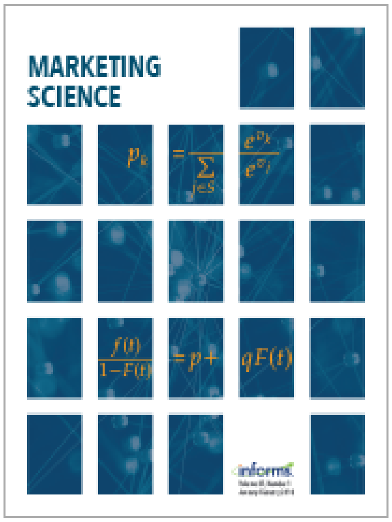

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Opinion Leaders and Product Variety

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Abstract. To form expectations of product quality, consumers frequently rely on opinion leaders who presumably have better expertise in the category. But opinion leader recommendations are influenced by both the product quality and the idiosyncratic preferences of the opinion leader. Consequently, the followers need to form expectations of how much a recommendation is driven by the product quality versus by the product's idiosyncratic fit to the opinion leader. Since the opinion leader is likely able to select a better fitting version from a larger variety, the opinion leader's idiosyncratic fit depends on the product variety. We analyze how the product variety affects consumer inference of quality, and consequently, formulate recommendations of how the firm should adjust its product variety in the presence of opinion leaders. We find that the adjustment may be either upward or downward. Generally, it is upward if opinion leaders are more difficult to satisfy. However, when the optimal variety absent consideration of opinion leaders is infinite, the optimal variety given this consideration may be finite. Moreover, the firm's knowledge of the true quality may further increase the distortion of the optimal variety even when the equilibrium variety is pooling across the product qualities.

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1. Introduction

The importance of word of mouth and opinion leader recommendations for consumer purchase decisions has been recognized by marketing professionals for a long time (see, e.g., Katz and Lazarsfeld 1955 or Dichter 1966). The idea is that some consumers have higher expertise and/or willingness to spend effort to understand products, and then they are willing to propagate their recommendations to other consumers. The other consumers (which eventually result in most of the product sales), although they may learn about products from mass media, make purchase decisions in large part on the basis of the opinion leader recommendations. Bass (1969) captures these types of consumers mathematically through the terms of the "innovators" and "imitators," respectively. According to Whitler (2014), a majority (64%) of marketing managers believe that word of mouth is the most effective marketing, yet only 6% claim to have mastered it.

The effectiveness of word of mouth lies perhaps in its relative trustworthiness. Recent technological advances in social media make posting and receiving opinions even easier. Did the consumer trust change? According to a 2012 Nielsen study, 92% of global consumers trust word of mouth and recommendations from friends and family, and 70% trust online reviews, both numbers an increase of at least 15% over the previous five years (Grimes 2012). Pertaining to the opinion leader influence through social media, Karp (2016) reports a joint study by Tweeter and Annalect indicating that 49% of respondents rely on digital influencers for product recommendations, and nearly 40% of Tweeter users have made a purchase because of an influencer's tweet. On the opposite side, consumer trust in advertising declined by at least 20% across the advertising type spectrum, and a majority of consumers no longer trust advertising, regardless of whether it is on TV, in newspapers, or online (Grimes 2012). The importance of word of mouth appears to be increasing even further in the digital age.

When opinion leaders are not professional judges of quality but rather more-or-less "usual" consumers from the point of view of their preferences, their evaluations and recommendations tend to be not very detailed and to be influenced both by the product quality and by their personal preferences for features, colors, styles, and so on. In other words, opinion leaders often provide feedback in a way that makes it difficult for followers to determine how much of the judgement is based on product quality (i.e., what is positively valued by all) and how much is based on the opinion leaders' idiosyncratic preferences (i.e., fit), which may not be relevant for other consumers. For example, in addition to the product quality, *mangakas* (manga artists) choose to adopt drawing tools that match their drawing habits, make-up artists choose to demonstrate cosmetics suitable for their skin types, and tennis players choose to use racquets that satisfy their needs for size and length.

In terms of how information flows online versus offline, one can make the following observation. Offline, when a recommendation comes from a family member or a friend, the recipient may have a natural chance to follow up with questions about the basis of the recommendation. Online, however, a recommendation may come in a form of a selfie on Instagram, a short note on Tweeter, a "like" on Facebook, or the fact that the opinion leader uses certain products. For example, consumers see drawing tools in painting tutorials (e.g., Steve Mitchell's pins on Pinterest), cooking utensils in cookery courses (e.g., Gordon Ramsay's videos on YouTube), sport equipment in sport-related blogs (e.g., Janae Jacobs's running blog *Hungry Runner Girl*), and beauty products in make-up demonstration videos (e.g., Michelle Phan's tutorials on YouTube). These situations do not present easy follow-up opportunities.

An implication of this observation is that when consumers try to infer a product's utility from an opinion leader's recommendation, especially in the case of digital influencers, they may find it difficult to determine whether the recommendation is due to an idiosyncratic fit of the product version the opinion leader uses, or to the quality of the product or brand that applies to every later adopter.[1]

Knowing that consumers infer the quality of products and brands from the positive or negative evaluations of opinion leaders, firms are trying to win the opinion leaders' support. Paying them for good reviews directly could be a risky strategy since if the opinion leader reveals to the general public that the brand offered a bribe to write a favorable review for a bad product, there could be either a considerable damage to the brand's image or consumers may no longer trust opinion leader's product recommendations of this brand. As a result, to earn an opinion leader's endorsement, the firm not only needs to have high-quality products, but also to provide a variant that satisfies the opinion leader's personal preferences.

Firms have long understood the impact of product variety on opinion leader product recommendations, and even tried to appeal to opinion leaders with customized product versions. This strategy dates back long before the rise of online opinion leaders. Some famous recent examples include the Birkin bag produced for the actress and singer Jane Birkin by high fashion company Hermès, and the Air Jordan shoes produced for the basketball player Michael Jordan by sportswear company Nike. In the case of a multitude of less influential opinion leaders, knowing their personal preference and providing a customized product variant for each of them becomes infeasible. However, firms are still concerned about how their product line design, including product variety or customizability, influences opinion leaders' product adoption and recommendation, and in turn, uninformed consumers' inference and purchase decisions. For example, according to Xiaohui (Alex) Xu, cofounder of PARKLU, "many firms consider impact of opinion leaders when making product assortment decisions."[2]

Let us consider the impact of a firm's product variety decision (that is, the number of product variants to provide) on the consumer inference of quality in the presence of opinion leaders. Opinion leaders are likely to have greater expertise and/or desire to educate themselves about the product category, which is how they obtain popularity and trust of their followers in the first place, and thus, are likely to be better able to understand and choose which variant fits them best. On the other hand, uninformed consumers, not being familiar with the product category or not wishing to spend the time and effort, may not be able to choose the best-fitting alternative and may benefit less from having many alternatives in the market. Moreover, although a larger number of alternatives is likely to increase an expert's satisfaction, and therefore the likelihood of a (positive) product recommendation, the uninformed consumers' rational inference of quality conditional on the (positive or negative) evaluation will likely decrease due to the anticipation of a better fit found by the opinion leader. Because of this decreased quality expectation, increasing the product variety may have a negative effect on the firm's profit.

In this paper, we study the impact of product variety on a firm's profit when uninformed consumers rely on the product evaluations of opinion leaders (or experts) to make purchase decisions. Henceforth, we will use the terms "opinion leader" and "expert," as well as "opinion leader's product evaluation" and "expert opinion," interchangeably. We default to the latter ones for brevity. We focus on the informational aspect of this context (i.e., on the flow of information) and seek to answer the following questions. How does product variety influence uninformed consumers' quality inference from expert opinion? Does the firm always benefit from adjusting the product variety in one direction (up or down) due to the presence of an expert opinion, or is there an intermediate optimal number of product variants from the point of view of affecting consumer inference in the way that is most beneficial to the firm? If the latter, what does the optimal variety depend on? And how are decisions affected if the firm knows the true quality versus the quality being uncertain to both the firm and the (nonexpert) consumers?

To analyze these questions, we first consider a model in which in the absence of expert opinion and the number of product variants affects neither the firm's cost nor the consumer utilities, and the firm has no more information about the quality than the consumers. Furthermore, we assume that the experts constitute a negligible part of the consumer demand. These assumptions allow us to isolate the effect of the consumer inference from the expert's product opinion. We then see how the presence of the expert's opinion affects the optimal decisions when increasing the number of product variants is costly to the firm (so that in the absence of the expert opinion, a single product would be strictly optimal to offer) and when consumers can partially observe their individual fit to each product variant (so that more variants would be preferable to the consumers, and in the absence of a per-variety cost, an infinite number of them spanning the range of consumer preferences would be optimal). We also consider how the optimal product variety would be different when the firm knows the product quality before making the variety decision. In the main model, we assume the expert's evaluation is only driven by the product itself, but in an extension, we also consider the possibility that the expert opinion depends on the product price.

