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Clandestine Information Gathering about Competitors' R&D: Good or Bad?

Abstract

Typically, intelligence gathering and spying on competitors is portrayed as being underhanded or sneaky: a form of skullduggery to acquire the secret recipe or proprietary information of a competitor. We take a different perspective and characterize information gathering as effort to learn or understand the status of a competitor's R&D effort. We simplify the activity as learning ahead of product launch time whether the competitor's R&D has been successful. When markets are characterized by a large and active segment of innovators (consumers who are excited and motivated to buy the most innovative products in a category), this motivates firms to engage in information gathering. We show that gathering information about competitor's R&D has positive effects on a) the focal firm (which is why it happens), b) the competitor (that benefits from a positive externality), c) R&D activity within the economy and d) the probability of innovation being introduced to the market. These benefits are based on how better informed players lead to more efficient decision making. As a result, the fundamental inefficiency of an R&D race is mitigated by information gathering.

Keywords: Competitor information gathering; R&D investment; Product innovation; Mixed-strategy

1 Introduction

Dedicated competitive intelligence functions are more and more common in business today. According to a survey conducted by the Competitive Intelligence Alliance, the percentage of organizations monitoring competitors at least once per month is substantial and increasing (from 64% in 2020 to 70% in 2021 according to Walton, 2024). In contrast to the covert, undercover and clandestine information gathering in the pre-internet area, today, competitive intelligence sits at the intersection of market research and revenue enablement. It is accomplished by gathering information via carefully analyzing exploring legal and observational sources of intelligence on key competitors, which includes monitoring activity at the competitor's place of business, speaking to industry insiders, and detailed examinations of filings with the government (e.g., patent office, building permit, and testing permits).

A key motivation behind gathering competitor information is to gain insight into the research and development (R&D) activities of competitors, which play a crucial role in successfully developing and introducing innovative products to the market. The secrecy surrounding the development of new innovative products is well known. Over the years, these have included the development of filters for cigarettes, the development of light beer and the launch of products such as the MacBook air.[1] For example, Miller test marketed early versions of Miller Lite in 1973, long before, its official launch in 1975. Test markets are conducted with the general public. The ability of key competitors to understand what Miller was planning depended on how much effort they took to understand what Miller was testing and why.

A more exciting example related to the importance of information gathering comes from Formula 1 racing competition, a fascinating microcosm of competition. Despite being the most popular motorsport in the U.S., many people fail to realize that "*F1 cars aren't really cars, so much as finely tuned computers, engineered into carbon fiber and propped up on rubber-fat tires.*" (Bernard, 2023). As indicated by the popular Netflix show "Drive to Survive," the real intrigue of this sport takes place not on the track but behind the scenes during the months of studious engineering, tireless testing, and rewiring to perfect the cars. In other words, the high-speed, seemingly fragile cars that appear on the racetrack of Las Vagas Grand Prix are the new products launched to the market after long months of R&D. Information about competitor's R&D, therefore, is essential in a team's preparation for the new race season. Red Bull and Mercedes had a heated competition

[1] See https://theconversation.com/filters-a-cigarette-engineering-hoax-that-harms-both-smokers-and-the-environment-85393,https://allaboutbeer.net/turning-lite-origins-miller-lite-light-beer/2/, https://www.linkedin.com/pulse/secrets-iconic-product-launches-feyisayo-oluwatade-n9v4e/ for details about these launches.

in the 2020 season. Red Bull learned through information gathering that Mercedes had invented dual-axis steering, an innovative system that would give their race car an advantage over the rest of the field. Despite protesting, Red Bull did not work to add such technology to their race car. F1 eliminated a 1982 ban for the 2022 season to allow downdraft vents that use the ground effect (Holding, 2023). While some teams, such as Ferrari, worked out technical solutions to use this to create better road gripping ability, Mercedes did not make the same commitment to understand how to best incorporate downdraft vents. As a result, the Mercedes' race cars suffered excessive porpoising and lost the championship in that season. These "dramas" from Formula 1 racing reveal key insights regarding gathering competitor R&D information. These are worth exploring because they have general implications for information gathering in technology-driven markets and industries. First, there is disparity in competitor information gathering. Not all firms engage in the collection of R&D information from their rivals. Second, even after firms successfully acquire insights into their competitors' R&D undertakings, they may choose not to develop or launch new products based on that information.

In this paper, we adopt the perspective from the above examples by characterizing information gathering as an effort to learn or understand the status of a competitor's R&D effort. The research objective is to explore the multifaceted impact of a company's gathering of competitors' R&D information by investigating the following questions: Does gathering competitors' R&D information benefit a firm profit-wise? How does it affect the rival firm whose R&D information is being gathered? Should the rival firm engage in such action as well? What is the overall impact on the industry's R&D activities and the number of innovative products introduced to consumers in the market?

To answer the above research questions, we develop a game theoretic model with two competing firms that serve a market comprised of three consumer segments. Each firm has a loyal segment, and the third segment is comprised of consumers who are not brand loyal but are motivated (if not obsessed) with buying and consuming the most innovative products in the category. Table 1 provides several examples of industries characterized by a large and active segment of innovators (consumers who are excited and motivated to consume the latest innovations). Before the market opens, the firms make R&D investments to develop a product which includes the latest in terms of innovative performance. In addition, firms can make a costly decision to invest in information gathering. The information gathering entails collecting and analyzing information about the progress and success of the competitor's R&D activities. When each firm's R&D activity is complete (and either successful or not), the firms decide whether to a) continue selling the old version of the

product or b) launch the innovative product (in the event of successful R&D) and how to price it. It is important to note that innovative products are, at best, marginally more expensive to produce than the old versions of the product.

Table 1

Markets characterized by technology-driven innovators

Category	Firms	Innovation Examples	Innovation Prone versus Brand Loyal Segments
Bike Computers (US &EU)	Garmin Wahoo	Touchscreen GPS enabled Altitude calculation Glucose monitoring	Some bikers want the latest technology/innovations. Others are comfortable with the Garmin (Wahoo) operating system
Sailboat Navigation	Garmin Airmar	AI empowered GPS enabled Sail selection Recommendation	Some sailors want the latest technology/innovations. Others are content (or stuck) with the system they have.
Cordless Electric Toothbrush	Philips Sonicare Oral-B	Sonic Vibration Changeable heads Teeth whitening	Some consumers are brand loyal. Others want to do exactly what the dentist recommends
Search Engines	Google Baidu Bing	Machine learning AI empowered search	Some consumers favor traditional search engines whereas other want to embrace AI technology to search for answers

It should be noted that in the model, we assume that information gathering provides a 100% reliable signal about the success of the competitor's R&D effort before the firm's decision to launch the innovative product becomes irreversible. Jeff Bezos referred those as "Type 1 decisions" (irreversible, unable to return to the previous status quo) in his 1996 letter to shareholders. The idea in our model is that the signal arrives before the product launch becomes a Type 1 decision.[2]

Our analysis shows that as long as innovative products are a) not too expensive in terms of marginal cost and b) R&D is sufficiently expensive, there exists a unique pure strategy equilibrium in which only one firm engages in clandestine information gathering. The reason only one firm engages in information gathering is that the competitor has no incentive to gather information once the focal firm does it. Moreover, the competitor realizes a positive externality because information gathering by a rival makes the rival less aggressive. In short, the focal firm gains by information gathering. It avoids launching a new innovation when its launch would lead to strictly lower profit. But the competitor gains even more.

