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Quality Disclosure in a Competitive Environment with Consumer's Elation and Disappointment

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Abstract: When the quality of a firm's product is unobservable, consumers may generate some psychological feelings of elation or disappointment when the perceived product quality exceeds or falls short of their initial expectations. This paper investigates firms' optimal information disclosure strategies in a competitive environment when consumers have such psychological feelings. We consider three market situations: a monopoly setting, a duopoly setting where firms do not share their quality information with each other, and a duopoly setting where firms share their quality information with each other, so as to understand how market competition and horizontal information sharing influence the equilibrium outcomes. We show that both psychological disappointment and elation can induce the firm(s) to disclose more quality information than that when the consumer is fully rational. In a monopoly setting, the increase of the magnitude of disappointment always undermines the firm's profit while the increase of the magnitude of elation may hurt the firm's profitability. In contrast, in a duopoly setting, the increase of the magnitude of disappointment and/or elation always improves the firm's profitability. Moreover, such improvement can be further enhanced when the competing firms share their quality information upfront before making their disclosure decisions.

Keywords: Information Disclosure; Elation and Disappointment; Competitive Environment; Game Theory

1 Introduction

New product innovation is a prevailing strategy for many firms to remain competitive and achieve market penetration. In the food and beverage industry, from 2011 to 2016, there are nearly twenty thousands of new food and beverage products introduced into the U.S market every year. For most food companies, more than 50 percent of their current

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revenues are generated from the products that were not in the product line five years earlier.[1] The reduced product lifespan and the expansion of product variety make consumers hard to assess the product's quality before making their purchase decisions. Under this circumstance, a consumer's purchase decision will depend highly on their expectations about the product quality, which is inevitably affected by psychological feelings such as elation and disappointment. In particular, abundant evidences have shown that a consumer's purchase decision can be influenced by her *initial* quality expectation and the *perceived/advertised* quality before consumption (Kahneman and Tversky, 1979; Bell, 1985; Putler, 1992; Kopalle and Lehmann, 1995). If the perceived product quality is inferior to her prior expectation, a sense of disappointment arises; while if the quality exceeds her expectation, a sense of elation occurs. These psychologic feelings generate additional detriment on the consumer's purchase utility besides the traditional intrinsic utility, and affect an emotionally rational consumer's purchase decision directly. For example, a recent survey shows that more than half of the consumers consider the inability to touch, feel, and try as the biggest drawback of online shopping. This is because the absence of physical contact would increase consumers' psychologic feelings (especially the possible disappointment), and thus consumers are becoming more conservative towards online purchasing (Zhao and Stecke, 2010). Consequently, the online seller needs to provide free samples or live demos to help consumers better learn his product quality, which becomes an effective means to stimulate sales as long as his product quality is higher than the consumer's initial quality expectation.

In business practice, a firm often voluntarily reveals its private quality information to those unknown consumers during the new product promotion process, whose conventional methods include informative advertising, free samples and labeling (Jovanovic, 1982; Matthews and Postlewaite, 1985; Shavell, 1994; Guan and Chen, 2017). However, given the consumers' psychologic feelings, quality disclosure is not merely a means for resolving the product quality uncertainty but also serves as an important tool to induce the consumer's psychologic elation or disappointment. Consider a food or cosmetics company that launches a new product (say, beverage or makeup), and consumers hold some prior expectations about the product quality. Nonetheless, after trying some free samples from the company, consumers may generate a sense of elation if the perceived quality is higher than their initial expectation. This elation consequently makes consumers more enthusiastic about purchasing and thus, generates additional sales for the company. In contrast, if a company does not take any action to resolve its quality uncertainty, a rational

[1] Source: http://www.ers.usda.gov/topics/food-markets-prices/processing-marketing/new-products/.

consumer may infer that the product quality must be relatively low and she would most likely encounter the disappointment after consuming the product. This then dampens the consumer's purchase incentive.

In this paper, we aim to investigate the strategic impact of consumer's disappointment or elation on the firm's information disclosure strategy for the new product promotion. Specifically, we are interested in answering the following questions: How does a consumer make her purchase decision in the presence of psychological disappointment and elation? When should a firm disclose its private quality information? How do these psychological feelings affect a firm's ex-ante payoff? What is the impact of the market conditions on the firms' equilibrium strategies and profitability?

To answer above questions, we consider a game-theoretical setting in which a firm privately observes its product quality information and sells to a representative consumer, who may experience psychological disappointment/elation (Tversky and Kahneman, 1991; Kőszegi and Rabin, 2006). We start with a baseline model with a monopolistic firm and show that in equilibrium, either type of psychological feelings (disappointment or elation) could induce the firm to *disclose more* of its quality information. Intriguingly, they arise from different rationales. Specifically, a higher magnitude of elation allows the firm to obtain a higher profit by disclosing the high quality information to the consumer. A higher magnitude of disappointment, however, significantly hurts the firm's profitability when the firm withholds its quality information (namely, the *non-disclosure* strategy), as the consumer would become more disappointed by inferring that the product quality is relatively low. Both lead to the firm more likely disclosing its quality information. As expected, a higher magnitude of disappointment undoubtedly undermines a monopolistic firm's profitability, as it pulls down the consumer's quality expectation as well as the firm's profit when the firm withholds its quality information. Surprisingly, a higher magnitude of elation does not necessarily benefit the firm. The underlying reason is that although consumer elation allows a firm to extract more surplus by disclosing its high quality information, it also incentivizes the firm to disclose more quality information to the consumer. This results in not only a higher expenditure on disclosing its quality information but also a diminished quality expectation from the consumer when the firm withholds its quality information, both of which offset the positive impact brought by the psychological elation. Consequently, the firm may be *worse off* when the consumer exhibits a strong feeling of elation.

We then extend our baseline model to a competitive setting to better capture the inherent characteristics of the new product promotion process.[2] Under a duopoly setting,

[2]Market competition is among the top reasons for new product failure, whose

we show that the consumer's psychological feelings still incentivize the firm to disclose more quality information, a result same as that under a monopoly setting. However, now both consumer elation and disappointment make the firms better off under a competitive environment, a result in sharp contrast to that under the monopoly setting. One particular driver for this unintended result is that under competition, a firm can hardly extract any surplus once it withholds its quality information. Instead, the firm can obtain the profit only if it discloses the quality information. Moreover, its price is solely determined by the gap of quality expectations between its own and the competitor's products. Under such circumstance, consumer psychological feelings actually widen the gap of quality expectations between the products of two firms. This then leads to a larger profit margin for the firm whose disclosed quality level is higher. Such *differentiation effect* induced by the consumer's psychological feelings consequently makes the competing firms more active at disclosing their quality information, which actually improves the firm profit. Note that if there does not exist disclosure channels for the firms to reveal their quality, the differentiation effect then vanishes.

Last, we investigate how firms can better utilize consumer disappointment/elation to achieve higher profitability under market competition. One solution is *horizontal information sharing*, wherein two competing firms can first share their quality information before making their disclosure decisions. Such information sharing can be viewed as a form of "collaboration between competitors". Compared to that of no information sharing between firms, horizontal information sharing can at least cause the following two significant changes.[3] First, in equilibrium, now only the firm with higher product quality would adopt information disclosure while the other firm (with lower product quality) would not invest in costly disclosure. This helps eliminate the possible "head to head" competition under the no-information-sharing scenario, wherein the firm with lower product quality may over-invest in information disclosure without any profit return. Second and more importantly, horizontal information sharing *complements* the effect of consumer disappointment and elation. It amplifies the positive impact of psychological feelings on differentiating the quality expectations over the two products. This is because when the consumer observes a firm withholding its quality information, she unavoidably generates a feeling of disappointment toward that firm. As a result, this further enlarges the consumer perceived quality gap between the two firms, resulting in a larger profit margin for the firm that discloses its quality information. Thus, horizontal information sharing

failure rate is nearly 70-80 percent in the food and beverage industry. Source: http://www.foodprocessing.com/articles/2013/increased-new-products/.

[3] Notably, the collaboration between competitors is quite prevalent in today's business world. See examples at https://hbr.org/1989/01/collaborate-with-your-competitors-and-win.

indeed can be an effective means to mitigate the market competition.

The rest of this paper is organized as follows. Section 2 reviews the relevant literature. In Section 3, we investigate the firm's information disclosure strategy in a monopoly setting. We then analyze the competing firms' equilibrium disclosure and pricing strategies, with and without horizontal information sharing, in Section 4. Concluding remarks are provided in Section 5. All proofs are relegated to the Appendix.

2 Literature Review

This paper belongs to the vast literature that investigates how consumer psychological feelings affect their purchase choices and firms' operational and marketing decisions (e.g., Bell (1985), Fibich et al. (2007), Kőszegi and Rabin (2007), Delquié and Cillo (2006), Nasiry and Popescu (2011), Baron et al. (2015),Wang et al. (2021),Zhang et al. (2014),Zhang and Chiang (2020)). For example, Popescu and Wu (2007) consider how reference price effects affect a firm's pricing decisions when customers remember prices in the past and form reference prices according to a simple heuristic rule. Baron et al. (2015) further investigate a situation in which a newsvendor sells to strategic customers who are loss averse with stochastic reference points in both price and product availability. In an advance selling setting, Nasiry and Popescu (2012) study how anticipated regret impacts customer purchasing behavior and Liu and Shum (2013) investigate a firm's optimal dynamic pricing and rationing decisions when consumers have psychological elation and disappointment. In a competitive environment, Jiang et al. (2017) analytically examines how consumer anticipated regret affects competing firms' product innovation and pricing decisions, in which a consumer may regret for the mismatch between the product's new attribute and her personal preferences.

Although there are certain differences among the concepts of *reference effect*, *anticipated regret* and *elation or disappointment*, the underlying principles are very similar. That is, due to unfamiliarity of the product/service, a consumer may develop some psychological feelings that generate certain psychological utility and make her expected utility deviate from the traditional intrinsic utility. In this paper, we consider the consumer' possible elation and disappointment under a competitive environment, where product quality offered by different firms is initially unknown to the consumer. Under this circumstance, firms may adopt costly disclosure to resolve the consumer's uncertainty about their products. Accordingly, psychological elation or disappointment may arise depending on whether the disclosed/updated quality is above or below the initial expectation of the consumer.

