role in endogenously creating and expanding the demand for the new product category, the firm’s incentive to disclose its innovation to competitors or to keep it secret is determined by the trade-off between the two effects. On the one hand, by disclosing its innovation to competitors, firms can invite the competitors to share costly communication efforts and thus expand the total market size through cooperation in 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 efforts.14 However, we show that when both firms’ and consumers’ communication efforts endogenously determine the market demand for the new product category, strategic consumers alleviate the potential free-riding effects of rival firms. 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 effort in deliberating about the new innovation. In turn, this increased consumer effort encourages firms further to put more effort into the communication stage. This complementarity in communication between firms and consumers through consumers’ strategic decision mitigates the potential free-riding problem. Therefore, to induce greater consumer efforts, an innovator may benefit from inviting competitors by sharing an idea. On the other hand, the firm 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 the 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 “cooperation” (Brandenburger and Nalebuff 1996) – whether to cooperate with competitors to increase the total market size (which can be achieved by sharing their innovation with competitors) or to compete against competitors

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13 In reality, we can observe the necessity of 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 time to pay attention, they will not absorb and 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 and accepted by the students. Both efforts are necessary for the communication to succeed.

14 The free-riding effect on competitor’s service efforts on retail competition (also, known as showroaming effect) is analyzed in Shin (2007).
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 and 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, with firms bearing all the costs. In those models, consumers become informed effortlessly and recognize their needs once they are exposed to a firm’s advertising. In contrast, we recognize that the success of communication requires both a firm’s persuasion efforts and consumers’ learning or elaboration efforts. Wernerfelt (1996) is the first paper that recognizes marketing communication as teamwork between firms and consumers, and he suggests that an efficient communication plan should induce the efficient division of labor between the two parties. Dewatripont and Tirole (2005) formalized this perspective and developed a model of communication. They argued that the acts of formulating and absorbing the content of communication are privately costly, and the successful communication depends on the efforts of both sender and receiver together. Furthermore, they suggested that communication efforts are strategic complements; that is, one side will try harder if the other side also tries harder. In contrast, Mayzlin and Shin (2011) consider firms’ and consumers’ efforts in communication as substitutes. They show that inducing consumers’ efforts in the communication is sometimes more efficient for firms to communicate its quality information. We expand the framework of Dewatripont and Tirole (2005) by incorporating the 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 efforts. Our model explores several interesting trade-offs between these two key strategic effects in communication and its implications for secrecy within an innovative firm.

Second, a number of papers examine 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 explore its implications for a firm’s strategy (Guo and Zhang 2012, Kuksov and Villas-Boas 2010, Villas-Boas 2009, Wathieu and Bertini 2007). Wathieu and Bertini (2007) explores the firm’s pricing strategy to spur deeper thinking among consumers about the personal relevance of product benefits; others (Guo and Zhang 2012, Kuksov and Villas-Boas 2010, Villas-Boas 2009) explore the firm’s optimal product line decisions when consumers need to incur costly deliberation efforts to evaluate the product. We also explore the implications of consumers’ costly efforts for deliberation to evaluate a new product, but our focus is on the
consumers’ essential 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 stream of research in this area focuses on a firm’s choice between patenting and secrecy. Several papers (Kultti et al. 2007, Denicolo and Franzoni 2004, Horstmann et al. 1985, and Anton and Yao 2004) have examined the conditions when to disclose secrets for patent protection and when to retain trade secrets internally emphasizing the fact that patents protect but publicize the firm’s proprietary knowledge. Competitors can imitate and create differentiated products. Thus, firms may sometimes forgo patenting and keep secrets internally.

Another stream of research in this area deals with the information sharing decision in the context of R&D – whether or not a firm discloses its interim R&D results to the public. If R&D contests are “winner-take-it-all”, firms disclose pessimistic or no information to discourage a rival’s investment (Hendricks and Kovenock 1989 and Gill 2008). If the appropriability of innovation is weak, the free-riding incentive arises and firms disclose positive information about their interim R&D results to further encourage a rival’s R&D investment (De Fraja 1993 and Jansen 2010). While the appropriability of innovation is exogenously given in these papers, the appropriability in our model is endogenously determined by the degree of information disclosure; more importantly, we further analyze how this endogenous appropriability affects the rival’s incentive to invest in communication efforts in equilibrium.

Fourth, broadly speaking, our research deals with a firm’s strategies around cooperation and competition with competitors, an important issue of coopetition (Brandenburger and Nalebuff 1996). A large body of literature examines various forms of coopetition such as strategic alliances among competing firms (Amaldoss et al. 2000, Bucklin and Sengupta 1993, Luo et al. 2007, Harbison and Pekar 1998), collaboration with a rival firm through licensing (Inkpen 1996, Steensma 1996), and impacts of these actions on innovation (Bonaccorsi and Lipparini 1994, Hamel et al. 1989, Nieto and Santamaria 2007, Tsai 2009). Our paper contributes to this literature by providing another new micro-foundation for coopetition based on the firm’s communication motives.

Similar to ours, there are several papers which 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 (Choi and Davidson 2004, Farrell and Gallini 1988, Shepard 1987, Wernerfelt 1994). More specifically, inviting competitors can serve as a credible commitment to lower future price (Farrell and Gallini 1988, Wernerfelt 1994) or higher future quality (Shepard 1987), both of which guarantee a higher future consumer surplus that would not be credible with the monopoly case. Our paper captures a similar insight, but differ in two major respects. First, the focus of our model is the role of the two-sided process of communication, and we provide a micro model for how and when a higher future con-

Harbison and Pekar (1998) find that more than 50% of strategic alliances are typically formed among competing firms within the same industry.
sumer surplus (generated by inviting competition) can lead to greater market demand based on
the communication mechanism. In 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 when second-sourcing can
generate higher total market demand by recognizing the potential free-riding problem in the pro-
cess of creating greater market demand. 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 strategic substitutes (between firms) and the strategic
complementarity (between consumers and firms) is 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 literature in this area is that the firm’s motive is to deter the entry of
competitors, and preannouncement can be used to achieve this end through communication with
competitors (Bayus et al. 2001, Haan 2003, and Ofek and Turut 2013) or consumers (Farrell and
Saloner 1986, Gerlach 2004, and Choi et al. 2005). Our paper primarily differs from these papers in
that we provide another strategic motive of preannouncement – to invite the competitor to enhance
the potential market demand through jointly communicating with consumers. In our extension, we
further investigate when inviting competition (through disclosing information or preannouncement)
can serve as an entry deterrence or an entry invitation.

3 Model Set-up

The market consists of two firms, firm 1 and 2, and a continuum of consumers with mass of 1. Firm
1 is an innovator who 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 $d$ as the amount of information that firm 1 chooses to
disclose, and thereby, $1 - d$ represents the level of secrecy. 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
or not to enter the market by following the new idea and developing a similar product in the same
product category, $\chi = \{0, 1\}$. If the follower decides not to enter ($\chi = 0$), the final product market

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16 In our model, the 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 the supply side efforts such as advertising to enhance consumer awareness or learning (Agarwal and Bayus 2002,
Shen and Xiao 2014; Shen 2014).

17 We use the terms “secrecy” and “disclosure” interchangeably throughout the paper.

18 Here, we make a simplifying assumption that the competitor can immediately understand the value of the new
innovation, and therefore, can always make a similar product once a little piece of the innovation is shared ($d > 0$).
Although competitors work on the identical concept (such as wearable technology or long-range electric car), the final
products are differentiated because firms can have different product designs and features (such as Google Glass vs.
Samsung Gear, Tesla Model S vs. BMW i5).
The innovator, the follower (if $\chi = 1$), and consumers choose communication efforts simultaneously.

Communication succeeds with probability $\sigma(e_1 + e_2, e_2)$.

Stage 1:
- The innovator discovers a new idea, and decides the degree of disclosure $d \in [0,1]$ after observing $d$.
- The follower decides whether or not to enter the new product market $\chi = \{0,1\}$ after observing $d$.

Stage 2:
- The innovator, the follower (if $\chi = 1$), and consumers choose communication efforts $\{e_1, e_2, e_c\}$ simultaneously.
- Communication succeeds with probability $\sigma(e_1 + e_2, e_2)$.

Stage 3:
- Firms choose their prices $\{p_1, p_2\}$ and compete in the product market.
- Consumers realize their idiosyncratic preference shock $\epsilon$ and make purchase decisions after observing $\{p_1, p_2\}$.

Figure 1: Sequence of the game

will be a monopoly. If the follower decides to enter ($\chi = 1$), the market 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 to be a two-sided costly process that involves both firms' and consumers' efforts. Successful communication endogenously generates consumers' need recognition and thereby market demand for a novel product.

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

We analyze the strategic interactions not only among the competing firms but also between the firms and the consumers. Thus, 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, which are endogenously interlinked. 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 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 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), (2) on the equilibrium outcomes of the communication game between firms and consumers (stage 2 – communication subgame), and (3) on the equilibrium outcomes of the pricing game in the product market (stage 3 – product market competition subgame). In addition, the communication efforts by firms and consumers endogenously determine the potential market demand, which clearly affects the equilibrium payoffs for the firms in the product market in stage 3. When the firms 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 the secrecy of the 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 the technological leadership 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, \( d \in [0, 1] \). Here, we impose a truth-telling assumption such that 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 which can directly affect the relative competitive advantage of the innovator (e.g., Tesla and semiconductor companies). 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 actual market availability through preannouncement. By making preannouncement, firms can deliver information on a product while it is still being developed. In the preannouncement cases, \( d \) can be interpreted as the length of time prior to 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 on 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 on time when the actual product is launched.

Note that the credibility of the announcement is an important issue, and preannouncement can be a pure cheap talk (Bayus et al. 2001, Choi et al. 2005, and 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 market competition, and analyze the strategic motives for a firm to convey its private information on a new innovation to change other parties’ behavior in a way that is beneficial to the firm.

We capture the influence of information disclosure on the innovator’s competitive advantage through cost advantage.\(^{20}\) We assume that the innovator can retain its cost advantage stemming from the fixed cost \( \epsilon > 0 \) associated with the information disclosure. The cost \( \epsilon \) is a tie-breaker: when the innovator is indifferent between disclosure and no disclosure, it chooses no disclose because of this fixed cost. Alternatively, one can model the competitive advantage through demand advantage (consumers have higher willingness to pay for the innovator’s product, and the sharing of innovation reduces this advantage). We explored this specification, but the qualitative results remain the same. Also, we restrict the effect of information disclosure on the competitive advantage. However, it is possible that “\( d \)” can directly influence consumer’s incentive to invest in the efforts (not just indirectly through the follower’s entry), which would strengthen our mechanism. Even without this direct effect, we can show the importance of consumers’ role in communication to enhance new product category demand.

\(^{19}\)We assume there is a fixed cost \( \epsilon > 0 \) associated with the information disclosure. The cost \( \epsilon \) is a tie-breaker: when the innovator is indifferent between disclosure and no disclosure, it chooses no disclose because of this fixed cost.