[2]Please see https://productschool.com/blog/product-fundamentals/product-management-launch-risks

The net result of clandestine information gathering in this asymmetric equilibrium is to increase both the level of R&D in the economy and the likelihood of innovation being introduced. The explanation is that the *simultaneous* nature of an R&D race (in which neither firm gains if both are successful) is a source of inefficiency. Simultaneous games are by definition games of imperfect information because neither firm knows if the other has succeeded. In a game where both firms attempt to develop the same type of innovation, firms will "hold back" investment in R&D if simultaneous introduction of the innovation leads to losses. From an industry perspective, this results in less R&D. With information gathering, the R&D investment made by the firm engaging in information gathering is certainly lower. The reason is the firm knows that there will be times when R&D yields a successful outcome but the fruits of the R&D are not be introduced. Conversely, any impediment to investing is completely eliminated for the competitor. The reason is the information gatherer knows that anytime the competitor's R&D program is successful, it will launch the innovation as a monopolist. In other words, the fundamental inefficiency of a R&D race is reduced if not completely eliminated by information gathering.

Our analyses also reveal the existence of a symmetric mixed strategy equilibrium in terms of information gathering. Here, the firms randomize their decision to engage in information gathering. Interestingly, in this equilibrium, most of the efficiency gain created by information gathering is eliminated. R&D levels and the likelihood of innovation in the market are higher than in the base case (where information gathering is not possible) but the increase is significantly smaller. Because firms are uninformed about whether the competitor has engaged in information gathering, firms are less confident about being in a monopoly situation when an R&D program is successful. This serves to depress R&D investment (overall) compared to the equilibrium where only one firm engages in information gathering. In a nutshell, the fundamental inefficiency of a R&D race (due to imperfect information) is mitigated by information gathering. However, when firms randomize the decision to engage in information gathering to learn about the success of the competitor's R&D (they employ mixed strategies), the gains from reducing imperfect information about the success of the competitor's R&D effort are largely replaced by imperfect information about whether the competitor is also "collecting information on me".

The remainder of the paper is organized as follows: Section 2 discusses the relevant literature and highlights the unique contribution of this paper. Section 3 introduces the modelling framework. The solution and analysis of the model are provided in Section 4. Section 5 further discusses the effects of clandestine information gathering on firm profitability, R&D investments at the firm and industry level, and the likelihood of innovations being introduced to the market. We conclude the

paper in Section 6.

2 Literature Review

First, this paper is substantively related to the literature that studies companies' research and development (R&D) for product innovation and the efficiency of R&D. Second, it is related to literature which examines the gathering of business intelligence especially information about competitors. Finally, the paper builds on the literature related to segmentation and how segmentation leads to mixed-pricing strategies. Below, we discuss the paper's connection and contribution to each of these literature streams.

2.1 R&D for Product Innovation and Inefficiency Concerns

The role of R&D in driving product innovation has been well-established. Dutta et al. (1999) highlight the importance of R&D capabilities, along with marketing and operations, in determining a firm's financial performance in high-technology markets. The authors underscore the transformational role of R&D in converting resources into innovative outputs, thereby driving firm performance. Despite its importance, R&D processes are often plagued by the concern of inefficiency. In his seminal paper, Arrow (1962) considers invention to be an example of a high-risk business activity. The central economic fact about R&D is that it is devoted to the production of information. By the very definition of information, invention is risky because output cannot be perfectly predicted from the inputs. Arrow also suggests that in competitive conditions, financial resource limitations are likely to result in under-investment in R&D given any unwillingness or inability to bear the risks associated with uncertainty. Haruna and Goel (2011) discussed how free-entry market conditions can lead to excessive and socially inefficient entry, exacerbating R&D inefficiency. This is particularly relevant in industries with high R&D intensity, where the duplication of efforts and resources can be costly. A recent study of Chu and Oldford (2023) discusses the role of company governance structure in mitigating R&D inefficiency by exploring the impact of board composition in directing R&D activities.

The implications of inefficiency in R&D are far-reaching. Yan et al. (2021) discuss how inefficiency in R&D can be mitigated through strategic customer relationship management and product development management, thereby improving new product performance. Verma and Agrawal (2023) examine the impact of ownership restructuring on R&D efficiency in the pharmaceutical industry. Their analysis shows that inefficiency in R&D can significantly affect an industry's ability to innovate, particularly in areas like complex generics and biosimilars. Addressing inefficiencies in

R&D requires strategic intervention. Matricano et al. (2022) demonstrate the importance of R&D investment to enhance the performance of start-ups in the food industry. The authors suggest that targeted investments in R&D can be an effective strategy to overcome inefficiencies. Ni et al. (2024) integrates a differential game model into a contracting framework to study product innovation in a supply chain where a manufacturer holds private information unknown to the supplier. Contrary to the popular belief that information asymmetry should have a negative effect on innovation efficiency, the authors find that the under-investment problem in supply chain innovation can be reduced with more private information.

Following the classic view of treating innovation as a risky business activity whose success depends on an "inextricable tangle of objective uncertainties" (Arrow 1962, p.613), a firm's innovation decision in this paper is modeled as a process where the firm chooses an investment level which leads to a probability of successfully realizing the innovation (e.g., Iyer and Soberman 2016). We contribute to this stream of research and identify a novel path by which inefficiency in R&D is reduced. That is, by learning about a competitor's R&D progress and status, companies can avoid launching new products that generate intense price competition. We find that such information gathering increases both the level of R&D and the likelihood of innovation in the economy.

2.2 Business Intelligence Gathering and Competitor Information

Talaoui and Kohtamäki (2021) conduct a comprehensive review of business intelligence (BI) processes, covering 120 articles over 35 years. The review identifies patterns and contradictions across eight dimensions of business intelligence gathering: environmental antecedents; organizational antecedents; managerial and individual antecedents; the process itself; strategic outcomes; firm performance outcomes; decision-making; and organizational intelligence. The authors highlight the importance of open participation from managers to generate research that better integrates BI processes. Talaoui and Kohtamäki (2021) also find a significant correlation between BI processes and various aspects of company performance, including strategic management, customer perceived value, decision-making speed, and organizational intelligence.

Cavallo et al. (2021) investigate the relationship between competitive intelligence (CI) and strategy formulation in firms. The paper highlights how CI practices inform, support, and integrate into a company's strategy formulation process. The study provides empirical evidence on how CI practices are conducted and factors that may enhance or limit their effectiveness. Botelho (2018) focuses on why buy-side investment professionals at competing firms openly share investment recommendations with one another. He finds that higher levels of market uncertainty about a stock

lead to higher odds that an individual shares detailed knowledge about it, suggesting a strategic role for knowledge sharing in certain conditions.

Our paper takes an alternative perspective. We characterize competitive information gathering as effort to learn or understand the status of a competitor's R&D effort. In the model, we represent the activity as learning ahead of product launch time whether a competitor's R&D has been successful. We assume that competitor information gathering provides a 100% reliable signal about the success of the competitor's R&D outcome *before* the firm's decision to launch the innovative product becomes irreversible. Our analysis explores the impact of this information gathering on the focal firm (that does it), the rival firm (whose information is being learned), and the entire industry to provide a complete picture about the impact of information gathering about competitors.

2.3 Market Segmentation and Mixed-Strategy Pricing

By analyzing competition between a firm launching an innovative product and a rival which sells a basic product, our paper is related to work that examines competition between firms where one product is of higher quality than another, i.e., the market is vertically differentiated (e.g., Moorthy 1988, Shaked and Sutton 1982, Vandenbosch and Weinberg 1995). Our paper adopts a three-segment setup to study the myriad effects of innovation on competition and firm profitability. Building on the work of Shilony (1977), we use mixed pricing strategies to characterize price competition between two firms that can offer a basic product or an innovation based on successful R&D. Today, mixed pricing strategies are broadly applied in economics and marketing to represent markets where two competitors sell a single product to satisfy the demand of a heterogeneous consumer base. Unlike the existing literature (e.g., Narasimhan 1988, Varian 1980, Raju et al. 1990) where each firm typically has a loyal customer segment and competes for a third price-sensitive "switching" segment , we model the non "firm/brand-loyal" segment as a large and active group of innovators - consumers who are excited and motivated to buy and use the most innovative product and are not brand loyal.

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

R&D.