The main results are as follows. First, we show that the informational forces discussed earlier may result in an intermediate product variety optimal for the firm. In other words, there can be a strictly optimal number of variants (more than one and less then infinity) even if the firm's costs do not increase in the product variety, and providing more alternatives does not increase the expected fit for an uninformed consumer. The intuition for this result is that increasing the number of product variants has two opposing effects on the firm's profit: (i) it increases the probability of getting a positive expert opinion, and therefore the product being recognized by consumers as of high quality, and (2) it decreases the consumer certainty that the quality is high conditional on the realized (positive or negative) expert opinion. Although the first effect is positive, the second is negative. It turns out that for a small number of variants, the first effect dominates the second, and for a large number of variants, the second effect dominates the first. We further find that the optimal number of product variants increases if the importance of fit for the expert or the expert's selectiveness (unwillingness to provide a positive recommendation) is higher.[3] These results are robust to the firm not being able to adjust the price based on the outcome of the expert's opinion, and to the expert opinion depending on the product's price.

Unsurprisingly, when the firm knows its quality, the low-quality firm may want to hide its quality by limiting the information transmitted through the expert opinion, and therefore mimicking the high-quality firm's product variety decision. It turns out that when the consumer inference from the expert opinion is the only factor affecting the length of the product line, the optimal number of variants when the firm is unsure of its quality remains the optimal choice when the firm knows its quality. If per-variety cost is also a consideration, or if consumers value higher variety, the effect of the expert presence could be even higher if the firm knows the quality (regardless of the quality level).

To relate our considerations to business practice, one can observe that firms often introduce a product line with a small number of products (or one product) promoted to opinion leaders. The idea is that the promotion of a smaller number of products makes communication easier and clearer. For example, Griner (2015) describes a promotional campaign by Lord & Taylor to introduce the Design Laboratory collection, with success attributed to its choice to promote exactly the same version of a dress to many influencers on Instagram. If it were to offer a large product choice, the influencers could each choose a different dress from the collection, and the followers might have attributed the choice to each influencer's idiosyncratic preference for a specific color pattern, which may or may not look well on a different person. But the fact that all agreed to post the same version perhaps indicates that the reason is not the fit to the individual complexion, but some good underlying quality of the dress. Note that in this case, the firm (Lord & Taylor) explicitly connected with the influencers and must have compensated them for the post, but the informational value of this act could be similar to the organic word of mouth because presumably, the value comes from the understanding that a firm would find it more difficult to convince the influencers to post if the dress was not good (most influencers disclosed the relationship by the hashtag #ad, and comments left on the feeds of others also made the sponsored nature of the posts clear).

The rest of the paper is organized as follows. Section 2 discusses the literature related to this paper. The following section (Section 3) formally defines the main model. Section 4 analyzes the main model where the firm faces no variety costs, the uninformed consumers have no information about their individual fit, and the firm does not know its true product quality. Section 5 examines several variations of the main model to both confirm that our main results are robust and to establish additional insights. Section 6 concludes the paper. It also presents an empirical validation of the intermediary result important for our main insight that consumer inference from a positive expert recommendation is hindered by an increased product variety. Details of proofs for Section 4 are in the appendix, and the proofs of claims in Section 5 are relegated to the online appendix.

2. Related Literature

There is a rich and growing literature on firms' strategies to provide or affect information available to consumers, for example, through informative advertising (e.g., Butters 1977, Lal and Matutes 1994, Soberman 2004, Villas-Boas 2004, Iyer et al. 2005), sales assistance (e.g., Wernerfelt 1994), or product returns (e.g., Shulman et al. 2010). A number of papers also examined the underlying question of whether and under what conditions firms benefit from providing information (e.g., Guo 2009, Guo and Zhao 2009, Kuksov and Lin 2010, Gu and Xie 2013, Branco et al. 2016), and what makes firm-supplied information credible (e.g., Milgrom and Roberts 1986, Balachander and Srinivasan 1994, Moorthy and Srinivasan 1995, Simester 1995, Anderson and Simester 1998, Zhao 2000, Shin 2005, Miklos-Thal and Zhang 2013).

Even closer to our paper is research on how product assortment affects consumer information and purchase decisions. For example, Villas-Boas (2004) considers how firms should choose the product line length given that communicating to consumers is more costly if the number of products is larger. Iyengar and Lepper (2000) and Boatwright and Nunes (2001) show that increased assortment may result in lower sales in experimental and empirical contexts, respectively. Kuksov and Villas-Boas (2010) explain this effect through an analytical analysis of how the expected consumer evaluation (search) costs depend on the number of products, and Kamenica (2008) considers how the number of products affects consumer inference of the likelihood of fit. This stream of research points to the importance of considering consumer information and communication when deciding on product variety.

As related to how product variety affects word of mouth, we know that word of mouth depends on customer satisfaction, in particular, that highly satisfied consumers are more important for promoting products to other consumers than less highly satisfied consumers (see, e.g., Anderson 1998 or Reichheld 2003), and Diehl and Poynor (2010) experimentally show that even conditional on consumers choosing a product, customer satisfaction could be lower if they have chosen from a larger assortment. Their rationale for this finding is that when consumers face a larger assortment, they expect to end up with a higher utility, and if satisfaction is driven not by the consumer's realized utility of the chosen product but by how much that utility exceeds expectations (a finding in Anderson and Sullivan 1993), then the higher expectations imply a lower satisfaction. Combining this result with the effect of satisfaction on word of mouth implies that larger assortment leads to a less beneficial word of mouth, which is an effect similar to one we have in this paper, although justified through a somewhat different mechanism. One may view understanding the implications of product variety on word of mouth as especially useful given that most managers do not have a very good grasp of how to manage word of mouth (Whitler 2014).

Extant research also examined how third-party reviews impact consumers' beliefs and, in turn, consumer decisions. For example, Reddy et al. (1998) find that critics have a significant impact on the choice of artistic goods.

There is also analytical research on how reviews should impact consumer beliefs (e.g., Sun 2012), how firms should adapt their strategies in response to reviews (Chen and Xie 2005), and how to affect them (e.g., Kuksov and Xie 2010, Fainmesser et al. 2019). As in most of the previous literature, we assume that experts always truthfully reveal the private information they have (although Durbin and Iyer 2009 consider the seller being able to make not fully truthful recommendations) and uninformed consumers make a rational inference from it. Extending the previous literature, we consider how the firm should choose the product variety to affect consumer inference from opinion leader recommendations, given that the assortment size is observed by all consumers and used in the inference process.

3. Main Model

Consider a market with one firm, one expert consumer, and a unit mass of uninformed consumers, each with a single-unit demand. The firm can produce a product in any number of variants at zero cost (we later consider positive costs).

We denote a consumer's valuation for the product category by v and assume it is heterogeneous across consumers and distributed uniformly on $[0, V]$.[4] Further, we assume that there are some characteristics of the product that are common across all versions of the firm's products in this category (either some objective quality or just a preference shared by all consumers), and some characteristics that are designed to match various idiosyncratic preferences. We call the former characteristics *quality* and represent it by the parameter q. We call an individual consumer i's utility from the latter characteristics *fit* and model it following Salop (1979) as the importance of fit parameter t times the distance between consumer i's ideal point

x_i and product variant j's location l_j on a circumference of a unit length, with x_i distributed uniformly on the circumference across consumers.[5] To summarize, consumer i's utility from version j of the product is

$$U_{i,j}(p) = v + q - d(x_i, l_j) \cdot t - p,$$

where p is the product's price.

Turning to the information structure, we assume that neither the firm nor the consumers know the exact value of q, but only know that it can be either low or high with equal probability, which reflects a situation when a firm introduces a new brand or a conceptually new product (the alternative assumption that the firm knows the exact value of q is considered in Section 5.1).[6] For example, one could argue that when Microsoft introduced and highly promoted its Zune MP3 player, it did so because it did not know how cool the consumers would perceive it to be. The same can be said about Apple when it introduced the iPod MP3 player. These two products could have had similar costs, but one was a flop and the other was a huge success. Similar uncertainty probably applied to the original iPhone and applies to many apparel brands. We normalize the high quality value to 1 and denote the low value by $q_0 \in (0,1)$. The firm decides the price p of the product and the number n of the product variants to offer to consumers (all variants are of the same quality). One can think of the product as the brand, and product variants as the different versions within the brand (i.e., customizable attributes of technology products, or different styles and colors of apparel), or the product can be more specific than a brand and the number of variants could represent how customizable it is (i.e., a TV could have plenty or a few picture and color adjustment options).

