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Impact of Social Interactions on Duopoly Competition with Quality Considerations

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Abstract. We study the impacts of social interactions on competing firms' quality differentiation, pricing decisions, and profit performance. Two forms of social interactions are identified and analyzed: (1) market-expansion effect (MEE)—the total market expands as a result of both firms' sales—and (2) value-enhancement effect (VEE)—a consumer gains additional utility of purchasing from one firm based on this firm's previous and/or current sales volume. We consider a two-stage duopoly competition framework, in which both firms select quality levels in the first stage simultaneously and engage in a two-period price competition in the second stage. In the main model, we assume that each firm sets a single price and commits to it across two selling periods. We find that both forms of social interactions tend to lower prices and intensify price competition for given quality levels. However, MEE weakens the product-quality differentiation and is benign to both high-quality and low-quality firms. It also benefits consumers and improves social welfare. By contrast, VEE enlarges the quality differentiation and only benefits the high-quality firm, but is particularly malignant to the low-quality firm. It further reduces the consumers' monetary surplus. Such impact is consistent, regardless of whether the VEE interactions involve previous or current consumers. We further discuss several model extensions, including dynamic pricing, combined social effects, and various cost structures, and verify that the aforementioned impacts of MEE and VEE are qualitatively robust to those extensions. Our results provide important managerial insights for firms in competitive markets and suggest that they need to not only be aware of the consumers' social interactions, but also, more importantly, distinguish the predominant form of the interactions so as to apply proper marketing strategies.

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1. Introduction

The proliferation of social interactions among consumers nowadays has been unprecedented in both breadth and depth. Almost every product can be discussed and recommended by people via various kinds of social activities, especially through the internet. Consumers' awareness and valuation concerning a product are thus constantly influenced by those social interactions. Because of their significant impacts on consumer behavior, social interactions should be taken into account by firms when making important managerial decisions such as product design and pricing, especially by those whose products heavily rely on the social activities.

Although social interactions in general affect the market-diffusion process in certain aspects, the exact underlying mechanism depends on the particular form of the interactions. In this paper, we focus on two major forms of social interactions that are commonly observed in practice and exhibit different ways of influencing the consumer behavior and market dynamics. First, the consumer-to-consumer interactions may be simply informative, bringing certain things to people's attention and expanding the product awareness. For instance, newly released products are often introduced to potential consumers by the existing consumers through social contagions, such as word-of-mouth communications (Libai et al. 2009). It is noteworthy that these interpersonal communications are not necessarily brand-specific. As a result, the whole potential market of a certain kind of products could be enlarged with more informed consumers. We refer to this form of social interactions as the *market-expansion effect*.

Second, interacting with other consumers may improve a consumer's utility toward a certain product. Various behavioral and psychological factors could contribute to the positive effect of such interactions. The well-documented network effect (Economides 1996), which enhances consumers' utility through the cascade of positive externalities when they consume social goods, serves as a good example. For another example, consumers of a specific product may derive additional utility from the purchase if many others have already purchased/used the same product. After all, the crowd's behavior imposes a considerable impact on consumers' preferences (Laja 2019). We remark that, depending on the context, consumers may gain the extra utility by interacting with those who are purchasing the product currently and/or have purchased previously.[1] This form of social interactions is referred to as the *value-enhancement effect*.

An illustrating example is the so-called MOBAs (multiplayer online battle arena games) in the video game industry. The MOBAs belong to the genre of real-time strategy games, where two teams (multiple players each) battle against each other with every player controlling one character. The hottest MOBAs include Heroes Evolved, DOTA 2, and League of Legends, etc. Abundant social interactions are present in the community of game players. On the one hand, by the spread of the words on the gaming forums (NeoGAF, etc.), more people become aware of MOBAs and join in as potential players every day. Because most MOBAs have similar settings, potential players can communicate with players of one MOBA, but eventually choose to play another. Because of this word-of-mouth spillover (Peres and Van den Bulte 2014), the potential market of all MOBA publishers could be expanded by the informative social interactions, which exemplifies the market-expansion effect. On the other hand, players of a MOBA can derive enhanced utility from interacting with peer players of the same game. Such value-enhancement effect is generally achieved in two ways: Players find it more fun to play with more people in real time; they can also gain a sense of belonging to a larger community, which includes the previous players, when exchanging game experiences with peers on the forum. No matter how the players derive the additional utility, the enhanced value originates mainly from playing the same MOBA game.

It is worth noting that which form of social interactions is prevailing depends on the specific characteristics of the industry. In a mature industry, where market potential remains stable, the market-expansion effect may be weak, and the value-enhancement effect is more prominent. By contrast, for an emerging industry, where product awareness is limited, market growth could be significant due to the market-expansion effect in the early stage. For example, when firms materialize an innovative idea into business (e.g., sharing platforms, cloud services, etc.), they first devote efforts to the awareness expansion among consumers and then take advantage of the grown market. Given the profound impacts of social interactions on market dynamic and consumer behavior, competing firms should exploit them in effective ways when making management and marketing decisions, such as product-quality design and pricing. Motivated by the above discussions, our research aims to address the following questions: How should competing firms select their quality levels and prices in the market that is influenced by social interactions? How do different forms of social interactions affect the firms' quality differentiation, profits, and consumers' surplus?

To address the above questions, we build a two-stage duopoly competition model with the consideration of social interactions. In stage 1, the two firms simultaneously choose product-quality levels with an exogenous upper bound determined by the current technology capacity. In stage 2, two firms make price decisions and sell products through two periods. We consider that each firm sets and commits to a single price throughout both periods in our main model and examine the intertemporal pricing scheme as a model extension in which firms can dynamically set prices in each period. Moreover, we consider two forms of social interactions: (1) *market-expansion effect* (*MEE*), which enlarges the total market size for both firms through informative interactions that expand product awareness; and (2) *value-enhancement effect* (*VEE*), which exclusively improves the consumer utility toward one particular product via dedicated social interactions with consumers of the same product. We further categorize VEE into two types: VEE via social interactions with consumers in the *current* period (VEE-C) and with consumers in the *previous* period (VEE-P).

We investigate the above forms of social interactions separately to distill their individual impacts. In each scenario, we solve for the unique pure-strategy subgame perfect equilibrium, in which one firm selects a high-quality level (high-quality firm) and the other selects a lower-quality level (low-quality firm). In a monopolistic setting, both MEE and VEE seem to favor the firm via different mechanisms. Yet, in a competitive environment, questions regarding whether they can truly benefit firms and how they affect firms' product-quality differentiation and profits remain unclear. As such, the main purpose of our research is to provide a systematic investigation on this matter. Interestingly, our study reveals that, although both MEE and VEE intensify the price competition, they have completely distinct impacts on the firms' quality differentiation and profits, as well as the consumer surplus and the overall social welfare. We elaborate these findings as follows.

Under the market-expansion effect, the equilibrium quality-differentiation level is smaller than the benchmark case without social interactions and decreases in the strength of MEE. In this case, the low-quality firm would increase quality and better utilize the informative social interactions to generate higher sales, even though doing so may lead to smaller differentiation and more intense competition. Moreover, because of the demand spillover induced by MEE, both firms' profits are improved. Hence, MEE is benign to the duopoly, despite the intensified competition. In addition, we find that MEE also benefits consumers and can improve the social welfare.

By contrast, under the value-enhancement effect, quality differentiation is enlarged and increases in the strength of VEE, because the competition becomes so fierce, and the low-quality firm prefers to further differentiate by choosing lower quality and focus on the lower-end market, rather than increasing quality to boost the impact of VEE. Moreover, VEE reduces the low-quality firm's profit, but improves the high-quality firm's profit, and the profit gap between the two firms is increasing as VEE becomes stronger, positing the Matthew effect of accumulated advantage. After all, a consumer's utility toward one product can be enhanced only by the interactions with consumers of the same product, and the high-quality firm can gain more advantages from VEE, whereas the low-quality firm loses competitive edge. Therefore, although these social interactions always benefit a firm in a monopoly setting, it is not necessarily true in a competitive environment. Lastly, we find that VEE reduces consumers' monetary surplus and may hurt the monetary part of social welfare. The above results remain the same, regardless of the type of VEE (VEE-C or VEE-P).

Finally, we also provide further discussions on several model extensions, including models with dynamic pricing scheme, combined effects of both MEE and VEE, and cost considerations, respectively. We not only show that the main results are qualitatively robust in different model extensions, but also gain additional insights regarding the incorporated model ingredient.

To conclude, we summarize our main contributions and insights. Although social interactions have been widely studied in the marketing literature, how different forms of interactions affect competing firms' quality differentiation and equilibrium profits remain unclear. Hence, we contribute by systematically examining and contrasting two major forms of social interactions, leading to a multifaceted analysis of the impetus for the dynamic changes in consumers' purchasing behaviors and the market potential. Our results suggest that, when firms consider product quality and pricing strategies in a competitive environment, they should not only be aware of the consumers' social interactions, but also, more importantly, distinguish the predominant form of the interactions so as to apply proper marketing strategies.

The rest of the paper is organized as follows. We position our work in the related literature in Section 2. Section 3 describes the model setup, and Section 4 discusses the results. Additional discussions on model extensions are provided in Section 5. We conclude by summarizing the managerial insights in Section 6. All proofs and additional results are relegated to the online appendices.

2. Literature Review

This paper is mainly related to two streams of literature: product differentiation and social interactions. First of all, product differentiation, especially in the contexts of quality design and pricing in competitive environments, has been studied extensively in the marketing and economics literature. In a duopoly setting, the seminal paper Shaked and Sutton (1982) shows that product differentiation is adopted to soften price competition. This result can be generalized to include different cost structures (Lehmann-Grube 1997) or special functional properties of costs (Chambers et al. 2006). Moreover, many studies have been conducted on this topic in various settings with interesting features incorporated, such as multiattribute product positioning (Vandenbosch and Weinberg 1995), market-entry decisions (Donnenfeld and Weber 1992), imperfect information for consumers (Jing 2007), and product-line design with consumer-anticipated regret (Zou et al. 2020). In the similar vein, our paper examines the strategic implications of product differentiation when firms compete in the market with different forms of social interactions. As such, we contribute by addressing the product-differentiation issue in competitive settings from a new perspective that has been practically often observed, yet never thoroughly studied before.

Secondly, our paper also contributes to the broad stream of literature on social interactions (Godes et al. 2005, Hartmann et al. 2008), especially their impacts on new product diffusion and adoption (Iyengar et al. 2011, Katona et al. 2011, Kuksov and Liao 2019). Regarding the nature of social interactions, Van den Bulte and Lilien (2001) summarize four different underlying mechanisms of social influence proposed by the existing literature. Two of those mechanisms—that is, information transfer and performance network effect—are considered to be most relevant to our motivating settings of MEE and VEE, respectively. Moreover, Hartmann et al. (2008) discuss social spillover and social multiplier engendered from social interactions, which underscore the aforementioned two mechanisms regarding how consumers' actions are influenced by the peers. These papers share a common approach: The impact of social interactions on consumer behavior is studied through multiple mechanisms, and the predominant mechanism is context-dependent.