3 Model Setup

3.1 Supply Side

The model is based on two firms that offer products to a differentiated market. Each firm invests in research and development for an innovative version of the existing product that provides new value. Following the setup of Iyer and Soberman (2016), a firm's R&D investment decision is denoted as $\omega_j \in (0,1)$ $(j = 1,2)$. This represents the probability that the firm's R&D successfully leads to the development of the innovation. We assume that the cost of R&D is an increasing and convex function of ω_j: $c(\omega_j) = \beta\omega_j^2$. The marginal cost of producing the "basic" product (using pre-R&D technology) is normalized to zero. A firm with successful R&D acquires the ability to launch the innovative product with a marginal cost of production c (> 0). The improvement provided by the innovation over the existing product is d (> 0). The outcome of a firm's R&D is considered private information. A firm can learn the outcome of its rival's R&D through clandestine information gathering which entails a fixed cost k (> 0). For simplicity, we refer to this type of competitor intelligence collection as "information gathering" in the remainder of the paper.

3.2 Demand Side

We assume that the total mass of consumers in the market equals 1 without loss of generality. All consumers have the same maximum willingness to pay V (> 0) for the basic product offered by either firm. The consumer market is divided into 3 segments which can be classified as two types: the "Traditional" versus "Innovator" customers based on their brand (firm) preference as well as preference for innovation.

Segment 1 (of size α) are traditional consumers who have strong brand preference for Firm 1. Consumers of Segment 1 will only buy from Firm 1 (basic or innovative product) as long as $p_1 \leq V$. Similarly, consumers from Segment 2 (of size α) are traditional consumers who have strong brand preference for Firm 2. They will only buy from Firm 2 (basic or innovative product) as long as $p_2 \leq V$. Remaining consumers in the market belong to Segment 3 (of size $1 - 2\alpha$). These are the consumers who have no brand preference but will pay a higher price for an innovative product. Mathematically, a consumer from Segment 3 has a maximum willingness to pay of V for the basic product of either firm and $V + d$ for the innovative product offered by either firm. The focus of our study is important innovations beyond changes that are better described as product improvements. We explain how we operationalize this idea in Section 4.1.

3.3 Sequence of Game Moves

We model a six-stage game between the firms which involves R&D investment, information gathering, product launch, and pricing.

In the first stage, the firms simultaneously make R&D investments $\omega_j \in (0,1)$, $j = 1,2$. In the second stage, the firms decide whether or not to engage in information gathering regarding the rival's R&D outcome (to be revealed in the next stage). In the third stage, each firm's R&D outcome, failure (f) or success (s), is determined by Nature. As the result, a firm that chooses to engage in information gathering (in the second stage) becomes informed about the success/failure of the R&D efforts of both self and the rival in the third stage. On the contrary, if a firm chooses not to engage in information gathering (in the second stage), the firm only learns about its own R&D success/ failure in the third stage. In the fourth stage, each firm makes a decision of whether to launch the innovative product if its R&D was successful. If a firm decides not to launch the new product or if its R&D failed, then it offers the existing product for sale. Here, we use notations $\{b, I\}$ to stand for basic and innovative products, respectively. In the fifth stage, the firms simultaneously set prices (p_1, p_2) for the products they choose to sell. In the final stage, consumers make purchase decisions and the demand and profits are realized by the firms.

3.4 Additional Justification of the Theoretical Model

The game-theoretic model presented in this paper serves as an abstraction of market reality. While the model simplifies certain real-world complexities, it retains the dynamics that are crucial to understand strategic interactions in industries where competing firms engage in R&D races, new product launches, and price competitions.

In practice, firms rarely complete their R&D processes at precisely the same time, i.e., "simultaneously". However, an extensive body of economic literature provides justification for modeling R&D competition as a simultaneous-move game. For example, seminal works like Fudenberg and Tirole (1985), Grossman and Shapori (1987) and D'Aspremont and Jacquemin (1988) model R&D races as simultaneous decisions, even though these processes occur over extended periods.[3] This paper follows this standard modeling approach, recognizing that while R&D efforts, nature's outcomes, and subsequent decisions unfold over time, the simultaneous-move framework effectively captures the strategic uncertainty and interdependence of firm actions during the race.

The simultaneous nature of each firm's R&D program implies that they operate under incomplete information, particularly regarding the status and outcomes of their rivals' pursuit of product

[3] G.M. Grossman, C. Shapiro (1987), "Dynamic R&D competition," The Economic Journal, 97 (386) (1987), pp. 372-387.

innovation. This incomplete information is critical, as it directly impacts a focal firm's decisions about whether to launch new products (following successful R&D) and how to price them. The ability to anticipate and respond to competitors' actions under such uncertainty is a defining characteristic of competitive R&D environments.

One potential consideration, drawn from common industry practices, is whether firms have an incentive to announce their R&D successes as a pre-emptive strategy. Such announcements could, in theory, influence rivals' decisions by signaling success and deterring a rival's product launch. However, in many R&D-intensive industries (pharmaceuticals for example), firms often overclaim the efficacy and potential of upcoming products. This is evidenced by the statistics of exaggeration claims highlighted in industry reviews and regulatory reports (e.g., Ferriman, 1999). A firm has an incentive to make its rivals believe that it has developed the Silver Bullet (even if it has not) because such a belief causes rivals to reduce their efforts (and investment): the potential gains from being successful are smaller if the competitor already has a Silver Bullet. The tendency to overstate success (and make unsubstantiated claims about scientific progress) means that rivals generally discount public announcements and instead invest in independent competitive intelligence gathering to find out what the truth is. Such information-gathering efforts, though costly, allow firms to base strategic decisions on verified insights rather than potentially biased claims. The main model in this paper thus focuses on firms' strategic decisions to learn about competitors' R&D outcomes through their own information-gathering. In the **Model Extension** section, we examine the conditions under which the incentive for information gathering can be replaced by credible disclosure. This extension delineates the boundary of the findings from the main model analyses, providing a broader perspective on the strategic context examined by this paper.

4 Model Analysis

4.1 Pricing Equilibrium

Depending on firms' R&D outcome and product launch decision, there are three possible competitive scenarios when the two firms make pricing decisions in the fifth stage of the game. The first two scenarios are symmetric where both firms offer basic or innovative products respectively. The third scenario is asymmetric where one firm offers an innovative product to compete with the competitor's basic product. We make two assumptions regarding the nature of innovative products developed in the market. The first is that we focus on products that unequivocally lead to higher profit for a firm that is the sole seller of the innovation. In other words, we restrict our analysis to products for which R&D investment is financially justified. The second is that we focus on

important innovations in that they enable the seller of the innovation to sustain higher prices than the prices observed for existing products. Indeed, many product improvements create incremental benefits for consumers but our interest is products that have the ability to create a new tier of benefits and prices in an existing market. This follows empirical observations related to important innovations across markets.[4] These assumptions imply that the innovations we examine provide greater surplus (to innovation-prone consumers of Segment 3) than the surplus they realize through consumption of the basic product based on pre-R&D technology. In addition, the marginal cost of producing such a product is assumed to be sufficiently low such that a "sole" seller of the innovation prefers to sell it versus the alternative of selling the existing product. These conditions on innovation surplus and production cost imply the following:

$$d > \frac{(1-3\alpha(1-\alpha))V}{(1-2\alpha)(1-\alpha)} - \frac{\alpha c}{(1-2\alpha)} \tag{1}$$

and

$$c < \frac{(1-2\alpha)^2}{(1-\alpha)^2} V \tag{2}$$

Due to the discrete nature of the segments in this model, the pricing equilibrium in all three scenarios (i.e., 2 basic products, 2 innovative products, 1 innovative product versus 1 basic product) is in mixed-strategies. It is straightforward to show that if both firms offer basic products, the mixed-strategy pricing equilibrium results in each firm earning an expected payoff of αV. While if both firms offer innovative products, the mixed-strategy pricing equilibrium leads to each firm earning an expected payoff of $\alpha(V-c)$. In Proposition 1, we focus on the more interesting pricing equilibrium that obtains between a firm offering the innovative product and a rival firm that offers the basic product. Without loss of generality, we assume that Firm 1 offers the innovative product and Firm 2 offers the basic product.