We further start with the assumption that consumers are uncertain about their own personal preferences (this assumption is relaxed in Section 5.3). An alternative interpretation is that uninformed consumers do not observe the location of any product variant. Either way, uninformed consumers are uncertain about the product fit, and thus they are indifferent between different variants. This allows us to isolate the effect of the number of variants on the expert product opinion and the consequent consumer inference.

The expert, on the other hand, knows own personal preference and the exact characteristics of the variants. Therefore, the expert can correctly identify the best-fitting product variant and always chooses to obtain it. This last assumption is only to make sure that the expert always posts the product opinion (the fact of purchase itself is inconsequential since the mass of uninformed consumers is assumed to be infinitely larger). In other words, an expert observes the precise value of $q - \min_j d(x_e, l_j) \cdot t$, where $\min_j d(x_e, l_j)$ is the distance between the expert's ideal variant, x_e, and the product variant providing the expert with the best match. The expert then broadcasts an opinion about the product, which is either positive or negative. Specifically, we model the opinion as being positive if and only if $q - \min_j d(x_e, l_j) \cdot t$ exceeds a certain threshold parameter u_0. One interpretation of u_0 is that it represents the utility of the outside option the expert considers, which means u_0 would be higher in a well-developed product category with a lot of good brands. Alternatively, it could be a consumer behavior or a social norm parameter indicating how critical opinion leaders tend to be. Note that if $u_0 \geq 1$, the expert opinion about the product will always be negative, and thus not informative. To focus on the interesting case where the expert product opinion can help resolve consumer uncertainty, we assume that $u_0 < 1$. Moreover, we assume that the expert's personal preference (x_e) is private information. In other words, the location of the expert's ideal variant on the circumference is unknown to both the firm and the other consumers.

To simplify the model and reduce the number of cases to consider, we assume that $V \geq \max\{1 - \frac{t}{4}, \frac{t}{4}\}$, which will imply that in equilibrium, the market is always partially covered.

The timing of the game is as follows. First, the firm offers a number of product versions. Then, the expert chooses a favorite variant and posts the product opinion based on that expert's overall experience. After observing the expert's opinion, the firm sets the price of the product to uninformed consumers, which amounts to the assumption that the firm can adjust the price after observing word of mouth (we later consider a model variation where the firm has to commit to price before knowing the expert opinion in Sections 5.4 and 5.5). This assumption can be viewed as realistic because most of the demand from opinion leaders (innovators) comes earlier than most of the demand from followers (imitators), and firms can increase prices if products turn out to be popular and offer discounts when demand is slack.[7] Finally, uninformed consumers decide whether to purchase the product based on the price and their expectation of the product quality given their prior beliefs, the expert opinion, and the number of variants the firm offers.

4. Main Model Analysis

We use perfect Bayesian equilibrium as a solution concept. Consequently, we first derive the uninformed consumers' beliefs about product quality as a function of the expert opinion and the number of variants n. Since we have so far assumed the firm does not know the quality beyond what it can infer from the expert opinion, the price is not informative of the true quality. Note that although the firm's decision on the number of variants is likewise not informative about the quality, it may enter the consumer evaluation because it affects the outcome of the expert's opinion. Then, we derive the optimal price given the number of product variants and conditional on the expert opinion. Finally, we derive which number of product variants is optimal for the firm and how its profit depends on the existence of the expert opinion and the parameters of the model.

To analyze the game, it is useful to observe from the onset that since the uninformed consumers do not know the product fit and the positive expert opinion is preferred by the firm, the firm's objective in deciding the variant locations is to maximize the probability of the positive expert opinion given n. The expert opinion is an additive function of the product quality and the disutility of the mismatch with the closest variant. Having no power over the value of q, the firm can only try to minimize the expert's mismatch between the expert's ideal variant and the best available variant. If the location of the expert's ideal product was known, the firm could simply provide the ideal variant to the expert. In this case, the expectation of the uninformed consumers would be that the expert's disutility from mismatch is zero, and for the purpose of the product opinion the expert is only comparing the value of q and u_0. However, if the firm cannot customize the product to the expert's preference, to minimize the expert's expected mismatch, the optimal locations of the variants are equidistant (i.e., $1/n$ from the adjacent ones along the circle). The probability of the expert opinion being positive can then be stated as in the following lemma.

Lemma 1. *If $q_0 > u_0$, the probability of a positive expert opinion is*

$$\text{Prob(pos.)} = \begin{cases} \dfrac{n(1+q_0-2u_0)}{t}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ \dfrac{t+2n(q_0-u_0)}{2t}, & \text{if } \dfrac{t}{2(1-u_0)} < n \le \dfrac{t}{2(q_0-u_0)} \\ 1, & \text{if } n > \dfrac{t}{2(q_0-u_0)}. \end{cases} \tag{1}$$

If $q_0 \le u_0$, on the other hand, it is

$$\text{Prob(pos.)} = \begin{cases} \dfrac{n(1-u_0)}{t}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ \dfrac{1}{2}, & \text{if } n > \dfrac{t}{2(1-u_0)}. \end{cases} \tag{2}$$

Thus, when $q_0 > u_0$ and $n \le \frac{t}{2(q_0-u_0)}$, or $q_0 \le u_0$ and $n \le \frac{t}{2(1-u_0)}$, the probability of the positive opinion is decreasing in the importance of fit parameter t and the threshold of the positive opinion u_0. Moreover, the probability is increasing in the number of variants n. This result is intuitive since as n increases, the expert's evaluation of the best-fitting variant increases. To see where these thresholds of n come from, note that $n \le \frac{t}{2(1-u_0)}$ corresponds to $1 - \frac{t}{2n} \le u_0$, that is, the expert opinion may be negative even for a high-quality product; in contrast, $q_0 > u_0$ and $n > \frac{t}{2(q_0-u_0)}$ correspond to $q_0 - \frac{t}{2n} > u_0$, that is, the expert opinion will always be positive even for a low-quality product.

We now consider how the uninformed consumers form their expectations of product quality rationally expecting that the expert's evaluation follows the rule derived previously.

4.1. Consumer Expectation of Product Quality

When uninformed consumers observe a positive expert opinion, they do not know whether it is driven by a high quality or a low disutility from mismatch. Bayes rule then leads to the following expected product quality conditional on the observed expert opinion.

Lemma 2. *If $q_0 > u_0$, the expected quality conditional on a positive expert opinion is*

$$\hat{q}_p = \begin{cases} \dfrac{1+q_0^2-u_0(1+q_0)}{1+q_0-2u_0}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ \dfrac{t+2nq_0(q_0-u_0)}{t+2n(q_0-u_0)}, & \text{if } \dfrac{t}{2(1-u_0)} < n \le \dfrac{t}{2(q_0-u_0)} \\ \dfrac{1+q_0}{2}, & \text{if } n > \dfrac{t}{2(q_0-u_0)}, \end{cases} \tag{3}$$

and conditional on a negative opinion, it is

$$\hat{q}_n = \begin{cases} \dfrac{t(1+q_0)-2n(1+q_0^2-u_0(1+q_0))}{2(t-n(1+q_0-2u_0))}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ q_0, & \text{if } n > \dfrac{t}{2(1-u_0)}. \end{cases} \tag{4}$$

If, on the other hand $q_0 \le u_0$, the expected quality conditional on a positive opinion is $\hat{q}_p = 1$, and conditional on a negative opinion, it is