\(^{20}\)Alternatively, one can model the competitive advantage through demand advantage (consumers have higher willingness to pay for the innovator’s product, and the sharing of innovation reduces this advantage). We explored this specification, but the qualitative results remain the same. Also, we restrict the effect of information disclosure on the competitive advantage. However, it is possible that “\( d \)” can directly influence consumer’s incentive to invest in the efforts (not just indirectly through the follower’s entry), which would strengthen our mechanism. Even without this direct effect, we can show the importance of consumers’ role in communication to enhance new product category demand.
from its technical breakthrough if the firm keeps it secret. For example, when Procter & Gamble first introduced disposable diapers in 1969, the company used a new synthetic fiber technology that helped them to enjoy the cost advantage over the competition (Morrison et al. 1992). First, we fix the innovator’s marginal production cost as $m_1 = 0$, and assume that the follower’s marginal production cost as $m_2(d)$, which is a decreasing function of $d$; i.e., $m_2(d) = \bar{m} \cdot (1 - d)$. Hence, $m_2(d = 1) = 0$, and $m_2(d = 0) = \bar{m} > 0$. This implies that when $d = 1$, the technical innovation is shared with the competitor perfectly, and the innovator has no relative cost advantage ($m_1 = m_2(d = 1) = 0$) while the competitive advantage is maximized when $d = 0$ ($m_2(d = 0) = \bar{m} > 0 = m_1$).

**Communication technology**

We consider a communication technology where both the firms and consumers simultaneously exert elaboration and learning efforts to transfer and assimilate the idea.\(^{21}\) The probability that the idea is properly communicated to and accepted by consumers is

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

where $e_f \in [0, 1]$ is the aggregate effort exerted by the firms to transmit an idea and persuade consumers to accept it, and $e_c \in [0, 1]$ is consumers’ effort to pay attention, deliberate and assess this message. 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 efforts. Then, the communication succeeds stochastically with a probability $\sigma(e_f, e_c)$, and therefore, some of them realize the value of the innovation and consumers become *ex-post* heterogeneous. Moreover, $k \in [0, 1]$ captures the relative importance of the efforts in communication.

For example, Tesla Model S and Toyota Corolla E160 (which is the 11th generation of Corolla) were introduced to the market around the same time in 2012. 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 the alternative new technology and deliberate their potential needs for it. Tesla Model S represents a case where $k$ is small where consumers play a critical role in marketing communication. In contrast, since Corolla E160 is the 11th generation of this series, consumers had prior experiences in driving gasoline cars and had seen different generations on the street. As long as they were just aware of the introduction of the 11th generation of Corolla, they might consider this car. This case corresponds to the case where $k$ is large.

When a radical new product category (such as HDTV, recordable DVD and satellite radio) is first introduced in the market, the market demand is unknown and, firms need to expand efforts to stimulate greater demand by showing advertisements that mainly promote the benefits and the

\(^{21}\)In our extension (Section 5.1), we allow firms’ and consumers’ effort choices to be sequential and show the robustness of our results.
advantages of the new product concepts without touting brand-specific features (Bass et al. 2005, Lu 2016). 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 the product’s uses and benefits to enhance product acceptance (Beardi 2001). One can think of these advertising activities as a firm’s communication effort $e_f$.

On the other hand, when consumers face these new radical product categories, which are often technically complicated, they are uncertain about the value or benefits of the product because they have no prior experience to understand it (Jing 2016, Li et al. 2016). Therefore, consumers need to expend significant costs of thinking (Shugan 1980) to deliberate the potential benefits or uses of new product innovation. For example, when Google Glass was first introduced, consumers need to imagine how her life would have changed using this new technology, which requires substantial deliberation or learning efforts. Consumers who have not experienced these products would find it difficult to assess the exact value of such a new feature. Thus, consumer efforts to resolve such uncertainty surrounding new innovation are substantial. Such efforts can consist of search cost for all relevant information, the 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 depletion of cognitive resources (Shugan 1980, Guo and Zhang 2012). Thus, communication efforts involve private costs $C(e)$ for the firms and consumers. We assume these costs are increasing and convex such that $C(e) = e^2$.

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 the consumers:

$$\sigma_{fc} = \frac{\partial^2 \sigma(e_f, e_c)}{\partial e_f \partial e_c} \geq 0.$$  

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).” Finally, another key characteristic of our communication technology is that the efforts of the two firms are strategic substitutes:

$$\sigma_{12} = \frac{\partial^2 \sigma(e_1, e_2)}{\partial e_1 \partial e_2} \leq 0.$$  

Because communication involves private costs, the 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, $\sigma_1 = \frac{\partial \sigma(e_1 + e_2, e_c)}{\partial e_1} = \frac{\partial \sigma(e_1 + e_2, e_c)}{\partial e_2} = \sigma_2$.  

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22 XM’s ads will be about continuing to ‘grow the whole category pie,’ rather than competing with Sirius” (Boston and Halliday 2003). Lu (2016) provides a micro-mechanism how and why such unbranded advertisement can be more efficient in generating the total demand than branded advertisement.

23 Note that this strategic complementarity arises because $\sigma$ is an endogenous outcome of the strategic choices by the firms and the consumers. On the other hand, as Dewatripont and Tirole (2005) explained, if $\sigma$ is fixed and exogenously given, one side expends less effort as the other side has expended more effort.

24 The firms may have asymmetric influences in persuading consumers. We can capture the asymmetry by setting the
Given this communication technology, the communication of idea can fail (with probability $1 - \sigma$). In this case, consumers cannot be aware of the potential benefits for the new idea (for example, consumers might think the new innovation such as Google Glass is only for geeks but not for them). Thus, they will not even consider purchasing the new product. On the other hand, if the idea is successfully communicated (with probability $\sigma$), consumers become educated about the radical innovation; they understand the potential benefits of the new product idea and consider purchasing the product. Those who become educated about the radical innovation are the potential buyers when the products become available in the market. Thus, marketing communication efforts endogenously create and expand the expected demand (i.e., total market size) for the new product category $\sigma^T = \sigma(e_f, e_c)$. Hence, $\sigma^T$ also measures the number of potential buyers.

**Competition in the product market**

The product market competition is captured through the Salop’s circular city model. The innovator, firm 1, can be located at any place on the circle, which becomes the center of the circle in the monopoly case. When the market is a duopoly, the two firms are located on the circle with the furthest distance. They compete in prices by charging $p_1, p_2$, respectively when the market is a duopoly. If the market is a monopoly, only the innovator chooses the monopoly price $p_1$.

Potential buyers receive a base consumption utility $v > 0$ if they purchase a product. Besides $v$, potential buyers receive an idiosyncratic match in terms of their location. The locations of the potential buyers 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 the half of the circumstance, $z_j \sim U \left[0, \frac{1}{2}\right]$. Accordingly, her distance from firm 2 is $\frac{1}{2} - z_j$ in the duopoly case because the two firms are furthest located on the circle. Potential buyer $j$ obtains utility $u_{1j} = v - tz_j - p_1$ if purchasing from firm 1 and utility $u_{2j} = v - t\left(\frac{1}{2} - z_j\right) - p_2$ if purchasing from firm 2, where the travel cost $t$ captures the extent of product differentiation between the two products. After observing their preferences $z_j$ and the prices, potential buyers make their purchase decisions and the firms receive their payoffs. We assume $v$ is sufficiently large ($v > \frac{3t}{2}$) that all potential buyers purchase from one of the two firms in the duopoly case in equilibrium.

4 Analysis

The game consists of three subgames: innovation disclosure, communication, and product market competition. We begin our analysis using backward induction to solve the game and use the Subtotal firm-side effort as $e_F = \beta e_1 + e_2$. The parameter $\beta$ affects the exact equilibrium effort levels, but the underlying mechanism and our main results do not change due to the additive form of the specification.
game Perfect Equilibrium as our solution concept. All the proofs are presented in the Appendix.

4.1 Stage 3: Product market competition

We first solve the final stage of the game – the product market competition. We denote firm 1’s disclosure level as $d$ and the firms’ aggregate communication effort and consumers’ effort as $(e_f, e_c)$. These will be endogenously determined in equilibrium, but 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 $d$ such that for all $d \geq d$, firm 2 chooses to follow firm 1’s idea and enter the market with a fixed cost $f$ ($\chi = 1$), and thus the market is a duopoly at Stage 3. For simplicity, we assume that a fixed cost $f = 0$.\footnote{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 much additional insight. Even under the imperfect observability of consumer effort, firms can infer the level of consumer effort correctly in equilibrium. The current approach to adopting SPE is a simplification of the reality to make our key messages more transparent and clear.}

Given a fixed $d \geq d$ and communication efforts $e_f = e_1 + e_2$ and $e_c$, the total number of potential buyers is fixed as $\sigma^T = \sigma(e_f, e_c)$. Those are consumers who are convinced about the need for the new product innovation through a successful communication with a probability $\sigma$. Potential buyer $j$ purchases from firm 1 if $u_{1j} = v - tz_j - p_1 \geq v - t(\frac{1}{2} - z_j) - p_2 = u_{2j} \Leftrightarrow z_j \leq \frac{1}{4} - \frac{p_1 - p_2}{2t} \equiv z^*$. Thus, firm 1’s demand is $D_1(p_1, p_2) = \sigma^T \cdot 2z^*$ and firm 2’s demand $D_2(p_1, p_2) = \sigma^T \cdot (1 - 2z^*)$.\footnote{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.}

Here, we can consider $\sigma^T$ as 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 $R_1, R_2$:

$$
\begin{align*}
    p_1^D &= \arg\max_{p_1} R_1(p_1; p_2^D) = \sigma^T (p_1 - m_1)(\frac{1}{2} - \frac{p_1 - p_2^D}{t}) \\
    p_2^D &= \arg\max_{p_2} R_2(p_2; p_1^D) = \sigma^T (p_2 - m_2)(\frac{1}{2} - \frac{p_2 - p_1^D}{t})
\end{align*}
$$

where firm 1’s marginal cost $m_1 = 0$ and firm 2’s marginal cost $m_2 = \overline{m} \cdot (1 - d)$.

Then, we have the equilibrium duopoly prices $p_1^D = \frac{t}{2} + (1 - d)\frac{m}{3}$, $p_2^D = \frac{t}{2} + (1 - d)\frac{2m}{3}$. Because the firm 2’s marginal production cost should be low enough to enable it to make positive profit in the product market $p_2^D \geq m_2$, we obtain that $d \geq d = 1 - \frac{3m}{2\overline{m}}$.\footnote{At any location on the circle, firm’s demands come from two different sides – the one from the area on the right side from the firm’s location and the other from the area on the left side from the firm’s location. On each side, consumers are distributed uniformly and the consumer’s distance to firm 1 follows $z_1 \sim U[0, \frac{1}{2}]$. Hence, the firm 1’s demand is $2z^*$ and firm 2’s demand is $1 - 2z^*$.}

We assume that $\overline{m} > \frac{3m}{2}$ for the existence of $d = 1 - \frac{3m}{2\overline{m}}$. Also, $v > \frac{3t}{2}$ ensures that even the marginal consumer...
Also, the equilibrium duopoly retail profits are
\[
\begin{align*}
R_1^D &= \sigma^T \cdot \frac{(3t+2(1-d)\bar{m})^2}{36t} = \sigma^T \cdot \pi_1^D, \\
R_2^D &= \sigma^T \cdot \frac{(3t-2(1-d)\bar{m})^2}{36t} = \sigma^T \cdot \pi_2^D,
\end{align*}
\]
where \( \pi_1^D = \frac{(3t+2(1-d)\bar{m})^2}{36t} \) and \( \pi_2^D = \frac{(3t-2(1-d)\bar{m})^2}{36t} \) are average profit that firm 1 and 2 make in the duopoly product market per customer, respectively. Note that this average profit \( \pi_i \) is independent of the total market size, and only captures the marginal benefit to the firm from the increase in the total category demand \( \sigma^T \). The average profit will play an important role in the subsequent analysis.