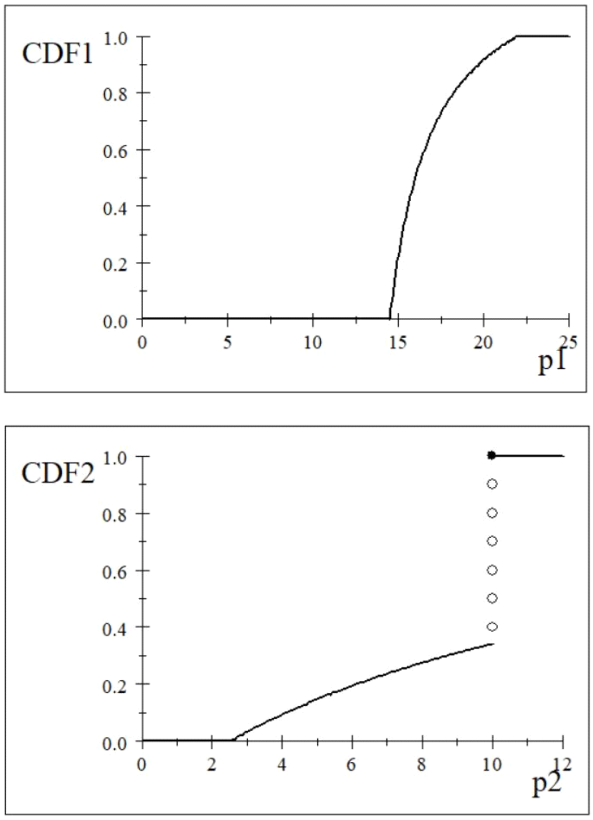
Proposition 1 *The pricing equilibrium between Firm 1 (offering innovative product) and Firm 2 (offering basic product) is that Firm 1 employs a mixed strategy in prices over the interval* $\left(\frac{\alpha V}{1-\alpha}+d, V+d\right)$ *with expected profit of* $E\pi_1 = (1-2\alpha)\left(\frac{\alpha V}{1-\alpha}+d-c\right)$. *The cumulative distribution function (CDF) for Firm 1's prices is:*

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

Firm 2 chooses a mixed strategy in prices over the interval $\left(\frac{\alpha V}{1-\alpha}, V\right)$ *with expected profit of*

[4] See, for examples, Sjofors (2023), Fleming (2023) and Reisn (2017).

Figure 1: Cumulative price density functions between Firm 1 (offering innovative product) and Firm 2 (offering basic product)



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

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

To illustrate the pricing equilibrium, we show the CDFs for Firms 1 and 2 using numerical values of $V = 10, d = 14$, and $\alpha = 0.2$ in Figure 1. The CDF of Firm 1 (the seller of the innovative product) is continuous, while the CDF of Firm 2 (the provider of a basic product) has a mass point at $p_2 = V$ with a probability mass of $\frac{(1-\alpha)d+\alpha V}{(1-\alpha)(V+d)} \in [0, 1]$, illustrated by the dotted line in Figure 1. In other words, there is a jump in the CDF of Firm 2 when the rival Firm 1 offers an innovative product to the market. Proposition 1 indicates that with an innovation of sufficient value, Firm 1 (as the sole seller of the innovation) focuses on extracting surplus from the innovator segment by pricing well above V. This means that Firm 1 does not serve its traditional segment after introducing the innovation. Firm 1 wishes to set a high price but is forced to discount from time to time to make its offer more attractive to the innovator segment when facing competitive pricing pressure from

Firm 2. Firm 2 however will not cut price unconditionally to capture the innovator segment. It limits its price cuts to ensure nothing less than the guaranteed profit from its traditional segment.

Profit comparison across the three scenarios of pricing equilibrium shows that an innovating firm enjoys highest profit $((1-2\alpha)\left(\frac{\alpha V}{1-\alpha}+d\right))$ when it offers an innovative product in competition with rival firm's basic product. If both firms offer innovative products to the market, intense price competition drives a focal firm's profit to $\alpha(V-c)$. This is less than the profit a firm earns by selling a basic product (αV).

4.2 Three Models Based on Firms' Decisions to Gather Competitor Information

Knowing the nature of the pricing equilibrium in the fifth stage of the game, each firm makes its product launch decision in the fourth stage. This decision depends on the outcome of its R&D efforts and that of the competitor's (if the firm engaged in information gathering earlier in the game).

In this subsection, we present three models corresponding to different information structures resulting from firms' decisions to gather competitor's R&D information. To simply the presentation, we denote the following three constant terms to report the equilibrium results for the rest of this section: $z_0=(1-2\alpha)\alpha V$, $z_1=(1-\alpha)(1-2\alpha)(d-c)$, and $z_2=(1-\alpha)((1-2\alpha)d-(1-3\alpha)c)$. We also restrict the range for β such that the equilibrium levels for R&D are less than 1, i.e. for $\omega_j\in(0,1)$ $(j=1,2)$. Specifically, we require:

$$\beta>\beta_0=\frac{z_1-\alpha^2V}{2(1-\alpha)} \tag{3}$$

4.2.1 Model-0 (benchmark): Neither firm engages in information gathering

With this benchmark, firms make launch decisions with no information about the outcome of the competitor's R&D. The analysis shows that a firm always launches the innovative product when its R&D effort succeeds. Proposition 2 summarizes the equilibrium results of Model-0.

Proposition 2 *When neither firm gathers competitor's R&D information, the equilibrium is symmetric and a firm always launches its innovative product when R&D is successful. For each firm, the equilibrium level of R&D is* $\omega_0=\frac{z_1-\alpha^2V}{z_2-\alpha^2V+2(1-\alpha)\beta}$ *and the equilibrium profit is* $\pi_0=(1-\omega_0)\alpha V+\omega_0(1-\omega_0)(1-2\alpha)\left(\frac{z_0+z_1}{1-\alpha}\right)+(\omega_0)^2\alpha(V-c)-\beta(\omega_0)^2$.

Next, we present a second model where the information structure is the opposite of Model-0. In particular, both firms are informed of the success/failure of the competitor's R&D.

4.2.2 Model-B: Both firms engage in information gathering

Firms make product launch decisions under complete information if both engage in information gathering about the outcome of the rival's R&D. The analysis shows that there are three possible equilibria in this subgame. In all three, the dominant strategy of a firm with successful R&D is to launch the innovative product when the competitor's R&D program fails. The differences between the equilibria are what happens when both firms succeed with their R&D. In the first two equilibria, firms employ pure strategies where one firm launches and the other continues to market the existing product. In the third equilibrium, the firms employ mixed strategies with regards to launching the innovative product. Proposition 3 reports the details of three equilibria under Model-B.

Proposition 3 *When both firms gather the competitor's R&D information, there are three equilibrium outcomes. In all cases, when the R&D of a single firm is successful, it launches the innovation and the other firm (with failed R&D) competes with the basic product. When the R&D of both firms succeeds, there are three possible outcomes:*

1. *There are two pure-strategy equilibria involving Firm i launching the innovation and Firm $j\,(\neq i)$ continuing with the basic product. The equilibrium level of R&D for the firm launching innovation is $\omega_i = \frac{\left(z_1-\alpha^2V\right)\left(2\beta(1-\alpha)+\alpha^2V-z_1\right)}{4\beta^2(1-\alpha)^2}$, while the equilibrium level of R&D for the firm selling basic product is $\omega_j = \frac{z_1-\alpha^2V}{2\beta(1-\alpha)}$.*

2. *There is a mixed-strategy equilibrium where each firm has a probability $\rho_b = \frac{z_1-\alpha^2V}{z_2-\alpha^2V}$ of launching the innovative product. In the mixed strategy equilibrium, the equilibrium level of R&D is $\omega_b = \frac{z_1-\alpha^2V}{z_1-\alpha^2V+2(1-\alpha)\beta}$ and the expected profit is $\pi_b = (1-\omega_b)\,\alpha V + \omega_b\,(1-\omega_b)\left(\frac{z_0+z_1}{1-\alpha}\right) + (\omega_b)^2\,\alpha V - \beta\,(\omega_b)^2 - k$.*

Information structures in both Model-0 and Model-B are symmetric with regards to firms' knowledge about the competitor's R&D. Next, we present a third model with an asymmetric information structure.