Similarly, we focus on two major forms of social interactions in this paper, which are exemplified by the word-of-mouth effect (e.g., Godes and Mayzlin 2004 and Godes 2017) and the network effect (e.g., Katz and Shapiro 1985, 1986, and Economides 1996). Relevant to our context, the impact of a specific form of social interactions on a firm's competitive strategy has been studied in the literature. For example, Xie and Sirbu (1995) investigate the impact of demand externality on competing firms' prices and profits under dynamic pricing. Chen and Xie (2007) study the strategic implication of cross-market network effect and consumer loyalty on competing firms' profitability. Doganoglu (2003) studies dynamic price competition with consumption externality under horizontal differentiation. Zhang and Sarvary (2015) examine the horizontal differentiation between firms with user-generated content, which displays a strong network effect. Kuksov and Liao (2019) study a firm's optimal choice of product variety in the presence of word-of-mouth through opinion leaders' product evaluations. We differ from the above papers by systematically examining and, more importantly, contrasting the impacts of different forms of social interactions on competing firms' vertical product differentiation and profit.

Moreover, there are studies that look at multiple forms of social interactions, but tackle different business problems with distinct settings. For example, when exploring financial implications of network externalities, Goldenberg et al. (2010) note the distinction and separate the network effect from the word-of-mouth effect in their study. Kamada and Ory (2020) study the use of free contract and referral rewards to encourage word-of-mouth about the existence of a network product. Particularly, Godes (2017) examines two types of word-of-mouth communication and their interactions with a monopoly firm's quality decision. Our work is in line with Godes (2017) in the rationale of categorizing the two forms of social interactions, but is also different in several important aspects. First, we focus on competing firms' quality-differentiation decision, which is not a concern in the monopoly setting of Godes (2017). Second, we view social interactions as a dynamic factor and formulate a multiperiod model, whereas Godes (2017) does not. Third, the value-enhancement effect in our paper not only can arise from the persuasive word-of-mouth defined in Godes (2017), but may also capture other ways of social interactions—for example, the network externality—that affect consumers' utility through interacting with either current or previous consumers.

To sum up, our paper contributes to the aforementioned streams of literature by uncovering the profound impacts of different forms of social interactions on competing firms' product design, price decisions, and profit, as well as the welfare implications. Our results suggest that conventional wisdom on the strategic adoption of product-quality differentiation should be applied with caution. Instead, firms facing competition should identify the prevailing form of social interactions, understand its impact, and adjust their product design and pricing decisions accordingly.

3. Model Preliminaries

In this section, we outline the model setup by describing the major players and game sequence in Section 3.1, and we present the benchmark model and its results in Section 3.2. The notations used in this paper are summarized on the first page of the online appendix.

3.1. Model Setup

3.1.1. Firms. We consider two competing firms selling vertically differentiated products in a market through two periods, and each firm offers a single product. The firms need to decide the quality levels of their own products. We denote the firm with higher-quality level q_H as firm H and lower-quality level q_L as firm L, respectively. Assume that $0 \le q_L < q_H \le \bar{q}$, where $\bar{q}$ represents the upper bound of the quality restricted by the overall technology level of the industry. Without loss of generality, we normalize $\bar{q}$ to one.

After selecting the quality levels for their products, the two firms engage in a two-period price competition. Let p_{in} denote firm i's price for period n, where $n \in \{1, 2\}$ and $i \in \{H, L\}$. We consider two different pricing schemes, both of which are commonly seen in practice. (1) *Committed pricing*: Each firm sets a single price at the beginning of the first period and commits to it throughout the two periods (i.e., $p_{i1} = p_{i2}$ for $i \in \{H, L\}$). (2) *Dynamic pricing:* Firms are allowed to set intertemporal prices in the beginning of each period. We focus on committed pricing as our main model in Section 4 and then study dynamic pricing as a model extension in Section 5.1 to investigate how the endowed pricing flexibility affects the main results. In addition, we assume that both firms have zero cost in our main model for analytical brevity. We will relax this assumption as a model extension in Section 5.3 and numerically verify that all the main results hold qualitatively when both marginal and fixed costs are considered. As such, firm i's total profit in two periods is given by $\pi_i = p_{i1}d_{i1} + p_{i2}d_{i2}$, where d_{in}

denote firm i's demand in period n, for $n \in \{1,2\}$ and $i \in \{H,L\}$.

3.1.2. Consumers. In period n, each consumer in the market will purchase at most one unit of the product from the two firms. We focus on nondurable goods in our setting where consumers with purchase needs will buy immediately without strategic waiting. More discussions on the issue of strategic purchase timing are provided in Section 6. The utility of purchasing from firm i is denoted by $u_{in}(\theta, q_i, p_{in})$, where θ represents the consumer's willingness to pay for quality and is assumed to be uniformly distributed over $[0,1]$, q_i is the product quality of firm i, and p_{in} is the price in period n. Consumers' utility of outside option is normalized to zero. A consumer will purchase from firm i in period n if and only if $u_{in} > \max\{u_{jn}, 0\}$, where $n \in \{1,2\}$, $i,j \in \{H,L\}$ and $i \neq j$.

In our model, the market diffusion process and the consumer utility structure are endogenously affected by social interactions across the two periods. We consider two forms of social interactions among consumers that have different mechanisms in influencing the potential market size and consumer utility (cf. Van den Bulte and Lilien 2001): market-expansion effect and value-enhancement effect. More specifically, the market-expansion effect refers to the phenomenon that the total potential market size could be enlarged due to the word-of-mouth effect and the cross-brand communications among consumers (Libai et al. 2009). That is, the total market size of the second period increases in the total sales from the first period. On the other hand, the value-enhancement effect refers to the phenomenon that consumers who purchase the product can gain additional utility through social interactions with other consumers of the same product. In addition, we further categorize VEE into two types according to the source of the additional utility: (1) value-enhancement effect from *current* consumers—additional utility is gained from the social interactions with consumers in the current period who are purchasing the same product—and (2) value-enhancement effect from *previous* consumers—additional utility is gained from the social interactions with consumers from the previous period who have purchased the same product. We remark that the network externality is one common interpretation of VEE, but our model admits broader interpretations that involve certain product-exclusive social interactions and takes the time-lag effect of the interactions into account. Hence, VEE could be viewed as a more general framework to capture the social interactions-related impact on consumers' utility.

Next, we capture MEE and VEE in the model setup. First, MEE affects the total market size by expanding the product awareness. The total market size in period n is given by:

$$D_n = \tilde{D}_n + r(d_{H,n-1} + d_{L,n-1}), n \in \{1,2\}.$$

Here, $\tilde{D}_n$ denotes base market size in period n without MEE, $r > 0$ represents the strength of MEE, and d_{in} is the demand of firm i in period n for $i \in \{H,L\}$. Note that $d_{H0} = d_{L0} = 0$. Hence, in period 1, the total market only consists of the base $\tilde{D}_1$—that is, $D_1 = \tilde{D}_1$. In period 2, the total market consists of the base $\tilde{D}_2$ and an additional group of consumers induced by the informative social interactions. Specifically, new consumers are made aware of the products by the peers who made purchase in period 1 and then become part of the potential market in period 2. It is noteworthy that both firms contribute to this awareness-expansion process with their respective existing consumers. Moreover, for analytical brevity, we assume that $\tilde{D}_n = 1$ for $n \in \{1,2\}$. Our results are qualitatively robust when we consider $\tilde{D}_n$ differs in each period (i.e., $\tilde{D}_1 \neq \tilde{D}_2$).

Second, VEE improves the consumers' utility of purchasing from a firm. The utility of purchasing product i in period n is given by

$$u_{in} = \theta q_i - p_{in} + t_c d_{in} + t_p d_{i,n-1}, \text{ for } i \in \{H,L\} \text{ and } n \in \{1,2\}.$$

Here, the parameters $t_c \geq 0$ and $t_p \geq 0$ represent the strength of VEE from current consumers and previous consumers, respectively. Although MEE creates mutual benefits for both firms, VEE features an exclusive utility boost induced via social interactions. Indeed, the consumers' utility toward a product is positively affected only by the sales of that product (in the current period and/or the previous period).[2]

To recap, the two forms of social interactions influence the market dynamics from two interrelated dimensions: The market-expansion effect enlarges the total pie for both firms, whereas the value-enhancement effect dictates the division of the pie. We remark that the parameters r, t_c, and t_p are assumed to be positive in our model setup. They can be relaxed to be negative to capture the negative impacts of social interactions due to congestion. See Section 6 for more discussions.

3.1.3. Sequence of Events. There are two stages in our model, with detailed game sequences given below.

Stage 1—Quality Decision. The two firms simultaneously decide their respective product-quality levels q_H and q_L within the feasible range $[0, \bar{q}]$. We remark that our results in the main model are found to be invariant whether the firms make quality decisions simultaneously or sequentially.[3]

Stage 2—Price Competition. Given the selected quality levels, the two firms engage in a two-period price competition. If a committed pricing scheme is adopted, the two firms simultaneously set their respective prices across the two periods at the beginning of period 1— that is, $p_{H1} = p_{H2} = p_H$ and $p_{L1} = p_{L2} = p_L$. If a dynamic pricing scheme is used, the two firms simultaneously set their own prices at the beginning of period n—that is, p_{Hn} and p_{Ln}—for $n \in \{1, 2\}$. After observing firms' quality and prices, consumers make purchase decisions to maximize their utilities in each period.

3.2. Benchmark Case

To reveal the impacts of social interactions on the duopoly competition, we first analyze the benchmark case, where no social interaction exists (i.e., $r = t_c = t_p = 0$). In this case, the market dynamics are removed, as the two periods are independent and identical, and the two different pricing schemes lead to the same equilibrium outcome. Moreover, the benchmark case is identical to the model studied in Tirole (1988). We use superscript "b" to denote this benchmark case and solve it via backward induction. Given quality q_H and q_L, the two firms' prices of each period are:

$$p_H^b(q_H, q_L) = \frac{2q_H(q_H - q_L)}{4q_H - q_L} \quad \text{and}$$
$$p_L^b(q_H, q_L) = \frac{q_L(q_H - q_L)}{4q_H - q_L}.$$

Moreover, the two firms' demands and profits in period n, for $n \in \{1, 2\}$, are given by:

$$\left(d_{Hn}^b(q_H, q_L), d_{Ln}^b(q_H, q_L)\right) = \left(\frac{2q_H}{4q_H - q_L}, \frac{q_H}{4q_H - q_L}\right) \text{ and}$$
$$\left(\pi_{Hn}^b(q_H, q_L), \pi_{Ln}^b(q_H, q_L)\right) = \left(\frac{4q_H^2(q_H - q_L)}{(4q_H - q_L)^2}, \frac{q_H q_L(q_H - q_L)}{(4q_H - q_L)^2}\right).$$

Lastly, we solve for the firms' quality decisions in stage 1 and use "$\hat{}$" over a symbol to denote the final equilibrium outcome. In the final equilibrium, the firms' quality levels, prices, and total profits over the two selling periods are, respectively, given by:

$$(\hat{q}_H^b, \hat{q}_L^b) = \left(1, \frac{4}{7}\right), \quad (\hat{p}_H^b, \hat{p}_L^b) = \left(\frac{1}{4}, \frac{1}{14}\right), \quad \text{and}$$
$$(\hat{\pi}_H^b, \hat{\pi}_L^b) = \left(\frac{7}{24}, \frac{1}{24}\right).$$

4. Equilibrium Analysis

In this section, we analyze the main model under the committed pricing scheme—that is, $p_{H1} = p_{H2} = p_H$ and $p_{L1} = p_{L2} = p_L$. To single out the individual impact of various forms of social interactions, we separately investigate the market-expansion effect in Section 4.1 and the value-enhancement effect in Section 4.2. In the latter case, we further scrutinize VEE from current consumers and VEE from previous consumers, respectively. For each scenario, we solve for the pure-strategy Subgame Perfect Equilibrium of the two-stage game via backward induction and examine the respective impacts of different forms of social interactions. Finally, in Section 4.3, we compare and contrast the results under scenarios MEE and VEE to provide managerial insights on product design and pricing decisions in the presence of social interactions in a competitive environment.