Since we investigate the impact of elation and disappointment on the firms' equilibrium disclosure strategies, our work is also related to the literature on voluntary information disclosure (Jovanovic, 1982; Matthews and Postlewaite, 1985; Shavell, 1994; Guo, 2009),Kanto and Schadewitz (2000). In this stream of research, one core issue is when a firm should adopt truthful quality disclosure to influence the consumer's quality speculation, and how different factors (e.g., disclosure cost, market competition) affect the firm's equilibrium disclosure strategy. Specifically, in a competitive environment, Guo and Zhao (2009) investigate firms' disclosure strategies under two decision sequences, in which firms may either simultaneously or sequentially determine their disclosure strategies. Dan et al. (2009) investigate two firms' equilibrium disclosure strategies in a Hotelling-type setup by considering both the horizontal and vertical differentiations between the products. Still in a Hotelling-type setup, Ghosh and Galbreth (2013) further examine the impact of searching cost and consumer inattention to disclosure on the firms' disclosure decisions. Our work, to our knowledge, is one of the first to examine how the consumers' psychological feelings influence the firm's disclosure strategy and their purchasing behaviors. Although Zhang and Li (2021) also investigate a similar issue by assuming that consumers are loss averse, our work differs from it in the following aspects: First, unlike Zhang and Li (2021) that consider a fluctuant quality reference point such that a consumer does not generate any psychological feeling when the firm discloses his quality information, we assume that consumers hold a fixed quality reference point that equals their initial quality expectation. As such, the firm's disclosure behavior would always entice consumers to generate psychological feelings and hence influence their purchasing decision. Second, we shed more lights on the interactions between firms in a competitive environment. Specifically, we consider how horizontal information sharing could improve firms' profitability when they need to disclose their private quality information to consumers with disappointment and elation feelings. This allows us to uncover the non-trivial impact of information structure on the firms' equilibrium strategies and profits, which is absent in Zhang and Li (2021).

3 The Monopoly Case

In this section, we first consider that a monopolistic firm (he) sells his product to a representative consumer (her) who purchases at most one unit of product. The product quality q is a random variable that can be privately observed by the firm, while the consumer keeps a prior belief that q follows a uniform distribution on the interval $[0, 1]$, i..e, $q \sim U[0, 1]$. Given the consumer's prior belief of the product quality, it is easy to derive that the consumer's initial quality expectation $E(q) = \mu = 1/2$. When the product's perceived quality is above her initial expectation, the consumer experiences feelings of elation; otherwise, the consumer experiences feelings of disappointment. We assume that the consumer is disappointment averse, which has been verified by psychological experiments and adopted in the related literature (Kahneman and Tversky, 1979; Tversky and Kahneman, 1991). That is, Similar to Anderson and Sullivan (1993), Bell (1985), Kopalle and Lehmann (1995) and Liu and Shum (2013), a disappointment-averse consumer's utility from purchase consists of two components: one is her intrinsic utility and the other is her psychological utility induced by disappointment or elation derived from comparing the perceived quality with her quality expectation. In particular, a consumer's utility from purchasing the product at quality q is

$$U = \begin{cases} v + q + \alpha\left(q - \frac{1}{2}\right), & \text{if } \frac{1}{2} < q \leq 1; \\ v + q - \beta\left(\frac{1}{2} - q\right), & \text{if } 0 < q \leq \frac{1}{2}, \end{cases}$$

where v represents the consumer's base utility from purchasing the product and q is the product quality. They together form the consumer's intrinsic utility from consumption, $v + q$. The term $\alpha(q - \frac{1}{2})$ is the consumer's psychological elation utility when the perceived quality is above her initial expectation, that is, when $q > \frac{1}{2}$. The parameter α represents the magnitude of elation, measuring the degree to which a unit of elation affects the consumer's purchasing utility. Similarly, the term $-\beta\left(\frac{1}{2} - q\right)$ is the consumer's psychological disappointment utility when the perceived quality is below her initial expectation, that is, when $q \leq \frac{1}{2}$. The parameter β represents the magnitude of disappointment, measuring the degree to which a unit of disappointment affects the consumer's purchasing utility. As the consumer is disappointment averse, $\beta > \alpha$ is required. Notably, the above utility setup is rooted in the vast literature that considers reference dependent consumers (Tversky and Kahneman, 1991; Kőszegi and Rabin, 2006). In particular, one can view the expected quality $1/2$ as the consumer's reference point toward the product quality and $(q - 1/2)$ is the consumer's gain-loss utility term. As aforementioned, although there are different concepts like reference effect, anticipated regret and elation or disappointment, their underlying principles are very similar. Regarding elation (or disappointment), in line with Kopalle and Lehmann (1995) and Liu and Shum (2013), it arises when a consumer's perceived quality is higher (or lower) than her initial quality expectation.

Anticipating the consumer's purchasing behavior, the firm needs to decide whether to disclose his private quality information upfront as well as the retail price p. We normalize the firm's production cost to be zero. If the firm adopts the *disclosure* strategy, the consumer can perfectly learn the true product quality. This subsequently forms her purchase utility, whose value is still influenced by the gap between the disclosed quality and her initial expectation. That is, when the disclosed quality $q > 1/2$, elation occurs and the consumer utility is $U_d = v + q + \alpha\left(q - \frac{1}{2}\right)$; when the disclosed quality $q \leq 1/2$, disappointment arises and the consumer utility is $U_d = v + q - \beta\left(\frac{1}{2} - q\right)$. The consumer purchases the product if and only if her surplus from purchase is nonnegative, that is, $U_d - p \geq 0$. In this light, we assume that the consumer's reserve utility from an outside option is zero.

If the firm chooses the *non-disclosure* strategy, the consumer rationally infers the range that the true product quality falls into a limited range of $[0, q^*]$. She then generates an expected utility U_{nd} by comparing her quality expectation ($\mu = 1/2$) with all possible quality levels. Both values of q^* and U_{nd} will be rigorously given in the following discussion. Similarly, the consumer purchases the product if and only if $U_{nd} - p \geq 0$. Note that in our paper, we assume that consumers hold a fixed quality reference point (i.e, the initial quality expectation $E(q) = \mu = 1/2$. Thus, consumers would always generate psychological elation of disappointment after observing the firm's disclosure behavior and then adjust their purchasing behaviors accordingly. This differs from Zhang and Li (2021) that consider a fluctuant reference point, under which a consumer does not generate any psychological feeling when the firm discloses his quality information but feels loss averse when the firm withholds his quality information.

We have assumed above implicitly that the disclosed information must be truthful. This truthful revelation policy is widely adopted in the literature (Grossman and Hart, 1980; Jovanovic, 1982) and can be enforced by the third party verifications or hard evidences. Moreover, the firm incurs a disclosure cost c when he decides to disclose his quality. The disclosure cost c is public information and represents the cost of effort that the firm spends to convince the consumer, which may include the cost of advertising, providing the free samples or obtaining the professional certifications (e.g., ISO 9000). To avoid the trivial scenario that no quality information will be disclosed, it is necessary to impose an upper bound on the disclosure cost. Specifically, here $c < (4 + 3\alpha + \beta)/8$ is required.

We now characterize the monopolistic firm's equilibrium disclosure and pricing strategy. If the firm discloses his product quality information, he can optimally set the retail price $p_d = U_d$. If the firm withholds his product quality information, the consumer would update her belief about the product quality and then generate an expected utility U_{nd}. Thus, the maximum price that the firm can charge if he keeps silent is $p_{nd} = U_{nd}$. Under both cases, the entire consumer surplus from purchase is extracted to be zero.

It is evident that the firm's equilibrium disclosure strategy exhibits a threshold type structure, wherein he discloses his quality information when his quality level is higher than a threshold q^* and remains silent otherwise. Upon observing the firm's non-disclosure behavior, the consumer believes that the product quality falls uniformly into the range $[0, q^*]$. Then, the firm extracts all the consumer surplus by setting the retail price p_{nd} equal to her expected utility U_{nd}, that is,

$$p_{nd}^* = U_{nd} = \begin{cases} v + \frac{q^*}{2} + \frac{1}{q^*} \underbrace{\int_0^{q^*} \beta \left(q - \frac{1}{2}\right) dq}_{\text{psychological disappointment}}, & \text{if } 0 < q^* \leq \frac{1}{2}; \\ v + \frac{q^*}{2} + \frac{1}{q^*} \left(\underbrace{\int_0^{\frac{1}{2}} \beta \left(q - \frac{1}{2}\right) dq + \int_{\frac{1}{2}}^{q^*} \alpha \left(q - \frac{1}{2}\right) dq}_{\text{psychological disappointment and elation}} \right), & \text{if } \frac{1}{2} < q^* \leq 1. \end{cases} \tag{1}$$

Note that when the firm withholds his quality information, his payoff just equals p_{nd}^*.

When the firm discloses his quality information, he again extracts the entire consumer surplus by setting the optimal retail price $p_d^* = U_d$. At the threshold $q = q^*$, the firm sets $p_d|_{p=q^*} = U_d|_{p=q^*}$, that is,

$$p_d^*|_{p=q^*} = U_d|_{p=q^*} = \begin{cases} v + q^* - \underbrace{\beta \left(\frac{1}{2} - q^*\right)}_{\text{Disappointment}}, & \text{if } 0 < q^* \leq \frac{1}{2}; \\ v + q^* + \underbrace{\alpha \left(q^* - \frac{1}{2}\right)}_{\text{Elation}}, & \text{if } \frac{1}{2} < q^* \leq 1. \end{cases} \tag{2}$$

As the firm incurs a disclosure cost c, his payoff when $q = q^*$ is $p_d^*|_{p=q^*} - c$. The firm is indifferent toward whether to disclose or withhold his quality information at the cutoff quality level q^*. We then have the following proposition.

Proposition 1. *When the consumer exhibits psychological disappointment and elation, in equilibrium,*

(i). if the disclosure cost $c < \frac{(\beta+1)}{4}$, the monopoly firm discloses his quality information when $q \geq q^* = \frac{2c}{1+\beta}$; otherwise, he adopts the non-disclosure strategy. Moreover, $\partial q^* / \partial \beta < 0$.

(ii). *if the disclosure cost* $c \in \left[\frac{(\beta+1)}{4}, \frac{(4+3\alpha+\beta)}{8}\right)$, *the monopoly firm discloses his quality information when* $q \geq q^*$ *and withholds such information when* $q < q^*$, *where* q^* *satisfies*

$$\frac{1+\alpha}{2}q^* + \frac{(\beta-\alpha)}{8q^*} = c. \tag{3}$$

Furthermore, $\partial q^*/\partial\alpha < 0$ *and* $\partial q^*/\partial\beta < 0$.