Therefore, as long as firm 1 discloses sufficient information \( d \geq d = 1 - \frac{3t}{2\bar{m}} \), firm 2 makes a non-negative profit by entering the market. Also, note that given \( \sigma^T \), 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., \( d < d \)).

**Monopoly (\( \chi = 0 \))**

As long as firm 1 keeps a sufficient degree of secrecy \( d < d \), 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 buyers make purchase decisions once they observe the prices and their preferences \( z_j \). Consumer \( j \)'s utility is \( v - tz_j - p_1 \) if he decides to buy. Consumer \( j \) purchases the product if the utility \( v - tz_j - p_1 \geq 0 \iff z_j \leq \frac{v-p_1}{t} \). Thus, the market demand for firm 1’s product is \( D_1(v, p_1) = \sigma^T \cdot \max \{2 \cdot \frac{v-p_1}{t}, 1\} \).

Under the market coverage condition in the duopoly \( v > \frac{3t}{2} \), the equilibrium price is \( p_1^M = v - \frac{t}{2} \), and the market demand is \( D_1 = \sigma^T \cdot 30 \). Firm 1’s monopoly retail profit is
\[
R_1^M = \sigma^T \cdot (v - \frac{t}{2}) = \sigma^T \cdot \pi_1^M
\]
where \( \pi_1^M = v - \frac{t}{2} \) is the average profit that firm 1 makes in the monopoly market per customer.

Clearly, the innovator enjoys greater average profits under the monopoly situation, \( \pi_1^M > \pi_1^D \). Moreover, we find that even the total firm-side average profit under the duopoly \( (\pi_1^D(d) + \pi_2^D(d)) \) is always smaller than under the monopoly case: \( \pi_1^D(d) + \pi_2^D(d) = \frac{t}{2} + \frac{2(1-d)^2\bar{m}^2}{9t} < \frac{t}{2} + \frac{2(1-d)^2\bar{m}^2}{9t} = \frac{t}{2} + \frac{(\frac{\bar{m}}{4\sigma^T} - 2\bar{m})}{9t} \| q_1 = t < v - \frac{t}{2} = \pi_1^M \), where \( d = 1 - \frac{3t}{2\bar{m}} \).

\( z^* = \frac{1}{4} + \frac{\bar{m}(1-d)}{6t} \) who is indifferent between purchasing from firm 1 and firm 2, receives a positive utility in equilibrium: \( u^* = v - t \left( \frac{1}{4} + \frac{\bar{m}(1-d)}{6t} \right) - \frac{t}{2} = (1-d)\bar{m} > 0 \).

\(^{30}\)The optimal price from F.O.C. is \( p_1 = \arg \max_{p_1} \pi^T p_1 2 \frac{\bar{m}}{t} = \frac{v}{2} \). However, even the consumer with the furthest location \( z_j = \frac{v}{2} \) finds a positive utility under this price: \( u_j = v - \frac{t}{2} - \frac{v}{2} > 0 \) because \( v > \frac{3t}{2} \). Hence, the equilibrium price is determined by making the furthest consumer indifferent between purchase and no purchase: \( u_j = v - \frac{t}{2} - p_1 = 0 \iff p_1^M = v - \frac{t}{2} \), and the market demand is \( D_1 = \sigma^T \).
Lemma 1. The total firm-side average profit is greater under the monopoly than the duopoly case: 
\[ \pi_1^D(d) + \pi_2^D(d) < \pi_1^M, \text{ for all } d \in [d, 1]. \]

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, a process in which firms and consumers both exert costly efforts. All three players involved in marketing communication (firm 1 and 2, and consumers) are strategic and forward-looking. For a given \( d \) from firm 1’s choice in the first stage, each player decides on their communication efforts anticipating the equilibrium product market outcomes at stage 3. Firm 1 and firm 2 decide on the communication efforts \( e_1, e_2 \), and consumers also decide on their efforts \( e_c \). Since consumers have not yet observed the idiosyncratic preferences \( z_j \sim U[0, \frac{1}{2}] \), they form expectations on the consumption utility taking into account the equilibrium prices offered by both firms in the product market at stage 3:

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

When we compare the expected utility of consumers between the monopoly and duopoly cases, it is immediate that the competition of duopoly provides a higher expected consumer utility. Thus, competition can serve as a credible commitment to guarantee a higher consumer surplus.

Lemma 2. The consumer’s expected utility from purchasing the product is higher under duopoly than monopoly market: \( \tilde{u}^D > \tilde{u}^M \).

Strategic complementarity and substitutability

When \( d < d \), 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:

\[
E\Pi_1 = \left( e_1^k \cdot e_c^{1-k} \right) \pi_1^M - \frac{e_1^2}{2}, \\
EU = \left( e_1^k \cdot e_c^{1-k} \right) \tilde{u}^M - \frac{e_2^2}{2}. \tag{6}
\]

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

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

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

\[ e_{1}^{M} = \left( k \pi_{1}^{M} (e_{c})^{1-k} \right)^{\frac{1}{1-k}}, \]

\[ e_{c}^{M} = \left( (1-k) \tilde{u}^{M} (e_{1})^{k} \right)^{\frac{1}{k+1}}, \] (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 the own expected average payoffs from the product market \( \pi_{i}^{M} \) and the expected utility \( \tilde{u}^{M} \), respectively.

Next, when \( d \geq d_{i} \), 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:

\[ E\Pi_{i} = (e_{f}^{k} \cdot e_{c}^{1-k}) \pi_{i}^{D} - \frac{c_{i}^{2}}{2}, \]

\[ EU = (e_{f}^{k} \cdot e_{c}^{1-k}) \tilde{u}_{i}^{D} - \frac{c_{i}^{2}}{2}, \]

where \( i = 1, 2 \), and \( e_{f} = e_{1} + e_{2} \) is the firm side total effort.

Same as in the monopoly market case \((\chi = 0)\), there exist a strategic complementarity effect between consumers’ effort and firms’ aggregate efforts:

\[ \frac{\partial^{2} E\Pi_{i}}{\partial e_{i} \partial e_{c}} = k (1-k) e_{f}^{k-1} e_{c}^{-k} \pi_{i}^{D} \geq 0, \quad \text{for all } i=1,2. \] (10)

The equilibrium efforts for firm \( i \in \{1, 2\} \) and consumers are implicitly given by the first-order conditions: \( e_{i}^{D} = k \pi_{i}^{D} (e_{c})^{1-k} \left( \frac{e_{f}^{k}}{e_{c}^{k-1}} \right)^{\frac{1}{k+1}}, \) \( e_{c}^{D} = \left( (1-k) \tilde{u}_{i}^{D} \left( e_{f}^{k} \right)^{k} \right)^{\frac{1}{k+1}} \). Similar to the monopoly case, the optimal effort of firm \( i \) \( (e_{i}^{D}) \) is increasing in consumer side’s effort \( e_{c}^{D} \), and its own expected average profit \( \pi_{i}^{D} \).31 However, different from the monopoly case, the firm \( i \)’s effort is now affected by the other rival firm \(-i\)’s effort. The communication game shows the strategic substitutability between each firm’s individual effort:

\[ \frac{\partial^{2} E\Pi_{i}}{\partial e_{i} \partial e_{-i}} = -k (1-k) e_{f}^{k-2} e_{c}^{-k} \pi_{i}^{D} \leq 0. \] (11)

This strategic substitutability between each firm’s individual effort creates a free-riding problem in communication. The success of communication benefits both firms, but efforts are costly. Therefore, each individual firm has an incentive to free ride on the other firm’s costly effort and lower its own effort in response to increased effort by the other firm.32

Because of the co-existence of the strategic complementarity and the strategic substitutability in communication, the total effect of an increase in the rival firm’s effort on the focal firm’s own effort

31 Also, the optimal level of effort for consumers \( e_{c}^{D} \) is again increasing in the other side’s efforts (the firm side’s total effort \( e_{f}^{D} \)) and its own expected utility in the product market \( \tilde{u}_{i}^{D} \).

32 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: \( \frac{\partial e_{i}}{\partial e_{-i}} = \frac{1}{1 + (\frac{c_{i}^{2}}{2})^{\frac{1}{k+1}} (1-k) \tilde{u}_{i}^{D}} \leq 0. \)
is ambiguous. There are two (direct and indirect) effects. On one hand, firm $i$’s best response to an increase in the rival firm’s effort is to decrease its own because of the free-riding effect (equation 11). On the other hand, due to the strategic complementarity effect between $e_c$ and $e_i$, consumers’ effort $e_c$ increases with firm $-i$’s effort ($\frac{\partial e_c}{\partial e_i} \geq 0$). Furthermore, this increased consumer-side effort ($e_c$) incentivizes firm $i$ to raise the effort ($\frac{\partial e_i}{\partial e_c} \geq 0$). This is the indirect effect of firm $-i$’s effort on the firm $i$’s effort through consumers. 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 surplus from the product market: $\frac{\partial e_i^M}{\partial \pi_i^M} \geq 0$, $\frac{\partial e_i^D}{\partial \pi_i^D} \geq 0$ (for $i = 1, 2$), and $\frac{\partial e_i}{\partial \tilde{u}} \geq 0$.

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

The incentives for all players (the firms and the consumers) 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 is only determined by the split of the total product market profits regardless of levels of consumers efforts. That is, the ratio of efforts $\frac{e_1}{e_2}$ between the two rival firms is equal to the ratio of their expected average profits $\frac{\pi_1^D}{\pi_2^D}$. Hence, the innovator may disclose more information to increase the competitor’s average profit, which can induce the competitor to shoulder more communication costs and expand the total market size. For example, when $d = 1$ (full disclosure), the expected average profits are identical ($\pi_1^D = \pi_2^D$), and thus, the equilibrium levels of efforts are the same ($e_1^D = e_2^D$). But the exact level of firms’ efforts is affected by consumer efforts, which are again influenced by consumers’ expected payoffs from the product market.

Further, we already know that the 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 have the following corollary.

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

The presence of a competitor serves as a commitment mechanism to assure consumers that they will receive higher utility in the product market (Lemma 2), which increases the incentives for consumers to expend more costly effort in deliberating about the new innovation. Therefore, consumers have more incentives to expend costly learning efforts under duopoly than under monopoly.
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

\[ \sigma^T = (k \pi_f)^k ((1 - k) \tilde{u})^{1-k} \]  

where \( \pi_f \) denotes the firm side aggregate average retail profit. If the market is a monopoly, \( \pi^M_f = \pi^1 \); if the market is a duopoly, \( \pi^D_f = \pi^1 + \pi^2 \).\(^{33}\)

The direct comparison of the total market size \( \sigma^T \) under duopoly and monopoly (equation 12 above) allows us to identify the exact condition under which the market expands under duopoly.

**Proposition 2.** For any given \( d \in [0, 1] \), there always exists a threshold \( \bar{k}(d) \equiv \frac{1}{1 + (\ln(\pi^1_M/\pi^1_D + \pi^2_D))/(\ln(\tilde{u}_D/\tilde{u}_M))} \) such that for all \( k \leq \bar{k}(d) \), the total market size is greater under duopoly than under monopoly: \( \sigma^{TD}(d) \geq \sigma^{TM} \).