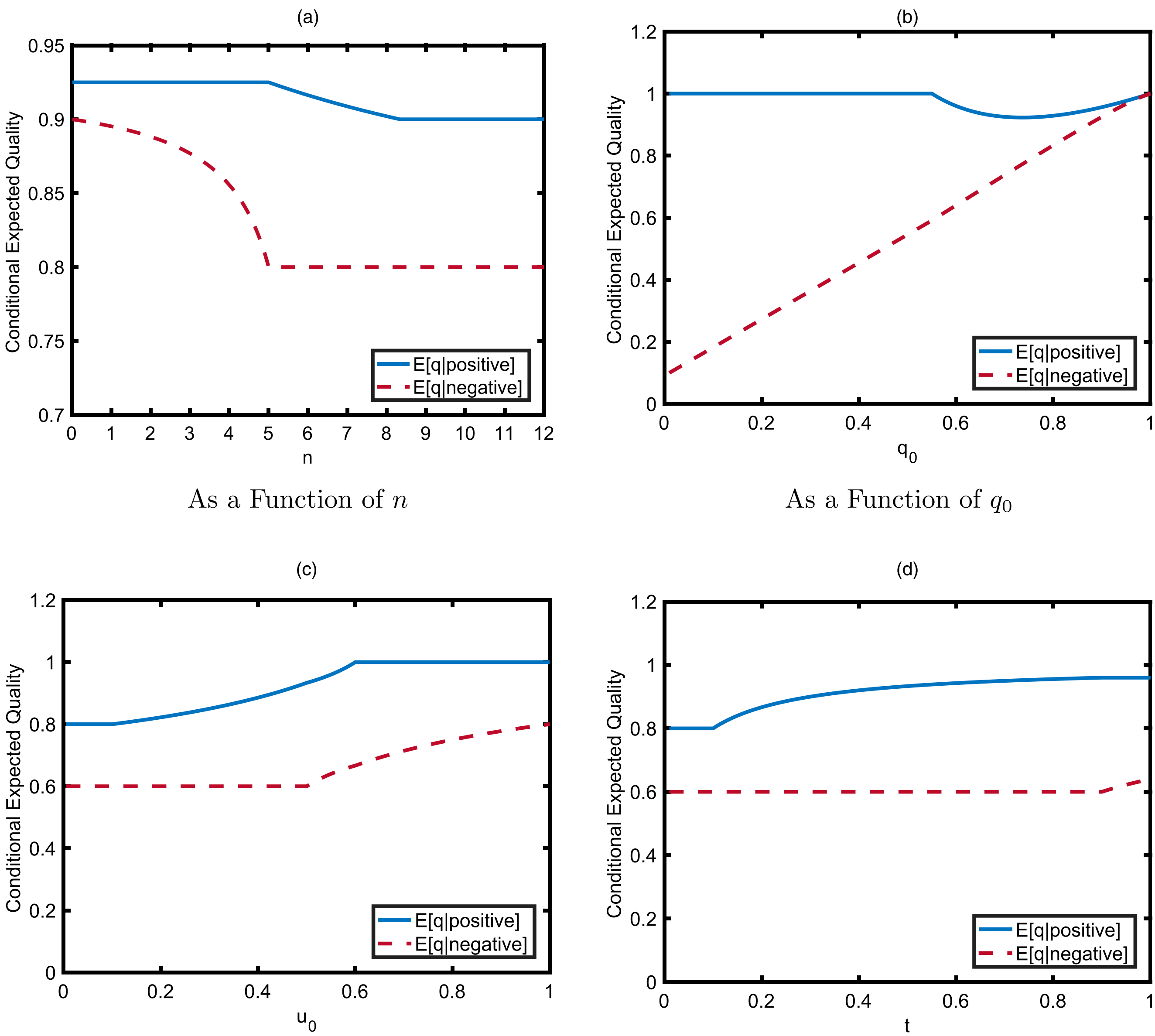
$$\hat{q}_n = \begin{cases} \dfrac{(1+q_0)t-2n(1-u_0)}{2(t-n(1-u_0))}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ q_0, & \text{if } n > \dfrac{t}{2(1-u_0)}. \end{cases} \tag{5}$$

The expected quality of the product conditional on a positive expert opinion is larger than $\frac{1+q_0}{2}$. It is decreasing in n if $\frac{t}{2(1-u_0)} < n \le \frac{t}{2(q_0-u_0)}$, and constant in n otherwise. It is increasing in t and u_0 if $n \le \max\{\frac{t}{2(1-u_0)}, \frac{t}{2(q_0-u_0)}\}$, and constant in t and u_0 otherwise. Moreover, it is first constant, then decreasing, and then increasing in q_0. The expected quality of the product conditional on a negative expert opinion, on the other hand, is smaller than $\frac{1+q_0}{2}$. It is decreasing in n and increasing in t and u_0 if $n \le \frac{t}{2(1-u_0)}$, and constant in n, t, and u_0 if $n > \frac{t}{2(1-u_0)}$. It is always increasing in q_0.

Figure 1 illustrates how the expectation of product quality changes as a function of the parameters.

Intuitively, as long as $q_0 \le u_0$ or $n \le \frac{t}{2(q_0-u_0)}$, both positive and negative expert opinions about the product are informative, in the sense that they imply an expected quality of the product other than the mean of the prior distribution $\frac{1+q_0}{2}$. Furthermore, and also intuitively, the informativeness (indicated by the difference between the prior mean and posterior mean) of a negative expert opinion weakly increases in n, and the informativeness of a positive expert

Figure 1. (Color online) Conditional Expected Product Quality



As a Function of n — As a Function of q_0 — As a Function of u_0 — As a Function of t

Notes. (a) $t = 5$, $q_0 = 0.8$, and $u_0 = 0.5$. (b) $t = 1$, $u_0 = 0.55$, and $n = 1$. (c) $t = 1$, $q_0 = 0.6$, and $n = 1$. (d) $q_0 = 0.6$, $u_0 = 0.55$, and $n = 1$.

opinion weakly decreases in n. As the number of product variants provided in the market increases, the satisfaction of the expert implied by a positive opinion should be attributed more to a low mismatch of personal preference than to high product quality.

The positive monotonicity of the conditional expected qualities in t and u_0 is also intuitive. A larger t corresponds to a higher expected disutility of mismatch, and a larger u_0 represents a higher baseline that the utility of the focal product is compared with.

Perhaps the most surprising part is that the uninformed consumers' expectation of product quality given a positive expert opinion may decrease in q_0, the value of the low quality level. In fact, when $q_0 \le u_0$, a positive opinion indicates a high-quality product for sure. When $q_0 > u_0$ and q_0 is very small, a positive opinion indicates a very large probability of high-type product. As q_0 increases a little bit, the probability of the product being low quality increases, and therefore there should be a higher weight on the low quality possibility, which decreases the expected quality. When the value of q_0 further increases, even though the weight on q_0 increases, the mean of the posterior distribution increases as the difference between q_0 and 1 becomes smaller.

4.2. The Pricing Decision

Denote the uninformed consumers' expectation about the product quality based on the expert opinion derived in the previous subsection by $\hat{q}$. Recall that since an uninformed consumer is uncertain about the fit of the product variant, the consumer essentially chooses a variant at random. Thus, the expected mismatch between the uninformed consumer's ideal variant and the chosen one is

$$E\big(d(x_i, l_j)\big) = \frac{1}{4}. \tag{6}$$

As a result, an uninformed consumer's expected utility from purchasing the product is $v + \hat{q} - t/4 - p$, where v is the consumer's valuation for the product category, $\hat{q}$ is the expected product quality, t is the importance of fit, and p is the product price. An uninformed consumer will purchase the product if $v + \hat{q} - t/4 - p \ge 0$, that is, if $v \ge p - \hat{q} + t/4$.

Since the distribution of v across consumers is $U(0, V)$, the expected demand for the product is 0 if $p > V + \hat{q} - t/4$, $\frac{V+\hat{q}-t/4-p}{V}$ if $\hat{q} - t/4 < p \le V + \hat{q} - t/4$, and 1 if $p \le \hat{q} - t/4$, meaning that the expected revenue is 0 if $p > V + \hat{q} - t/4$, $\frac{(V+\hat{q}-t/4-p)p}{V}$ if $\hat{q} - t/4 < p \le V + \hat{q} - t/4$, and p if $p \le \hat{q} - t/4$. Therefore, given our assumption that $V \ge \max\{1 - t/4, t/4\} \ge \max\{\hat{q} - t/4, t/4 - \hat{q}\}$, the optimal price is

$$p^*(\hat{q}) = \frac{1}{2}\left(V + \hat{q} - \frac{t}{4}\right), \tag{7}$$

and the profit at the optimal price is

$$\pi^*(\hat{q}) = \frac{1}{4V}\left(V + \hat{q} - \frac{t}{4}\right)^2. \tag{8}$$

Intuitively, the firm can obtain a higher profit if consumers have higher valuation (parameter V) for the product category, higher expectation $\hat{q}$ of the product quality, or lower weight (parameter t) they place on the fit.

This derivation implies that in the benchmark case of no expert (i.e., consumers cannot observe expert's opinion), $\hat{q} = (1 + q_0)/2$ and therefore, the optimal price is $\frac{1}{2}(V + \frac{1+q_0}{2} - \frac{t}{4})$ and the expected firm profit is $\frac{1}{4V}(V + \frac{1+q_0}{2} - \frac{t}{4})^2$. Since consumers have the same expected disutility of mismatch with any product variant regardless of the firm's variety decision, the firm is indifferent between any n. If we would assume that the profit from sales to expert consumers is at least slightly positive (instead of zero), we would have that the optimal number of variants is infinite.