Proposition 1 implies that the monopoly firm's disclosure incentive always increases in the magnitude of disappointment β. This is mainly driven by the fact that when the firm withholds his quality information, the consumer would always form an updated quality expectation $q^*/2$ that is below her initial quality expectation $1/2$. Therefore, the consumer would feel disappointed and becomes more conservative at purchasing. This inevitably gives the firm a higher incentive of disclosure; otherwise he may suffer a greater loss from non-disclosure due to consumer disappointment. Proposition 1 also implies that when the disclosure cost is relatively high, the increase of α, the magnitude of elation, makes the monopoly firm more likely disclose his quality information as $\partial q^*/\partial\alpha < 0$. This is because when the magnitude of elation increases, disclosing the high quality information would induce the consumer to generate a stronger feeling of elation, which in turn allows the firm to extract more surplus from disclosure. This subsequently incentivizes the firm to more actively disclose his quality information.

We now derive the firm's ex-ante payoff based on his equilibrium disclosure strategy stated in Proposition 1. The firm's ex-ante payoff can be written as

$$\Pi_M = v + \begin{cases} \underbrace{\int_0^{q^*}\left(\frac{q^*(1+\beta)}{2} - \frac{\beta}{2}\right)dq}_{\text{non-disclosure+disappointment}} + \underbrace{\int_{q^*}^{\frac{1}{2}}\left(q(1+\beta) - \frac{1}{2}\beta - c\right)dq}_{\text{disclosure+disappointment}} \\ + \underbrace{\int_{\frac{1}{2}}^{1}\left(q(1+\alpha) - \frac{1}{2}\alpha - c\right)dq}_{\text{disclosure+elation}}, \quad \text{if } 0 < q^* \leq \frac{1}{2}; \\ \underbrace{\int_0^{q^*}\left(\frac{q^*(1+\alpha)}{2} - \frac{\alpha}{2} - \frac{(\beta-\alpha)}{8q^*}\right)dq}_{\text{non-disclosure+disappointment/elation}} + \underbrace{\int_{q^*}^{1}\left(q(1+\alpha) - \frac{1}{2}\alpha - c\right)dq}_{\text{disclosure+elation}}, \\ \text{if } \frac{1}{2} < q^* \leq 1. \end{cases} \tag{4}$$

Proposition 2. *When the consumer exhibits psychological disappointment and elation, in equilibrium,*

(i). *the monopoly firm's ex–ante payoff monotonically decreases in the magnitude of disappointment* β.

(ii). the monopoly firm's ex-ante payoff increases in the magnitude of elation α when the disclosure cost c is less than a threshold c_0 and decreases in α otherwise, where $\frac{(\beta+1)}{4} \leq c_0 < \frac{(4+3\alpha+\beta)}{8}$.

Proposition 2 shows that although consumer disappointment and elation affect the firm's disclosure incentive in the same direction, their impact on the firm's ex-ante payoff differs significantly. Specifically, the firm is always worse off when the consumer possesses a stronger feeling of disappointment. The increase of β, the magnitude of disappointment, not only undermines the firm's profitability upon non-disclosure but also induces the firm to undertake disclosure more frequently, which leads to a higher expenditure on disclosure. Both are detrimental to the firm's profitability. However, Proposition 2 shows that the increase of the magnitude of elation α can either improve or impair the firm's profitability, depending on the magnitude of the disclosure cost. Intuitively, a higher α facilitates the firm to extract more surplus from the consumer by disclosing the high quality information, which should be beneficial to its profitability. Nonetheless, this also incentivizes the firm to disclose more quality information in equilibrium. This not only pulls down the consumer's quality expectation upon observing the firm's non-disclosure behavior but also increases the firm's expenditure on disclosure. When the disclosure cost is sufficiently high, such downside from the high magnitude of elation can be strong enough to result in a lower profit for the firm. We further obtain the following result.

Corollary 1. *The firm obtains a lower ex-ante payoff when the consumer exhibits psychological disappointment and elation than that when the consumer is fully rational.*

Corollary 1 shows that consumer disappointment and elation hurt the monopoly firm's profit. Such psychological feeling alters the firm's voluntary information disclosure structure by pushing down his disclosure quality threshold. With consumer disappointment and elation, the firm is unable to strategically withhold the relatively low quality information than that when the consumer is fully rational. We can also show that this result continues to hold when the consumer is disappointment neutral (i.e., $\alpha = \beta$) rather than disappointment averse ($\alpha < \beta$).

4 The Duopoly Case

In the foregoing section, we consider the firm's information disclosure strategy in a monopoly setting. We now further examine the firms' information disclosure strategy in a duopoly setting where two firms are engaged in horizontal competition. We would like to examine how competition and consumer disappointment and elation jointly affect the firms' information disclosure behavior.

Consider that two firms each sell one product to a representative consumer who buys at most one product from them. Product quality of each firm i, q_i is exogenously given, $i \in \{1,2\}$ (Ghosh and Galbreth, 2013; Dan et al., 2009). The consumer holds a prior belief that the product quality of each firm is an independent, identically distributed random variable with a uniform distribution over the interval $[0,1]$, where 1 represents the highest quality level and 0 represents the lowest quality level. Therefore, one can infer that the consumer's quality expectation towards both firms is the same and equals $E(q_1) = E(q_2) = \mu = 1/2$. Similar to that under the monopoly setting, the consumer utility from purchasing firm i's product, U_i, is still composed of two parts: her intrinsic utility from purchasing firm i's product at the quality level q_i and her psychological utility induced from the comparison between the updated quality level (inferred from firm i's disclosure behavior) and the initial quality expectation $E(q_i)$, $i \in \{1,2\}$. The corresponding consumer purchase surplus is thus $U_i - p_i$, where p_i is the retail price charged by firm i, $i = 1,2$.

Each firm i, $i = 1,2$, in contrast, can privately observe his own quality level but holds the same prior belief as that of the consumer about the rival party's product quality. The firms may share their private quality information with each other. Below, we first consider the scenario where the firms do not share the information about their quality level. That is, each firm does not know the quality level of the other party, namely, the *no information sharing* scenario. We then consider the scenario where the firms share such information and know each other's quality level, namely, the *horizontal information sharing* scenario. We shall derive the firm's equilibrium pricing and disclosure decisions under both scenarios. Hereafter, let $p^i_{s_i}$ and $U^i_{s_i}$ respectively represent the retail price of firm i and the consumer utility from purchasing firm i's product when he adopts s_i strategy, where $i \in \{1,2\}$ and $s_i \in \{d, nd\}$.

4.1 When Firms Do Not Share Their Quality Information

In this subsection, we consider the *no information sharing* scenario where firms do not know each other's true quality level. The sequence of events is as follows. First, both firms simultaneously decide whether to costly disclose their private quality information without knowing the rival firm's disclosure decision. Next, both firms observe the other party's disclosure decision and decide their retail prices accordingly. Finally, the consumer observes the firms' disclosure and price decisions and decides which product to purchase. Naturally, the consumer would buy the product of firm i only if it gives her a higher nonnegative utility, i.e, $U^i_{s_i} - p^i_{s_i} \geq \max(0, U^{3-i}_{s_{3-i}} - p^{3-i}_{s_{3-i}})$, where $i \in \{1, 2\}$. Thus, from the firms' perspective, after observing each other's disclosure behavior, their equilibrium prices are determined by the consumer utility difference between the two firms; that is, $p^i_{s_i} = \max(0, U^i_{s_i} - U^{3-i}_{s_{3-i}})$, $i \in \{1, 2\}$.

Without loss of generality, we focus on the symmetric equilibrium. That is, in equilibrium both competing firms would disclose their quality information only if their product quality q_i is higher than a threshold level denoted by q^*_d, $i \in \{1, 2\}$. When the product quality q_i is lower than q^*_d, firm i would choose the non-disclosure strategy. Given this equilibrium disclosure structure, the key step is to derive the disclosure cutoff point q^*_d, at which point both firms are indifferent between disclosing and withholding their quality information. Let us first assume that firm 1 chooses the *non-disclosure* strategy at $q_1 = q^*_d$. Then, the consumer's expected utility from purchasing firm 1's product can be written as

$$U^1_{nd}|_{q_1=q^*_d} = \begin{cases} v + \dfrac{q^*_d}{2} + \dfrac{1}{q^*_d} \underbrace{\displaystyle\int_0^{q^*_d} \beta \left(q - \frac{1}{2}\right) dq}_{\text{psychological disappointment}}, & \text{if } 0 < q^*_d \leq \dfrac{1}{2}; \\ v + \dfrac{q^*_d}{2} + \dfrac{1}{q^*_d} \left(\underbrace{\displaystyle\int_0^{\frac{1}{2}} \beta \left(q - \frac{1}{2}\right) dq + \int_{\frac{1}{2}}^{q^*_d} \alpha \left(q - \frac{1}{2}\right) dq}_{\text{psychological disappointment and elation}} \right), & \text{if } \dfrac{1}{2} < q^*_d \leq 1. \end{cases}$$

We then consider firm 2's possible action to identify firm 1's equilibrium price, when firm 1 withholds his quality information at $q_1 = q^*_d$. If firm 2 also chooses non-disclosure, it indicates that his product quality is below q^*_d. Then, it can be easily shown that the consumer's expected utility from purchasing firm 2's product satisfies $U^2_{nd} = U^1_{nd}|_{q_1=q^*_d}$. This subsequently leads to the following equilibrium prices for both firms: $p^1_{nd} = p^2_{nd} = 0$. While if firm 2 chooses disclosure, which indicates that his product quality is above q^*_d, one can infer that the consumer's expected utility from purchasing firm 2's product is

$$U^2_d|_{q_2 \geq q^*_d} \geq U^2_d|_{q_2=q^*_d} = U^1_d|_{q_1=q^*_d} > U^1_{nd}|_{q_1=q^*_d}.$$

Thus, in equilibrium $p^1_{nd} = 0$ and $p^2_d = U^2_d|_{q_2 \geq q^*_d} - U^1_{nd}|_{q_1=q^*_d} > 0$. Based on the above discussions, we can conclude that firm 1 can never extract any consumer surplus if he withholds his quality information in a competitive environment.

On the other hand, if firm 1 chooses disclosure at $q_1 = q^*_d$, the consumer utility from purchasing firm 1's product now equals

$$U^1_d|_{q_1=q^*_d} = v + q^*_d + \alpha \left(q^*_d - \frac{1}{2}\right) \text{ when } q^*_d > \frac{1}{2};\ U^1_d|_{q_1=q^*_d} = v + q^*_d - \beta \left(\frac{1}{2} - q^*_d\right), \text{ otherwise.}$$

Under such circumstance, if firm 2 also chooses disclosure (when $q_2 \geq q_d^*$), we have $U_d^1|_{q_1=q_d^*} \leq U_d^2|_{q_2 \geq q_d^*}$ and in equilibrium $p_d^1|_{q_1=q_d^*} = 0$ and $p_d^2|_{q_2 \geq q_d^*} \geq 0$. However, if firm 2 chooses non-disclosure, the consumer utility from purchasing firm 2's product is

$$U_{nd}^2|_{q_2 \leq q_d^*} < U_d^2|_{q_2=q_d^*} = U_d^1|_{q_1=q_d^*}.$$

Consequently, in equilibrium, the firms' retail prices are $p_d^1|_{q_1=q_d^*} = U_d^1|_{q_1=q_d^*} - U_{nd}^2|_{q_2 \leq q_d^*} > 0$ and $p_{nd}^2 = 0$. Thus, conditional on firm 2's disclosure strategy, firm 1's expected payoff from disclosure at $q_1 = q_d^*$ can be written as $\int_0^{q_d^*} \left(p_d^1|_{q_1=q_d^*} \right) dq_2 - c$. Because the firm is indifferent between disclosure and non-disclosure at the quality level q_d^*, we can derive the firms' equilibrium disclosure strategies as follows.