4.1. Market-Expansion Effect

Suppose only the market-expansion effect is present—that is, $r > 0$ and $t_c = t_p = 0$. In this case, the potential market size is expanded in period 2 as more consumers are drawn to the two products, but the consumers' utilities retain the same structure. Here, social interactions are informative and contribute to awareness expansion, and thus display a spillover effect on the total market size. In what follows, we will first solve the firms' price decisions in stage 2 and then the firms' quality decisions in stage 1 to characterize the final equilibrium. The final equilibrium outcomes are written as functions of r, with superscript "M" referring to "*market*-expansion effect." Moreover, we assume $0 < r \le 1$ so that the market increment never exceeds the previous total sales. This assumption ensures that the market will not be fully covered with both firms having positive demands in each period (i.e., $d_{in} > 0$ and $d_{Hn} + d_{Ln} < 1$ for $i = H, L$ and $n = 1, 2$), which is not only commonly observed in practice, but also shown by Proposition 1 as the unique equilibrium outcome in our setting. We refer to conditions $t_c = t_p = 0$ and $0 < r \le 1$ as the MEE case.

4.1.1. Pricing Decisions. We first analyze the price competition in the second stage for given quality levels q_H and q_L.

Firm H's and firm L's demands in period n are $d_{Hn}^M = D_n(1 - \bar{\theta}_H^M)$ and $d_{Ln}^M = D_n(\bar{\theta}_H^M - \bar{\theta}_L^M)$, respectively, for $n \in \{1, 2\}$, where $\bar{\theta}_H^M = (p_H - p_L)/(q_H - q_L)$ represents the consumer who is indifferent between purchasing high-quality and low-quality product, and $\bar{\theta}_L^M = p_L/q_L$ represents the consumer who is indifferent between purchasing low-quality product and nothing. Given q_H and q_L, firm i selects its price by maximizing its total profit—that is, solving $\max_{p_i} p_i(d_{i1}^M + d_{i2}^M)$.

Lemma 1 establishes the existence and uniqueness of the subgame equilibrium prices, denoted by $p_H^M(q_H, q_L, r)$ and $p_L^M(q_H, q_L, r)$, respectively. Moreover, let $d_i^M(q_H, q_L, r)$ and $\pi_i^M(q_H, q_L, r)$ be firm i's ($i \in \{H, L\}$) corresponding total demand and profit of the two periods. Then, Lemma 1 further discusses how these equilibrium outcomes are affected by the strength of MEE, r.

Lemma 1. *In the MEE case, given the firms' quality levels $0 \le q_L < q_H \le 1$, the firms' subgame equilibrium prices are characterized by a unique pair $(p_H^M(q_H, q_L, r), p_L^M(q_H, q_L, r))$ with detailed expressions shown in Online Appendix A.1. Moreover, the following statements hold:*

a. *$p_H^M(q_H, q_L, r)$ and $p_L^M(q_H, q_L, r)$ decrease in r.*
b. *$d_H^M(q_H, q_L, r)$ and $d_L^M(q_H, q_L, r)$ increase in r.*
c. *$\pi_H^M(q_H, q_L, r)$ and $\pi_L^M(q_H, q_L, r)$ increase in r.*

Lemma 1 reveals the critical role that MEE plays in the duopoly price competition for fixed quality levels. First, Lemma 1(a) shows that both firms decrease their prices when MEE gets stronger. As r increases, each firm can benefit more from a larger market coverage in period 1. Indeed, because the total demand of the two firms in period 1 is given by $(1 - p_L/q_L)$, firm L tends to cut its price p_L to expand market coverage and amplify the effect of market expansion. Such a pricing strategy, however, is deemed as aggressive and, thus, intensifies price competition to some extent. As a response, firm H also cuts its price to maintain its own first-period demand. Second, Lemma 1(b) shows that each firm's total demand increases as MEE becomes stronger. On the one hand, each firm decreases price to expand the market coverage as r increases; on the other hand, stronger MEE leads to larger market size in the second period. Hence, both firms are able to capture more total demand as r increases. Third, by Lemma 1(c), although a stronger MEE intensifies the price competition and decreases both firms' profit margins, it eventually benefits both firms. In fact, as r increases, both firms suffer from profit loss in the first period due to the intensified competition, but will enjoy a larger profit increase in the second period with the expanded market size; and, as a result, firms' total profits increase in r. This indicates that MEE's positive impact, which is mainly manifested in the second period, outweighs the firms' sacrifice in the first period profits.

4.1.2. Quality Decisions. Given the firms' price decisions in stage 2, we fold back to solve the firms' quality decisions in stage 1. In this stage, firm i selects quality q_i to maximize its profit $\pi_i^M(q_H, q_L, r) = p_i^M(q_H, q_L, r) d_i^M \times (q_H, q_L, r)$, for $i \in \{H, L\}$. Proposition 1 shows the existence and uniqueness of the firms' equilibrium-quality decisions ($\hat{q}_H^M(r)$ and $\hat{q}_L^M(r)$). By substituting the equilibrium-quality levels into the corresponding subgame equilibrium, we can derive the firms' final equilibrium prices ($\hat{p}_i^M(r)$), demands ($\hat{d}_i^M(r)$), and profits ($\hat{\pi}_i^M(r)$), for $i \in \{H, L\}$. Then, Proposition 1 further investigates how those final equilibrium outcomes are influenced by the strength of MEE, r.

Proposition 1. *In the MEE case, there exists a unique equilibrium, in which firm H's quality is $\hat{q}_H^M = 1$ and firm L's quality $0 < \hat{q}_L^M(r) < 1$ is given in Online Appendix A.1. In the equilibrium, the market is partially covered, and each firm has positive demand in each period. Moreover, the following statements hold:*

a. *$\hat{q}_L^M(r)$ increases in r, and $\hat{q}_L^M(r) > \hat{q}_L^M(0) = \hat{q}_L^b$.*
b. *$\hat{p}_H^M(r)$ and $\hat{p}_L^M(r)$ decrease in r; $\hat{p}_H^M(r) < \hat{p}_H^b$ and $\hat{p}_L^M(r) < \hat{p}_L^b$.*
c. *$\hat{d}_H^M(r)$ and $\hat{d}_L^M(r)$ increase in r.*
d. *$\hat{\pi}_H^M(r)$ and $\hat{\pi}_L^M(r)$ increase in r. Moreover, $\hat{\pi}_H^M(r) - \hat{\pi}_H^b > \hat{\pi}_L^M(r) - \hat{\pi}_L^b > 0$, whereas $(\hat{\pi}_L^M(r) - \hat{\pi}_L^b)/\hat{\pi}_L^b > (\hat{\pi}_H^M(r) - \hat{\pi}_H^b)/\hat{\pi}_H^b > 0$.*

For any given q_L, firm H's profit always increases in q_H because a higher q_H not only improves consumers' utility, but also enlarges quality differentiation between the firms and thereby reduces competition. Thus, firm H's optimal quality reaches the upper bound of the quality level (i.e., $\hat{q}_H^M = 1$) in the equilibrium, and the degree of quality differentiation between the two firms in this case is simply $1 - \hat{q}_L^M(r)$. One may intuit that firm L would reduce the quality and further differentiate itself in the presence of MEE because the price competition is intensified (see Lemma 1). However, Proposition 1(a) indicates the opposite: Firm L's quality actually increases as MEE becomes stronger and is always higher than that in the benchmark case without MEE (i.e., $\hat{q}_L^M(r) > \hat{q}_L^M(0) = \hat{q}_L^b$). Such a result can be explained in the following way. Although higher q_L implies lower-quality differentiation and intensifies quality competition, it also attracts more low-end consumers and increases the total market coverage, which, in turn, expands the market size through MEE. As the benefit of expanded market size outweighs the drawback of intensified quality competition, firm L increases its quality as MEE becomes stronger. It is noteworthy that the quality change brought by MEE is continuous in r. Hence, $\hat{q}_L^M(r) > \hat{q}_L^M(r = 0) = \hat{q}_L^b$ holds for every $r \in (0, 1]$.

Proposition 1(b) further shows that both firms' equilibrium prices decrease in the strength of MEE and are lower than the benchmark prices. The reason for this result is twofold. First, as shown in Lemma 1, for given quality levels, higher r induces firm L to reduce price to expand the market coverage, which intensifies price competition and forces firm H to follow suit. Second, as mentioned above, the equilibrium-quality differentiation level decreases in r, resulting in fiercer competition and lower prices from both firms. As such, the fact that firms' prices decrease in r is driven by both the intensified price competition and the reduced quality differentiation.

As MEE becomes stronger, firm L increases quality, and both firms decrease prices to expand the market coverage in order to fully utilize MEE, which leads to a higher total demand for each firm (i.e., Proposition 1(c)). Hence, although the competition is intensified, both firms can benefit from stronger MEE due to the enlarged total demand (i.e., Proposition 1(d)). It is noteworthy that, when comparing the profits to the benchmark case, firm H's *absolute* increase is higher than firm L's, whereas firm L enjoys a higher *relative* (percentage) increase.

4.1.3. Welfare Implications. Finally, we conclude this section by studying how MEE affects consumers' total surplus and the social welfare. Let $\hat{D}_2^M(r) = 1 + r(\hat{d}_{H1}^M(r) + \hat{d}_{L1}^M(r))$ be the equilibrium total market size of period 2. We define the equilibrium *consumer surplus* of period 1 and 2 with MEE as $CS_1^M(r) = \int_{\bar{\theta}_H^M}^1 (\theta - \hat{p}_H^M(r))d\theta + \int_{\bar{\theta}_L^M}^{\bar{\theta}_H^M} (\theta\hat{q}_L^M(r) - \hat{p}_L^M(r))d\theta$ and $CS_2^M(r) = \hat{D}_2^M(r)CS_1^M(r)$, respectively, where θ_H^M and θ_L^M are previously defined in the pricing-decision stage. Then, $CS^M(r) = CS_1^M(r) + CS_2^M(r)$ is the total consumer surplus in two periods and $SW^M(r) = CS^M(r) + \hat{\pi}_H^M(r) + \hat{\pi}_L^M(r)$ is the social welfare in the MEE case. The effect of MEE is characterized in Corollary 1 below.[4]

Corollary 1. *The following statements hold in the MEE case*:

a. $CS_1^M(r)$, $CS_2^M(r)$, *and* $CS^M(r)$ *all increase in* r; *and* $CS^M(r) > CS^b$;

b. $SW^M(r)$ *increases in* r; *and* $SW^M(r) > SW^b$.

As shown in Corollary 1, consumers always benefit from stronger MEE. In fact, the increased quality of firm L, the reduced prices, and the enlarged market size at period 2 altogether contribute to the positive impact of MEE. As such, it is interesting to notice that stronger MEE would benefit both firms and their consumers, a desirable *win–win* outcome that improves the social welfare.