Note that our analysis so far does not depend on a firm optimizing the product variety. We next consider how the product variety influences a firm's profit in the presence of expert opinion, and what product variety is optimal for the firm.

4.3. The Optimal Product Variety

So far, we have analyzed how expert opinion, consumer expectation of product quality, firm pricing decision, and consumer purchase decision depend on the fact that the firm offers a number n of product variants to the market. In this subsection, we first study the effect of n on firm's expected profit, and then discuss what number of variants is best to provide. To simplify the expressions, when deriving the optimal n, let us ignore the integer constraint on n and allow it to be continuous.[8]

The firm's expected profit is

$$\begin{aligned} E[\pi(n)] = E[R(n)] &= E[R(n)|\text{pos.}] \cdot \text{Prob}(\text{pos.}|n) \\ &\quad + E[R(n)|\text{neg.}] \cdot \text{Prob}(\text{neg.}|n), \end{aligned} \tag{9}$$

where $R(n)$ is the firm's revenue from sales, "pos." stands for the expert opinion being positive, and "neg." stands for it being negative. Substituting the optimal price obtained in the previous subsection and the consumer expectation about quality based on the number of product variants and the expert opinion, we obtain that if $q_0 > u_0$, the expected profit is

$$E[\pi(n)] = \begin{cases} \dfrac{1}{4Vt}\Bigg[n(1+q_0-2u_0)\left(\dfrac{1+q_0^2-(1+q_0)u_0}{1+q_0-2u_0}+V-\dfrac{t}{4}\right)^2 \\ \quad +(t-n(1+q_0-2u_0)) \\ \quad \cdot\left(\dfrac{t(1+q_0)-2n(1+q_0^2-u_0(1+q_0))}{2(t-n(1+q_0-2u_0))}+V-\dfrac{t}{4}\right)^2\Bigg], & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ \dfrac{1}{4V}\Bigg[\left(V-\dfrac{t}{4}\right)^2+\left(V-\dfrac{t}{4}\right)(1+q_0) \\ \quad +\dfrac{t(1+q_0^2)+4nq_0(q_0-u_0)}{2(t+2n(q_0-u_0))}\Bigg], & \text{if } \dfrac{t}{2(1-u_0)} < n \le \dfrac{t}{2(q_0-u_0)} \\ \dfrac{1}{4V}\left(\dfrac{1+q_0}{2}+V-\dfrac{t}{4}\right)^2, & \text{if } n > \dfrac{t}{2(q_0-u_0)}; \end{cases} \tag{10}$$

whereas if $q_0 \le u_0$, the expected profit is

$$E[\pi(n)] = \begin{cases} \dfrac{1}{4V}\Bigg[\left(V-\dfrac{t}{4}\right)^2+\left(V-\dfrac{t}{4}\right)(1+q_0) \\ \quad +q_0+\dfrac{(1-q_0)^2 t}{4(t-n(1-u_0))}\Bigg], & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ \dfrac{1}{8V}\left(\left(1+V-\dfrac{t}{4}\right)^2+\left(q_0+V-\dfrac{t}{4}\right)^2\right), & \text{if } n > \dfrac{t}{2(1-u_0)}. \end{cases} \tag{11}$$

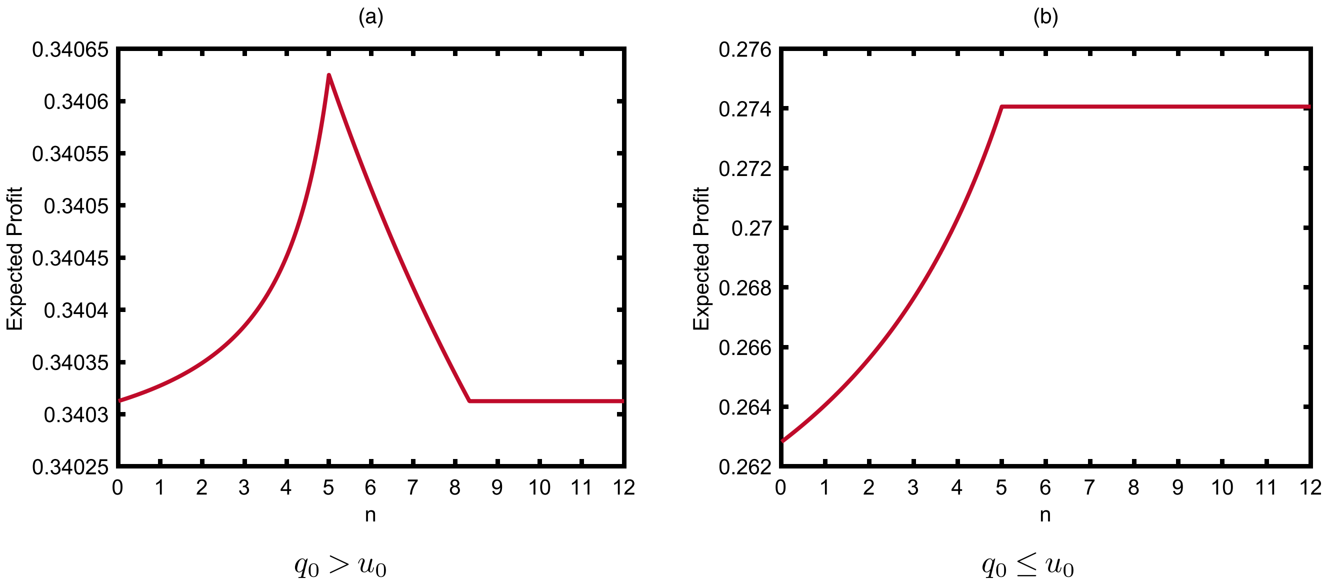
Examining how this expression depends on the number of variants n, we obtain the following proposition.

Proposition 1. *The expected firm profit is increasing in n if $n \le \frac{t}{2(1-u_0)}$, decreasing in n if $\frac{t}{2(1-u_0)} < n \le \frac{t}{2(q_0-u_0)}$, and constant in n otherwise. Thus, if $q_0 > u_0$, the strictly optimal number of product variants is $\frac{t}{2(1-u_0)}$, whereas if $q_0 \le u_0$, any number at or above $\frac{t}{2(1-u_0)}$ is optimal.*

For an intuitive interpretation of the effect of product variety n on firm profit and of the optimal value of the product variety, note that $n \le \frac{t}{2(1-u_0)}$ is equivalent to $1-\frac{t}{2n} \le u_0$, meaning that the expert opinion may be negative even for a high-quality product. In this range, expanding the assortment size increases the probability of positive opinion for both low- and high-type firms. Although uninformed consumers' expected product quality conditional on the expert's opinion is weakly decreasing in n, as indicated by Lemma 2, the loss is outweighed by the gain from having a more positive opinion, and the firm still benefits from having more product variants. When $q_0 \le u_0$ and $n > \frac{t}{2(1-u_0)}$, or $q_0 > u_0$ and $n > \frac{t}{2(q_0-u_0)}$, neither the probability of positive expert opinion nor the conditional expected product quality changes in the value of n, and the firm is neutral over different values of n in this range. As for the case with $q_0 > u_0$ and $\frac{t}{2(1-u_0)} < n \le \frac{t}{2(q_0-u_0)}$, only the low-quality firm obtains higher probability of positive expert opinion by increasing n. However, the expected product quality conditional on a positive opinion is decreasing in n. In this range, a firm uncertain about its own type does not find it profitable to offer a large number of product variants. Figure 2 illustrates how the expected profit changes in the number of product variants n.

According to Proposition 1, the firm may find it strictly optimal to provide more than one product variant, even if consumers do not directly benefit from more alternatives. The reason is that although increasing n does not change the uninformed consumers' expected mismatch cost, it changes their inference of the product quality. The firm has the incentive to be perceived as of high quality, but it also understands that consumers adjust their inference from the expert product opinion as they recognize that the number of variants affects it. The firm can increase the probability of the positive opinion by providing more alternatives for the expert to choose from. This strategy is anticipated by the uninformed consumers, and therefore, although increasing the number of variants increases the probability of a positive opinion, it decreases the expected quality conditional on a given (positive or negative) opinion. One could speculate that since a rational consumer is able to deduce the firm's strategy, the firm would not be better off due to a distortion of the number of product variants away from the one optimal to satisfy consumer preferences. However, according to Proposition 1, the firm may benefit from increasing the number of variants even if consumers are able to deduce the firm's strategy. Moreover, when $q_0 > u_0$, the firm may find it strictly optimal to limit the number of product variants provided to the market, even if it is able to add new variants at no cost. In this case, the expert opinion may be positive for a low-quality product, as long as the expert is able to choose a variant with low enough disutility of mismatch.