4.2.3 Model-A: Only one firm gathers the competitor's R&D information

Proposition 4 summarizes the equilibrium decisions in R&D investment, product launch and profits when only one firm engages in information gathering. Without loss of generality, Firm 1 is assumed to be the focal firm that makes the decision to learn about rival Firm 2's R&D outcome while Firm 2 does not gather information.

Proposition 4 *When only Firm 1 engages in gathering the competitor's R&D information:*

1. *With successful R&D, Firm 1 only launches the innovative product if Firm 2's R&D fails. On the contrary, Firm 2 always launches an innovative product when its R&D succeeds;*

2. *Firm 1's equilibrium level of R&D is* $\omega_1 = \frac{\left(z_1-\alpha^2 V\right)\left(2\beta(1-\alpha)+\alpha^2 V-z_1\right)}{4\beta^2(1-\alpha)^2}$, *while Firm 2's equilibrium level of R&D is* $\omega_2 = \frac{z_1-\alpha^2 V}{2\beta(1-\alpha)}$.

3. *The equilibrium profit of Firm 1 is* $\pi_1^A = \left((1-\omega_1)+\omega_1\omega_2\right)\alpha V + \omega_1\left(1-\omega_2\right)\left(\frac{z_0+z_1}{1-\alpha}\right) - \beta\omega_1^2 - k$, *while the equilibrium profit of Firm 2 is* $\pi_2^A = \left(1-\omega_2\right)\alpha V + \omega_2\left(1-2\alpha\right)\left(\frac{\alpha V}{1-\alpha} + d - c\right) - \beta\omega_2^2$.

A key implication of Proposition 4 is that a focal firm may decline to launch an innovation even with successful R&D. This happens when the focal firm, through clandestine information gathering, learns about the rival's R&D success. Without information about the focal firm's R&D, the rival firm always launches the innovation with successful R&D. Here, the focal firm prefers to offer the basic product to compete with rival firm's innovative product. Such a decision delivers higher payoff (αV) to the focal firm in comparison to the payoff $(\alpha\left(V-c\right))$ due to intense price competition between two innovative products. In sum, a focal firm's clandestine information gathering confers a positive externality on the competitor.

We now discuss the firm's equilibrium decision in information gathering about a rival's R&D. We analyze this question under different market conditions detailed in the next subsection.

4.3 Equilibrium Decision in Gathering Competitor Information

Comparing firms' equilibrium profits from Propositions 2 and 3, $\pi_2^A > \pi_b$ even with a fixed cost of $k = \varepsilon \to 0$. In other words, there is no equilibrium in pure strategies where both firms engage in gathering information about the rival's R&D. Proposition 5 summarizes the market conditions under which Model-0 or Model-A results in a pure-strategy equilibrium of firms' information gathering about the competitor's R&D.

Proposition 5 *Under the market conditions defined by Equations 1, 2, and 3,*

1. *When* $0 < \alpha < \frac{1}{4}$, *there exists a threshold* β_t *(which is the solution for* $\pi_1^A = \pi_0$*)*[5] *such that:*

   (a) *If* $\beta_0 < \beta < \beta_t$, *the pure-strategy equilibrium is for neither firm to engage in information gathering about the rival's R&D;*

   (b) *If* $\beta \geq \beta_t$, *the pure-strategy equilibrium is asymmetric with only one firm that engages in information gathering about the rival's R&D.*

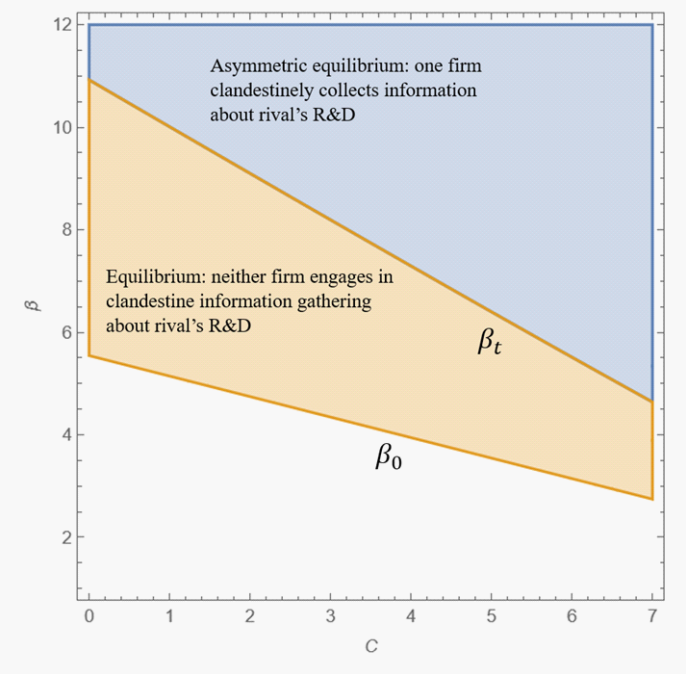
[5] The expressions of π_0 and π_1^A are reporeted in Propositions 2 and 4, respectively.

2. *When $\frac{1}{4} \leq \alpha < \frac{1}{2}$, the unique pure-strategy equilibrium is asymmetric with only one firm that engages in information gathering about the competitor's R&D.*

Figure 2 numerically illustrates the different pure-strategy equilibria of competitor information gathering reported in Proposition 5 - Part (1) using numerical values of $V = 10, d = 14$, and $\alpha = 0.1$. In Figure 2, we show that the pure strategy equilibria as a function of two cost dimensions. The horizontal dimension is the firm's marginal cost (c) of producing an innovative product (based on successful R&D) and the vertical dimension is the cost parameter (β) for R&D investment. In this figure, α is sufficiently small (less than $\frac{1}{4}$), such that the size of Segment 3 (of size $1 - 2\alpha$) is large. The consumers in Segment 3 have no brand preference but are willing to pay high prices for the latest technology. In other words, the potential prize for a firm that launches the innovation (alone) is big. This motivates the firm that does not gather information (Firm 2) to invest substantially to develop the innovation especially when β is relatively low. High levels of investment by Firm 2 tend to depress investment by Firm 1 because the likelihood of Firm 2 launching the innovation is high. Holding β constant, if the cost of the innovative product is sufficiently low, neither firm gains by being informed about the status of the competitor's R&D. This is why we move from a zone where one firm gathers information to a zone where neither firm gathers information as we move from right to left in Figure 2. In addition, in the zone where neither firm engages in information gathering, the level of investment by both firms increase, as the marginal production cost (c) and the cost parameter (β) for R&D investment decrease. For this reason, the feasibility condition (β_0) in Figure 2 is downward sloping (such feasibility condition ensures that $\omega \in (0, 1)$).