Proposition 3. *In a duopoly game without horizontal information sharing, in equilibrium,*

(i). when $0 < c \leq (\beta + 1)/8$, firm i discloses his quality information when the product quality $q_i \geq q_d^* = \sqrt{2c/(1+\beta)}$ and remains silent otherwise, $i \in \{1, 2\}$. Moreover, $\partial q_d^* / \partial \beta < 0$.

(ii). When $(\beta + 1)/8 < c \leq (4 + 3\alpha + \beta)/8$, firm i discloses his quality information when product quality $q_i \geq q_d^*$ and remains silent otherwise, $i \in \{1, 2\}$, where q_d^* satisfies

$$\frac{1+\alpha}{2} (q_d^*)^2 + \frac{\beta - \alpha}{8} = c.$$

Furthermore, $\partial q_d^* / \partial \alpha < 0$ and $\partial q_d^* / \partial \beta < 0$.

A comparison of Propositions 1 and 3 reveals that the disclosure threshold under the duopoly case (q_d^*) is higher than that under the monopoly case (q^*); that is, the firm's disclosure incentive is much lower in a competition context than that when the firm is a monopoly. In other words, horizontal competition induces both firms to withhold more private quality information. The underlying reason is that if now a firm wants to derive additional profit via disclosure, he has to ensure that the competitor's product quality is lower than his, and the optimal price he can charge is determined by the gap of quality expectations over the two products. Thus, the benefit a firm can enjoy through disclosing his product quality information is now significantly reduced. Accordingly, in a competitive environment both firms become more conservative in terms of voluntary information disclosure.

How does consumers' psychological feeling affect the competing firms' equilibrium disclosure strategies? Proposition 3 shows that each firm's disclosure cutoff point is monotonically decreasing in either the magnitude of disappointment or elation, indicating that both firms are more likely to disclose the quality information when the consumer possesses stronger psychological feelings. Although this result is the same as that under a monopoly setting stated in Proposition 1, the underlying reasons are totally different. Notably, under market competition, a firm can win the consumer only via disclosure, whose effect is determined by the gap of consumer quality expectations over the two products. When either psychological feeling becomes stronger, it actually widens the quality expectation gap over the two products and thus, allows the firm that discloses the higher quality information to extract more profit. For example, given the perceived quality q_1 and q_2, the gap of the updated consumer quality expectations over the two products changes from $q_1 - q_2$ to either $(1+\beta)(q_1 - q_2)$ when the consumer feels disappointed with both products (i.e., $q_2 < q_1 < 1/2$) or $(1+\alpha)(q_1 - q_2)$ when the consumer feels elated with both products (i.e., $1/2 < q_2 < q_1$); and it changes to $q_1 - q_2 + a(q_1 - 1/2) + \beta(1/2 - q_2)$ when $q_2 < 1/2 < q_1$. Under all the above circumstances, the expectation gap is indeed enlarged. This indicates that in a competitive environment, consumer psychological feelings can generate a *differentiation effect* on her quality expectations over the two products, which in turn makes firms more active in disclosure.

Proposition 4. *In a duopoly game without horizontal information sharing, in equilibrium,*

(i). the firm's ex-ante payoff monotonically increases in both the magnitude of elation (α) and the magnitude of disappointment (β);

(ii). the firm is better off when the consumer exhibits psychological disappointment and elation than that when the consumer is fully rational.

Proposition 4 indicates that consumer psychological feelings always make the firms better off when they are engaged in competition. This is in sharp contrast to that under the monopoly case where consumer psychological feelings hurt the firm (see Corollary 1). This is because under competition, consumer psychological feelings not only incentivize the firms to disclose more quality information but also widen the gap of quality expectations over the two products, which turns out to be beneficial to the firms. This shows that how consumer psychological feelings impact the firm profitability highly depends on the market environment.

4.2 When Firms Share Their Quality Information

We next investigate an alternative scenario by considering that two competing firms first observe each other's product quality and then decide whether to costly disclose their quality information to the consumer. This is realistic in business practice, which can be viewed as a form of horizontal collaboration between competing firms (Basso et al., 2020). Similar to Board (2009), we consider a setting in which the competing firms could first reach a collaboration agreement by sharing the product information before launching their products into the market. We also assume that the consumers can confirm such kind of collaboration (i.e., horizontal information sharing) between competing firms (which is not uncommon in practice), and then make their rational inferences about the product quality after observing the firms' disclosure behaviors. Note that the similar assumption has been adopted in the related literature like Guo and Zhao (2009) and Zhang and Li (2021), in which they assume that the consumers can confirm the timing of firms' disclosure decisions (simultaneously or sequentially) before the firms make the disclosure decisions.

Let the subscript $\widehat{}$ denote the notation under this scenario. We assume that in equilibrium the firm with an ex post higher product quality can always obtain a weakly higher payoff than the firm with an ex post lower product quality. (Note that when this assumption is violated, there may not exist a pure equilibrium disclosure strategy as the low-quality firm may also choose disclosure to misguide the consumer.) Under such a circumstance, in equilibrium, it is never optimal for both firms to disclose their quality information. This is because the firm with a lower quality cannot derive any profit from disclosure. Then, there are two possible equilibrium disclosure strategies: one, the high-quality firm discloses the quality information but its rival firm does not; and two, both firms choose non-disclosure. Building upon the above reasoning, we next characterize the firms' equilibrium disclosure strategies when they share information horizontally.

Without loss of generality, we name the ex post high-quality firm as firm 1 and the ex post low-quality firm as firm 2; that is, $q_1 > q_2$. If firm 1 chooses disclosure and firm 2 chooses non-disclosure, the consumer not only knows the product quality of firm 1 but also infers that firm 2's product quality q_2 is lower than q_1. Subsequently, she updates her belief about firm 2's quality level: q_2 shall be uniformly distributed between $[0, q_1]$. Building upon this quality inference, the consumer utility, influenced by her psychological feelings, from purchasing the firms' products can be written as

$$\widehat{U}_d^1 = v + q_1 - \beta\left(\frac{1}{2} - q_1\right) \text{ and } \widehat{U}_{nd}^2 = v + \frac{(1+\beta)q_1}{2} - \frac{\beta}{2}, \text{ if } q_1 < \frac{1}{2};$$
$$\widehat{U}_d^1 = v + q_1 + \alpha\left(q_1 - \frac{1}{2}\right) \text{ and } \widehat{U}_{nd}^2 = v + \frac{(1+\alpha)q_1}{2} - \frac{\alpha}{2} - \frac{\beta-\alpha}{8q_1}, \text{otherwise.}$$

Consequently, firm 1 shall set the price $\widehat{p}_d^1 = \widehat{U}_d^1 - \widehat{U}_{nd}^2$ and firm 2 sets the price $\widehat{p}_{nd}^2 = 0$. If both firms choose non-disclosure, they get zero payoff as the consumer cannot infer which product quality is higher. Thus, their prices $\widehat{p}_{nd}^1 = \widehat{p}_{nd}^2 = 0$.

Proposition 5. *In a duopoly game with horizontal information sharing, in equilibrium, the ex-post low-quality firm 2 always adopts non-disclosure strategy. As to the ex-post high-quality firm 1, we have:*

(1). if $0 < c < \frac{(\beta+1)}{4}$*, the ex-post high-quality firm 1 discloses his quality information when product quality* $q_1 \geq \widehat{q}_d^* = \frac{2c}{\beta+1}$ *and remains silent otherwise.*

(2). if $\frac{(\beta+1)}{4} \leq c < \frac{(4+3\alpha+\beta)}{8}$*, the ex-post high-quality firm 1 discloses his quality information when* $q_1 \geq \widehat{q}_d^*$ *and withholds his quality information otherwise, where* $\widehat{q}_d^*$ *satisfies*

$$\widehat{q}_d^* \frac{1+\alpha}{2} + \frac{(\beta-\alpha)}{8\widehat{q}_d^*} = c.$$

A comparison of Propositions 3 and 5 shows that horizontal information sharing between the competing firms dramatically impacts the equilibrium disclosure strategies. Now, the firm that has the ex-post low quality never discloses his quality information, while he may disclose such information when the firms do not share their private quality information upfront. This is because horizontal information sharing alters the consumer quality speculation process. It facilitates the consumer to better infer the firms' product quality after observing their disclosure behaviors. When the firms do not share their quality information, the consumer believes that each firm's disclosure decision is independent and her quality expectation towards the firm that withholds his information would converge to a fixed point. However, when the firms share their quality information, firms' disclosure decisions are now dependent on their observed quality levels. The consumer then can take the disclosed quality level as a benchmark to further infer the quality level of the firm that withholds his information. Thus, only the ex-post high-quality firm has incentive to disclose his quality when firms share their information upfront.

Corollary 2. *In a duopoly game with horizontal information sharing, in equilibrium,*

(1). the firm's disclosure incentive monotonically increases when the magnitude of disappointment (or elation) increases, i.e., $\partial\widehat{q}_d^*/\partial\alpha < 0$ *and* $\partial\widehat{q}_d^*/\partial\beta < 0$*.*

(2). the firm's ex-ante payoff monotonically increases in both the magnitude of disappointment and the magnitude of elation, i.e., $\partial\widehat{\Pi}_D/\partial\alpha > 0$ *and* $\partial\widehat{\Pi}_D/\partial\beta > 0$*.*

Again, Corollary 2 indicates that even when the firms share their quality information upfront, their information disclosure incentives still increase as the consumer's psychological feelings become stronger. The rationale behind is similar to that in §4.1 when firms do not share their quality information. That is, the psychological feelings actually widen the gap between the quality expectations over the two products. The high-quality firm then is able to extract more profit from disclosing his quality information and thus becomes more active in disclosure. Consequently, the increase of the magnitude of psychological feelings is always beneficial to the competing firms, a conclusion same as that stated in Proposition 4 in the absence of horizontal information sharing. That is, in a competitive environment, the *differentiation effect* induced by psychological feelings holds no matter whether the firms share their quality information or not.