Figure 2. (Color online) Expected Profit as a Function of n



Notes. (a) $V = 2$, $t = 5$, $q_0 = 0.8$, and $u_0 = 0.5$. (b) $V = 2$, $t = 5$, $q_0 = 0.4$, and $u_0 = 0.5$.

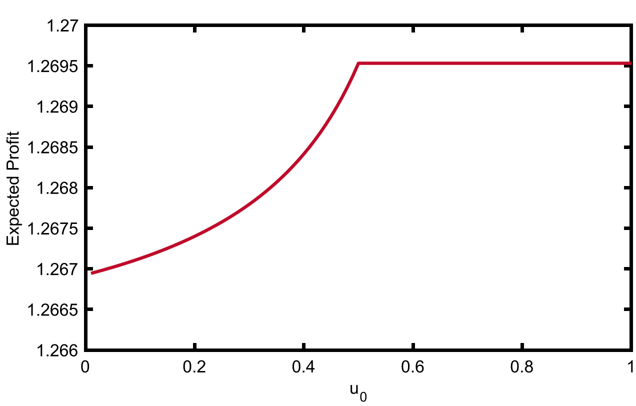
The expression for the optimal number of variants in Proposition 1 immediately implies the following corollary.

Corollary 1. *The optimal number of product variants is higher if the expert has a stronger personal preference (high t) and/or a higher threshold for the positive opinion (high u_0).*

By substituting the optimal number of variants for n in the expression for $E[\pi(n)]$, we derive the expected firm profit given the optimal number of variants and price. Specifically, if $q_0 > u_0$, the expected profit is

$$\pi^* = \frac{1}{4V}\left[\left(V - \frac{t}{4}\right)^2 + \left(V - \frac{t}{4}\right)(1 + q_0) + \frac{1 + 3q_0^2 - (1 + q_0)^2 u_0}{2(1 + q_0 - 2u_0)}\right], \tag{12}$$

Figure 3. (Color online) Equilibrium Profit as a Function of u_0



Note. $t = 1$, $V = 4$, $q_0 = 0.5$.

whereas if $q_0 \leq u_0$, the expected profit is

$$\pi^* = \frac{1}{8V}\left(\left(1 + V - \frac{t}{4}\right)^2 + \left(q_0 + V - \frac{t}{4}\right)^2\right). \tag{13}$$

Since uninformed consumers' expectation of product quality is weakly increasing in u_0, the equilibrium firm profit is weakly increasing in u_0. When $u_0 < q_0$, both high- and low-quality firms can get a positive expert opinion, and thus the high-quality firm is not perfectly distinguishable from its low-quality counterpart. In this range, the firm benefits from a higher u_0, that is, a more demanding expert. Moreover, this benefit also increases in u_0. In fact, when $u_0 < q_0$, the profit is convex in u_0. When $q_0 \leq u_0 < 1$, on the other hand, the separation between the high- and low-quality firm can be perfect, and the firm is thus indifferent over u_0. Figure 3 illustrates how the equilibrium profit changes in u_0. Unsurprisingly, the equilibrium firm profit is always decreasing in t (consumers' weight on mismatch), and increasing in V (consumers' valuation for the product category).

Note also that an implication of the profit in Equations (12) and (13) is that if the firm is able to affect u_0, the firm would prefer it to be not too low (i.e., not below q_0), but even if the firm can choose u_0, the choice of product variety is still relevant: without the expert, $n = 1$ is optimal, whereas with the expert, it is strictly optimal to increase n to $\frac{t}{2(1-u_0)}$, that is, at least to $\frac{t}{2(1-q_0)}$. Assuming the firm weakly prefers not to have too many product variants due to the costs of variety (see e.g., Section 5.2), the optimal choice of u_0 would be q_0 and the optimal variety would be $n = \frac{t}{2(1-u_0)}$.

The equilibrium profit in the presence of the expert opinion (see Equations (12) and (13)) is always higher than it is without the expert opinion ($\frac{1}{4V}(\frac{1+q_0}{2}+V-\frac{t}{4})^2$). In a nutshell, this is because a firm's profit is convex in consumers' expectation of quality and therefore, the firm benefits from resolving consumer uncertainty. A more detailed intuition is as follows. When the market is always partially covered, the demand is a linear function of the consumer belief about the quality. Therefore, the average demand is the demand at the average quality. If there would be no expert opinion, then the expected (average) profit would be the profit at the average quality level. But when the firm can choose a (price) response to the changed beliefs based on the expert opinion, the firm strictly benefits relative to the case where it would keep the price constant in the absence of the expert opinion.

5. Model Variations and Extensions

In the main model, we made some simplifying assumptions to both zero in on the effect of the expert opinion and simplify the analysis. In this section, we relax some of our assumptions and consider several extensions to see how our main results are robust to model variations and what additional insights may be gained. We first consider the possibility that the firm knows the exact quality level before choosing the number of variants (Section 5.1) and show that the optimal product variety remains exactly the same (in particular, the equilibrium is pooling across the quality levels). We then consider two model variations where either the firm prefers to have a lower number of variants due to the positive per-variant fixed cost (Section 5.2), or a larger number of product variants has a positive direct effect on the profits because uninformed consumers can partially observe fit before purchase (Section 5.3). We then consider an extension where the firm has positive marginal costs but cannot change the price based on the expert's opinion (Section 5.4). It turns out that the main implications are unchanged when these two features are added. We also change the expert recommendation rule to consider the value net of price rather than gross of price of the expert forming a recommendation (Section 5.5) and conceptually discuss the industry practice of paying influencers for recommendations (Section 5.6).

5.1. Quality Known to the Firm

In the main model, we assumed that the true value of q is unknown to the firm when the product first comes out. Although justifiable due to firms' frequent mispredictions of the consumer reception and aggregate demand, this assumption was mainly done for ease of the analytical analysis. The consequence of this assumption is that the optimal number of variants n does not depend on the firm's type. We now consider the alternative assumption that the firm knows the exact value of q and bases product line decisions on it.

In this case, the optimality of having equidistant variants and the analysis of Section 4.2 (pricing as a function of the consumer expectations of quality) still apply. However, since the firm knows q before making the assortment decision, the optimal choice of n may depend on the value of q, and therefore consumers may infer q not only from the expert opinion but also from the firm's decision on n. Nevertheless, it is easy to see that if the low- and the high-quality firm choose different n in equilibrium (i.e., if equilibrium is separating), the uninformed consumers would perfectly infer quality from n, and therefore the low-quality firm will do no worse by imitating the high-quality firm (since the cost of offering any number of alternatives is the same and the consumers do not care about the number provided beyond what it implies about the quality). Therefore, the equilibrium has to be pooling on n and price.[9] In a pooling equilibrium, the previous statement about the uninformed consumers' expectations of product quality, as listed in Lemma 2, also applies here.

It remains to consider the firms' optimization problem over n, since now the preferred n may depend on the quality. Clearly, there are multiple pooling equilibria sustained by the consumer beliefs that any deviation implies a low-quality product. To select a unique equilibrium, we will apply the concept of strongly undefeated equilibrium (see Mezzetti and Tsoulouhas 2000, with applications in Gill and Sgroi 2012, Miklos-Thal and Zhang 2013, and Subramanian and Rao 2016; see also Mailath et al. 1993), which, when applied to our model, focuses on the equilibrium where the high-quality firm achieves its highest profit possible across all equilibria.

To derive the undefeated equilibrium, we need to consider the firm's profits assuming that consumers believe the choice of n is an equilibrium one and therefore, as discussed previously, a pooling one. In other words, consumer inference is as if they do not take n into account when forming their expectations of quality. Under this rule, the probability that the expert product opinion is positive conditional on the product quality q is

$$\text{Prob}(\text{pos.}|n,q) = \begin{cases} 0, & \text{if } q \le u_0 \\ \dfrac{2n(q-u_0)}{t}, & \text{if } q > u_0 \text{ and } n \le \dfrac{t}{2(q-u_0)} \\ 1, & \text{otherwise.} \end{cases} \quad (14)$$

Here, the threshold of n depends on the value of q. When $q > u_0$ and $n > \frac{t}{2(q-u_0)}$, we have $q - \frac{t}{2n} > u_0$, and the expert will always post a positive opinion about the product given the variants provided.

As in the main model, the expected profit conditional on q is

$$E[\pi(n)|q] = E[R(n)|q] = E[R(n)|\text{pos.}] \cdot \text{Prob}(\text{pos.}|n,q) + E[R(n)|\text{neg.}] \cdot \text{Prob}(\text{neg.}|n,q), \tag{15}$$

where $R(n)$ is the revenue when both firms choose to provide n variants to the market (and consumers expect this).