4.2. Value-Enhancement Effect

In this section, we study the value-enhancement effect, which is categorized into two types. VEE-C refers to the interactions with peers who purchase the same product in the current period, and VEE-P captures the interactions with those who purchased the same product in the previous period. These two types of VEE share similar nature, but differ in the source of social interactions. They may or may not coexist for different products in practice. To distill the individual impact of each one, we analyze VEE-C and VEE-P separately. As shown in the sequel, the central results for the VEE-C case and the VEE-P case are qualitatively similar. Hence, we devote Section 4.2.1 to a detailed investigation on VEE-C, which parallels with Section 4.1. Then, we use Section 4.2.2 to briefly report the relevant findings for VEE-P and, more importantly, to discuss the similarities and distinctions between the systematic impacts of the two types of VEE.

4.2.1. Value-Enhancement Effect from Current Consumers. Consider the scenario VEE-C, in which $r = t_p = 0$ and $t_c > 0$. The total market size is one in each period, but consumers' utility toward a firm's product positively depends on that firm's demand in the current period. We use superscript "VC" to represent the case of *value*-enhancement effect from *current* consumers. Because the first period has no impact on the second period under VEE-C, the two periods are independent, and each firm's demand and profit in the two periods are identical (i.e., $d_{i1}^{VC} = d_{i2}^{VC}$ and $\pi_{i1}^{VC} = \pi_{i2}^{VC}$ for $i \in \{H, L\}$). Similar to the analysis in the MEE case, we first solve the price competition in stage 2 and then characterize firms' quality decisions in stage 1 to obtain the final equilibrium outcomes, which are written as functions of the strength of VEE-C, t_c. Furthermore, we simplify the analysis by assuming that t_c is a small fraction—that is, $t_c \le \bar{t}_c$, where $\bar{t}_c$ is given in Online Appendix A.2. This assumption guarantees that the market is not fully covered and each firm has positive demand in the final equilibrium, which is commonly observed and consistent with many practical situations. In the following, we refer to conditions $r = t_p = 0$ and $0 < t_c \le \bar{t}_c$ as the VEE-C case.

4.2.1.1. Pricing Decisions. We analyze the duopoly price competition in the second stage for given quality levels. Note that, unlike the MEE case, the market may be fully covered, and one of the firms may have zero demand in the subgame equilibrium for some quality levels, because consumers' utility is changed in the VEE-C case. However, as shown in Proposition 2, in the final equilibrium, the market is partially covered, and each firm has positive demand. This indicates that any quality levels that lead to a fully covered market or zero demand of either firm cannot be a final equilibrium. Hence, for expositional brevity, we exclude the off-equilibrium cases in the following subgame discussion by assuming partial market coverage and positive demand for each firm.

Given firms' quality levels q_H and q_L, it is straightforward to see that firms' demands in period n are $d_{Hn}^{VC} = 1 - \bar{\theta}_H^{VC}$ and $d_{Ln}^{VC} = \bar{\theta}_H^{VC} - \bar{\theta}_L^{VC}$, for $n \in \{1, 2\}$, where $\bar{\theta}_H^{VC} = [q_L(p_H - p_L) - (q_L + p_H - t_c)t_c]/[q_L(q_H - q_L) - (q_L + q_H - t_c)t_c]$ represents the consumer who is indifferent between purchasing high-quality and low-quality product, and $\bar{\theta}_L^{VC} = [p_L(q_H - q_L) - (p_L + p_H - t_c)t_c]/[q_L(q_H - q_L) - (q_L + q_H - t_c)t_c]$ captures the consumer who is indifferent between purchasing low-quality product and nothing. Hence, firm i's problem is to maximize its total profit—that is, $\max_{p_i} p_i(d_{i1}^{VC} + d_{i2}^{VC})$, $i \in \{H, L\}$. In Lemma 2, we characterize the firms' subgame equilibrium prices $p_H^{VC}(q_H, q_L, t_c)$ and $p_L^{VC}(q_H, q_L, t_c)$ in stage 2, and then discuss the impact of t_c on firm i's price, total demand ($d_i^{VC}(q_H, q_L, t_c)$), and total profit ($\pi_i^{VC}(q_H, q_L, t_c)$), for $i \in \{H, L\}$.

Lemma 2. *In the VEE-C case, given the quality levels q_H and q_L, the firms' subgame equilibrium prices are characterized by a unique pair ($p_H^{VC}(q_H, q_L, t_c), p_H^{VC}(q_H, q_L, t_c)$), with the detailed expressions shown in Online Appendix A.2. Moreover, the following statements hold:*

a. *$p_L^{VC}(q_H, q_L, t_c)$ decreases in t_c, whereas $p_H^{VC}(q_H, q_L, t_c)$ may increase or decrease in t_c;*

b. *$d_H^{VC}(q_H, q_L, t_c)$ increases in t_c, whereas $d_L^{VC}(q_H, q_L, t_c)$ may increase or decrease in t_c;*

c. *Both $\pi_H^{VC}(q_H, q_L, t_c)$ and $\pi_L^{VC}(q_H, q_L, t_c)$ may increase or decrease in t_c.*

There are several useful takeaways from Lemma 2 that can help us understand the important role VEE-C plays in the price competition with fixed quality levels. With VEE-C, consumers' utility improves as the product sales increase. That is, product i gains additional value via social interactions, $t_c d_{in}$, in period n, for $i \in \{H, L\}$ and $n \in \{1, 2\}$. However, because firm H has quality advantage and can capture more demand than firm L, the high-quality product can gain higher social value than the low-quality one. Consequently, despite the additional social value received by the low-quality product, firm L ends up falling to a more disadvantageous position in the price competition, as VEE-C makes firm H even more competitive. In this sense, VEE-C actually favors the high-quality product and lets firm H gain more competitive edge. Therefore, by Lemma 2(a), regardless of the given quality levels, firm L has to reduce its price to compete for consumers as VEE-C gets stronger. Firm H, by contrast, may either raise or cut its price depending on the quality levels. Moreover, we can further show that firm H's price decreases in t_c when $q_H = 1$, implying that a stronger VEE-C can result in a more competitive environment.

The same rationale explains the properties of firms' demands in Lemma 2(b). As firm H can obtain more added social value via VEE-C, it has more advantage to gain higher demand. However, although the low-quality product's additional social value increases as VEE-C becomes stronger, firm L indeed becomes less competitive. Hence, its demand may be higher or lower as t_c increases, depending on the quality levels. Finally, Lemma 2(c) shows that both firms' profits may increase or decrease in t_c for given quality levels. Even though VEE-C renders an exclusive positive effect by improving consumers' utilities for both products, the two firms may or may not benefit from a stronger VEE-C, as it may intensify the price competition and reduce both firms' profit margins.

4.2.1.2. Quality Decisions. Given the firms' subgame equilibrium price decisions, we proceed to solve for firms' quality decisions in stage 1. In this stage, firm i chooses quality q_i to maximize its profit $\pi_i^{VC}(q_H, q_L, t_c) = p_i^{VC}(q_H, q_L, t_c) d_i^{VC}(q_H, q_L, t_c)$, for $i \in \{H, L\}$. Proposition 2 first establishes the existence and uniqueness of the final equilibrium and then examines how the strength of VEE-C (t_c) influences the final equilibrium outcomes, including firm i's equilibrium quality ($\hat{q}_i^{VC}(t_c)$), price ($\hat{p}_i^{VC}(t_c)$), demand ($\hat{d}_i^{VC}(t_c)$), and profit ($\hat{\pi}_i^{VC}(t_c)$), for $i \in \{H, L\}$.

Proposition 2. *In the VEE-C case, there exists a unique equilibrium, in which firm H's quality is $\hat{q}_H^{VC} = 1$ and firm L's quality $0 < \hat{q}_L^{VC}(t_c) < 1$ is given in Online Appendix A.2. In the equilibrium, the market is partially covered, and each firm has positive demand in each period. Moreover, the following statements hold:*

a. *$\hat{q}_L^{VC}(t_c)$ decreases in t_c, and $\hat{q}_L^{VC}(t_c) < \hat{q}_L^{VC}(0) = \hat{q}_L^b$.*

b. *$\hat{p}_H^{VC}(t_c)$ increases in t_c and $\hat{p}_L^{VC}(t_c)$ decreases in t_c. In addition, $\hat{p}_H^{VC}(t_c) > \hat{p}_H^b$ and $\hat{p}_L^{VC}(t_c) < \hat{p}_L^b$.*

c. *$\hat{d}_H^{VC}(t_c)$ increases in t_c, and $\hat{d}_L^{VC}(t_c)$ may decrease or increase in t_c.*

d. *$\hat{\pi}_H^{VC}(t_c)$ increases in t_c and $\hat{\pi}_L^{VC}(t_c)$ decreases in t_c; moreover, $\hat{\pi}_H^{VC}(t_c) - \hat{\pi}_H^b > 0 > \hat{\pi}_L^{VC}(t_c) - \hat{\pi}_L^b$.*

As firm H's profit increases in q_H for any given q_L, it is optimal to set q_H as the upper bound (i.e., $\hat{q}_H^{VC} = 1$). Hence, $1 - \hat{q}_L^{VC}(t_c)$ represents the quality differentiation between the two firms. Different from the MEE case, Proposition 2(a) shows that firm L's equilibrium quality level decreases as VEE-C becomes stronger and is lower than the benchmark case. As mentioned, the presence of VEE-C provides uneven additional social values to the products and tends to intensify the price war, leaving firm L in an undesirable situation as it loses competitiveness to firm H. To combat, firm L has to reduce the product quality to further differentiate from firm H. In other words, with VEE-C, firm L simply cannot effectively exploit consumers' enhanced utility; instead, it has to reduce its quality to target on the lower-end consumers. Similar to the MEE case, firm L's equilibrium quality without VEE-C coincides with the benchmark—that is, $\hat{q}^{VC}(t_c = 0) = \hat{q}_L^b$. Thus, $\hat{q}_L^{VC}(t_c) < \hat{q}_L^b$ holds.

Compared with the subgame results shown in Lemma 2, the impact of VEE-C on the final equilibrium outcomes exhibits some differences. By Lemma 2(a), for given quality levels, firm H's price may increase or decrease in t_c. In particular, p_H^{VC} decreases in t_c for $q_H = 1$, as mentioned previously. However, Proposition 2(b) shows that firm H's final equilibrium price always increases in t_c. This seemingly contradictory finding can be understood as follows. On the one hand, for given $q_H = 1$ and $q_L < 1$, stronger VEE-C decreases firm H's price; on the other hand, stronger VEE-C decreases firm L's quality, which incentivizes firm H to increase its price. The latter impact turns out to outweigh the former, and firm H's equilibrium price $\hat{p}_H^{VC}(t_c)$ increases in t_c as a result.

Proposition 2(c) characterizes interesting properties of firms' equilibrium demands. Because of the strengthened advantageous position, firm H's equilibrium demand $\hat{d}_H^{VC}(t_c)$ is larger than that in the benchmark model and always increases as VEE-C becomes stronger, but firm L's equilibrium demand $\hat{d}_L^{VC}(t_c)$ could be lower than the benchmark case. It is noteworthy that, although the market is still partially covered, the total market coverage from the two firms under VEE-C is larger than that in benchmark case—that is, $\hat{d}_H^{VC}(t_c) + \hat{d}_L^{VC}(t_c) > \hat{d}_H^b + \hat{d}_L^b$. Hence, firm H's demand increase always dominates firm L's demand loss, if there is any.