The proposition suggests that whether or not the market expands under duopoly depends on the consumers’ expected utility \( \tilde{u} \) and the firms’ aggregate average retail profits \( \pi_f \). More importantly, as consumers play an even more important role (i.e., \( k \leq \bar{k} \)), the market tends to expand under duopoly. Thus, the innovator is more likely to disclose its innovation to invite competitor.

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

### 4.2.1 One-sided Communication – Only firm-side effort matters

Here, we look at a benchmark where marketing communication is purely one-sided; that is, only firms’ efforts matter. This is a situation where consumers can passively learn about the potential

\(^{33}\)It immediately follows from the calculation of the equilibrium efforts in the proof of Proposition 1. We know the total firm-side equilibrium effort is \( e_f = (k \pi_f)^{(1+k)/2} ((1 - k) \tilde{u})^{(1-k)/2} \), and consumer-side equilibrium effort is \( e_c = ((1 - k) \tilde{u})^{1-k/2} (k \pi_f)^{k/2} \). Thus, \( \sigma^T = (e_f)^k (e_c)^{1-k} = (k \pi_f)^{k(1+k)+k(1-k)/2} ((1 - k) \tilde{u})^{k(1-k)+(2-k)(1-k)} = (k \pi_f)^k ((1 - k) \tilde{u})^{1-k} \).
benefit of the product through firms’ efforts such as advertising. We study the extreme case of
\( k = 1 \), where only firms’ efforts affect the success of communication and the size of the potential
market. Consumer effort \( e_c \) has no effect on the outcome of communication.

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

When \( d \geq d^* \), the market becomes duopoly. Both firms decide their communication efforts. Since
consumers do not play a role in the marketing communication, there only exists the free-riding
effect between the two firms. Firm 1 and 2’s efforts \( e_1 \) and \( e_2 \) maximize
\[
E\Pi_1^D = (e_1 + e_2) \pi_1^D - \frac{e_1^2}{2},
\]
\[
E\Pi_2^D = (e_1 + e_2) \pi_2^D - \frac{e_2^2}{2},
\]
respectively. Then, their optimal efforts are
\[
e_i^D = \pi_i^D, \quad i = 1, 2.
\]
And the total firm-side effort is
\[
e_{12}^D = \pi_1^D + \pi_2^D = \frac{t}{2} + \frac{2(1-d)^2 m^2}{9t}.
\]
Then, their expected payoffs under duopoly are
\[
E\Pi_1^D = (\pi_1^D)^2 + \pi_1^D \cdot \pi_2^D
\]
\[
E\Pi_2^D = (\pi_2^D)^2 + \pi_1^D \cdot \pi_2^D,
\]
where
\[
\pi_1^D = \frac{(3t+2(1-d)m)^2}{30t} \text{ and } \pi_2^D = \frac{(3t-2(1-d)m)^2}{30t}.
\]

Comparing the equations (13) and (14), it is immediate that
\[
e_1^M > e_1^D > e_2^D \quad \text{from Lemma 1.}
\]
The market size is only determined by the firm-side effort:
\[
\sigma^M = e_{12}^D = \sigma^TD.
\]

Lemma 3. When the marketing communication is one-sided, the firm-side aggregate effort is always
greater under the monopoly, and so is the total market size: \( e_{12}^M > e_{12}^D \) and \( \sigma^M > \sigma^TD \).

When consumers do not play a role in marketing communication, a duopoly market always leads
to a smaller market size (\( \sigma^TD < \sigma^TM \)). This is a stark contrast to the two-sided communication
case, where the aggregate firm-side effort, as well as the total market size, can be greater under the
duopoly. Moreover, when the communication is only one-sided such that the market does not expand
under the duopoly, the innovator has no incentive to disclose innovation or invite the 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 consumers and firms, the potential benefit from
disclosing information (such as cost-sharing effect in communication – in the next subsection, we
discuss these potential effects of information disclosure in more details) does not compensate for its
profit loss in the product market. Hence, the innovator always prefers to become the monopolist,
and it is never optimal for an innovator to invite competition. The result suggests that sharing
communication costs is not a key driver for the innovator’s information disclosure in stage 1.
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 (\(e_1, e_2, e_c\)), and (3) the equilibrium profits from the product competition (\(\pi_1(d), \pi_2(d)\)). Firm 2 follows the idea and enters the market (\(\chi = 1\)) if \(d \geq d^*_e\), and does not enter the market (\(\chi = 0\)) if \(d < d^*_e\). 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 \(d \geq d^*_e\). Firm 1 chooses a disclosure level \(d\) that maximizes its expected payoff:

\[
E\Pi_1(d) = \sigma^{TD}(d)\pi_1^D(d) - C(e_1^D(d)) = \sigma^{TD}(d)\pi_1^D(d) - \frac{1}{2} (e_1^D(d))^2
\]

(15)

Hence, firm 1 solves the following optimality condition:

\[
\frac{\partial E\Pi_1}{\partial d} = \frac{\partial E\Pi_1}{\partial \pi_1} \cdot \frac{\partial \pi_1^D}{\partial d} + \frac{\partial E\Pi_1}{\partial \sigma} \cdot \frac{\partial \sigma^{TD}}{\partial d} + \frac{\partial E\Pi_1}{\partial C} \cdot \frac{\partial C(e_1^D)}{\partial d}
\]

\[
= \pi_1^D (\frac{\partial \sigma^{TD}}{\partial e_1} \cdot \frac{\partial C(e_1^D)}{\partial d} + \frac{\partial \sigma^{TD}}{\partial e_2} \cdot \frac{\partial C(e_1^D)}{\partial d} + \frac{\partial \sigma^{TD}}{\partial \sigma} \cdot \sigma^{TD} \frac{\partial \pi_1^D}{\partial d}) + \sigma^{TD} \frac{\partial \pi_1^D}{\partial d} - C'(e_1^D) \frac{\partial C(e_1^D)}{\partial d}
\]

(16)

The above equation demonstrates that there are three effects of disclosure in play: (1) the market expansion effect through successful marketing communication \((\frac{\partial E\Pi_1}{\partial \pi_1} \cdot \frac{\partial \pi_1^D}{\partial d})\), (2) the cost-saving effect from the sharing of communication costs with the competitor \((- \frac{\partial E\Pi_1}{\partial \sigma} \cdot \frac{\partial \sigma^{TD}}{\partial d})\), and (3) the retail profit loss from forgoing competitive advantage \((- \frac{\partial E\Pi_1}{\partial \sigma} \cdot \frac{\partial \pi_1^D}{\partial d})\). When the innovator discloses more information about its innovation, its average profit decreases due to the increased competition \((- \frac{\partial E\Pi_1}{\partial \sigma} \cdot \frac{\partial \pi_1^D}{\partial d} \leq 0\), and its saving in communication cost can be larger \((- \frac{\partial E\Pi_1}{\partial \sigma} \cdot \frac{\partial C(e_1^D)}{\partial d} \geq 0\). However, as we have seen from the one-sided communication case, without the market expansion, the cost-saving effect alone cannot fully compensate for the profit loss in the product market (Proposition 3). 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 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 \(k^* = \left(\ln \frac{\pi_1^M}{\pi_1^D} \frac{\pi_1^M}{\pi_1^M} - \ln \frac{\pi_1^M}{\pi_1^D} \frac{\pi_1^M}{\pi_1^M}\right) + \left(\ln \frac{\pi_1^M}{\pi_1^D} \frac{\pi_1^M}{\pi_1^M} + \ln \frac{\pi_1^M}{\pi_1^D} \frac{\pi_1^M}{\pi_1^M}\right)\) such that

1. When \(k > k^*\), the optimal strategy for the innovator is not to disclose any information \(d^c = 0\), and the market becomes a monopoly.\(^{34}\)

\(^{34}\)Technically, without any disclosure cost, any amount of information disclosure \(d \in [0, d^*_c]\) can be optimal. The overall
2. When \( k \leq k^* \), the optimal strategy for the innovator is to disclose sufficient information \( d^e \in [d, 1] \), where \( d = 1 - \frac{3t}{2m} \), such that the follower decides to enter the market \( (\chi = 1) \) and the market becomes duopoly.

When the consumers’ role in communication is sufficiently important (or \( k \) is sufficiently low), the market expansion effect \( \left( \frac{\partial E\Pi_1}{\partial \sigma} \cdot \frac{\partial \sigma^{TD}}{\partial d} \right) \) 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 mechanism to guarantee the greater surplus for consumers, which generates higher consumers’ effort in communication. Only when consumers play an important role in communication, this increased consumer-side effort can lead to higher market demand \( \sigma^{TD} \). Otherwise (i.e., \( k > k^* \)), inviting competition does not increase the market demand due to the free-riding effect between the two rival firms and therefore, the innovator prefers maintaining its competitive advantage by keeping its innovation secret.\(^{35}\)

Figure 2 demonstrates the trade-offs in the innovator’s disclosure decision under two different cases \((k = 0.1 \text{ vs. } k = 0.9)\). 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 avoiding competition by keeping its innovation secret. On the other hand, when the importance of consumers is high \((k = 0.1)\), the innovator’s expected payoff under duopoly can be greater than under monopoly due to the market expansion effect. Hence, the firm can benefit from inviting the competition by disclosing sufficient innovation to the competitor \((d^e \geq d)\).

Next, we examine the role of market expansion effect for the information sharing. Note that \( d = 1 - \frac{3t}{2m} \) 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 \( \bar{k}(d) \) and the threshold \( k^* \) at which the innovator shares innovation (Proposition 4).

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

This relationship \((k^* \leq \bar{k}(d))\) suggests that market expansion is a necessary condition for infor-
equilibrium payoffs for both firms and consumers are independent of \( d \) because the follower does not enter the market anyway when \( d < d \) (and thus, the market is monopoly). When the market is a monopoly, the consumers’ expected utility and the optimal communication effort are the same irrespective of \( d \in [0, d] \). 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 \( d^e = 0 \).

\(^{35}\)We assume that the entry costs for the firm \( f = 0 \) for simplicity. However, one can relax this assumption and allows a more realistic scenario that a firm needs to incur positive entry costs \( f > 0 \) (for example, 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 assure 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 is corresponding to the example of Tesla. However, including the fixed costs \( f > 0 \) makes the analysis unnecessarily complicated without providing further insight and makes it impossible to gain a closed form solutions. Hence, we keep the simplifying assumption of \( f = 0 \).
Information sharing. For example, when $k^* \leq k \leq \bar{k}(d)$, the market size can be larger under duopoly than under monopoly. However, 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 its innovation more than the minimum level of information disclosure ($d$) if the role of consumers becomes even greater.

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

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 ($d^e > d$). In particular, this can occur only when the horizontal differentiation becomes sufficiently large ($t > \frac{4v}{7}$). As $t$ increases, consumers have lower expected utility from product consumption and thereby less incentive to incur upfront learning costs. In this case, firm 1 has to convince consumers to exert more upfront communication efforts by committing to even more intense competition and lower prices. Disclosing more information to the competitor can serve as a commitment device for higher consumer utility in this case.