In the zone where one firm (Firm 1) gathers information, price competition between both firms launching innovative products leads to less profit than what is earned by one firm defecting and offering the basic product. This explains why it is attractive for one firm to learn about the competitor's R&D outcome. Doing so allows the firm (Firm 1) to withdraw from a "fist fight" by continuing to sell the basic product when Firm 2's R&D is successful (Firm 2 has a strict policy of launching an innovative product if it is developed). Firm 2, by making a product launch decision solely based on the success of its own R&D, free rides on Firm 1's information gathering. However, in this zone, as β decreases, the firm that does not gather information (Firm 2) increases its R&D investment substantially. At some point, the gap between ω_1 and ω_2 becomes so large, that Firm 1 is better off not gathering information and defecting to the equilibrium where neither firm gathers information. Lower levels of β are needed to reach this defection point as c increases because the gap between ω_1 and ω_2 is also driven by the "size of the prize", $d - c$. This explains why the boundary (β_t) between the zone where one firm collects information (the top shaded area) and

Figure 2: Pure-strategy equilibrium in clandestine information gathering of rival's R&D ($V = 10, d = 14, \alpha = 0.1$)



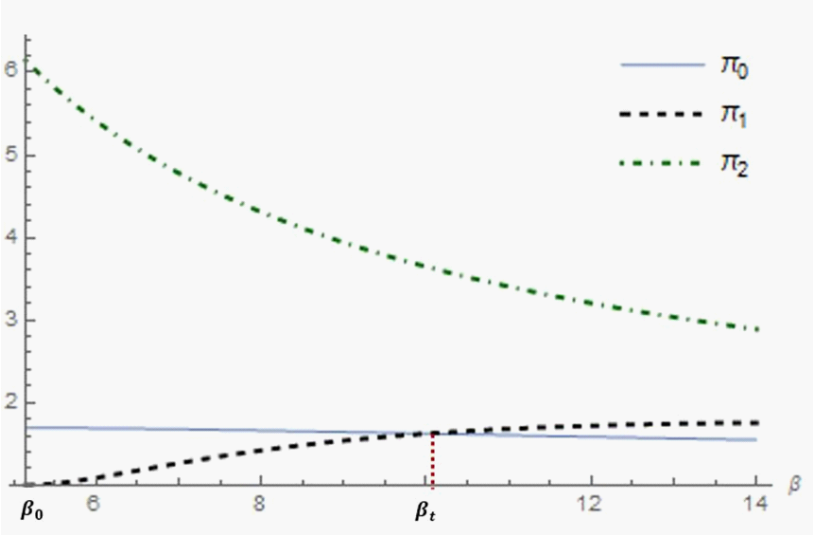
no firms collect information (the middle shaded area) is downward sloping. This boundary (β_t) is defined in Proposition 5.

In reality, a firm does not know if the competitor is gathering information about its R&D activities. This suggests the potential for a mixed strategy equilibrium with regards to information gathering. We derive a symmetric mixed-strategy equilibrium where each firm has a probability $\gamma \in (0,1)$ of information gathering about the competitor's R&D. We further denote $\phi \in (0,1)$ as the conditional probability that Firm 1 launches an innovative product when i) its R&D is successful, and ii) it knows via information gathering that Firm 2's R&D also succeeded. Proposition 6 reports the details of the mixed-strategy equilibrium in the information gathering and product launch.

Proposition 6 *The mixed-strategy equilibrium for a firm's clandestine information gathering (γ) and product launch (ϕ) satisfies* $\gamma(1-\phi) = \frac{\alpha(1-\alpha)c}{(z_2-\alpha^2 V)}$. *Under such mixed-strategy equilibrium, a firm's optimal level of R&D is* $\omega_m = \frac{z_0+z_1-\alpha(1-\alpha)V}{z_0+z_1-\alpha(1-\alpha)V+2\beta(1-\alpha)}$, *with the equilibrium profit being* $\pi_m = \omega_m\left((1-\omega_m)\frac{z_0+z_1}{1-\alpha} + \omega_m \alpha V\right) + (1-\omega_m)\alpha V - \beta\omega_m^2 - \gamma k$.

With the equilibrium results derived, we now move to a discussion of how information gathering about the competitor's R&D affects profitability, investment, as well as the probability of innovations at both the company and industry level.

Figure 3: Profit Comparison when α is small ($V = 10, d = 14, c = 1, \alpha = 0.1$)



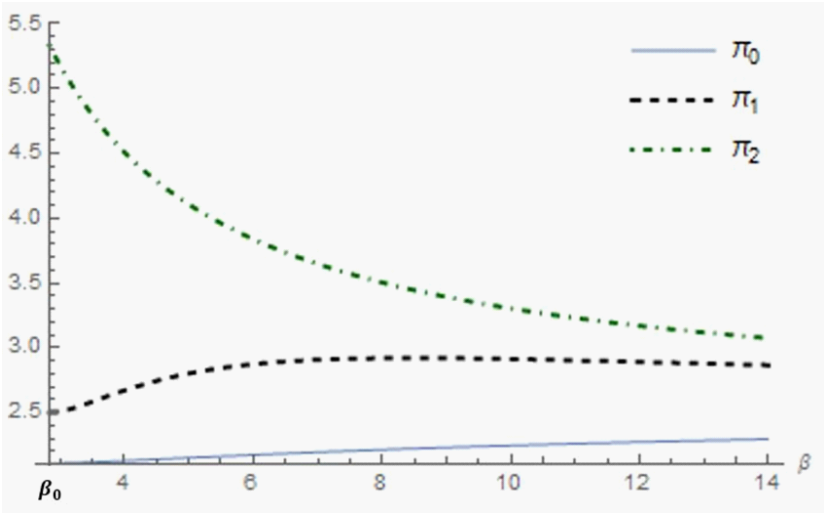
5 The Effects of Clandestine Information Gathering

5.1 The Impact on Firm Profitability

Figures 3 and 4 numerically illustrate the profits of both firms under Model-A where Firm 1 clandestinely gathers Firm 2's R&D information while Firm 2 does not engage in such activity. The figure also shows the symmetric firm profit under benchmark Model-0 where neither firm engages in information gathering. Figure 3 uses the numerical value of $\alpha = 0.1$ which corresponds to Part (1) of Proposition 5, and Figure 4 assigns the numerical value of $\alpha = 0.25$ corresponding to Part (2) of Proposition 5 where the unique equilibrium is for only one firm to engage in information gathering about the competitor's R&D. Both Figures 3 and 4 indicate that compared to the benchmark case where neither firm engages in information gathering, Firm 2 enjoys higher profit when its rival Firm 1 engages in such activity. Following the intuition for Proposition 4, this is due to the positive externality conferred to Firm 2 by Firm 1's information gathering. In particular, this information gathering leads Firm 1 to become a diffident competitor that often chooses not to launch an innovation despite having developed it. Another persistent pattern from Figures 3 and 4 is that Firm 2 enjoys higher profit than Firm 1 due to Firm 1's information gathering. This underlines how Firm 2 is a free riding beneficiary of Firm 1's decisions.

Figure 4 corresponds to the area in Part (2) of Proposition 5 where the unique equilibrium is for one firm to engage in information gathering. Firm 1's profit is always higher when it engages in information gathering versus the benchmark case. Figure 3 corresponds to the area in Part (1)

Figure 4: Profit Comparison when α is large ($V = 10, d = 14, c = 1, \alpha = 0.25$)



of Proposition 5 and the intersection point of Firm 1's profits from Model-0 and Model-A is β_t as defined in Proposition 5. When $\beta < \beta_t$, Firm 1 realizes lower profit (than the benchmark case) when it is the only firm engaged in information gathering. As a result, the equilibrium is that neither firm engages in such activity.