Finally, in contrast to the previous result that MEE induces mutual benefits, Proposition 2(d) shows that firms cannot simultaneously benefit from a stronger VEE-C. In fact, as VEE-C becomes stronger, firm H always enjoys an increased profit that is higher than the benchmark case, whereas firm L's profit decreases and is lower than the benchmark case. Such Matthew effect of accumulated advantage indicates that VEE-C is competitive in nature and is particularly detrimental to the low-quality firm. In other words, being a high-quality firm is a persistent advantage when consumers actively engage in value-enhancing social interactions with their peers in the current period.

4.2.1.3. Welfare Implications. Finally, we study how VEE-C affects both the consumers and the social welfare. We first define consumers' total surplus in period n, including the additional utility caused by VEE-C, as $CS_n^{VC}(t_c) = \int_{\bar{\theta}_H^{VC}}^1 (\theta - \hat{p}_H^{VC}(t_c) + t_c\hat{d}_{Hn}^{VC}(t_c))d\theta + \int_{\bar{\theta}_L^{VC}}^{\bar{\theta}_H^{VC}} (\theta\hat{q}_L^{VC}(t_c) - \hat{p}_L^{VC}(t_c) + t_c\hat{d}_{Ln}^{VC}(t_c))d\theta$, where $\bar{\theta}_H^{VC}$ and $\bar{\theta}_L^{VC}$ are given previously in the pricing decision stage, for $n = 1, 2$. Then, we exclude the additional social utility and define consumers' monetary surplus in each period as $CM_1^{VC}(t_c) = CM_2^{VC}(t_c) = \int_{\bar{\theta}_H^{VC}}^1 (\theta - \hat{p}_H^{VC}(t_c))d\theta + \int_{\bar{\theta}_L^{VC}}^{\bar{\theta}_H^{VC}} (\theta\hat{q}_L^{VC}(t_c) - \hat{p}_L^{VC}(t_c))d\theta$. Let $CM^{VC}(t_c) = CM_1^{VC}(t_c) + CM_2^{VC}(t_c)$ and $CS^{VC}(t_c) = CS_1^{VC}(t_c) + CS_2^{VC}(t_c)$ be the consumer monetary surplus and total surplus of two periods, respectively.

We further define $SW^{VC}(t_c) = \hat{\pi}_H^{VC}(t_c) + \hat{\pi}_L^{VC}(t_c) + CS^{VC}(t_c)$ as the social welfare under VEE-C. Note that we can divide the social welfare into two parts:

$$SW^{VC}(t_c) = \underbrace{\hat{\pi}_H^{VC}(t_c) + \hat{\pi}_L^{VC}(t_c) + CM^{VC}(t_c)}_{\text{MonetaryTerm}} + \underbrace{\left(CS^{VC}(t_c) - CM^{VC}(t_c)\right)}_{\text{SocialUtilityTerm}}.$$

Let $SM^{VC}(t_c) = \hat{\pi}_H^{VC}(t_c) + \hat{\pi}_L^{VC}(t_c) + CM^{VC}(t_c)$ represent the monetary term of social welfare that excludes consumers' additional social utility. Corollary 2 summarizes the social impacts of VEE-C.

Corollary 2. *The following statements hold in the VEE-C case*:

a. $CM^{VC}(t_c)$ *decreases in* t_c, *and* $CM^{VC}(t_c) < CM^{VC}(0) = CM^b$;
b. $CS^{VC}(t_c)$ *first decreases and then increases in* t_c;
c. $SM^{VC}(t_c)$ *decreases in* t_c, *and* $SM^{VC}(t_c) < SM^b$;
d. $SW^{VC}(t_c)$ *increases in* t_c, *and* $SW^{VC}(t_c) > SW^b$.

Under VEE-C, consumers' total surplus (i.e., $CS^{VC}(t_c)$) includes the monetary surplus and the additional social utility. We find that although consumers' additional social utility increases as VEE-C becomes stronger, their monetary surplus always decreases, and their total surplus could be lower compared with the benchmark without VEE-C. The lowered quality from firm L and increased price from firm H are the main drivers of this result, outweighing the fact that firm L's price becomes lower. Similarly, social welfare contains the monetary part and consumers' social utility part under VEE-C. As VEE-C becomes stronger, the reduction in both firm L's profit and consumer monetary surplus reduces the monetary term of social welfare, despite the increased profit of firm H, as shown in Corollary 2(c). However, the overall social welfare would increase in t_c because consumers' additional social utility becomes higher as t_c increases (see Corollary 2(d)). The social impacts of VEE-C are in sharp contrast to the MEE case, which induces a win–win outcome for both firms and consumers (see Corollary 1). As such, the distinct nature of social interactions indirectly affects consumers via its impact on competing firms' product design and pricing decisions.

4.2.2. Value-Enhancement Effect from Previous Consumers. Now, we turn to study the scenario when only VEE-P is present—that is, $r = t_c = 0$ and $t_p > 0$. Similar to VEE-C, VEE-P can also improve consumers' utility exclusively for the chosen product; however, in the VEE-P case, there is a time lag between demand realization and the value-enhancing interactions, as the firm's first-period demand affects consumers' utility in the second period. We take the same analytical approach to solve the game. Particularly, we assume that t_p is a small fraction—that is, $t_p \leq \bar{t}_p$, where $\bar{t}_p$ is given in Online Appendix A.3. Hereafter, the VEE-P case means $r = t_c = 0$ and $0 < t_p \leq \bar{t}_p$, and we write the equilibrium outcomes with superscript "*VP*" referring to "*value*-enhancement effect from *previous* consumers." We have mentioned previously that the main results in scenario VEE-P are qualitatively similar, as in VEE-C. Therefore, in what follows, we will briefly outline the study on the VEE-P case without unnecessary reiteration. After presenting each main result, we will discuss the similarities and, more importantly, highlight the distinctions between the two types of VEE.

4.2.2.1. Pricing Decisions. In stage 2, firms choose prices for given q_H and q_L to maximize their profits. Again, we exclude the off-equilibrium cases in the following discussion for expositional brevity by assuming partial market coverage and positive demand for each firm. The subgame equilibrium outcome is examined by the following lemma, which is in parallel with Lemma 2 in Section 4.2.1.

Lemma 3. *In the VEE-P case, given the quality levels q_H and q_L, the firms' subgame equilibrium prices are characterized by a unique pair $(p_H^{VP}(q_H, q_L, t_p), p_H^{VP}(q_H, q_L, t_p))$, with the detailed expressions shown in Online Appendix A.3. Moreover, the following statements hold:*

a. *Both $p_H^{VP}(q_H, q_L, t_p)$ and $p_L^{VP}(q_H, q_L, t_p)$ decrease in t_p;*

b. *$d_H^{VP}(q_H, q_L, t_p)$ increases in t_p, whereas $d_L^{VP}(q_H, q_L, t_p)$ may increase or decrease in t_p;*

c. *Both $\pi_H^{VP}(q_H, q_L, t_p)$ and $\pi_L^{VP}(q_H, q_L, t_p)$ may increase or decrease in t_p.*

Consistent with the VEE-C case, the presence of VEE-P improves consumers' utilities by providing additional social value to the product, and the high-quality product gains higher social value and enjoys a more advantageous position, whereas firm L loses its competitive edge. Thus, the impact of VEE-P is almost identical to that of VEE-C in this regard. However, comparing Lemma 3 and Lemma 2, one distinction stands out of the overall similarities. Specifically, Lemma 3(a) states that $p_H^{VP}(q_H, q_L, t_p)$ decreases in t_p in the VEE-P case, whereas Lemma 2(a) says that $p_H^{VC}(q_H, q_L, t_c)$ may increase or decrease in t_c in the VEE-C case. In other words, for given quality levels, different types of VEE have different impacts on firm H's price. Because the value enhancement is exclusive to the chosen product, both types of VEE are favorable to firm H. As a result, firm H may actually increase the price as VEE-C gets stronger. However, firm H is shown to always cut the price as VEE-P becomes stronger. This result reveals an important distinction between VEE-C and VEE-P: The time lag for the value enhancement to take effect in the VEE-P case weakens firm H's advantage. Indeed, if additional social value is from interacting with the previous consumers, then firm H can only enjoy the benefit in period 2, and it has to drop price for given quality levels in order to capture sufficient first-period sales to effectively exploit value enhancement in period 2.

4.2.2.2. Quality Decisions. Given the firms' price decisions in stage 2, we now solve the first stage of the game. The existence and uniqueness of the equilibrium quality decisions are established by Proposition 3, which is a counterpart of Proposition 2 in Section 4.2.1. Additionally, the impact of the strength of VEE-P—that is, t_p—on the final equilibrium outcomes is also studied by Proposition 3.

Proposition 3. *In the VEE-P case, there exists a unique equilibrium, in which firm H's quality is $\hat{q}_H^{VP} = 1$ and firm L's quality $0 < \hat{q}_L^{VC}(t_p) < 1$ is given in Online Appendix A.3. In the equilibrium, the market is partially covered, and each firm has positive demand in each period. Moreover, the following statements hold:*

a. *$\hat{q}_L^{VP}(t_p)$ decreases in t_p, and $\hat{q}_L^{VP}(t_p) < \hat{q}_L^{VP}(0) = \hat{q}_L^b$.*

b. *$\hat{p}_H^{VP}(t_p)$ increases in t_p and $\hat{p}_L^{VP}(t_p)$ decreases in t_p. In addition, $\hat{p}_H^{VP}(t_p) > \hat{p}_H^b$ and $\hat{p}_L^{VP}(t_p) < \hat{p}_L^b$.*

c. *$\hat{d}_H^{VP}(t_p)$ increases in t_p, and $\hat{d}_L^{VP}(t_p)$ may decrease or increase in t_p.*

d. *$\hat{\pi}_H^{VP}(t_p)$ increases in t_p and $\hat{\pi}_L^{VP}(t_p)$ decreases in t_p; and $\hat{\pi}_H^{VP}(t_p) - \hat{\pi}_H^b > 0 > \hat{\pi}_L^{VP}(t_p) - \hat{\pi}_L^b$.*

Comparing the parallel results listed in Propositions 2 and 3, it is immediate that both VEE-C and VEE-P exhibit qualitatively identical impacts on the firms' equilibrium decisions and outcomes. This is because both effects unilaterally improve consumers' utility toward a chosen product, with the only difference that the additional utility gain is originated from interacting with current consumers in VEE-C and previous consumers in VEE-P. Hence, value-enhancing social interactions, regardless of their sources, always reduce firm L's quality and enlarge the degree of quality differentiation. Besides, we again have $\hat{q}_L^{VP}(t_p) < \hat{q}^{VP}(t_p = 0) = \hat{q}_L^b$. Furthermore, both types of VEE tend to increase firm H's profit and reduce firm L's profit in the final equilibrium. Hence, the Matthew effect of accumulated advantage emerges, benefiting firm H at the expense of hurting firm L.

The above discussions indicate that the impacts of the value-enhancement effect on competing firms' quality and price decisions and profits are consistent and robust, regardless of whether there is a time lag between the demand realization and social interactions. Given the consistent impacts, we conjecture that the individual impacts of VEE-C and VEE-P remain unchanged when both effects are present. Indeed, Section 5.2 provides a comprehensive numerical study to check and confirm our prediction with more detailed discussions.