On the other hand, when horizontal differentiation is not large enough ($t \leq \frac{4v}{7}$), even if firm 1 prefers to invite the competitor to the market, firm 1 keeps the maximal secrecy $d^e = d$ (since there does not exist $\bar{k} > 0$). In this case, firm 2 does not exert any communication effort (since $d$ is the level of information disclosure that makes firm 2 zero profit by entering the market). Given the 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.

Figure 2: Firm 1’s expected payoff under $k = 0.1$ and $k = 0.9$
The purpose of information disclosure is not to use competitors for expanding 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, a direct effect on the competitor’s entry decision and communication efforts. 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 the higher consumer surplus, which accelerates consumer learning in communication. The increased consumer effort can contribute to market expansion through the complementarity between the consumers and the firms in communication.

5 Extensions

5.1 Sequential two-sided communication

In our main model, we consider a case where firms and consumers simultaneously decide their communication efforts without observing the others’ decisions. In our first extension, we relax this assumption and study a realistic case where communication decisions are sequential such that consumers adjust their learning effort after observing firms’ marketing efforts.\(^{36}\) We find that the complementarity effect is amplified in the sequential communication, which results in a higher equilibrium level of communication efforts and thereby the innovator is more likely to disclose its information with competitor compared to the simultaneous communication case.

The last stage of retail competition remains the same as the simultaneous communication case. However, at the communication stage, the sequentiality would affect the equilibrium results. Under the sequential communication, consumers adjust their effort \(e_c\) in reaction to the firm-side efforts. Consumers maximize their expected utility, \(EU = (e_f^k \cdot e_c^{1-k}) \tilde{u} - \frac{\epsilon^2}{2}\), after observing a given effort \(e_f\). Hence, the best reply function for consumers is still the same as the simultaneous case, which is \(e_c^{BR} = ((1-k) \tilde{u} e_f^k) \frac{1}{\epsilon^2 + \sigma}\). However, the firm is now a Stackelberg leader. Anticipating the consumers’ best response \(e_c\), the firm solves the following maximization problem, \(\max_{e_i} E\Pi_i = (e_f^k \cdot e_c^{1-k}) \cdot \pi_i - \frac{\epsilon^2}{2}\), where \(e_f = e_1 + e_2\) when \(\chi = 1\) whereas \(e_f = e_1\) when \(\chi = 0\). Subsequently, we know the total firm-side effort is implicitly determined by

\[
\left( \frac{\partial \sigma}{\partial e_f} + \frac{\partial \sigma}{\partial e_c} \cdot \frac{\partial e_c^{BR}}{\partial e_f} \right) \pi_f = e_f
\]  

\(^{36}\)In the current extension, both firms decide their communication efforts simultaneously once they have information, which mirrors the situation where firms advertise without knowing the competitor’s actions such as XM and Sirius satellite radio case. But one can also think that the innovator can advertise first and then, the follower responds to the innovator’s move. We analyze this case where even firms move sequentially in our Technical Appendix; the main results remain the same. Only the amplified complementarity effect in communication is mitigated.
Compared to the simultaneous communication case, there is an additional incentive for the firm(s) to exert effort, i.e., \( \frac{\partial \sigma}{\partial e_c} \cdot \frac{\partial \sigma_{BR}^c}{\partial e_f} > 0 \). Consequently, firm-side efforts expand in a sequential communication case, which in turn leads to greater effort from consumers in the sequential communication than the simultaneous case. More specifically, in equilibrium, both consumer effort and the total firm-side effort can be understood as products of the equilibrium efforts in the simultaneous case and a multiplier effect in terms of \( k \) (see the proof of Proposition 6 for the derivation).

\[
e_f = \frac{2}{1 + k} \left( \frac{1 + k}{2} \right)^{(1+k)/2} \times \left( \frac{k \pi_f}{(1 - k) \tilde{u}} \right)^{(1-k)/2} \text{equilibrium effort in simultaneous case}
\]

\[
e_c = \frac{2}{1 + k} \left( \frac{1 + k}{2} \right)^{(1+k)/2} \times \left( \frac{k \pi_f}{(1 - k) \tilde{u}} \right)^{1-k/2} \text{equilibrium effort in simultaneous case}
\]

At the first stage, firm 1 chooses the optimal disclosure level \( d_{\text{seq}}^* \in [0, 1] \). Similarly to the simultaneous case, the innovating firm prefers to sharing information only when the role of consumers in communication becomes critical (i.e., \( k \) becomes smaller such that \( k \leq k_{\text{seq}}^* \)). Moreover, we find that the innovating firm is more likely to share its innovation with the competitor compared to the simultaneous case. That is, the set of \( k \) which makes the innovator prefers the monopolist situation is strictly smaller under the sequential communication case than under the simultaneous case. This is so because both firms and consumers incur more communication efforts and thereby the market expansion effect through communication is amplified, which increases the firm 1’s incentive to disclose information.

**Proposition 6.** (1) When \( k \) becomes smaller such that \( k \leq k_{\text{seq}}^* \), firm 1 has an incentive to invite the competitor. Moreover, it is more likely for firm 1 to invite competitor under sequential communication than simultaneous communication: \( k_{\text{sim}}^* \leq k_{\text{seq}}^* \). (2) Also, total communication efforts are higher under sequential case than simultaneous case.

### 5.2 Myopic consumers and bounded rationality

Next, we relax one of our key assumptions about consumers’ perfect foresight.\(^\text{37}\) In our model, consumers are forward-looking; when they decide their effort levels in communication stage, they take into account their expected future utility from the product market in stage 3. One can ask the validity of this assumption especially in the context of novel product markets 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 greater surplus under duopoly and thereby

\(^{37}\text{We thank an anonymous referee for suggesting us to explore this interesting issue.}\)
exert more communication efforts. The increased consumer efforts prompt complementarity in the communication and lessen the potential free-riding effect in communication between firms (especially when the role of consumers becomes more important). This is the key insight in our main model.

However, if consumers are completely myopic, inviting competition would not affect the level of consumers’ communication efforts because their expected future utility remains the same irrespective of the market structure. Further, the total firm-side profit is smaller under a duopoly than a monopoly case (Lemma 1), which leads to considerably lower efforts from the firm-side. Therefore, either firms or consumers would not initiate higher communication efforts. The desired effect of complementarity in communication would not ensue by inviting the 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 may argue the bounded rationality of consumer’s decision making (Ellison 2006, Ho et al. 2006, Rabin 2013, and Goldfarb et al. 2012 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 due to a wider variety of products under a duopoly than a monopoly market from their past experience or rule of thumbs (Ellison 2006). Consumers may have some incentives to exert more efforts under 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 $\Delta_u$ as the log difference between the expected utility under the monopoly $\tilde{u}^M$ and the duopoly $\tilde{u}^D$:

$$
\Delta_u = \log \frac{\tilde{u}^D}{\tilde{u}^M} = \log \tilde{u}^D - \log \tilde{u}^M,
$$

(19)

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

The proposition suggests that as long as consumers expect a little bit higher utility in the duopoly case, our main result still holds: when consumers play a more important role in a two-sided communication, the innovator may find it more profitable to share the innovation with the rival to encourage its entry into the market.
5.3 Disclosure as entry deterrence

Finally, we explore another possible role that information disclosure can play. In our main model, the innovator is the only party which possesses the information about the innovation. The innovator can disclose information, which is assumed to be truthful, and its purpose is to invite the competitor to enter the market (information disclosure as an invitation to enter). 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 (information disclosure as an entry deterrence).

To accommodate this possibility, 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. But the marginal production cost \( m_2 \) will be either \( \bar{m} \) or \( m \) with equal probability \( \frac{1}{2} \), where \( m \leq \frac{\bar{m}}{2} \). That implies that in the low-cost state \( m \), firm 2 can compete with the innovator and 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 sufficient amount of information.

Also, we assume that the innovator can disclose two different types of verifiable information: (1) the existence of a new technology \( (\phi \in \{0,1\}) \) and (2) the amount of the key information concerning the new technology that reduces the relative competitive advantage \( (d \in [0,1]) \). Our main model focuses on the second type of information, which obviously implies the existence of the new innovation when \( d > 0 \). Moreover, we impose one more assumption that there is uncertainty whether the innovator truly holds a new technology idea \( (I \in \{0,1\}) \): firm 1 succeeds in discovering a radical innovation \( (I = 1) \) with probability \( \mu \), 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. This assumption implies that firm 2 always find it optimal to enter the market when there is no disclosure \( (\phi = 0) \) and thus, it creates an incentive for firm 1 to disclose the information to deter the entrance of competition.

Once firm 1 successfully discovers an idea, it can produce a product at marginal cost \( m_1 = 0 \), which is common knowledge. Firm 1’s strategy of disclosing the existence of innovative idea is \( \phi : I \in \{0,1\} \rightarrow \{0,1\} \). If firm 1 fails in discovering an idea \( (I = 0) \), it cannot disclose anything (i.e., \( \phi = 0 \)) given the nature of 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 \( (\phi = 0) \), it does not

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38 We thank the AE and an anonymous reviewer for encouraging us to think about this issue.
39 Again, the credibility of information and possibility of cheap-talk can be an interesting issue. However, the cheap-talk analysis is beyond the scope of this paper, and we only restrict our analysis on truthful information.
40 Because of the zero marginal cost \( m_1 = 0 \), firm 1 always enters the market upon having an idea \( I = 1 \). Also, firm 2’s marginal cost is \( \bar{m}_2 = \min \{m_2, \bar{m}(1 - d)\} \), where \( d \in [0,1] \). To avoid a trivial case, we assume that \( \bar{m} \leq \bar{m} (1 - d^{opt}) \), where \( d^{opt} = \arg \max_d E\Pi_1(d) \).
disclose any key information \((d = 0)\).

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

The timeline of the game differs from the main model to reflect those modeling changes. Here, before the game starts (at stage 0), the innovator tries to develop a new innovation. It may succeed \((I = 1)\) with a probability \(\mu\), or it may fail \((I = 0)\) with probability \(1 - \mu\). Firm 2 is also endowed with a similar idea with the marginal production cost \(m_2\), which is either \(m\) or \(\bar{m}\).

At stage 1 of the 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, \(\mu_2(I|\phi, d)\). Then, it chooses whether to enter the market \(\chi \in \{0, 1\}\). At the end of Stage 1, firm 2’s marginal cost become public. Such timing assumption enables us to apply the existing results of communication subgame and retail competition subgame from the main model with minor modifications to avoid unnecessary complexity. Thus, stage 2 (communication subgame) and stage 3 (product market competition) are the same as the main model. We use Perfect Bayesian Equilibrium as our solution concept, in which \((\phi, d)\) is sequentially rational given \(\mu_2(I|\phi, d)\) and \(\mu_2(I|\phi, d)\) is consistent with \((\phi, d)\).

The detailed analysis can be found in our Technical Appendix, but here we present a sketch of the model analysis. The analysis of the last two stages (product market competition and communication subgame) are very similar to the main model except for the fact that there is one more possible subgame such that firm 2 becomes a monopoly. This scenario can arise when the firm 1 fails to discover \((I = 0)\) but firm 2 enters the market \((\chi = 1)\).