4.3 The Impact of Horizontal Information Sharing

In this subsection, we further compare the firm performance when they share quality information with each other with that when they do not share information, so as to investigate the effect of horizontal information sharing in the presence of consumer psychological feelings.

Information transparency. Under our setting, the level of information transparency stands for how likely the firm would voluntarily disclose his private quality information to the market. Mathematically, it is represented by the *ex-ante information disclosure probability* that is the aggregate probability over all the scenarios in which the firm would disclose his quality information ex post after observing his quality level.

Recall that horizontal information sharing between the firms has the following two effects when firms are engaged in competition. One, a firm would never disclose his quality information once his quality is ex post lower that that of the rival firm. Compared to that with no information sharing, horizontal information sharing naturally reduces a firm's ex-ante disclosure incentives as in a no-information-sharing scenario, a firm may over-invest in disclosure without seeing the competitor's quality level. Two, if a firm observes that his quality is ex post higher than that of the rival firm, he becomes more active in disclosure than that under the no-information-sharing scenario. This is because under this circumstance, the firm can anticipate that the rival firm would choose non-disclosure to avoid the fierce competition, which undoubtedly leaves him more surplus from disclosure and thus enhances his disclosure incentive. The overall impact of these two ex-post effects then determines the firm's ex-ante disclosure incentives.

Let $\widehat{P}_D$ and P_D denote the firm's ex-ante disclosure probability in the presence and absence of horizontal information sharing, respectively. $\widehat{P}_D - P_D$ then represents the ex-ante disclosure probability gap under the two information scenarios. Figure 1 illustrates how the disclosure cost c, along with the change of the magnitude of elation (α) or disappointment (β), affect this difference gap.

As shown in Figure 1, there exists a disclosure cost threshold, below which the firm

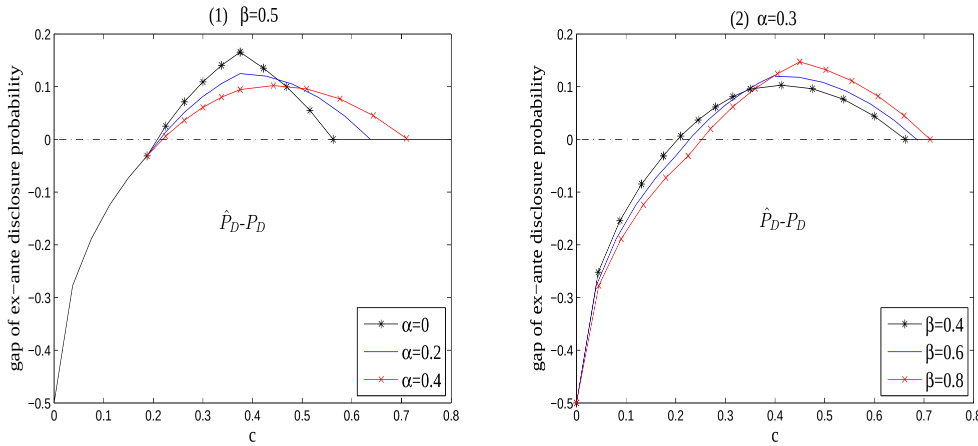

Figure 1: The firm's ex-ante disclosure probability difference ($P_D - \widehat{P}_D$)): with versus without horizontal information sharing.

ex-ante discloses more quality information under the no information sharing scenario than that with horizontal information sharing while above which the reverse holds. When the disclosure cost is sufficiently high, the firm prefers the 'non-disclosure' strategy under both information scenarios. That is, the firms do not disclose any information no matter whether they horizontally share information with each other or not. Thus, the ex-ante disclosure probability difference vanishes. Figure 1 also implies that the change of consumer psychological feelings, either elation or disappointment, does not materially influence the gap of information transparency between these two information scenarios. Next, we examine the impact of horizontal information sharing on the firm's ex-ante profitability and obtain the following resutls.

Corollary 3. *In a duopoly game, when the disclosure cost* $c \in (0, (\beta+1)/4]$*,*

(i). the firm enjoys a higher ex-ante payoff under the horizontal information sharing than that with no information sharing.

(ii). an increase of the magnitude of elation and/or the magnitude of disappointment further enlarge(s) the firm's ex-ante payoff difference under the two information scenarios and makes horizontal information sharing more desirable; that is, $\widehat{\Pi}_D - \Pi_D$ *(weakly) increases in both* α *and* β*.*

Corollary 3 shows that sharing the private quality information with the rival firm always makes a firm better off when consumers exhibit psychological disappointment and elation. This additional profit gain is due to that firms now can make more precise disclosure decisions to avoid over-investment in costly disclosure. Moreover, it bypasses the possible fierce "head to head" competition that may occur under the no-information-sharing scenario, wherein both firms disclose their quality information. Corollary 3 also implies that the increase of the magnitude of psychological feeling further intensifies the positive effect of horizontal information sharing. Recall that under horizonal information sharing, in equilibrium only one firm would disclose the quality information while the other firm simply keeps silent. Thus, the consumer utility from purchasing the product of the silent firm is inevitably reduced due to the psychological disappointment, which entices the firm that discloses his quality information to charge a higher retail price. Consequently, this increases the firm's ex-ante payoff. In contrast, under no information sharing, the positive effect of psychological feelings can be mitigated by the firms' disclosure behaviors when they both disclose their quality information.

Table 1: Summary of Parameter Values

Magnitude of Elation	$\alpha \in [0, 0.9]$	Step length= 0.01
Magnitude of Disappointment	$\beta \in [\alpha, 1]$	Step length= 0.01
Disclosure Cost	$c \in [(\beta+1)/4, (4+3\alpha+\beta)/8]$	Step length= 0.1

Note that when $(\beta+1)/4 < c \leq (4+3\alpha+\beta)/8$, it is quite challenging to identify the relationship between $\widehat{\Pi}_{D|\left(\widehat{q}_d^*>1/2\right)} - \Pi_{D|\left(q_d^*>1/2\right)}$ and α/β, due to the complexity of payoff functions. Thus, we have to rely on the extensive numerical study to verify their relationship by varying the magnitude of elation, the magnitude of disappointment and the magnitude of disclosure cost; see Table 1 for the summary of parameter values. In total, we have 1545000 feasible combinations. Our extensive numerical studies show that the results stated in Corollary 3 continue to hold when the disclosure cost $(\beta+1)/4 < c \leq (4+3\alpha+\beta)/8$; see Figure 2 for an illustration. This implies that regardless of the magnitude of the disclosure cost, horizontal information sharing always makes the firm better off and the existence of consumer psychological feelings further strengthes such positive effect.

5 Conclusion

When a customer is not familiar with the new product's quality offered by the firm(s), she relies on her quality expectation to make the purchasing decision. The quality expectation, however, is unavoidably influenced by some psychological feelings like elation and disappointment. This paper investigates the firm' optimal quality information disclosure strategy by taking such consumer psychological feelings into account.

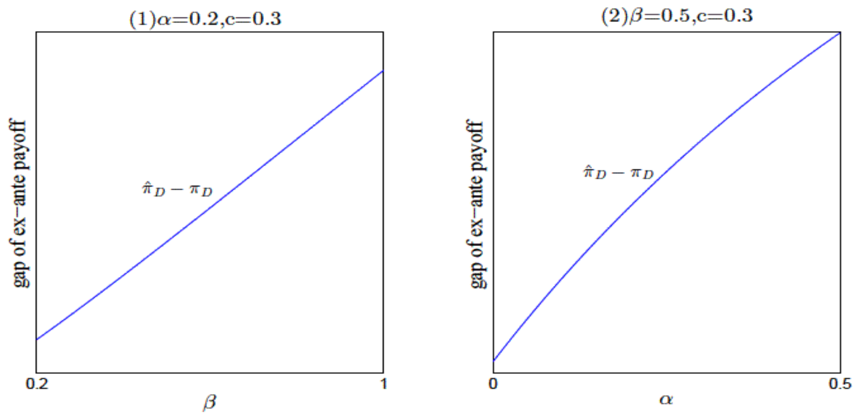

Figure 2: A comparison of firm ex-ante payoffs: with versus without horizontal information sharing.

We show that both psychological disappointment and elation induce the firm to disclose more quality information than that when the consumer is fully rational, regardless of the market condition (whether the firm is a monopoly or engaged in competition). Moreover, under duopoly competition, the firm's disclosure incentive is further enhanced by the gap of consumer quality expectations over the products of two firms, whose value also increases in the magnitudes of consumer psychological feelings.

Nonetheless, the impact of consumer psychological feelings on the firm's payoff varies significantly under different market environments. When the firm is a monopoly, the firm's payoff decreases in the magnitude of disappointment but may increase in the magnitude of elation. However, under the duopoly competition, the firm's payoff always increases in both the magnitudes of disappointment and elation. Such a striking contrast is driven by the fact that in a monopoly game, disclosing more quality information is not always beneficial to the firm as it mitigates the positive effect of strategic information withholding. While in a competitive environment, a firm can make profit only via disclosure and his profitability is determined by the gap of consumer quality expectations over the products of two firms. Under this circumstance, consumer psychological feelings can generate a differentiation effect that amplifies the gap between the consumer's quality expectations over the products of two firms and thus makes the competing firms more profitable from disclosure.

We also examine the case when the competing firms can first share their private quality information before making their disclosure decisions. This horizontal information sharing affects the consumer's quality inference and therefore, alters the firms' disclosure strategies. In equilibrium, at most one firm would choose to disclose his quality information when the firms share their quality information upfront. Thus, compared to the case without information sharing, horizontal information sharing alleviates the "head to head" competition between the firms and leaves more profit margin to the firm that discloses his quality information. Interestingly, the firm may ex-ante disclose more quality information in the presence of ex post horizontal information sharing than that with no information sharing when the consumer possesses strong psychological feelings.

In our study, when competing firms can share their quality information upfront, we have assumed that the consumers can confirm this information structure before they observe the firms' disclosure behaviors. Although this kind of assumption is prevalent in the literature, it is still worthwhile for us to consider a more complicated setting in which the consumers need to infer whether the firms would first share their quality with each other before they decide their disclosure decisions. This setting is very interesting but the related analysis is much more complicated and challenging. We would like to leave it as future research.