4.2.2.3. Welfare Implications. Finally, we check the properties of consumer monetary surplus (i.e, $CM^{VP}(t_p)$), consumer total surplus (i.e, $CS^{VP}(t_p)$), social welfare (i.e., $SW^{VP}(t_p)$), and the monetary term of social welfare (i.e., $SM^{VP}(t_p)$) in the VEE-P case, which are defined in a similar way as their counterparts under VEE-C. The effects of t_p are captured by Corollary 3.

Corollary 3. *The following statements hold in the VEE-P case*:

a. $CM^{VP}(t_p)$ *decreases in* t_p; *and* $CM^{VP}(t_p) < CM^{VP}(0) = CM^b$;

b. $CS^{VP}(t_p)$ *first decreases and then increases in* t_p;

c. $SM^{VP}(t_p)$ *may decrease or increase in* t_p;

d. $SW^{VP}(t_p)$ *increases in* t_p, *and* $SW^{VP}(t_p) > SW^b$.

Comparing Corollary 3 with Corollary 2, there are three interesting observations. First, both VEE-C and VEE-P hurt consumers' monetary surplus and could reduce their overall surplus, because firm L lowers the quality and firm H raises the price (even though firm L cuts its price). Second, both VEE-C and VEE-P lead to higher social welfare due to the increased consumers' additional social utility and firm H's profit. Finally, stronger VEE-C always reduces the monetary term of social welfare, but stronger VEE-P may either increase or decrease it. This difference is due to the one-period lag for the value-enhancing interactions to take effect in the VEE-P case. Therefore, although both types of VEE hurt consumers' monetary surplus, the monetary term of social welfare is possible to increase only under VEE-P.

4.3. Comparisons Between MEE and VEE

In this section, we compare and contrast the main results obtained in Sections 4.1 and 4.2 to shed light on the similarities and differences of the two fundamental forms of social interactions. Although both MEE and VEE introduce positive impacts to the market, we emphasize the importance of identifying the prevailing form of social interactions. Our results can provide managerial insights into how competing firms should leverage the social interactions to guide their product design and pricing strategies. Among others, we highlight the following major findings.

First, a stronger MEE strengthens the level of product-quality differentiation (i.e., larger $q_H - q_L$), while a stronger VEE weakens it (i.e., smaller $q_H - q_L$). Note that firm H always selects quality at the upper bound under both cases, and only firm L's quality is influenced by MEE or VEE. Both effects are more powerful with higher demands: MEE can generate a larger market size if total demand of the previous period is higher, whereas VEE can lead to higher consumer utility if demand of the current/previous period is larger. Given that a higher product quality can generate larger demand, one may intuit that firm L will select a higher-quality level to exploit social interactions. However, based on our findings, this intuition is valid only in the MEE case. Indeed, firm L's equilibrium quality in the MEE case is higher than the benchmark value 4/7 and increases in the strength of MEE (i.e., r). This shows that selecting a higher-quality level to utilize MEE is more beneficial to firm L than further differentiating itself to soften the competition. However, the opposite is true under VEE: Firm L's quality is always lower than 4/7 and decreases in the strength of VEE (i.e., either t_c or t_p). Different from MEE, VEE favors firm H at the expense of hurting firm L, because it provides higher social value to a high-quality product than a low-quality one. To alleviate such a disadvantage, firm L chooses to reduce its quality to further differentiate from firm H and soften the competition, rather than being aggressive to increase quality and exploit VEE. As such, the effectiveness of VEE to firm L is compromised because it simply does not have enough competitive edge to leverage VEE and has to lower the quality to survive the competition.

Second, both MEE and VEE tend to intensify the price competition. Given predetermined quality levels, firms are likely to reduce prices in the second stage, regardless of the present effect, which intensifies the ensuing price competition. Moreover, recall that both MEE and VEE are more effective with higher demand, which can be induced via lower prices. One may think that both MEE and VEE should incentivize firms to reduce prices to effectively exploit the consumers' social interactions. Although our results support this intuition, we find that the underlying reasons are essentially different: MEE incentivizes firm L to take an active role and aggressively reduce price to amplify the ensuing market expansion, and firm H, in turn, decreases the price to retain its own market share; whereas VEE provides more advantages to firm H and thus forces firm L to passively reduce its price in order to keep market share under the intensified competition.

Third, both MEE and VEE benefit firm H, whereas MEE benefits, but VEE hurts, firm L. Although both effects introduce positive factors and intensify price competition, they lead to different implications on firms' profit performance. The competition in MEE is benign to both firms due to the spillover effect in market growth, and the enlarged market size benefits both firms. As such, despite the intensified competition, both firms' profits will increase as MEE becomes stronger. On the other hand, the intensified competition under VEE induces the Matthew effect, where firm H is better off, but firm L is worse off; and, furthermore, their profit gap increases in the strength of VEE. Our findings reveal that, different from the MEE's win–win outcome, VEE makes a high-quality product more appealing, but is malignant to a low-quality product's survival in the market.

Finally, MEE benefits consumers and improves social welfare, whereas VEE could hurt consumers' monetary surplus. Consumers benefit from stronger MEE due to firm L's improved quality, the reduced prices, and the inflated market size in period 2. Therefore, consumer surplus increases as MEE becomes stronger.

As MEE leads to a win–win–win outcome, the social welfare is also improved. This indicates that the intensified competition in MEE is benign not only to firms, but also to consumers. Quite the opposite, consumers' monetary surplus drops, and their total surplus may also decline under VEE because firm L's quality decreases and firm H's price increases. This shows that the intensified competition caused by VEE is malignant not only to firm L, but also to consumers.

5. Additional Discussions

In this section, we provide additional discussions on the key model assumptions and related issues. Specifically, we study how a dynamic pricing scheme may affect our main results in Section 5.1, investigate the combined effects of MEE and VEE in Section 5.2, and extend our base model to include costs in Section 5.3. In the subsequent analysis and discussions, we will demonstrate that our main results remain qualitatively valid and also provide additional managerial insights.

5.1. Model with Dynamic Pricing Scheme

Our main model in Section 4 assumes that each firm sets a single price and commits to it across two selling periods. In reality, however, firms in different industries may adopt different pricing schemes, among which dynamic pricing is also commonly observed. For example, new sharing-economy platforms or new social-goods producers may offer discounted prices at an early stage and then return back to the normal prices later. In this section, we examine dynamic pricing in which both firms simultaneously decide their selling prices at the beginning of each period. Adopting the same approach, we study MEE and VEE separately by solving the competition model with the dynamic pricing scheme. We focus on the following two aspects: (1) We replicate the investigations on the impact of the social interactions (i.e., r, t_c, and t_p) on firms' equilibrium decisions; and (2) we compare the results under different pricing schemes to examine how pricing flexibility affects the equilibrium outcomes in the presence of social interactions. In this way, we could understand both the qualitative and the quantitative changes of our results under dynamic pricing. We briefly report our main findings in the following.

First, our main results in Section 4 continue to hold qualitatively when considering the model with dynamic pricing. As such, we claim that the impacts of social interactions on competing firms' quality and price decisions and profits are robust with respect to firms' pricing schemes. For simplicity, we do not repeat the results here; instead, we show the detailed results in Online Appendix B.

Second, more interesting results arise when we quantitatively compare the respective equilibrium outcomes under the two pricing schemes to distill the impact of pricing flexibility and its interplay with social interactions. We elaborate our findings below.

5.1.1. Market-Expansion Effect. We keep our convention in notation and use the superscript "*DM*" to represent "*dynamic* pricing with *market*-expansion effect." Hence, $\hat{q}_i^{DM}(r)$, $\hat{p}_{in}^{DM}(r)$, $\hat{d}_i^{DM}(r)$, and $\hat{\pi}_i^{DM}(r)$ denote firm i's equilibrium quality, price of period n, total demand, and total profit, respectively. First, we emphasize that the impacts of MEE on the final equilibrium under dynamic pricing remain qualitatively unchanged as those from committed pricing. Then, by comparing the equilibrium outcomes under the two pricing schemes, we reveal how pricing flexibility affects firms' decisions and profits under MEE in Proposition 4.

Proposition 4. *The following statements hold in the MEE case for* $i \in \{H, L\}$.

a. $\hat{q}_H^M = \hat{q}_H^{DM} = 1$ *and* $\hat{q}_L^M(r) > \hat{q}_L^{DM}(r) > \hat{q}_L^b$*—that is, firms are more differentiated under dynamic pricing.*

b. *Each firm's committed price is between its first-period and second-period dynamic prices—that is,* $\hat{p}_{i1}^{DM}(r) < \hat{p}_i^M(r) < \hat{p}_{i2}^{DM}(r)$.

c. *Each firm's total demand is larger under dynamic pricing—that is,* $\hat{d}_i^{DM}(r) > \hat{d}_i^M(r) > \hat{d}_i^b$.

d. *Each firm's profit is higher under dynamic pricing—that is,* $\hat{\pi}_i^{DM}(r) > \hat{\pi}_i^M(r) > \hat{\pi}_i^b$.

The comparison between the two pricing schemes in the MEE case, as characterized in Proposition 4, has several interesting implications. Parts (a) and (b) together reveal how firms' quality and price decisions are affected by dynamic pricing. Specifically, firm H chooses the same quality level under both pricing schemes, whereas firm L chooses lower quality under dynamic pricing than committed pricing; and each firm's committed price is higher than its first-period dynamic price, but is lower than its second-period one. This shows that, with pricing flexibility, firm L exploits MEE with a different approach. Instead of raising quality level to attract more consumers, it now lowers the first-period price to induce large sales, which is more effective. In period 2, the prices are set higher under dynamic pricing due to the end-of-horizon effect, which allows firms to maximize their profits. Moreover, because firm L does not have to increase quality too much under dynamic pricing (compared with committed pricing), the quality differentiation is larger and the competition is softer. Indeed, as shown in Proposition 4(c) and (d), both firms' profits and total demands are higher than those under committed pricing. Therefore, pricing flexibility amplifies the overall impact of MEE and benefits both firms. However, a close look at the percentage increase in profit shows that $(\hat{\pi}_i^{DM}(r) - \hat{\pi}_i^{M}(r))/\hat{\pi}_i^{M}(r)$ is below 0.3% for $0 < r \le 1$ and $i \in \{H, L\}$. Hence, the difference between dynamic pricing and committed pricing is only modest.

5.1.2. Value-Enhancement Effect. We first remark that all the equilibrium outcomes and results for VEE-C remains the same regardless of the adopted pricing scheme, because social interactions under VEE-C occur only within the current period, making each period independent and identical. Thus, only VEE-P is relevant in this section. Similarly as before, we assume that the parameter $t_p < \bar{t}_p$ so that the market is partially covered and each firm has positive demand in the equilibrium. Moreover, all the notations are defined in the same manner, except that here we use the superscript "*DVP*" to represent "*dynamic* pricing with *value*-enhancement effect from *previous* consumers." Again, we remark that the impacts of VEE-P on the final equilibrium under dynamic and committed pricing are qualitatively the same. Then, we compare the equilibrium outcomes of the VEE-P case under the two pricing schemes in Proposition 5.