There exist two types of pure strategy equilibrium in disclosure subgame: (1) the “separating equilibrium” where firm 1 truthfully discloses the existence of idea only when it discovers an idea, i.e., \(\phi(I = 1) = 1\) and \(\phi(I = 0) = 0\); and (2) the “pooling strategy” where firm 1 does not disclose the existence of idea irrespective of discovery, i.e., \(\phi(I) = 0\), for all \(I \in \{0, 1\}\). In the separating equilibrium, \(\phi^c = I\) and \(\mu_2^c(I = 1|\phi = 1) = 1\) and \(\mu_2^c(I = 1|\phi = 0) = 0\), where \(\mu_2^c(I|\phi)\) is the firm 2’s posterior belief about the existence of firm 1’s new innovation.\(^{41}\) More importantly, depending on firm 1’s strategic disclosure of key information \(d\), firm 1’s disclosure of the existence of idea \(\phi\) can serve two opposite purposes: (1) entry deterrence and (2) entry invitation. If firm 1 only discloses the idea existence \((\phi = 1)\) but not revealing any key information \((d = 0)\), firm 1’s incentive of disclosure is to discourage the competitor from entering the market. On the other hand, if firm 1 discloses not only the existence of innovation \((\phi = 1)\) but also the key information \((d \geq \bar{d})\),

\(^{41}\)More precisely, the posterior belief should be a function of both \(\phi\) and \(d\) such that \(\mu_2(I|\phi, d)\), but given the fact that \(d > 0\) is contingent on \(\phi = 1\), we use the notation \(\mu_2(I|\phi)\) for simplicity.
disclosure serves as an invitation to encourage firm 2’s entry. In both cases, the 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 \( (I = 1) \). Further, a 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”).\(^{42}\) In particular,
   
   (a) When \( k \) is sufficiently large, entry deterrence occurs. Firm 1 never reveals any key information \( (d^e = 0) \), which deters firm 2 from entering the market when \( m_2 = \bar{m} \).
   
   (b) When \( k \) is sufficiently small, entry invitation occurs. Firm 1 reveals sufficient key information \( (d^e \geq d) \), which encourages firm 2 to enter the market.

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

The formal proof of this proposition can be found in the Technical 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 \((d > 0)\) 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 as the market monopolist. Disclosing the existence of the innovation here can effectively serve as an entry deterrence to discourage the competitor from entering the market. 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 pooling equilibrium when \( k \) is in the intermediate range. In this range, the innovator can still benefit from the presence of the competitor, 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, i.e., \( \phi(I) = 0 \) for all \( I = \{0, 1\} \).\(^{43}\) We illustrate those equilibriums in Figure 3.\(^{44}\)

\(^{42}\)In any equilibrium, when firm 2’s marginal cost is low \((m_2 = m)\), firm 1’s disclosure has no real effect on firm 2, and firm 2 always enters the market. Moreover, if the innovator does not disclose the existence of innovation \((I = 0)\), firm 2 always enters the market irrespective of the realization of the cost.

\(^{43}\)The innovator prefers \( \phi(1) = 0 \) to \( \phi(1) = 1 \) so that it does not prevent the entry of the competitor when the
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 firms should share innovation with competitors or keep it secret. Our explanation is based 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 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 effort 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 more communication efforts in assimilating the new idea, examining an unproven product category, and deliberating their needs.

Our analysis shows some interesting trade-offs the innovating firms face when they choose the level of secrecy. Publicly disclosing 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 to expand the market through cooperation in communication stage. However, this desired cooperation may not necessarily arise due to the potential free-riding incentives. Only when consumers play an important role in communication can an innovating firm benefit from sharing innovation; the

\( m_2 = \overline{m} \).

Here, we set the \( v = 1, t = 0.5 \), and \( \overline{m} = 0.9 \). The graph shows the case when \( d^{\text{opt}} = \overline{d} \), which demonstrates the lower bound of \( \bar{k} \) such that firm 1 is indifferent between no disclosure and discloses as an invitation because \( \bar{k} \) can be even higher due to higher expected payoff \( \Pi_1^D (d^{\text{opt}}) \geq \Pi_1^D (\overline{d}) \). In this sense, we are showing a least favorable case here. The region of disclosure as an invitation can be even larger.
presence of competition, which is induced by innovation sharing, can serve as a commitment to guarantee greater surplus for consumers so that firms can convince consumers to expend more communication effort. Furthermore, the increased consumer effort can result in market expansion through the complementarity effect between consumers and firms 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 duopoly market structure.

Essentially, the fundamental issue that any innovator faces is the basic trade-off embedded in “coopetition” situation – whether to increase market size with competitors or to capture market share against competitors. In this sense, we believe our research can shed light on the understanding of this important issue in coopetition by providing one micro-mechanism that explains when to cooperate with competitors to reach a higher value creation (such as market expansion) or compete against competitions to achieve a larger competitive advantage.

Finally, our results critically depend on the key features of communication: strategic complementarity between consumers’ effort and the firms’ aggregate effort and strategic substitutability between each firm’s efforts. Although we believe that imposing those characteristics in marketing communication is reasonable in many situations, we would 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 product information on their own instead of bearing all communication costs if communication can be more efficiently accomplished by consumers (Mayzlin and Shin 2011 formalize this perspective by considering firms’ and consumers’ efforts in communication as substitutes. They show that inducing consumers’ efforts in the communication is sometimes more efficient for firms to communicate the quality information). Nonetheless, communication between firms and consumers can be better captured through strategic complementarity in many situations like radical innovations, in which consumers are unsure of the uses and the benefits of a product and even their innate needs. In these situations, the firm-side effort cannot fully substitute for consumers’ effort, 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 costly two-sided process that involves efforts from both firms and consumers) and its strategic implications.
Appendix A

Proof of Lemma 2.

Proof. Under monopoly, all consumers purchase the product at the monopoly price $p_1^M = v - \frac{t}{2}$. Thus, we have $\tilde{u}^M = \int_0^2 2 \left( v - t \cdot z - v + \frac{t}{2} \right) dz = \frac{t}{4}$. Under duopoly, consumers with $z_j \leq z^*$ purchase from firm 1 and the rest purchase from firm 2 at $\{p_1^D, p_2^D\} = \left\{ \frac{t}{2} + (1 - d) \frac{M}{3}, \frac{t}{2} + (1 - d) \frac{2M}{3} \right\}$, where $z^* = \frac{1}{4} - \frac{p_1^D - p_2^D}{2t}$. Thus, $\tilde{u}^D = \int_0^1 2 \left( v - tz_1 - p_1^D, v - t \left( \frac{1}{2} - z \right) - p_2^D \right) dz = \int_0^{z^*} 2 \left( v - tz_1 - p_1^D \right) dz + \int_{z^*}^1 2 \left( v - t \left( \frac{1}{2} - z \right) - p_2^D \right) dz = \frac{4(1-d)(3-2(1-d)M+9t(8v-5t))}{72t}$. When $v > 2t$, $\tilde{u}^D > \tilde{u}^M$ for all $d \in [d_1, 1]$. When $v \leq 2t$, $\tilde{u}^D \geq \tilde{u}^M$ if $d \leq d_1 = 1 - \frac{1}{M} \left( \frac{9}{2}t + 3\sqrt{2t(2t-v)} \right)$ or $d \geq d_2 = 1 - \frac{1}{M} \left( \frac{9}{2}t - 3\sqrt{2t(2t-v)} \right)$. Here, we note that the market is duopoly ($\chi = 1$) only when $d \geq d_1 = 1 - \frac{3t}{2M}$, and $d > d_2$ because $v > \frac{3}{2}t$. \hfill \square

Proof of Proposition 1.

Proof. (1) Consumers’ equilibrium effort is $e_c = ((1 - k) \tilde{u})^{1-k} (k \pi_f)^\frac{k}{2}$, where $f \in \{M, D\}$; i.e., $\tilde{u}_f = u\tilde{u}_M$ and $\pi_f = \pi_1^M$ if monopoly or $\tilde{u}_f = \tilde{u}_D$ and $\pi_f = \pi_1^D + \pi_2^D$ if duopoly. $\frac{\partial e_c}{\partial \pi_i} = (1 - \frac{k}{2}) ((1 - k) \tilde{u})^{-\frac{k}{2}} (k \pi_f)^\frac{k}{2} \geq 0$. Next, we check the firms’ efforts. In the monopoly case, firm 1’s equilibrium effort is $e_1^M = ((1 - k) \tilde{u})^{1-k} (k \pi_1^M)^\frac{1-k}{2}$. So, $\frac{\partial e_1^M}{\partial \pi_1} = (1 - k) \tilde{u}^{1-k} (k \pi_1^M)^{-\frac{k}{2}}$. $\frac{1-k}{2} (k \pi_1^M)^{\frac{k-1}{2}} > 0$. In the duopoly case, the equilibrium effort of firm $i \in \{1, 2\}$, is $e_i^D = ((1 - k) \tilde{u})^{1-k} (k \pi_1^D + \pi_2^D)^{\frac{1-k}{2}}$. So, $\frac{\partial e_i^D}{\partial \pi_1} = (1 - k) \tilde{u}^{1-k} (k \pi_1^D + \pi_2^D)^{-\frac{k}{2}} (k \pi_1^D + \pi_2^D)^{\frac{1-k}{2}} (k \pi_1^D + \pi_2^D)^{-\frac{1-k}{2}} (k \pi_1^D + \pi_2^D) \geq 0$.

(2) It is straightforward from $e_i^D = k \pi_i^D \left( e_c^D \right)^{1-k} \left( e_f^D \right)^{-k} = k \frac{\pi_i^D}{\pi_1^D} \frac{\pi_1^D}{\pi_1^D} = \frac{\pi_i^D}{\pi_1^D}$. \hfill \square

Proof of Corollary 1.

Proof. First, when $k = 1$, consumer’s efforts do not affect the communication outcome and thus, consumers do not exert costly efforts; $e_c^D = e_c^M = 0$. Next, when $k \in [0, 1]$, we show that $e_c^D > e_c^M$. Consumers’ equilibrium effort is $e_c = ((1 - k) \tilde{u})^{1-k} (k \pi_f)^\frac{k}{2}$. So, $e_c^D > e_c^M$ when $\frac{e_c^D}{e_c^M} = \left( \frac{\tilde{u}_D}{\tilde{u}_M} \right)^{1-k} \left( \frac{\pi_1^D + \pi_2^D}{\pi_1^M} \right)^{\frac{1-k}{2}} > 1$. Since $e_c^D$ and $e_c^M$ are positive for $k \in [0, 1)$, we take logarithm of both sides of the aforementioned inequality and get the equivalent condition $\ln \left( \frac{\tilde{u}_D}{\tilde{u}_M} \right)^{1-k} \left( \frac{\pi_1^D + \pi_2^D}{\pi_1^M} \right)^{\frac{1-k}{2}} > 1$. Since $\frac{\tilde{u}_D}{\tilde{u}_M}$ and $\frac{\pi_i^D}{\pi_1^M}$ are positive for $k \in [0, 1)$, we take logarithm of both sides of the aforementioned inequality and get the equivalent condition $\ln \left( \frac{\tilde{u}_D}{\tilde{u}_M} \right)^{1-k} \left( \frac{\pi_1^D + \pi_2^D}{\pi_1^M} \right)^{\frac{1-k}{2}} > 1$.
\[d \in [d, 1], \ln \frac{\tilde{u}^D(d)}{\tilde{u}^M} = \left(\frac{1}{\ln (1-d)}\right)(1-d)^{1-\frac{1}{2}(1-d)m + v - \frac{1}{2}l)/\gamma_4) > \frac{(v-\frac{1}{2})\left(\frac{1}{2} + \frac{2(1-d)^2m^2}{\gamma_4}\right)}{\ln \frac{\pi^M_1}{\pi^P_1(d) + \pi^P_2(d)}}.\] This proves that for all \(k \in [0, 1], e^D_c \geq e^M_c.\]