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Appendix: Proofs

Proof of Proposition 1. Given the firm's payoffs under different disclosure options stated in (1) and (2), it is evident that at q^* we have $p_d - c = p_{nd}$. We first assume that the disclosure cutoff point $0 < q^* < 1/2$. Based on (1) and (2), we get

$$v + q^* - \beta(\frac{1}{2} - q^*) - c = v + \frac{q^*(1+\beta)}{2} - \frac{\beta}{2},$$

which leads to the equilibrium $q^* = \frac{2c}{\beta+1}$. Because the cutoff point must be lower than $1/2$, the essential condition for this equilibrium result is that $c < \frac{(\beta+1)}{4}$. Otherwise, if $c > \frac{(\beta+1)}{4}$, in equilibrium we have

$$v + q^* + \alpha(q^* - \frac{1}{2}) - c = v + \frac{q^*(1+\alpha)}{2} - \frac{\alpha}{2} - \frac{(\beta-\alpha)}{8q^*}.$$

Then we can derive that

$$q^*\frac{1+\alpha}{2} + \frac{(\beta-\alpha)}{8q^*} = c \to q^* = \frac{2c + \sqrt{(1+\alpha)(\alpha-\beta)+4c^2}}{2\alpha+2}.$$

Because $q^* \leq 1$, it requires that $c \leq \frac{(4+3\alpha+\beta)}{8}$.

Next, we derive the relationship between q^* and β or α. Note that when $0 \leq c < \frac{(\beta+1)}{4}$, $q^* = \frac{2c}{1+\beta}$ and it is evident that $\partial q^*/\partial\beta < 0$. When $\frac{(\beta+1)}{4} \leq c < \frac{(4+3\alpha+\beta)}{8}$, $q^* = \frac{2c+\sqrt{(1+\alpha)(\alpha-\beta)+4c^2}}{2\alpha+2}$. Obtaining the first-order condition with respect to α, we have

$$\frac{\partial q^*}{\partial\alpha} = \frac{\alpha+\beta-4c\sqrt{\alpha-\beta+\alpha^2-\alpha\beta+4c^2}+\alpha\beta-8c^2+1}{4\left(\alpha+1\right)^2\sqrt{\alpha-\beta+\alpha^2-\alpha\beta+4c^2}}.$$

Let $G(\alpha,\beta,c) := \alpha+\beta-4c\sqrt{\alpha-\beta+\alpha^2-\alpha\beta+4c^2}+\alpha\beta-8c^2+1$. We can show that

$$\frac{\partial G(\alpha,\beta,c)}{\partial c} = -4\frac{\left(2c+\sqrt{\alpha-\beta+\alpha^2-\alpha\beta+4c^2}\right)^2}{\sqrt{\alpha-\beta+\alpha^2-\alpha\beta+4c^2}} < 0.$$

Furthermore, we can show that $G(\alpha,\beta,c)\big|_{c=\frac{(\beta+1)}{4}} = 0$, which implies that $G(\alpha,\beta,c) < 0$ for all $c \in \left[\frac{(\beta+1)}{4}, \frac{(4+3\alpha+\beta)}{8}\right]$. Then, $\frac{\partial q^*}{\partial\alpha} < 0$.

Similarly, for the relationship between q^* and β, we can show that

$$\frac{\partial q^*}{\partial\beta} = -\frac{1}{4\sqrt{\alpha-\beta+\alpha^2-\alpha\beta+4c^2}} < 0.$$

Note that q^* decreases in either β or α, indicating that the firm is more likely to disclose the quality information under such a circumstance.

Proof of Proposition 2. Given the firm's payoff in (4), we can combine the two subcases ($q^* < 1/2$ and $q^* > 1/2$) together through some mathematical derivation and algebraic calculation, and the firm's payoff can be simplified as

$$\Pi_M = v + \frac{1}{8}\alpha - \frac{1}{8}\beta - c(1-q^*) + \frac{1}{2}.$$

Taking the first order condition of Π_M with respect to β, we get

$$\frac{\partial \Pi_M}{\partial \beta} = \frac{d\Pi_M}{d\beta} + \frac{d\Pi_M}{dq^*}\frac{dq^*}{d\beta} = -\frac{1}{8} + c\frac{dq^*}{d\beta} < 0.$$

The firm's payoff monotonically decreases in β.

For the elation magnitude α, we have

$$\frac{\partial \Pi_M}{\partial \alpha} = \frac{d\Pi_M}{d\alpha} + \frac{d\Pi_M}{dq^*}\frac{dq^*}{d\alpha} = \frac{1}{8} + c\frac{dq^*}{d\alpha}.$$

Note that $\frac{dq^*}{d\alpha} = 0$ when $q^* < 1/2$ and $\frac{dq^*}{d\alpha} < 0$ when $q^* > 1/2$. Thus, when $q^* < 1/2$, $\frac{\partial \Pi_M}{\partial \alpha} = \frac{1}{8} > 0$. When $q^* > 1/2$,

$$\frac{\partial \Pi_M}{\partial \alpha} = \frac{1}{8} + c\frac{\partial q^*}{\partial \alpha}.$$

We then verify the relationship between c and $\frac{\partial q^*}{\partial \alpha}$. Based on the first order condition, we have

$$d\left(\frac{\partial q^*}{\partial \alpha}\right)/dc = -\frac{\left(c + 5c\alpha - 3c\beta + 4c\alpha^2 + \left(\alpha - \beta + \alpha^2 - \alpha\beta + 4c^2\right)^{\frac{3}{2}} + 8c^3 - 3c\alpha\beta\right)}{\left(\alpha+1\right)^2\left(\alpha - \beta + \alpha^2 - \alpha\beta + 4c^2\right)^{\frac{3}{2}}}.$$

Let $G(c) := \left(c + 5c\alpha - 3c\beta + 4c\alpha^2 + \left(\alpha - \beta + \alpha^2 - \alpha\beta + 4c^2\right)^{\frac{3}{2}} + 8c^3 - 3c\alpha\beta\right)$, we then have $\partial^2 G(c)/\partial c^2 = 12\frac{\left(2c+\sqrt{\alpha-\beta+\alpha^2-\alpha\beta+4c^2}\right)^2}{\sqrt{\alpha-\beta+\alpha^2-\alpha\beta+4c^2}} > 0$. Thus, we can derive that

$$\partial G(c)/\partial c > \partial G(c)/\partial c\Big|_{c=\frac{(\beta+1)}{4}} = 4(a+1)^2 > 0.$$

Therefore, $G(c)|_{c=\frac{(\beta+1)}{4}} = \frac{1}{2}\left(\alpha+1\right)^2\left(2\alpha - \beta + 1\right) > 0$. This indicates that $d\left(\frac{\partial q^*}{\partial \alpha}\right)/dc < 0$. Therefore, when $c = \frac{(\beta+1)}{4}$ (lowest value), we have $q^* = 1/2$, $\frac{\partial q^*}{\partial \alpha} = 0$ and $\frac{\partial \Pi_M}{\partial \alpha} = \frac{1}{8} > 0$. When $c = \frac{(4+3\alpha+\beta)}{8}$ (highest value), we have $q^* = 1$ and

$$\frac{\partial \Pi_M}{\partial \alpha} = -\frac{1}{8}\frac{1}{5\alpha - \beta + 4}\left(7\beta - 5\alpha + 2\right) < 0.$$

This implies that there exists a unique threshold value of c_0, below which the firm's payoff increases in the magnitude of elation while above which the firm's payoff decreases in the magnitude of elation.

Proof of Corollary 1. Note that when the consumer is fully rational, it can be viewed as a special case that $\alpha = \beta = 0$ and the firm's payoff when the consumer is fully rational is $\Pi_{M(\alpha=\beta=0)} = v + 1/2 - c(1-2c)$. According to (3), for any $\beta > \alpha$ we have $\Pi_{M(\alpha\leq\beta)} > \Pi_{M(\alpha=\beta=0)}$.

Proof of Proposition 3. Note that the firm is indifferent between disclosure and non-disclosure at the cutoff point q_d^*. Because in a competitive environment the firm's payoff with non-disclosure is always kept at zero ($p_{nd}^i = 0$), the firm's payoff with disclosure at q_d^* is given by $\int_0^{q_d^*}\left(p_d^1|_{q_1=q_d^*}\right)dq_2 - c = \int_0^{q_d^*}\left(U_d^1|_{q_1=q_d^*} - U_{nd}^2|_{q_1\leq q_d^*}\right)dq_2 - c = 0$. When $q_d^* < 1/2$,

$$\begin{aligned}
& \int_0^{q_d^*}\left(U_d^1|_{q_1=q_d^*} - U_{nd}^2|_{q_1\leq q_d^*}\right)dq_2 - c \\
= & \int_0^{q_d^*}\left(v + q_d^* - \beta\left(\frac{1}{2} - q_d^*\right) - \left(v + \frac{q_d^*}{2} + \int_0^{q_d^*}\beta\left(q - \frac{1}{2}\right)dq_1\right)\right)dq_2 - c \\
= & \frac{1}{2}\left(q_d^*\right)^2(\beta+1) - c = 0 \\
\rightarrow & \; q_d^* = \sqrt{2c/(1+\beta)}.
\end{aligned}$$

When $q_d^* > 1/2$, $\int_0^{q_d^*}\left(U_d^1|_{q_1=q_d^*} - U_{nd}^2|_{q_1\leq q_d^*}\right)dq_2 - c =$

$$\begin{aligned}
\int_0^{q_d^*}\left(U_d^1|_{q_1=q_d^*} - U_{nd}^2|_{q_1\leq q_d^*}\right)dq_2 - c &= \int_0^{q_d^*}\left(\frac{1}{8q_d^*}\left(4\alpha(q_d^*)^2 - \alpha + \beta + 4(q_d^*)^2\right)\right)dq_2 - c \\
&\rightarrow \frac{1+\alpha}{2}\left(q_d^*\right)^2 + \frac{\beta-\alpha}{8} = c.
\end{aligned}$$

We next derive the relationships between the disclosure cutoff point q_d^* and the elation or disappointment parameter (α, β). When $q_d^* < 1/2$, $q_d^* = \sqrt{2c/(1+\beta)}$ and it is evident that $\partial q_d^*/\partial\beta = -\frac{1}{2}\sqrt{2}\frac{c}{\sqrt{b(\beta+1)^3}} < 0$ and $\partial q_d^*/\partial\alpha = 0$.

When $q_d^* > 1/2$, we have $q_d^* = \sqrt{(\alpha+1)(8c+\alpha-\beta)}/\left(2(\alpha+1)\right)$. Thus,

$$\begin{aligned}
\frac{\partial q_d^*}{\partial\beta} &= -\frac{1}{4\sqrt{(\alpha+1)(8c+\alpha-\beta)}} < 0; \\
\frac{\partial q_d^*}{\partial\alpha} &= \frac{(\beta-8c+1)}{4(\alpha+1)\sqrt{(\alpha+1)(8c+\alpha-\beta)}} < 0.
\end{aligned}$$

Thus, the firm's disclosure incentive increases in the magnitudes of elation and disappointment.