Therefore, if $q_0 > u_0$, the conditional expected profits are

$$E[\pi(n)|q=1] = \begin{cases} \frac{1}{4Vt}\Big(2n(1-u_0)\Big(\frac{1+q_0^2-(1+q_0)u_0}{1+q_0-2u_0}+V-\frac{t}{4}\Big)^2 \\ +(t-2n(1-u_0))\Big(\frac{t(1+q_0)-2n(1+q_0^2-u_0(1+q_0))}{2(t-n(1+q_0-2u_0))} \\ +V-\frac{t}{4}\Big)^2\Big), & \text{if } n \le \frac{t}{2(1-u_0)} \\ \frac{1}{4V}\Big(\frac{t+2nq_0(q_0-u_0)}{t+2n(q_0-u_0)}+V-\frac{t}{4}\Big)^2, & \text{if } \frac{t}{2(1-u_0)} < n \le \frac{t}{2(q_0-u_0)} \\ \frac{1}{4V}\Big(\frac{1+q_0}{2}+V-\frac{t}{4}\Big)^2, & \text{if } n > \frac{t}{2(q_0-u_0)}, \end{cases} \tag{16}$$

and

$$E[\pi(n)|q=q_0] = \begin{cases} \frac{1}{4Vt}\Big(2n(q_0-u_0)\Big(\frac{1+q_0^2-(1+q_0)u_0}{1+q_0-2u_0}+V-\frac{t}{4}\Big)^2 \\ +(t-2n(q_0-u_0))\Big(\frac{t(1+q_0)-2n(1+q_0^2-u_0(1+q_0))}{2(t-n(1+q_0-2u_0))} \\ +V-\frac{t}{4}\Big)^2\Big), & \text{if } n \le \frac{t}{2(1-u_0)} \\ \frac{1}{4Vt}(2n(q_0-u_0))\Big(\frac{t+2nq_0(q_0-u_0)}{t+2n(q_0-u_0)}+V-\frac{t}{4}\Big)^2 \\ +\big(t-2n(q_0-u_0)\big)\big(q_0+V-\frac{t}{4}\big)^2\big), & \text{if } \frac{t}{2(1-u_0)} < n \le \frac{t}{2(q_0-u_0)} \\ \frac{1}{4V}\Big(\frac{1+q_0}{2}+V-\frac{t}{4}\Big)^2, & \text{if } n > \frac{t}{2(q_0-u_0)}, \end{cases} \tag{17}$$

and if $q_0 \le u_0$, the conditional expected profits are

$$E[\pi(n)|q=1] = \begin{cases} \frac{1}{4Vt}\Big(2n(1-u_0)\big(1+V-\frac{t}{4}\big)^2+(t-2n(1-u_0)) \\ \cdot\Big(\frac{(1+q_0)t-2n(1-u_0)}{2(t-n(1-u_0))}+V-\frac{t}{4}\Big)^2\Big), & \text{if } n \le \frac{t}{2(1-u_0)} \\ \frac{1}{4V}\Big(1+V-\frac{t}{4}\Big)^2, & \text{if } n > \frac{t}{2(1-u_0)} \end{cases} \tag{18}$$

and

$$E[\pi(n)|q=q_0] = \begin{cases} \frac{1}{4V}\Big(\frac{(1+q_0)t-2n(1-u_0)}{2(t-n(1-u_0))}+V-\frac{t}{4}\Big)^2, & \text{if } n \le \frac{t}{2(1-u_0)} \\ \frac{1}{4V}\Big(q_0+V-\frac{t}{4}\Big)^2, & \text{if } n > \frac{t}{2(1-u_0)}. \end{cases} \tag{19}$$

Moreover, examining when $\frac{dE[\pi(n)|q]}{dn}$ is positive, we obtain that when consumers do not infer the product quality from the number of variants provided by the firm (as in the case of pooling equilibrium), $E[\pi(n)|q=1]$ is increasing in n if $n \le \frac{t}{2(1-u_0)}$, decreasing in n if $\frac{t}{2(1-u_0)} < n \le \frac{t}{2(q_0-u_0)}$, and constant in n otherwise. On the other hand, $E[\pi(n)|q=q_0]$ is decreasing in n if $n \le \frac{t}{2(1-u_0)}$, increasing in n if $\frac{t}{2(1-u_0)} < n \le \frac{t}{2(q_0-u_0)}$, and constant in n otherwise. In other words, when uninformed consumers rely purely on the expert opinion for their quality inference, whereas the high-quality firm favors an assortment size such that the firm type can be identified,[10] the low-quality firm favors the one such that the firm type is indistinguishable.[11] Comparing the preferred choice of the high-quality firm with the equilibrium in the main model, we obtain the following proposition.

Proposition 2. *The equilibrium product line decisions when the quality is uncertain to the firm are also equilibrium ones when the quality is known to the firm.*

According to Proposition 2, firm's knowledge of the true quality level does not change the equilibrium product line decision. The intuition is that the high-quality firm favors the number of product variants that facilitates the uninformed consumers to identify the high type, which is also the optimal choice when the firm is uncertain about its product quality. By choosing the value of n optimal for the high-quality firm, the low-quality firm may still be identified as the low type through the expert product opinion. However, if it chooses another value of n, uninformed consumers expect it to be of the low type even before seeing the expert's opinion. As a result, the low-quality firm has an incentive to mimic the decision of its high-quality counterpart if it is costless to do so.

Moreover, if $q_0 > u_0$, the equilibrium profit is

$$\frac{1}{4V}\left(\frac{1+q_0^2-(1+q_0)u_0}{1+q_0-2u_0}+V-\frac{t}{4}\right)^2$$

for the high-quality firm, and

$$\frac{1}{4V(1-u_0)}\left[(q_0-u_0)\left(\frac{1+q_0^2-(1+q_0)u_0}{1+q_0-2u_0}+V-\frac{t}{4}\right)^2 + (1-q_0)\left(q_0+V-\frac{t}{4}\right)^2\right]$$

for the low-quality firm. If $q_0 \le u_0$, on the other hand, the equilibrium profit is $\frac{1}{4V}(1+V-\frac{t}{4})^2$ for the high-quality firm, and $\frac{1}{4V}(q_0+V-\frac{t}{4})^2$ for the low-quality firm.

As expected, the equilibrium profit is decreasing in t, increasing in V, and weakly increasing (decreasing) in u_0 for the high-quality (respectively, low-quality) firm. Note that the value of u_0 (compared with q_0) determines how easy it is for uninformed consumers to identify the firm type from the expert product opinion. Although a high u_0 benefits the high-quality firm, it is detrimental to the low-quality firm. Moreover, the equilibrium profit is first constant, then decreasing, and then increasing in q_0 for the high-quality firm, and increasing in q_0 for the low-quality firm.

Note that when $q_0 \le u_0$, the low-quality product can be identified perfectly in equilibrium. In other words, the "mimicking" is not fully successful. In this case, the low-quality firm can do as well by not choosing the same assortment size as the high-quality one. However, even if the separating equilibrium is chosen, the resulting expected payoff of each player is equivalent to the one in the pooling equilibrium.

In the main model, since the firm did not know q, we had to assume the marginal production cost of the high- and low-quality products is the same (otherwise, the firm could infer quality from cost). This is the case when quality represents the average consumer valuation and is not driven by an observable quality of the input materials (in the case of apparel) or whether the components are high or low end (in the case of technology products). It can also represent the case when a new technology is unproven, and it is not clear under what conditions it works well.

On the other hand, when quality is driven by the known quality of input materials, the firm may know the quality, and high quality is likely to have higher cost. It makes sense then to consider whether the cost increasing in quality would affect the results within the model variation of this section (i.e., when quality is known to the firm). It turns out that the results remain conceptually the same. The reasons are (1) the high-quality firm still wants to choose the number of variants as to best separate from the low-quality firm, (2) production costs do not enter the expert recommendation and the consumer inference, and (3) the low-quality firm still wants to pool. Of course, per-variant fixed costs (or marginal costs increasing in the number of variants) would affect the decision on product variety. We consider these costs in the following subsection.

5.2. Positive Fixed Per-Variety Cost

As an extension of the main model, let us now assume that the firm faces a positive cost C per product variant, so that the firm incurs a cost to increase the number of variants. Another alternative reason for why the firm may face cost of variety is that larger variety results in higher marginal production costs due to the economies of scale. The implications of this alternative reason for variety being costly in our setting turn out to be the same, and to be specific, we consider fixed costs of variety. Consistently with the main model, we first assume that the firm is uncertain about product quality. We then briefly mention what happens if the firm knows the quality (with full analysis and discussion of that case presented in the online appendix).