**Proof of Proposition 2.**

Proof. The relative market size \(\sigma^{TD} = \frac{\pi^D_1D}{\pi^M_1}\), where \(\pi^D_1\) and \(\pi^M_1\) are functions of \(d\). Hence, \(\sigma^{TD} \geq \sigma^{TM}\) if and only if \(\frac{\pi^D_1 + \pi^D_2}{\pi^M_1} = \left(\frac{\tilde{u}^D}{\tilde{u}^M}\right)^{1-k} \left(\frac{\pi^D_1 + \pi^D_2}{\pi^M_1}\right)^{k}\), where \(\tilde{u}^D\) and \(\pi^D_1 + \pi^D_2\) are functions of \(d\). This leads to \(k \leq 1/\left(1 + \ln \frac{\tilde{u}^M}{\pi^M_1 + \tilde{u}^P}\right) = \overline{k}(d).\) Moreover, \(\ln \frac{\pi^M_1}{\pi^M_1 + \tilde{u}^P} > 0\) and \(\ln \frac{\tilde{u}^M}{\tilde{u}^M} > 0\) from the proof of Corollary 1. Hence, \(\ln \frac{\pi^M_1}{\pi^M_1 + \tilde{u}^P} \ln \frac{\tilde{u}^D}{\tilde{u}^M}\) is also positive, and therefore, \(1/\left(1 + \ln \frac{\pi^M_1}{\pi^M_1 + \tilde{u}^P}\right) = \overline{k}(d) \in (0, 1).\)

**Proof of Proposition 3 .**

Proof. In the monopoly case, \(E^M_1 = \frac{1}{2}(\pi^M_1)^2\), whereas in the duopoly case, \(E^D_1 = \pi^D_1 \cdot \left(\frac{\pi^D_1}{\pi^D_2}\right)^2\). Because \(\pi^D_1 + \pi^D_2 < \pi^M_1\), the following inequality should hold: \(E^M_1 = \frac{1}{2}(\pi^M_1)^2 > \frac{1}{2}(\pi^D_1 + \pi^D_2)^2 = \frac{1}{2}(\pi^D_1)^2 + \frac{1}{2}(\pi^D_2)^2 = E^D_1 + \frac{1}{2}(\pi^D_1)^2 > E^D_1\).

**Proof of Proposition 4.**

Proof. We start with a lemma whose proof can be found in the Technical Appendix.

**Lemma 4.** \(E^M_1(d)\) is monotonically decreasing in \(d \in [d, 1]\) when \(k > k^*\).

From this lemma, it is immediate that \(d^*\) is the optimal disclosure level in the duopoly case. We note that the expected payoff under duopoly is \(E^D_1(d) = \sigma^{TD}(d) \pi^D_1(d) - \frac{1}{2} \left(e^D_1(d)\right)^2 = \left(k \left(\pi^D_1(d) + \pi^D_2(d)\right)\right)^k \left((-1 - k) \tilde{u}^D(d)\right)^{-1-k} \pi^D_1(d) \left(1 - \frac{k}{2} \frac{\pi^D_1(d)}{\pi^D_1(d) + \pi^D_2(d)}\right)\), where \(\sigma^{TD}(d) = \left(k \left(\pi^D_1(d) + \pi^D_2(d)\right)\right)^k \times \left((-1 - k) \tilde{u}^D(d)\right)^{-1-k} e^D_1(d) = \left(k \left(\pi^D_1(d) + \pi^D_2(d)\right)\right)^k \frac{\pi^D_1(d)}{\pi^D_1(d) + \pi^D_2(d)} \times \frac{\pi^M_1(d)}{\pi^M_1(d) + \pi^M_2(d)}\). At \(d^*\) firm 1 does not leave any surplus to firm 2, i.e., \(\pi^D_2(d^*) = 0\). Thus \(E^D_1(d)\) can be simplified as \(E^D_1(d) = \left(k \pi^D_1(d)\right)^k \left((-1 - k) \tilde{u}^D(d)\right)^{-1-k} \pi^D_1(d) \left(1 - \frac{k}{2}\right)\). Similarly, we calculate firm 1’s expected payoff under monopoly, \(E^M_1(d) = \left(k \pi^M_1(d)\right)^k \left(\left(1 - k\right) \tilde{u}^M(d)\right)^{-1-k} \pi^M_1(d) \left(1 - \frac{k}{2}\right)\).

Together, we have the following: \(E^M_1 > E^D_1(d)\) \(\iff \frac{E^M_1}{E^D_1(d)} = \left(\frac{\pi^M_1}{\pi^D_1}\right)^{1-k} \left(\frac{\pi^M_1}{\pi^D_1}\right)^{1+k} > 1.\) Take logarithm of both sides of the above inequality, we have \((1 - k) \ln \frac{\pi^M_1}{\pi^D_1(d)} + (1 + k) \ln \frac{\pi^M_1}{\pi^D_1(d)} > 0 \iff k \left(\ln \frac{\pi^M_1}{\pi^D_1(d)} + \ln \frac{\pi^M_1}{\pi^D_1(d)}\right) > \ln \frac{\pi^D_1(d)}{\pi^M_1(d)} - \ln \frac{\pi^M_1}{\pi^D_1(d)}\). Since both \(\ln \frac{\pi^D_1(d)}{\pi^M_1(d)} > 0\) and \(\ln \frac{\pi^M_1}{\pi^D_1(d)} < 0\) (from the proof of Corollary 1), we can restate the condition in terms of \(k\): \(k > \left(\ln \frac{\pi^D_1(d)}{\pi^M_1(d)} - \ln \frac{\pi^M_1}{\pi^D_1(d)}\right)/\left(\ln \frac{\pi^D_1(d)}{\pi^M_1(d)} + \ln \frac{\pi^M_1}{\pi^D_1(d)}\right) \equiv k^* \in (0, 1).\) Therefore, when \(k > k^*\), \(E^M_1 > E^D_1(d)\) and the market becomes a monopoly and the optimal strategy for the innovator is not to disclose \(d^* = 0.\) Conversely, when \(k \leq k^*\), we at least know that \(E^M_1 \leq E^D_1(d)\). That is, the market becomes a duopoly and not disclosing anything information is a dominated strategy \(d^* \in [d, 1].\)
Proof of Corollary 2.

Proof. \( \bar{k}(d) = 1/(1+\left(\frac{\ln \pi_1}{\pi_1(d)} + \frac{\ln \pi_2}{\pi_2(d)}\right)) \Rightarrow \left(\ln \frac{\pi_1}{\pi_1(d)}\right)/\left(\ln \frac{\pi_2}{\pi_2(d)}\right) = 1/\bar{k}-1. \) Also, \( k^* = \left(\frac{\ln \pi_2(d) - \ln \frac{\pi_1}{\pi_1(d)}}{\ln \frac{\pi_2}{\pi_2(d)}}\right) = 2\bar{k}(d)-1. \) Thus, \( k^* = 2\bar{k}(d) - 1 \leq \bar{k}(d) \) for all \( \bar{k}(d) \in [0, 1]. \)

Proof of Proposition 5.

Proof. From the proof of Lemma 4 in the Technical Appendix, we know that \( \partial \log \pi_D^P = \Psi \cdot G(k, d), \) where \( \Psi > 0. \) Moreover, \( G(k, d) \) is a convex function of \( k \) for all \( d \in [d, 1] \) and there are two roots \( k_1 \) and \( k_2 \) such that \( G(k_1|d) = G(k_2|d) = 0, \) where \( k_1 < 1 < k_2. \) Also, we find that \( G(k, d) \leq 0 \) for all \( d \in [d, 1] \) if and only if \( k \geq k_1(d) = \frac{\ln 1 - \ln d}{\ln 1 - \ln 2} \equiv k \) where \( d = 1 - \frac{\ln 2}{\ln 3^t}. \) Then \( \pi_D^P \) monotonically decreases in \( d \in [d, 1] \) and the minimal level \( d \) is the optimal disclosure level under duopoly. Conversely, if \( k < k \), there must exist some \( d \) such that \( G(k, d) > 0 \) for some \( d \in [d, 1], \) where \( k \) exists in \( (0, 1) \) when \( t > \frac{4t}{5}. \) To show the optimal disclosure level under duopoly is greater than \( d \) (i.e., \( d^e > d \)), we use the following lemma.

Lemma 5. When \( t > \frac{4t}{5}, k_1(d) \) is strictly decreasing in \( d \in [d, 1]. \) Moreover, \( k_1(d) = \bar{k} \in (0, 1) \) and \( k_1(1) < 0. \)

The proof can be found in the Technical Appendix. From Lemma 5, we know that there exists \( \bar{d} \in (d, 1), \) \( k_1(\bar{d}) = 0. \) 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 \( [0, \bar{k}] \) to \([d, \bar{d}]. \) Then, for a given \( k < \bar{k}, \) there always exists a \( d^e = H_1^{-1}(k) \) such that \( k_1(d^e(k)) = k \) when \( t > \frac{4t}{5}. \) Therefore, for a given \( k < \bar{k}, \) \( G(d^e(k)|k) = 0, \) which implies \( \partial \log \pi_D^P (d^e) = 0. \)

Since we have not yet analyzed how \( G \) behaves in \( d \in [d, 1] \) for a given \( k, \) we need to show that at \( d^e(k) \) 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 \( G(k_1(d)|d^e) = 0. \) Then \( G(k_1(d)|d^e) > G(k_1(d)|d^e) = 0 \) due to the convexity of \( G(k|d) \). So, for any given \( k < \bar{k}, \) \( G(d^e|k) > 0 \) for all \( d^e \in [d, d^e]. \) Similarily, \( G(d^e|k) < 0 \) for any \( d^e \in [d, d^e]. \) Therefore, for any \( k < \bar{k}, \) we can find a unique \( d^e \) such that \( G(d^e(k)|k) = 0, \) and \( G(d|k) \geq 0 \) (i.e., \( \pi_D^P (d) \) increases) when \( d \leq d^e; \) whereas \( G(d|k) \leq 0 \) (i.e., \( \pi_D^P (d) \) decreases) when \( d \geq d^e). \) Therefore, \( d^e \) is the unique optimal disclosure amount. \( \square \)

Proof of Proposition 6.