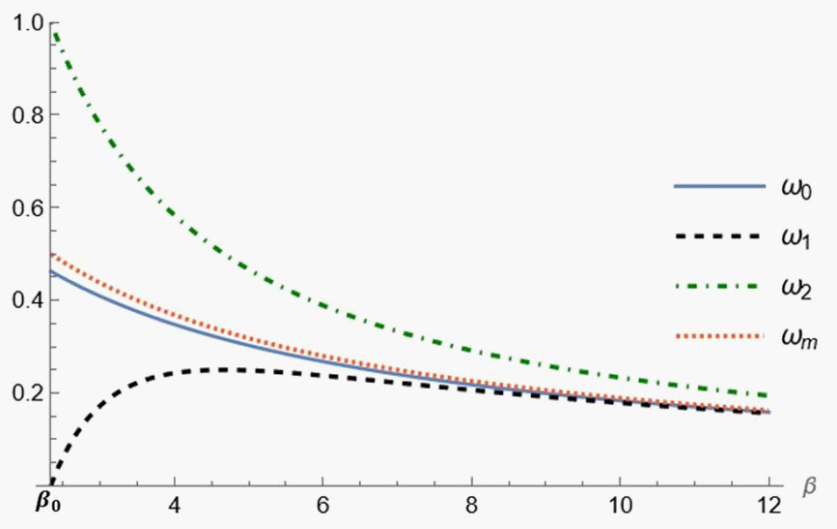
5.2 The Impact on Firm/Industry Level R&D

Comparing the levels of firms' R&D investment under benchmark Model-0 (Proposition 2) and Model-A (Proposition 4), it is straightforward to see that $\omega_2 > \omega_1$. This implies that in the asymmetric pure-strategy information gathering equilibrium, R&D investment is lower for the firm that engages in information gathering versus the rival that does not. It is also easy to show that $\omega_2 > \omega_0$. This implies that a firm invests more in R&D when the rival engages in competitor information gathering (Model-A) versus the case when neither firm engages in information gathering (Model-0). Lemma 1 compares the R&D investment for a focal firm (ω_1) when it is the only one that gathers competitor's R&D information with the level under the benchmark Model-0 (ω_0) when neither firm engages in information gathering.

Lemma 1 *If* $\beta > \beta_1 = \frac{(z_1 - \alpha^2 V)(z_2 - \alpha^2 V)}{2(1-\alpha)(z_2 - z_1)}$, $\omega_1 > \omega_0$*; Otherwise if* $\beta < \beta_1$, $\omega_1 < \omega_0$.

Notice that $\beta_1 > \beta_0$ (defined in Equation 3). Lemma 1 presents a seemingly counter-intuitive result that a focal firm increases its investment when R&D is more expensive (when β is higher). The intuition is similar to that of targeted advertising (Iyer, Soberman and Villas-Boas 2005). When R&D is more expensive ($\beta > \beta_1$), the focal firm invests more because gathering the competitor's

Figure 5: Comparison of individual firm's R&D investment ($V = 10, d = 14, c = 3, \alpha = 0.25$)



R&D information helps to improve the precision of R&D to create incremental profit (similar to the intuition related to Proposition 5). In contrast, the focal firm reduces spending when R&D becomes less expensive. Lemma 2 reports the difference in R&D spending at the industry level between Model-A and that of the benchmark Model-0.

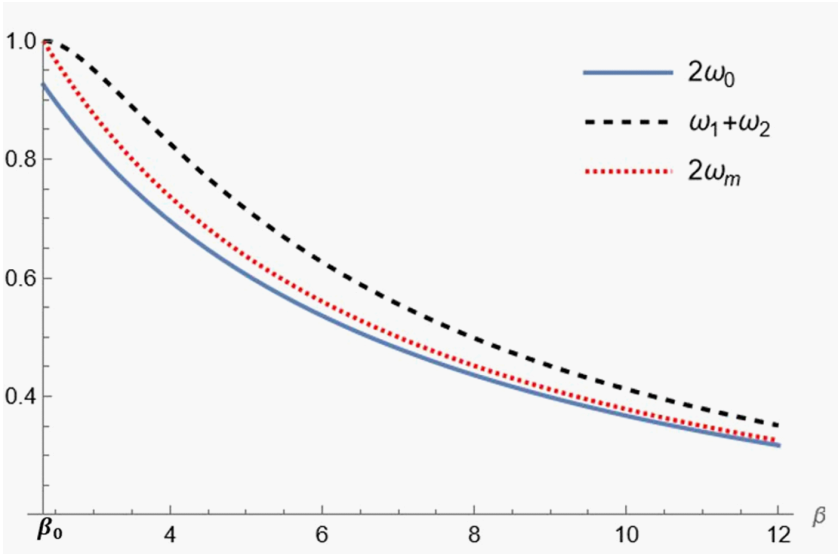
Lemma 2 *The industry-level R&D investment is higher under the asymmetric equilibrium when only one firm gathers competitor R&D information compared to the benchmark case where neither firm gathers information.*

Figure 5 illustrates equilibrium investment at the firm level from Model-0 (benchmark - ω_0), Model-A (asymmetric information gathering - ω_1, ω_2), and the case of mixed-strategy information gathering (ω_m). The starting point of the horizontal axis is β_0 (Equation 3) where $\omega_1 < \omega_0$, yet the gap closes as β increases. Eventually $\omega_1 > \omega_0$ when $\beta > \beta_1$ (not shown on Figure 5) as reported in Lemma 1 representing the condition when R&D becomes sufficiently expensive.[6]

Figure 6 illustrates the industry-level R&D investment across the three models. As reported in Lemma 2, the graphical pattern shows that the industry level R&D investment is highest when one firm engages in information gathering before making its product launch decision. The R&D investment level under the mixed-strategy information gathering equilibrium (Proposition 6) is also plotted on Figures 5 and 6 and is in between the levels under benchmark Model-0 and the pure-strategy asymmetric information gathering equilibrium (Model-A).

[6] $\beta_0 \approx 2.33, \beta_1 \approx 16.85$ given the numerical parameter values used in drawing Figure 5.

Figure 6: Comparison of industry-level R&D investment ($V = 10, d = 14, c = 3, \alpha = 0.25$)

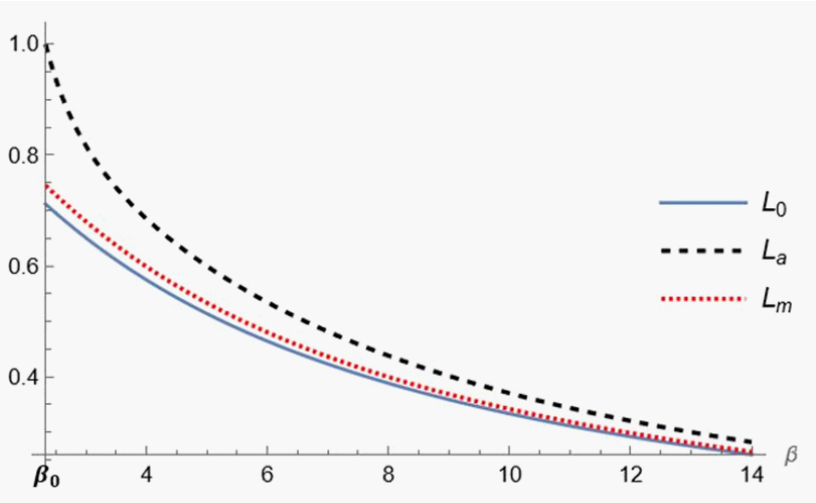


Because the decisions to launch a newly developed innovation are made in Model-0 without knowing the result of the competitor's R&D effort, the game is one of imperfect information. This is a source of inefficiency because investment is directed towards R&D that may lead to losses in the final stage of the game (when both firms are successful and launch the innovation). As a result, firms reduce R&D spending. Gathering information about the success of the competitor's R&D effort does not eliminate the possibility that the innovation generates incremental profit but it does eliminate the possibility of the innovation generating losses. The improvement in information (delivered by information gathering) leads to an overall increase in R&D investment for all feasible levels of β. In this sense, clandestine information gathering allows the market to move closer to the investment levels that a central planner would choose with the objective of maximizing total welfare.