Proof of Proposition 4. The result can be derived from the first order conditions of Π_D with respect to α and β. For example, when the disclosure cost $c \in \left[\frac{(\beta+1)}{8}, \frac{(4+3\alpha+\beta)}{8}\right]$, the firm's disclosure cutoff point $q_d^* > 1/2$ and his ex-ante payoff is

$$\begin{aligned}
\Pi_D\big|_{q_d^*>1/2} &= \int_{q_d^*}^{1} \left(\int_0^{q_d^*} \left(v + q_1 + \alpha\left(q_1 - \frac{1}{2}\right) - U_{nd}^2|_{q_d^*>1/2} \right) dq_2 + \int_{q_d^*}^{q_1} (1+\alpha)(q_1 - q_2) dq_2 - c \right) dq_1 \\
&= \frac{1}{6}\left(2q_d^*+1\right)(\alpha+1)\left(q_d^*-1\right)^2, \text{ where } q_d^* \text{ satisfies } \frac{1+\alpha}{2}\left(q_d^*\right)^2 + \frac{\beta-\alpha}{8} = c.
\end{aligned}$$

Following the same principle, we can derive the firm's ex-ante payoffs when disclosure cost $c \in \left[0, \frac{(\beta+1)}{8}\right]$ as follows:

$$\begin{aligned}
\Pi_D\big|_{q_d^*<1/2} &= \int_{q_d^*}^{1/2} \left(\int_0^{q_d^*} \left(v + q_1 + \beta\left(q_1 - \frac{1}{2}\right) - U_{nd}^2|_{q_d^*<1/2} \right) dq_2 + \int_{q_d^*}^{q_1} (1+\beta)(q_1 - q_2) dq_2 \right) dq_1 \\
&\quad + \int_{1/2}^{1} \left(\begin{array}{c} \int_0^{q_d^*} \left(v + q_1 + \alpha\left(q_1 - \frac{1}{2}\right) - U_{nd}^2|_{q_d^*<1/2} \right) dq_2 \\ + \int_{q_d^* 1}^{1/2} \left(\alpha\left(q_1 - \frac{1}{2}\right) - q_2 - \beta\left(q_2 - \frac{1}{2}\right) \right) dq_2 \end{array} \right) dq_1 \\
&\quad + \int_{1/2}^{1} \left(\int_{1/2}^{q_1} (1+\alpha)(q_1 - q_2) dq_2 \right) dq_1 - c(1 - q_d^*) \\
&= \frac{1}{6} + \frac{(\alpha+\beta)}{12} - \frac{q_d^{*2}(3 - 2q_d^*)(1+\beta)}{6}, \text{ where } q_d^* = \sqrt{2c/(1+\beta)}.
\end{aligned}$$

Note that as shown in Proposition 3, $\frac{dq_d^*}{d\beta} < 0$ and $\frac{dq_d^*}{d\alpha} < 0$. If $q_d^* < 1/2$, we have

$$\begin{aligned}
\Pi_D &= \frac{1}{6} + \frac{(\alpha+\beta)}{12} - \frac{q_d^{*2}(3 - 2q_d^*)(1+\beta)}{6}; \\
\frac{\partial \Pi_D}{\partial \alpha} &= \frac{d\Pi_D}{d\alpha} + \frac{d\Pi_D}{dq_d^*}\frac{dq_d^*}{d\alpha} = \frac{1}{12} > 0; \\
\frac{\partial \Pi_D}{\partial \beta} &= \frac{d\Pi_D}{d\beta} + \frac{d\Pi_D}{dq_d^*}\frac{dq_d^*}{d\beta} = \frac{1}{12}\left(1 - 6q_d^{*2} + 4q_d^{*3}\right) + q_d^*(\beta+1)\left(q_d^*-1\right)\frac{dq_d^*}{d\beta} > 0.
\end{aligned}$$

On the other hand, if $q_d^* > 1/2$,

$$\begin{aligned}
\Pi_D &= \frac{1}{6}\left(2q_d^*+1\right)(\alpha+1)\left(q_d^*-1\right)^2, \\
\frac{\partial \Pi_D}{\partial \alpha} &= \frac{d\Pi_D}{d\alpha} + \frac{d\Pi_D}{dq_d^*}\frac{dq_d^*}{d\alpha} = \frac{1}{6}\left(2q_d^*+1\right)\left(q_d^*-1\right)^2 + q_d^*(a+1)\left(q_d^*-1\right)\frac{dq_d^*}{d\alpha} > 0; \\
\frac{\partial \Pi_D}{\partial \beta} &= \frac{d\Pi_D}{d\beta} + \frac{d\Pi_D}{dq_d^*}\frac{dq_d^*}{d\beta} = q_d^*(a+1)\left(q_d^*-1\right)\frac{dq_d^*}{d\beta} > 0.
\end{aligned}$$

Thus, we show that the firm's payoff monotonically increases in either α and β under both scenarios.

Proof of Proposition 5. For firm 1, at the disclosure cutoff point q_d^*, there is no different between disclosure and non-disclosure, wherein $\widehat{p}_d^1 - c = \widehat{U}_d^1 - \widehat{U}_{nd}^2 - c = 0$. Then, we can derive the equilibrium cutoff point by following the proof of Proposition 1. This subsequently leads to the equilibrium q_d^* as shown in Proposition 5.
Proof of Corollary 2. The result can be derived from the first order conditions of $\widehat{\Pi}_D$ with respect to α and β. When $0 < c < \frac{(\beta+1)}{4}$, the firm's disclosure cutoff point $\widehat{q}_d^* = \frac{2c}{\beta+1}$ and his ex-ante payoff is

$$\begin{aligned}
\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} &= \int_{\widehat{q}_d^*}^{1/2}\int_0^{q_1}\left(q_1 - \beta(\frac{1}{2} - q_1) - \left(\frac{q_1(1+\beta)}{2} - \frac{\beta}{2}\right) - c\right) dq_2 dq_1 + \\
&\quad \int_{1/2}^{1}\int_0^{q_1}\left(q_1 + \alpha(q_1 - \frac{1}{2}) - \left(\frac{q_1(1+\alpha)}{2} - \frac{\alpha}{2} - \frac{\beta-\alpha}{8q_1}\right) - c\right) dq_2 dq_1 \\
&= \frac{1}{6} + \frac{(\alpha+\beta)}{12} - \frac{1+\beta}{4}\widehat{q}_d^* + \frac{1+\beta}{12}\left(\widehat{q}_d^*\right)^3 \text{ where } \widehat{q}_d^* = \frac{2c}{\beta+1}.
\end{aligned}$$

It is evident that $\frac{d\widehat{q}_d^*}{d\alpha} = 0$ and $\frac{d\widehat{q}_d^*}{d\beta} = -\frac{2c}{(\beta+1)^2} < 0$. As to the relationship between $\widehat{\Pi}_D$ and α/β, plugging $\widehat{q}_d^* = \frac{2c}{\beta+1}$ into the above payoff funciton, we have

$$\begin{aligned}
\frac{\partial \widehat{\Pi}_D}{\partial \alpha} &= \frac{1}{12} > 0; \\
\frac{\partial \widehat{\Pi}_D}{\partial \beta} &= \frac{-16c^3 + \beta^3 + 3\beta^2 + 3\beta + 1}{12\left(\beta+1\right)^3}.
\end{aligned}$$

Because $c < \frac{(\beta+1)}{4}$, $\frac{\partial\widehat{\Pi}_D}{\partial\beta} > \left[\frac{-16c^3+\beta^3+3\beta^2+3\beta+1}{12(\beta+1)^3}\right]_{c=\frac{(\beta+1)}{4}} = \frac{1}{16} > 0$.

When $\frac{(\beta+1)b}{4} \le c < \frac{(4+3\alpha+\beta)b}{8}$, the firm's disclosure cutoff point $\widehat{q}_d^* > \frac{1}{2}$ and meets the condition that

$$\widehat{q}_d^*\frac{1+\alpha}{2} + \frac{(\beta-\alpha)}{8\widehat{q}_d^*} = c.$$

Based on this, we can derive the relationship between $\widehat{q}_d^*$ and α/β based on the implicit function theorem that

$$\begin{aligned}
\frac{d\widehat{q}_d^*}{d\alpha} &= -\widehat{q}_d^*\frac{4(\widehat{q}_d^*)^2 - 1}{\alpha - \beta + 4(\widehat{q}_d^*)^2\alpha + 4(\widehat{q}_d^*)^2} < 0; \\
\frac{d\widehat{q}_d^*}{d\beta} &= \frac{-\widehat{q}_d^*}{\alpha - \beta + 4(\widehat{q}_d^*)^2\alpha + 4(\widehat{q}_d^*)^2} < 0
\end{aligned}$$

The firm's ex-ante payoff is given by

$$\begin{aligned}
\widehat{\Pi}_D|q_d^* > 1/2 &= \int_{\widehat{q}_d^*}^{1}\int_0^{q_1}\left(q_1 + \alpha(q_1 - \frac{1}{2}) - \left(\frac{q_1(1+\alpha)}{2} - \frac{\alpha}{2} - \frac{\beta-\alpha}{8q_1}\right)\right) dq_2 dq_1 \\
&= (1-\widehat{q}_d^*)^2\left(\frac{(1+\alpha)}{6} + \frac{\widehat{q}_d^*(1+\alpha)}{12} + \frac{\alpha-\beta}{16\widehat{q}_d^*}\right) \text{ where } \widehat{q}_d^*\frac{1+\alpha}{2} + \frac{(\beta-\alpha)}{8\widehat{q}_d^*} = c.
\end{aligned}$$

Then, regarding the relationship between $\widehat{\Pi}_D$ and α, we have

$$\begin{aligned}
\frac{\partial \widehat{\Pi}_D}{\partial \alpha} &= \frac{d\widehat{\Pi}_D}{d\alpha} + \frac{d\widehat{\Pi}_D}{d\widehat{q}_d^*}\frac{d\widehat{q}_d^*}{d\alpha};\\
\frac{d\widehat{\Pi}_D}{d\alpha} &= \frac{\left(\widehat{q}_d^*-1\right)^2\left(4\widehat{q}_d^{*2}+8\widehat{q}_d^*+3\right)}{48\widehat{q}_d^*} > 0;\\
\frac{d\widehat{\Pi}_D}{d\widehat{q}_d^*} &= \frac{\left(\widehat{q}_d^{*2}-1\right)\left(\alpha-\beta+4\widehat{q}_d^{*2}\alpha+4\widehat{q}_d^{*2}\right)}{16\widehat{q}_d^{*2}} < 0;\\
\frac{\partial \widehat{\Pi}_D}{\partial \alpha} &> 0.
\end{aligned}$$

As to the relationship between $\widehat{\Pi}_D$ and β, we have

$$\begin{aligned}
\frac{\partial \widehat{\Pi}_D}{\partial \beta} &= \frac{d\widehat{\Pi}_D}{d\beta} + \frac{d\widehat{\Pi}_D}{d\widehat{q}_d^*}\frac{d\widehat{q}_d^*}{d\beta};\\
\frac{d\widehat{\Pi}_D}{d\widehat{q}_d^*} &= -\frac{1}{16(\widehat{q}_d^*)^2}\left(1-(\widehat{q}_d^*)^2\right)\left(\alpha-\beta+4(\widehat{q}_d^*)^2\alpha+4(\widehat{q}_d^*)^2\right) < 0;\\
\frac{d\widehat{q}_d^*}{d\beta} &= \frac{-\widehat{q}_d^*}{\alpha-\beta+4(\widehat{q}_d^*)^2\alpha+4(\widehat{q}_d^*)^2} < 0;\\
\frac{\partial \widehat{\Pi}_D}{\partial \beta} &= \frac{d\widehat{\Pi}_D}{d\beta} + \frac{d\widehat{\Pi}_D}{d\widehat{q}_d^*}\frac{d\widehat{q}_d^*}{d\beta} = \frac{1}{8}(1-\widehat{q}_d^*) > 0.
\end{aligned}$$

Proof of Corollary 3. Building upon the firm's equilibrium disclosure strategies and payoff functions (Π_D and $\widehat{\Pi}_D$) under different scenarios, the result can be derived directly from the comparison between the equilibrium payoffs.