Proposition 5. *The following statements hold in the VEE-P case*:

a. $\hat{q}_H^{VP} = \hat{q}_H^{DVP} = 1$, *and there exists* $\tilde{t}$ *such that* $\hat{q}_L^{VP}(t_p) < \hat{q}_L^{DVP}(t_p) < \hat{q}_L^b$ *if* $t_p < \tilde{t}$ *and* $\hat{q}_L^{DVP}(t_p) < \hat{q}_L^{VP}(t_p) < \hat{q}_L^b$ *otherwise.*

b. *Each firm's committed price is between its first-period and second-period dynamic prices—that is,* $\hat{p}_{i1}^{DVP}(t_p) < \hat{p}_i^{VP}(t_p) < \hat{p}_{i2}^{DVP}(t_p)$, *for* $i = H, L$.

c. *Firm H's total demand is lower under dynamic pricing—that is,* $\hat{d}_H^{DVP}(t_p) < \hat{d}_H^{VP}(t_p)$*—whereas firm L's is higher— that is,* $\hat{d}_L^{DVP}(t_p) > \hat{d}_L^{VP}(t_p)$.

d. *Firm L's profit is higher under dynamic pricing—that is,* $\hat{\pi}_L^{VP}(t_p) < \hat{\pi}_L^{DVP}(t_p) < \hat{\pi}_L^b$; *for firm H, there exists a threshold* $\hat{t}$ *such that* $\hat{\pi}_H^{VP}(t_p) > \hat{\pi}_H^{DVP}(t_p) > \hat{\pi}_H^b$ *if* $t_p < \hat{t}$ *and* $\hat{\pi}_H^{DVP}(t_p) > \hat{\pi}_H^{VP}(t_p) > \hat{\pi}_H^b$ *otherwise.*

Proposition 5(b) confirms the rationale mentioned in the MEE case. That is, endowed with the pricing flexibility, firms cut the first-period prices to generate high sales and enhance consumers' utility via VEE-P, and set higher prices in period 2 (the end period) to avoid unnecessary competition and revenue loss. In addition, Proposition 5(a) shows that when t_p is sufficiently small, firm L does not have to set a very low quality level as it does under committed pricing, because dynamic pricing can already help firm L avoid fierce competition against firm H. By contrast, when t_p is relatively large, firm L has to set an even lower quality to further differentiate from firm H.

Recall that, under committed pricing, VEE-P benefits firm H at the expense of hurting firm L, positing the Matthew effect. Although this phenomenon persists under dynamic pricing, it is weakened to some extent. Specifically, by Proposition 5, (c) and (d), firm L captures more demand, whereas firm H loses demand under dynamic pricing; moreover, firm L's profit is improved, but firm H's profit may decline. To wit, the pricing flexibility helps firm L combat the negative impact of VEE-P and improves its competitive edge. Thus, comparing to committed pricing under VEE-P, dynamic pricing can either lead to a Pareto improvement for both firms, or create a more balanced duopoly competition by alleviating the Matthew effect. Finally, we note that the percentage change in profit between the two pricing schemes is not significant in magnitude. Particularly, for firm L, $0 < (\hat{\pi}_L^{DVP}(t_p) - \hat{\pi}_L^{VP}(t_p))/\hat{\pi}_L^{VP}(t_p) < 3.5\%$ and, for firm H, $|\hat{\pi}_H^{DVP}(t_p) - \hat{\pi}_H^{VP}(t_p)|/\hat{\pi}_H^{VP}(t_p) < 1.5\%$.

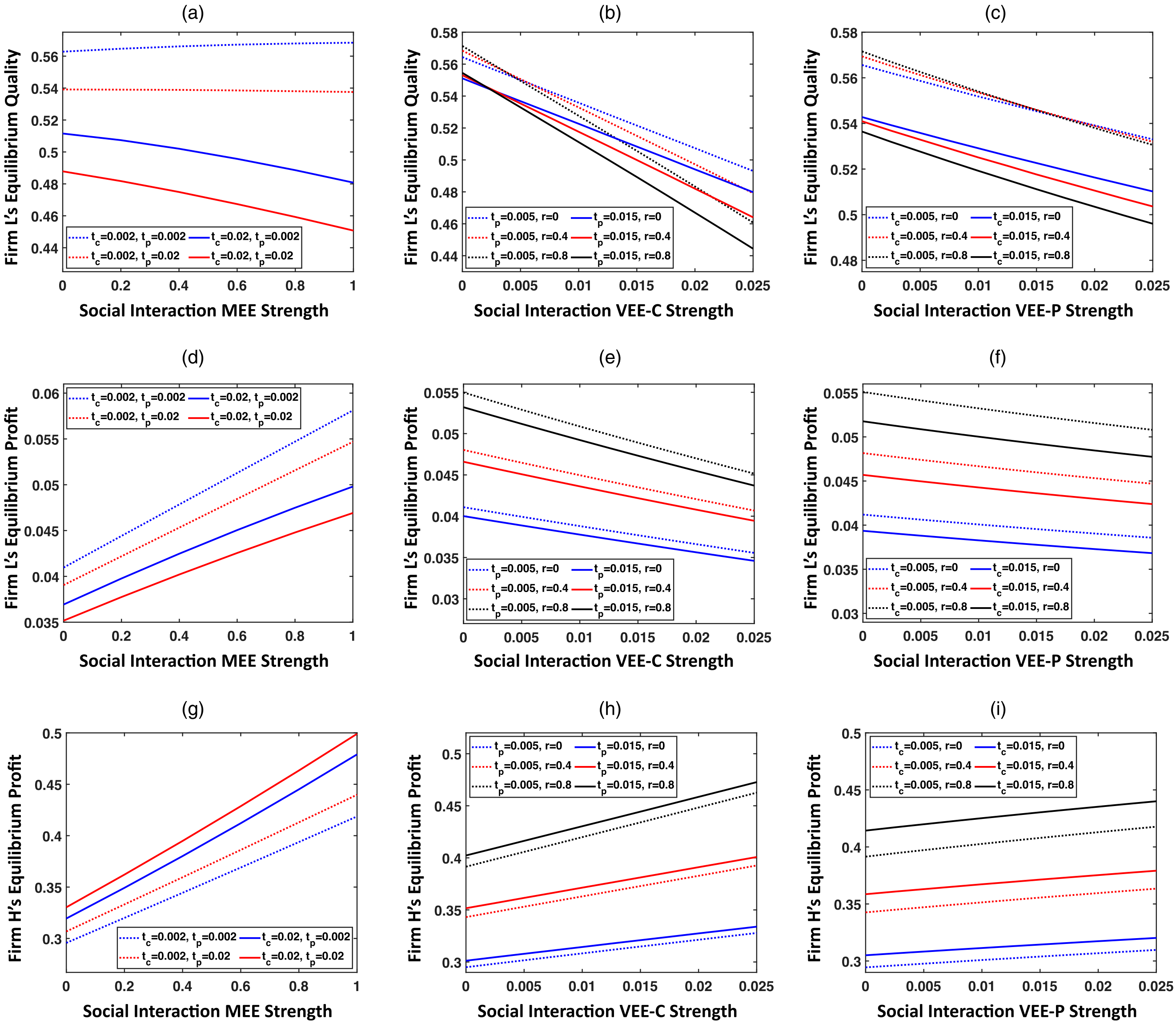
5.2. Model with Combined Effects of MEE and VEE

In this subsection, we investigate the situation where both MEE and VEE (including VEE-C and VEE-P) exist. The model can be solved in the same manner as before. However, the presence of both MEE and VEE greatly increases the complexity of the problem, making the analytical approach intractable. Therefore, we resort to numerical analysis. In the sequel, we focus on $r \in [0, 1]$, $t_c \in [0, 0.025]$, and $t_p \in [0, 0.025]$ (recall that t_c and t_p are small fractions). Our analysis particularly focuses on the degree of product differentiation and the firms' equilibrium profits. Moreover, we will only discuss the analysis for committed pricing; in fact, similar numerical experiments have been conducted for dynamic pricing, and the observations are qualitatively identical.

We conduct extensive studies with numerous instances. For each instance, we obtain firms' equilibrium quality levels and profits, and then compare them with their counterparts where only one form of social interactions exists. Figure 1 illustrates our main results on this matter. Note that Figure 1, (a)–(c) focuses on the combined effects on firm L's quality level, which reflects product differentiation between the two firms (firm H's equilibrium quality is always one because there is no cost), and Figure 1, (d)–(i) shows the interplay of multiple effects on firms' profits.

By and large, our previous findings in Section 4 are robust. For example, in Figure 1(a), we observe that, when VEE-C is relatively weak (i.e., $t_c = 0.002$), the product differentiation is reduced as MEE becomes stronger. Hence, our result from Proposition 1(a) is qualitatively retained. Similarly, Figure 1, (b) and (c) supports the robustness of our results in Propositions 2(a) and 3(a) with respect to the possible existence of MEE. Moreover, observations drawn from the firms' profit curves in Figures 1, (d)–(i) are also consistent with our

Figure 1. (Color online) Combined Effect of Social Interactions under Committed Pricing



previous results. Therefore, the combined effect of MEE and VEE may be decomposed into the individual effects, and the exact implication hinges on their respective magnitudes.

Apart from confirming the robustness of our main results, the numerical analysis also highlights two additional observations that complement our previous results: (1) The original impact of MEE on quality differentiation could be distorted in the presence of relatively strong VEE. As illustrated by the two solid curves associated with $t_c = 0.02$ in Figure 1(a), firm L tends to decrease quality as MEE becomes stronger. Rather than a means to facilitate the market expansion, the product quality in this case becomes an instrument for firm L to alleviate fierce competition induced by strong VEE ($t_c = 0.02$). (2) VEE-C has a stronger impact on firms' quality differentiation and profits than VEE-P. This is revealed by the comparison between the dotted and the solid curves in Figure 1. Such an observation echoes our previous discussion on the time-lag effect that contributes to a weaker impact of value enhancement from interacting with previous consumers.

5.3. Model with Cost Considerations

In this subsection, we extend our main model to include cost considerations for the firms. Typically, when firms invest in the product quality and run the production process, they incur both fixed setup cost and per-unit marginal cost. To capture these costs, we assume that, for a firm with product quality q and demand d, the total cost incurred is given by $C(q,d) = S(q)\delta(d) + V(q,d)$, where $\delta(d)$ equals one if $d > 0$ and zero otherwise. In accordance with the classic assumption that the quality-dependent setup cost $S(q)$ is convex increasing in q, we assume $S(q) = sq^2/2$ for some $s \geq 0$. In addition, $V(q, d)$ represents the total production cost. We focus on the linear functional form and assume $V(q, d) = (v_0 + v_1 q)d$ for some $v_0, v_1 \geq 0$.[5] Firms are assumed to have the same cost structure, and the same parameters apply to both firms.

Given the above specified cost function, we conduct extensive numerical experiments to test whether the respective impacts of MEE, VEE-C, and VEE-P on firms' equilibrium product differentiation and profits are robust when costs are considered. To purely focus on the cost considerations, we follow the main model of committed pricing and do not involve combined effects of social interactions. Because the results are quite consistent across different combinations of parameters, we only present the results for a few representative instances ($v_0 = 0.01, v_1 \in \{0.1, 0.2, 0.3\}$, and $s \in \{0, 0.01\}$) in Figure 2 and highlight some major observations below.