5.3 The Impact on the Likelihood of Innovation in the Market

The impact of information gathering about the competitor's R&D also affects the probability of innovation in the market. Denote L_0 as the likelihood of having at least one innovative product in the market under the benchmark Model-0 where neither firm engages in information gathering. Earlier analysis (for Proposition 2) shows that without knowing the competitor's R&D status, a firm always launches an innovation when its R&D is successful. Hence $L_0 = 1 - (1 - \omega_0)^2$ where $(1 - \omega_0)^2$ refers to the situation when both firms' R&D fail. Similarly, we derive the likelihood of having at least one innovative product in the market under Model-A (denoted as L_a) and

Figure 7: Comparing the likelihood of at least one innovation introduced to the market ($V = 10, d = 14, c = 3, \alpha = 0.25$)



the mixed-strategy case (denoted L_m). Figure 7 numerically depicts the likelihood of innovation for three market scenarios (no information gathering, asymmetric information gathering in which one firm gathers information and the other does not, and the symmetric outcome in which both firms randomize between gathering and not gathering information). Interestingly, the pattern of innovation likelihood is consistent with that of industry-level R&D investment as reported in Lemma 2. The likelihood of having at least one innovative product in the market is highest under Model-A where only one firm engages in information gathering. The intuition for this comes from the observation that information gathering improves the efficiency of R&D investment. This leads to a higher likelihood of innovation in a market with information gathering.

A key question however, is why the likelihood of innovation is lower when *both* firms engage in information gathering albeit randomly (L_m). The explanation is that the inefficiency under Model-0 (which arises due to incomplete information about the competitor's R&D) is largely eliminated when a single firm engages in information gathering (neither the information gatherer, nor its rival, waste investment on R&D). When only one firm gathers information, its competitor remains uninformed about the information gatherer's R&D success. However, the competitor's decision to launch is unaffected by its lack of information and, its payoffs from successful R&D are guaranteed. Conversely, when both firms employ mixed strategies in terms of information gathering, firms are frequently informed about the success of the competitor's R&D. However, a new problem arises. A firm with successful R&D that gathered information does not know if the competitor also engaged in information gathering. Suppose the competitor engaged in information gathering. If the R&D

efforts of both firms are successful, *neither firm* can launch the innovation and be confident about capturing value from the innovation. The lack of confidence in the ability to capture value, depresses the incentive to invest in R&D and mostly eliminates the gain in efficiency created when a single firm gathers information.

6 Conclusion

6.1 Key Results

The objective of this study is to understand the likely impact that clandestine information gathering (about a competitor's R&D activity) affects markets in terms of profitability, investment in R&D and the likelihood that innovations are introduced to the market. Our interest is markets driven to innovate by a segment of consumers who are obsessed with buying and consuming the most advanced innovations. The model is based on the idea that early on, a firm makes a decision about whether or not to gather information. If the firm goes ahead with information gathering, it gains knowledge about whether the competitor has been successful with its R&D before the product launch decision is made. If and only if a firm has been successful with R&D does it make a choice about whether to continue selling the existing version of the product or to launch the innovative product. A firm that has been unsuccessful with its R&D activity continues to sell the existing version of the product. Why is this important? The reason is that when both firms launch the innovative product (which costs more to produce), the intensity of price competition that results leads to lower profits for both firms. This is precisely why information gathering is valuable. It allows the information gatherer to avoid the outcome which has the characteristics of a Prisoners' Dilemma.

Our analysis shows that in the feasible range for the parameters of the model, there is a pure strategy equilibrium where only one firm engages in information gathering. The reason a single firm engages in the activity (and not the competitor) is that the competitor benefits from a positive externality created by the information gatherer's new-found reluctance to launch innovation (even when the information gatherer's R&D has been successful). Information gathering effectively transforms a firm from being an *aggressive* to a *meek* competitor. Indeed, the *meek* information gatherer gains from information gathering but the uninformed competitor gains even more.

A second key finding is that clandestine information gathering increases both the level of R&D investment and the likelihood of innovation in the economy. The explanation is that the simultaneous nature of an R&D race (in which neither firm gains if both are successful) creates inefficiency. Simultaneous games are games of imperfect information because neither firm knows if the other

has succeeded. In a game where both firms race to develop the same innovation, this causes firms to limit R&D investment. To clearly illustrate this dynamic, we analyze a simple model in which two firms make an investment $\beta\tau_i^2$ to develop an innovation with probability τ_i. The innovation delivers a benefit A to a unitary market. The marginal cost of the innovation is c and without loss of generality, we assume $A > c > 0$. When both firms launch the innovation simultaneously, the benefit A is competed away but the firms split the market and incur the cost of selling the expensive innovation. The details of this model are provided in the Appendix. It is straightforward to show that the profit maximizing probability of innovation for each firm is $\frac{2A-2c}{2A-c+4\beta}$. In contrast, a welfare-maximizing central planner would choose $\frac{A-c}{A-c+2\beta}$ (for each firm) as long as $c > 0$. In other words, firms limit their investment in R&D compared to a central planner. The explanation for this is that firms want to reduce the likelihood of the outcome where both firms launch the innovation. This situation, while profit-reducing for firms, is welfare enhancing for society (because the innovation is introduced). From an industry perspective, this tendency leads to less R&D. When one firm gathers information, any impediment to investing is eliminated for an uninformed competitor. Concurrently, the R&D investment made by the firm engaging in information gathering is significantly lower. Such a firm knows that there will be times when R&D yields a successful outcome but the fruits of the R&D effort will not be introduced. Despite that, the added incentive for the competitor more than makes up for this reduction. In a nutshell, the fundamental inefficiency of a R&D race is reduced if not eliminated by information gathering.

Due to the asymmetric nature of the pure strategy outcome, there is also a symmetric mixed strategy equilibrium in terms of information gathering. When both firms randomize their decisions to engage in clandestine information gathering, much of the efficiency gain created by information gathering is eliminated. Nevertheless, R&D levels and the likelihood of innovation in the market are still higher than the base case where information gathering is not possible. But the gain is marginal compared to the pure strategy outcome. With randomized choices to gather information, firms often know if the competitor's R&D is successful but they do not know if the competitor engaged in information gathering. Plain and simple, this reduces the attractiveness of successful R&D. As a result, industry-wide R&D investment is lower compared to the equilibrium where only one firm engages in information gathering. When firms randomize their information gathering activities, the gains from reducing imperfect information about the success of the competitor's R&D effort are largely replaced by imperfect information about whether the competitor is also "spying on me".

6.2 Limitations and Future Research

It is important to identify the limitations of the analysis that we present regarding information gathering about the R&D status of competitors. Below we offer some additional discussions followed by thoughts for future research.

First, we assume that loyal (or traditional) consumers of the two competing firms place no value on the innovations developed by R&D. In reality, it is likely that traditional consumers place a degree of value on such innovations too. However, many markets are characterized by a segment of consumers who always want to consume "the latest and greatest" in a category. These consumers tend to be significantly less brand-loyal than other segments. Our model is nothing more than a discrete representation of this preference structure. We believe that the central insight of our model would stand even were this assumption relaxed to a degree.

Second, our model is based on both competitors developing innovations that a) deliver the same value and b) are perfectly substitutable. Empirically, many innovations deliver similar value; however, there are taste-based differences between innovations. That being said, the innovations across brands that characterize the evolution of categories like those shown in Table 1 tend to be similar. The difference across brands is rather the launch timing of competitive innovations. Without a doubt, a brand that innovates well in advance of its competitor gains a significant advantage. Our model is intended to depict the competitive dynamics that precede the introduction of such innovations. As long as the innovations developed by the firms are highly substitutable, we believe the insights of the current paper apply. As the degree of substitutability drops, the insights will be weaker because the findings are predicated on intense competition that happens when the two firms introduce the innovations simultaneously.

Finally, our model is based on innovative products that are, at best, marginally more expensive to produce than the existing product. In most cases, we believe this is reasonable. There are however, innovations that create value solely through their design and not the marginal cost. This is sometimes the case when products are intangible or digital in nature. In these cases, we believe that information gathering will lead to a higher probability of innovation but it is unclear whether this gain in innovation will be socially optimal.

Interesting avenues for future research are to investigate the model's limitations by relaxing some of the assumptions discussed above. For example, consumer heterogeneity in the valuation of innovative products could be further combined with brand preferences. In addition, differentiation along a horizontal dimension could further affect the substitutability between innovative products launched by competitors. In addition, market development processes are different across indus-

tries. Thus, it could be meaningful to compare the impact of competitor information gathering for industries characterized by short versus long market development.

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