Condition	No Information Sharing	Horizontal Information Sharing
$0 < c \le \frac{(\beta+1)}{8}$	$q_d^* = \sqrt{2c/(1+\beta)}$.	$\widehat{q}_d^* = \frac{2c}{\beta+1}$.
$\frac{(\beta+1)}{8} < c \le \frac{(\beta+1)}{4}$	$q_d^* = \frac{\sqrt{(\alpha+1)(8c+\alpha-\beta)}}{2(\alpha+1)}$.	$\widehat{q}_d^* = \frac{2c}{\beta+1}$.
$\frac{(\beta+1)}{4} < c < \frac{(4+3\alpha+\beta)}{8}$	$q_d^* = \frac{\sqrt{(\alpha+1)(8c+\alpha-\beta)}}{2(\alpha+1)}$.	$\widehat{q}_d^* = \frac{2c+\sqrt{\alpha-\beta+\alpha^2-\alpha\beta+4c^2}}{2\alpha+2}$.

Case (1): when $0 < c < \frac{(\beta+1)}{8}$, we have

$$\begin{aligned}
\Pi_D|_{q_d^*\le 1/2} &= \frac{1}{6} + \frac{(\alpha+\beta)}{12} - \frac{q_d^{*2}(3-2q_d^*)(1+\beta)}{6}, \text{ where } q_d^* = \sqrt{2c/(1+\beta)};\\
\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} &= \frac{1}{6} + \frac{(\alpha+\beta)}{12} - \frac{1+\beta}{4}\widehat{q}_d^* + \frac{1+\beta}{12}\left(\widehat{q}_d^*\right)^3 \text{ where } \widehat{q}_d^* = \frac{2c}{\beta+1}.
\end{aligned}$$

Thus,

$$\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*\le 1/2} = \frac{1}{12}q_d^{*2}\left(\beta+1\right)\left(q_d^*-1\right)^2\left(q_d^{*2}+2q_d^*+3\right) > 0, \text{ given that } \widehat{q}_d^* = q_d^{*2}.$$

The firm's payoff with information sharing is higher than that without information sharing. Moreover, one can verify that

$$\frac{\partial\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*\leq 1/2}\right]}{\partial\beta} = \frac{\sqrt{2}\sqrt{\frac{c}{\beta+1}}(c + c\beta^2 + 2c\beta) - 4c^3}{3\beta^3 + 9\beta^2 + 9\beta + 3} > 0,$$

indicating that the gap is monotonically increasing in β.

Case (2): when $\frac{(\beta+1)}{8} < c < \frac{(\beta+1)}{4}$, we have

$$\begin{aligned}
\Pi_D|_{q_d^*>1/2} &= \frac{1}{6}\left(2q_d^*+1\right)(\alpha+1)\left(q_d^*-1\right)^2, \text{ where } q_d^* \text{ satisfies} \frac{1+\alpha}{2}\left(q_d^*\right)^2 + \frac{\beta-\alpha}{8} = c; \\
\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} &= \frac{1}{6} + \frac{(\alpha+\beta)}{12} - \frac{1+\beta}{4}\widehat{q}_d^* + \frac{1+\beta}{12}\left(\widehat{q}_d^*\right)^3 \text{ where } \widehat{q}_d^* = \frac{2c}{\beta+1}.
\end{aligned}$$

Obtaining the first and second order conditions of $\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}$ with respect to c, we have

$$\frac{\partial^2\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}\right]}{\partial c^2} = -\frac{2\sqrt{(\alpha+1)(8c+\alpha-\beta)}\left(2\beta+\beta^2-2c\sqrt{(\alpha+1)(8c+\alpha-\beta)}+1\right)}{(8c+\alpha-\beta)(\alpha+1)(\beta+1)^2}.$$

Note that $\left.\frac{\partial^2\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}\right]}{\partial c^2}\right|_{c=\frac{(\beta+1)}{4}} < 0$, one can verify that $\frac{\partial^2\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}\right]}{\partial c^2} < 0$. Then,

$$\begin{aligned}
\left.\frac{\partial\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}\right]}{\partial c}\right|_{c=\frac{(\beta+1)}{4}} &= \frac{1}{8\alpha+8}\left(5\alpha - 4\sqrt{(\alpha+1)(\alpha+\beta+2)} + 5\right) < 0; \\
\left.\frac{\partial\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}\right]}{\partial c}\right|_{c=\frac{(\beta+1)}{8}} &= \frac{(\alpha+1)}{32\alpha+32} > 0.
\end{aligned}$$

Thus, the gap between $\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}$ first increases and then decreases in the disclosure cost c, and one can verify that

$$\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}\right]\Big|_{c=\frac{(\beta+1)}{4}} > 0 \text{ and } \left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}\right]\Big|_{c=\frac{(\beta+1)}{8}} > 0.$$

We now derive the relationships between $\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}$ and α/β. We can show that

$$\frac{\partial\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2} - \Pi_D|_{q_d^*>1/2}\right]}{\partial\alpha} = \frac{4\alpha + 2\alpha^2 + 8ct - 2\alpha t - \beta t - 3t + 2}{48(\alpha+1)^2}, \text{where } t = \sqrt{(\alpha+1)(8c+\alpha-\beta)}.$$

Because,

$$\begin{aligned}
\frac{\partial\left[4\alpha + 2\alpha^2 + 8ct - 2\alpha t - \beta t - 3t + 2\right]}{\partial c} &= -12\frac{\alpha+1}{\sqrt{(\alpha+1)(8c+\alpha-\beta)}}(\beta - 8c + 1) > 0, \\
\text{and } \left[4\alpha + 2\alpha^2 + 8ct - 2\alpha t - \beta t - 3t + 2\right]_{c=\frac{(\beta+1)}{8}} &= 0,
\end{aligned}$$

one can confirm that $\frac{\partial\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2}-\Pi_D|_{q_d^*>1/2}\right]}{\partial\alpha} > 0$.

Similarly, we can show that

$$\begin{aligned}&\frac{\partial\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2}-\Pi_D|_{q_d^*>1/2}\right]}{\partial\beta}\\ = & -\frac{2\alpha+6\beta+6\beta^2+2\beta^3+6\alpha\beta-9\beta t+64c^3\alpha-3t+6\alpha\beta^2+2\alpha\beta^3-9\beta^2 t-3\beta^3 t+64c^3+2}{48\left(\alpha+1\right)\left(\beta+1\right)^3},\end{aligned}$$

where $t=\sqrt{(\alpha+1)\left(8c+\alpha-\beta\right)}$. Let us define

$$G(\beta,c):=2\alpha+6\beta+6\beta^2+2\beta^3+6\alpha\beta-9\beta t+64c^3\alpha-3t+6\alpha\beta^2+2\alpha\beta^3-9\beta^2 t-3\beta^3 t+64c^3+2,$$

and derive that

$$\frac{\partial G(\beta,c)}{\partial c}=-12\frac{\sqrt{(\alpha+1)\left(8c+\alpha-\beta\right)}}{8c+\alpha-\beta}\left(3\beta+3\beta^2+\beta^3-16c^2\sqrt{(\alpha+1)\left(8c+\alpha-\beta\right)}+1\right).$$

We can show that

$$\frac{\partial\left[3\beta+3\beta^2+\beta^3-16c^2\sqrt{(\alpha+1)\left(8c+\alpha-\beta\right)}+1\right]}{\partial c}=-32c\frac{\sqrt{(\alpha+1)\left(8c+\alpha-\beta\right)}}{8c+\alpha-\beta}\left(10c+\alpha-\beta\right)<0.$$

Then, we can derive that $\left[3\beta+3\beta^2+\beta^3-16c^2\sqrt{(\alpha+1)\left(8c+\alpha-\beta\right)}+1\right]_{c=\frac{(\beta+1)}{8}}>0$ and $\left[3\beta+3\beta^2+\beta^3-16c^2\sqrt{(\alpha+1)\left(8c+\alpha-\beta\right)}+1\right]_{c=\frac{(\beta+1)}{4}}<0$. Subsequently, we derive that $\frac{\partial G(\beta,c)}{\partial c}\Big|_{c=\frac{(\beta+1)}{8}}<0$ and $\frac{\partial G(\beta,c)}{\partial c}\Big|_{c=\frac{(\beta+1)}{4}}>0$. This implies that $G(\beta,c)$ first decreases and then increases in c. Finally, we can show that

$$\begin{aligned}G(\beta,c)|_{c=\frac{(\beta+1)}{8}} &= -\frac{1}{8}\left(\beta+1\right)^3\left(7\alpha+7\right)<0;\\ G(\beta,c)|_{c=\frac{(\beta+1)}{4}} &= 3\left(\beta+1\right)^3\left(\alpha-\sqrt{(\alpha+1)\left(\alpha+\beta+2\right)}+1\right)<0.\end{aligned}$$

This confirms that $\frac{\partial\left[\widehat{\Pi}_D|_{\widehat{q}_d^*<1/2}-\Pi_D|_{q_d^*>1/2}\right]}{\partial\beta}=-\frac{G(\beta,c)}{48(\alpha+1)(\beta+1)^3}>0$.