Proof. (1) Denote \( \Lambda \) as a set that includes \( k \) under which firm 1’s optimal strategy is not to disclose any information: \( \Lambda = \{k : \pi_M^P(k) > \pi_D^P(k|d), \forall d \in [d, 1]\}. \) We need to show that \( \Lambda_{seq} \subseteq \Lambda_{sim} \). We first define an auxiliary set \( \Phi = \{k : \pi_M^P(k) > \pi_D^P(k|d)\}. \) By the definition of equilibrium,
\[ \Lambda \subseteq \Phi. \] Because of Lemma 4, we have already known that \( \Phi_{\text{sim}} = \Lambda_{\text{sim}}. \) We will show that the cutoff \( k^*_\text{seq} \) for the sequential case is the same as the simultaneous case; \( k^*_\text{seq} = k^*_\text{sim} = k^* \) 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 efforts and specify the expected payoff functions in the sequential communication case. Following equation (17) and knowing \( e^c_D = ((1 - k) \tilde{u} e_f)^{k+1} \), we have the first-order condition for optimal effort \( e_i \):

\[
\left( \frac{\partial \pi^D}{\partial e_i} + \frac{\partial \pi^D}{\partial e_i} \right) \pi^D_i = e_i \Leftrightarrow ke^{k-1}_f e^{1-k}_c + e^k_f (1 - k) e^{-k}_c \frac{1}{1+k} \left( (1 - k) \tilde{u} e^k_f \right)^{1+k-1} ke^{k-1}_f \pi^D_i = e_i \Leftrightarrow ke^{k-1}_f e^{1-k}_c \left( 1 + \frac{1-k}{1+k} e^k_f e^{1-k}_c \right) \pi^D_i = e_i. \]

By adding up the first-order conditions of the two firms, \( ke^{k-1}_f e^{1-k}_c \left( 1 + \frac{1-k}{1+k} e^k_f e^{1-k}_c \right) \pi^D_i = e_f \Leftrightarrow ke^{k-1}_f (1 + \frac{1-k}{1+k} e^k_f e^{1-k}_c) \tilde{u} e^k_f \left( (1 - k) \tilde{u} e^k_f \right)^{-1} \).

((1 - k) \tilde{u} e^k_f)^{1+k} (\pi^D + \pi^D_f) = e_f. \] After a few algebraic steps, we have the equilibrium total efforts: \( e^{D,seq}_f = e^1_f + e^2_D = \left( \frac{2}{1+k} \right)^{1+k} (k (\pi^D_1 + \pi^D_2))^{1+k} \left( (1 - k) \tilde{u} D_1 \right)^{1+k} = \left( \frac{2}{1+k} \right)^{1+k} e^{D,seq}_f. \) Firm \( i \)'s equilibrium effort is simply \( e_i^{D,seq} = \frac{\pi^D_i}{\pi^D_{i+1}} (e^1_f + e^2_D) \), \( i = 1, 2 \). And consumers’ equilibrium effort is: \( e^{D,seq}_c = \left( (1 - k) \tilde{u} (e^1_f + e^2_D)^k \right)^{1+k} = \left( \frac{2}{1+k} \right)^{1+k} \left( (1 - k) \tilde{u} D_1 \right)^{1+k} (k (\pi^D_1 + \pi^D_2))^{1+k} = \left( \frac{2}{1+k} \right)^{1+k} e^{D,seq}_c. \)

Then, we can compute firm 1’s expected payoff in the duopoly market: \( E^P_D = \sigma (e^1_D + e^2_D, \pi^D) \pi^D_D - \frac{1}{2} (e^1_D)^2 \left( e^1_D \right)^k (k (\pi^D_1 + \pi^D_2))^{1-k} \pi^D_1 \left( 1 - \frac{k}{1+k} \pi^D_1 \right) \). Moreover, at \( d \), \( E^P_D (d) = \left( \frac{2}{1+k} \right)^{1+k} \left( (1 - k) \tilde{u} D_1 \right)^{1+k} \pi^D_1. \)

Similarly, we compute the equilibrium efforts and firm 1’s expected payoff in the monopoly case:

\[
e^M,seq = \left( \frac{2}{1+k} \right)^{1+k} \left( (1 - k) \tilde{u} \pi^M \right)^{1-k} (k \pi^M)^{1+k} = \left( \frac{2}{1+k} \right)^{1+k} e^M,seq, \text{ and } \Pi^M_D = \sigma (e^1_M, e^2_M) \pi^M_D = \left( \frac{2}{1+k} \right)^{1+k} \pi^M_D (1 - k \tilde{u} D^M) \pi^M_1. \]

It is straightforward that the cutoff \( k^*_\text{seq} \) in the sequential setting remains the same as the simultaneous case because the decision rule \( \Pi^M_D (\tilde{u} (d)) = \left( \tilde{u} (d) \pi^M_D \pi^M_1 \right)^{1+k} = 1 \), which gives the same \( k = k^*_\text{sim} \). 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, \( e^M,seq = \left( \frac{2}{1+k} \right)^{1+k} e^M,seq > e^M,seq, \) and \( e^M,seq = \left( \frac{2}{1+k} \right)^{1+k} e^M,seq > e^M,seq, \) under monopoly situation, \( e^{D,seq}_f = \left( \frac{2}{1+k} \right)^{1+k} e^{D,seq}_f > e^{D,seq}_f \) and \( e^{D,seq}_c = \left( \frac{2}{1+k} \right)^{1+k} e^{D,seq}_c > e^{D,seq}_c \) under duopoly situation. Thus, total efforts are always higher under a sequential case than a simultaneous case. \( \square \)

**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 \( EU = e^k_f e^{1-k}_c \tilde{u} - e^2_t/2 \). Hence, myopic consumers’ best reply in effort is \( BR (e_f) = (1 - k) \tilde{u} (e^{k})^{1/(1+k)} \). 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: \( e^D_f + e^D_c = k (\pi^D + \pi^D_c) (e^D_f)^{1-k} (e^{D}_f)^{k-1}. \) Knowing consumers' best reply, we can compute the equilibrium firm-side effort as \( e_f = ((1 - k) \tilde{u})^{(1-k)/2} (k \tilde{u})^{(1+k)/2}, \)
where \( \pi_f = \pi_1^M \) if monopoly and \( \pi_f = \pi_1^D + \pi_2^D \) if duopoly. Then, consumers’ equilibrium effort is \( e_c = ((1 - k) \bar{u})^{(1-k)/2}(k \pi_f)^{(k)/2} \). Also from the main analysis, we already know that \( e_1^D = e_f^D \cdot (\pi_1^P/\pi_1^D) \) and \( \sigma^T = (k \pi_f)^k ((1 - k) \bar{u})^{1-k} \), thereby we can get firm 1’s expected payoffs as \( E \Pi_1^M = (k \pi_1^M)^k ((1 - k) \bar{u})^{1-k} \pi_1^M (1 - (k/2)) \) and \( E \Pi_1^D = (k \pi_1^D)^k ((1 - k) \bar{u})^{1-k} \pi_1^D (1 - (k/2) (\pi_1^P/\pi_1^D)) \).

Next, we show \( E \Pi_1^D < E \Pi_1^M \) always holds. That is, \( \frac{E \Pi_1^D}{E \Pi_1^M} < 1 \iff (\pi_1^D/\pi_1^M)^k \cdot \frac{1-(k/2)(\pi_1^P/\pi_1^D)}{1-(k/2)} \cdot (\pi_1^P/\pi_1^D) < 1 \), which is equivalent to \( (\pi_1^D/\pi_1^P)^{1+k} \frac{1-(k/2)(\pi_1^P/\pi_1^D)}{1-(k/2)} < 1 \). Because \( \pi_f^D = \pi_1^D + \pi_2^D < \pi_1^M \), the first argument \((\pi_1^D/\pi_1^P)^{1+k} < 1 \). Next, we show \((\pi_1^D/\pi_1^P)^{1-(k/2)(\pi_1^P/\pi_1^D)} \leq 1 \). The result of the retail competition tells us that \((\pi_1^D/\pi_1^P) \in \left[\frac{1}{2}, 1\right] \). Notice that \((\pi_1^D/\pi_1^P) \frac{1-(k/2)(\pi_1^P/\pi_1^D)}{1-(k/2)} \) increases in \( k \in [0, 1] \) as the derivative \( \frac{2}{(2-k)^2} (1 - \pi_1^D/\pi_1^P) (\pi_1^P/\pi_1^D) > 0 \). So, we only need to show \((\pi_1^D/\pi_1^P)^{1-(k/2)(\pi_1^P/\pi_1^D)} \leq 1 \) when \( k = 1 \). That is, \((\pi_1^D/\pi_1^P)^{\frac{1-(k/2)(\pi_1^P/\pi_1^D)}{1/2}} = (\pi_1^D/\pi_1^P)^2 (2 - (\pi_1^D/\pi_1^P)) \leq 1 \) for \((\pi_1^D/\pi_1^P) \in \left[\frac{1}{2}, 1\right] \). Hence, \( E \Pi_1^D < E \Pi_1^M \).

\[ \Box \]

Proof of Proposition 8.

Proof. Note that \( e_f = ((1 - k) \bar{u})^{1-k} (k \pi_f)^{1/2} \) and \( e_c = ((1 - k) \bar{u})^{1-k} (k \pi_f)^{1/2} \), where \( \bar{u} = \bar{u}^bM \) and \( \pi_f = \pi_1^M \) if monopoly; whereas \( \bar{u} = \bar{u}^D \) and \( \pi_f = \pi_1^D + \pi_2^D \) if duopoly. Firm 1’s expected payoffs: \( E \Pi_1^M = (k \pi_1^M)^k ((1 - k) \bar{u}^b)^{1-k} \pi_1^M (1 - k/2) \) and \( E \Pi_1^D = (k \pi_1^D)^k ((1 - k) \bar{u}^D)^{1-k} \pi_1^D (1 - k/2) \).

Firm 1 finds more profitable to invite competition when \( \frac{E \Pi_1^D}{E \Pi_1^M} = (\pi_1^D/\pi_1^M) \cdot (\pi_1^P/\pi_1^D)^k \cdot (\bar{u}^D/\bar{u}^M)^{1-k} \). Let us define the left hand side of the inequality as \( LHS = \frac{1-(k/2)(\pi_1^P/\pi_1^D)}{1-(k/2)} \), and the right hand side as \( RHS = \frac{2}{(2-k)^2} (1 - \pi_1^P/\pi_1^D) \cdot (\bar{u}^M/\bar{u}^D) \cdot (\pi_1^M/\pi_1^D)^k \). We note that the (LHS) monotonically increases in \( k \in [0, 1] \) because the derivative \( \frac{2}{(2-k)^2} (1 - \pi_1^P/\pi_1^D) > 0 \) for all \( \pi_1^P/\pi_1^D \in \left[\frac{1}{2}, 1\right] \). Also, (RHS) monotonically increases in \( k \in [0, 1] \) because \( \frac{\pi_1^M}{\pi_1^D} \frac{\bar{u}^D}{\bar{u}^M} \geq 1 \). At the extreme \( k = 1 \), \( E \Pi_1^D < E \Pi_1^M \iff LHS = 2 - \frac{\pi_1^D}{\pi_1^D} \frac{\pi_1^M}{\pi_1^D} \frac{\bar{u}^D}{\bar{u}^M} = RHS \) from Proposition 3. For \( k^* \) to exist in the range of \([0, 1]\), it must be the case that when \( k = 0 \), \( \text{LHS} \geq \text{RHS} \iff 1 \geq (\pi_1^M/\pi_1^D) \cdot (\bar{u}^M/\bar{u}^D) \iff (\bar{u}^D/\bar{u}^M) \geq \pi_1^M/\pi_1^D \). We take a natural logarithm in both sides, then we have the desired result that \( \Delta \bar{u}^D \equiv \log \bar{u}^D - \log \bar{u}^M = \log \pi_1^M - \log \pi_1^D > 0 \). Therefore, for \( k^* \) to exist in the range of \([0, 1]\), it must be the case that \( \Delta \bar{u}^D \equiv \log \bar{u}^D - \log \bar{u}^M > 0 \). \[ \Box \]
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