In Figure 2, (a)–(c), we observe that the monotonicity of the quality differentiation $\hat{q}_H^k - \hat{q}_L^k$ ($k \in \{M, VC, VP\}$) is consistent with our previous results, as described in Propositions 1(a), 2(a), and 3(a) (note that firm H's equilibrium quality is always one without cost in the main model, but may be less than one with cost considerations). Specifically, the quality differentiation decreases as MEE becomes stronger, but as VEE-C/VEE-P becomes weaker. This shows the robustness of our main result, even when we consider the fixed setup cost and marginal production cost.

Second, the individual impact of each form of social interaction on firms' profits with cost considerations is the same as before, which is presented in

Figure 2. (Color online) Impact of Social Interactions under Committed Pricing with Cost Considerations (Fix $v_0 = 0.01$)

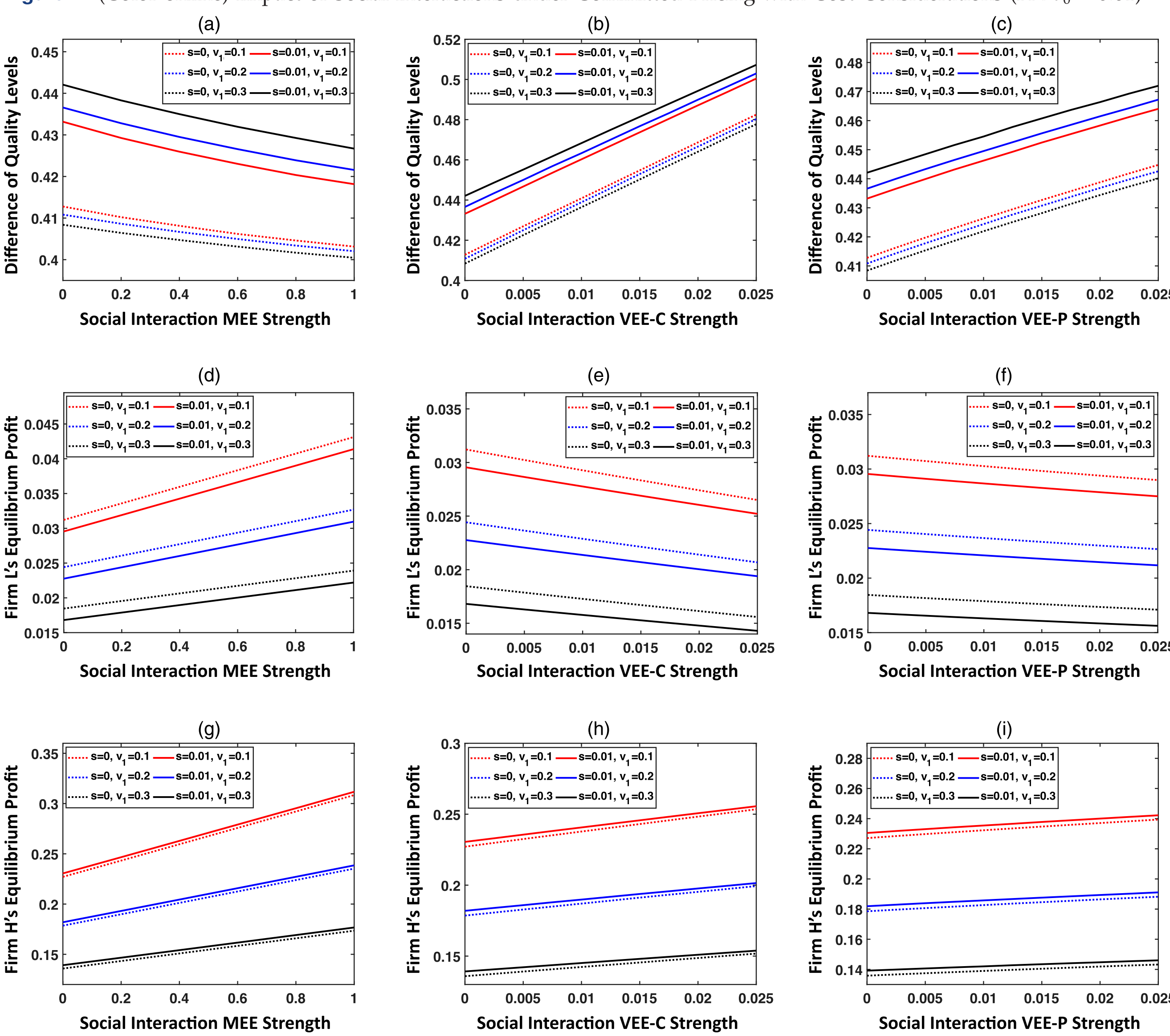


Figure 2, (d)–(i). Specifically, stronger MEE improves both firms' profits, whereas stronger VEE-C or VEE-P only benefits firm H, but hurts firm L. Therefore, our results are quite robust with respect to the general cost structure. In addition, Figure 2, (d)–(i) further reveals the impacts of costs on firms' profits: (1) Both firms are negatively affected by the marginal cost factor, as their profits are lower for larger v_1; and (2) the setup cost factor (s) has different impacts on different firms, as larger s may benefit firm H, but hurt firm L.

In sum, we extend our model to include fixed setup cost and marginal production cost, both of which depend on the quality level. We numerically confirm that our main results are qualitatively robust, which indicates that it is a legitimate simplification to assume zero cost in our main model. Moreover, our findings also shed light on the impacts of cost parameters on firms' profits.

6. Concluding Remarks

Consumers' social interactions are commonly seen in many marketplaces. Our paper aims to understand how different forms of social interactions affect duopoly firms' product differentiation, pricing decisions, and profits in a competitive environment. Specifically, we focus on two forms of commonly observed social interactions: The market-expansion effect that causes the total market size to increase for competing firms through social interactions that expand products awareness, and the value-enhancement effect that exclusively increases the consumers' utility toward one firm when interacting with consumers in either the current or previous period.

Using a two-stage multiperiod duopoly competition model, we uncover an interesting interplay between product-quality differentiation and consumers' social interactions. Indeed, quality differentiation not only bears the purpose of alleviating the price competition, but also has impacts on the effective exploitation of the consumer-to-consumer contagions. Our results reveal that it is important for firms to distinguish the aforementioned two forms of social interactions, because although the price competition is intensified in both cases, the strategic implications on the product differentiation and profitability are quite different. Specifically, the quality-differentiation level between the duopoly decreases in the strength of MEE, but increases in that of VEE. Moreover, MEE is benign to firms and makes consumers better off, fostering a healthy competitive environment (win–win situation); however, VEE (both VEE-C and VEE-P) benefits the high-quality firm at the expense of hurting both the low-quality firm and consumers, leading to the Matthew effect of accumulated advantage. Hence, firms' quality and price decisions, as well as their profitability, eventually depend on which form of the social interactions is more prominent.

As the main managerial insights, we connect consumers' social interactions with competing firms' product design and pricing decisions and highlight the importance of distinguishing different forms of social interactions. Our results can be applied to many industries where social interactions are prevalent and product quality is a critical decision. Consider our motivating example of the MOBAs marketplace (or the video game industry in general). Here, informative social interactions include players' introducing games to the community on gaming forums. Hence, if this form of interactions is strong, publishers may consider selecting a relatively aggressive product-quality level to exploit MEE, such as improving the level of gaming experience, character design, in-game purchase options, and so forth. However, from the high-quality publisher's standpoint, it may employ various marketing strategies to actively boost the value-enhancement effect, thereby leveraging the advantageous market position endowed by VEE.

In addition, competing firms should also pay close attention to the possible evolution of the prominent form of social interactions and adjust their marketing strategies accordingly. For instance, in the infant stage of the bike-sharing industry, the market-expansion effect is prevalent, because the future market growth could be potentially significant, and major bike-sharing companies (such as Mobike and Ofo) aim to introduce this innovative service to potential consumers to rapidly enlarge the overall bike-sharing market. When the industry becomes mature, the market size remains stable, as almost all potential consumers are aware of the products. Then, social interactions would go through a paradigm shift, such that exchanging user experiences with specific product prevails (Ouyang 2017). In this case, the value-enhancement effect could become dominant, and efforts should be primarily devoted to product differentiation and branding. As Mobike CEO Wang Xiaofeng commented, "without a strong differentiation from similar products, the users will eventually abandon you" (Hu 2017). As such, firms may focus on enlarging product differentiation against their opponents to leverage and benefit from the value-enhancing social interactions.

To conclude, we discuss a couple of interesting model extensions as future research directions. In contrast to the current nondurable goods setting, where consumers purchase immediately without strategic waiting, we could assume the focal product is durable and consider the consumers' strategic waiting behavior. As suggested by Coase (1972), consumers may wait for future price reduction under dynamic pricing; moreover, under VEE-P, they may delay their purchase to join into a potentially larger user base later so that their utility could be further strengthened. To study the aforementioned strategic behaviors, we could incorporate consumers' heterogeneous patience levels so that impatient ones will find it too costly to wait. As such, in each period, there will be a group of impatient consumers who choose to purchase, and social interactions will continue to take effect in this case. Hence, we conjecture that our main findings regarding the impacts of social interactions will hold qualitatively. Moreover, the interaction between consumers' strategic waiting and social effects may generate new interesting insights, and we leave the thorough analysis for this case as future research.

Second, although we focus on positive social interactions in the main paper, it is also practically possible that the strength of the social interactions may be negative, especially for the case of VEE. For example, when all orders or service requests are processed by a common server (e.g., the Internet bandwidth for all players in a game or the logistic provider that serves multiple online retailers), too many current users may result in server congestion, which negatively affects consumers' utility. In this case, we find that, when the parameters r, t_c, or t_p are negative, but close to zero, our results are exactly reversed. That is, for MEE, $\hat{q}_L^M$ is lower than the benchmark when r is negative, and for VEE, $\hat{q}_L^{VC}$ and $\hat{q}_L^{VP}$ are higher than the benchmarks when t_c and t_p are negative, respectively. When the social interactions have negative impacts, each firm may prefer a lower demand in the first period, and the competition is softened, which is opposite to the findings under positive social interactions. Although we can partially extend our findings to the aforementioned situation, we leave the comprehensive analysis for the negative social interactions as future research.

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Endnotes

[1] This phenomenon is prevalent in practice. When consumers shop online, they observe past sales, which is usually provided by the e-commerce platforms such as Taobao and eBay. When consumers visit a physical store/restaurant, the present crowd size is a direct indication of current sales. In both cases, the consumers' utility is enhanced by the popularity (despite possible time lag) of the product.

[2] A consumer who promotes a product to others might base on the overall utility derived from purchasing the product, rather than the product quality alone (see, e.g., Kuksov and Xie 2010).

[3] For the case of simultaneous quality decision, the firm choosing high quality is called firm H, and the one choosing low quality is called firm L, and the equilibrium is unique up to a role swap. For the case of sequential quality decision, in the equilibrium, the first mover will choose to be firm H and decide q_H, and the follower will be firm L and decide q_L. These two cases yield the same equilibrium outcome in the main model.

[4] Note that we focus on total consumer surplus of the MEE case. Indeed, even examining consumer average surplus by dividing the market size (i.e., $CS_n^M(r)/\hat{D}_n^M(r)$, $n \in \{1,2\}$), we can still show that all the results in Corollary 1 hold.

[5] We have repeated our study with other alternatives—e.g., quadratic functional form—and drawn the same conclusion.

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