The firm chooses n to maximize the expected revenue net of the accumulated per-variant cost:

$$\max_n E[\pi(n)] = E[R(n) - C\cdot n] = E[R(n)] - C\cdot n. \quad (20)$$

Extending the analysis of Section 4, we obtain that the firm may provide many variants even though it faces costs of doing so, and a higher number of variants does not increase the consumer utility directly. Interestingly, when the optimal number of variants is higher than 1, the optimal choice is exactly the same as when $C = 0$. This is because the profit function is piecewise convex in the number of product variants (the derivative is first positive and increasing and then negative and increasing). To emphasize this curious result, we summarize the effect of product variety on firm profit and the optimal variety under fixed costs in the following proposition.

Proposition 3. *Although with $C > 0$, the profit of a firm in the absence of expert opinion decreases in n and $n = 1$ is optimal, in anticipation of consumers' quality inference, the profit of a firm uncertain about its true quality level may increase in n for small n, and $n > 1$ is optimal when C is small. Moreover, this optimal choice n_u^* is the same as in the* *case of $C = 0$ for small and positive C (i.e., $n_u^* = \frac{t}{2(1-u_0)}$), whereas $n_u^* = 1$ otherwise.*

Again, the firm may benefit from providing more than one variant to the market, even if it is costly and does not help average consumers to find a better match, to affect the expert's opinion about the product. Moreover, with positive per-variant fixed cost, there is a jump in the value of n_u^*. In fact, as we have shown in the main model, even if $C = 0$, the firm does not earn a higher profit by providing more than $\frac{t}{2(1-u_0)}$ product variants. Here, $n = \frac{t}{2(1-u_0)}$ is the number of product variants that is just enough to guarantee a positive expert opinion for the high-quality product. Thus, when $C > 0$, the optimal n may be further decreased. Moreover, when we look at the expected revenue $E[R(n)]$ in the range of $n \le \frac{t}{2(1-u_0)}$, it is both increasing and convex in n. In other words, the marginal benefit of adding one more variant increases in n. The marginal cost of doing so (i.e., C), on the other hand, is constant. Consequently, as long as $\frac{t}{2(1-u_0)} > 1$ and it is profitable to provide more than one product variant, it is optimal to provide $\frac{t}{2(1-u_0)}$ product variants.

The result about the optimal distortion in n does not rely on the assumption that the firm is uncertain about quality. As we show in the online appendix, if the firm knows the quality before choosing the variety, the optimal variety is distorted further due to the presence of the expert opinion. Furthermore, it is possible that the distortion is larger even if the equilibrium is pooling (i.e., if the firm selects the same variety regardless of quality).

5.3. Expected Consumer Fit Increases in n

Let us now consider the opposite case, where having more alternatives is beneficial. To achieve that, we assume that the firm has no cost of increasing the number of variants, but the uninformed consumers can benefit from having more alternatives, that is, not only the expert consumer can see how much a product version matches one's personal preference, but so can other consumers to some extent.

Specifically, let us assume that although uninformed consumers do not know which product location is best (i.e., consumers do not know their ideal product), each uninformed consumer receives a signal about own personal preference $\hat{x}_i$. With probability λ, the signal is accurate, that is, the observed value $d(\hat{x}_i, l_j)$ is indeed the mismatch between the consumer's ideal variant and variant j. In this case, by choosing the available variant that is closest to the consumer's observed personal preference along the circle, the mismatch is minimized to $\min_j d(x_i, l_j)$. However, with probability $1-\lambda$, the signal is inaccurate (a mistake) and represents a random location. In the latter case, although the consumer chooses the available variant with the smallest observed mismatch (hoping that the signal is accurate), the actual expected mismatch is 1/4 as in Equation (6).

Let us denote consumer i's smallest observed mismatch $\min_j d(\hat{x}_i, l_j)$ by $\Delta\hat{x}_i$. After choosing the variant with the smallest observed mismatch, consumer i's expected actual mismatch is $\lambda \times \Delta\hat{x}_i + (1-\lambda) \times 1/4$. Thus, consumer i will make the purchase if $v \ge p - \hat{q} + (\lambda \cdot \Delta\hat{x}_i + \frac{1-\lambda}{4})t$, where $\hat{q}$ is the expected product quality. Since $\Delta\hat{x}_i \sim U(0, \frac{1}{2n})$, the expected consumer demand equals to

$$\mathrm{Prob}\left(v \ge p - \hat{q} + \left(\lambda \cdot \Delta\hat{x}_i + \frac{1-\lambda}{4}\right)t\right) = \frac{V + \hat{q} - \left(\frac{1}{4} - \frac{(n-1)\lambda}{4n}\right)t - p}{V}$$

if $\hat{q} - \frac{1-\lambda}{4}t < p \le V + \hat{q} - (\frac{1-\lambda}{4} + \frac{\lambda}{2n})t$. Similar to Section 4.2, to make the market not fully covered in equilibrium, we assume $0 \le \lambda \le \min\{1, \frac{4(V-1)+t}{2t}, \frac{4V-t}{2t}\}$. Thus, given the expected product quality $\hat{q}$, the optimal price is

$$p^*(\hat{q}) = \frac{1}{2}\left(V + \hat{q} - \frac{n-(n-1)\lambda}{4n}t\right), \tag{21}$$

and the profit at the optimal price is

$$\pi^*(\hat{q}) = \frac{1}{4V}\left(V + \hat{q} - \frac{n-(n-1)\lambda}{4n}t\right)^2. \tag{22}$$

As we can see, for a given $\hat{q}$, consumers' willingness to pay for the product increases both in n and λ. Since increasing the product variety improves consumers' fit, without the consideration of consumer quality inference, the firm should provide as many product variants as possible. However, as we will show later, because uninformed consumers infer the product quality from expert's positive or negative opinion, the firm interested in providing uninformed consumers with product information may limit the number of variants if $q_0 > u_0$ and λ is small. This is true for the firm uncertain about its own type and the firm of the high quality. The analysis presented further assumes the firm does not know the quality, whereas the alternative case is analyzed in the online appendix.

Recall that when $q_0 > u_0$ and $\lambda = 0$ (the main model), the expected profit is first strictly increasing, then strictly decreasing, and then constant in n. Since the profit function is piecewise polynomial in λ, this trend remains when λ is positive but close to 0. Thus, it directly follows that limiting n is optimal if $q_0 > u_0$ and λ is small. We therefore obtain the following proposition.

Proposition 4. *Even when $\lambda > 0$, when the firm is uncertain about the product quality, the optimal n is strictly finite if $q_0 > u_0$ and λ is small.*

This result shows the robustness of the effect of the expert opinion on the optimal product variety when there is a direct benefit of a larger set of alternatives for consumers.

As with the case considered in the previous subsection, the main results remain qualitatively valid when the product quality is known to the firm, and in that case, the optimal distortion downward can be larger due to the presence of expert opinion (see the online appendix for details).

5.4. Constant Price and Positive Marginal Costs

In the main model, we allowed the firm to adjust the product price p after observing the expert opinion. This was to capture the idea that the pricing decision is more flexible than the product variety decision and that the price can be changed based on any new information about the expected aggregate demand. Alternatively, and especially if the timeline of purchase decisions of opinion leaders overlaps that of the purchase decisions of consumers, one could argue that it would be reasonable to assume that the opinion leaders and regular consumers face the same price, that is, that the firm should not have the opportunity to adjust the price after observing the recommendation of the opinion leader. Furthermore, it is also realistic to assume that the marginal (per product) cost is positive rather than zero. In this section, we consider a model variation with both of these features to verify the robustness of the main results.

Namely, in a change from the main model, assume that the marginal cost is $c > 0$ per product sold, and the game sequence is: first, the firm chooses the number of product variants and sets the price; next, the expert chooses a product and evaluates it; and finally, the consumers make purchase decisions based on the price, variety, and the expert opinion. Following the main model, for the sake of the ease of analysis, we assume that the firm does not know the product's quality. We still assume that the expert opinion is based on whether the expert sees the value derived from the expert's chosen product as clearing the bar defined by the parameter u_0 and is not dependent on price (as we show in the following section, the results are similar, albeit more analytically complex, when the expert opinion is based on the expert's utility net of price).

Since this model variation does not change the expert's situation, the probability of a positive expert opinion and the consumers' expectations of the product quality given the expert opinion are the same as in the main model (see Lemmas 1 and 2, respectively). Therefore, the consumer demand is also a function of price and variety. However, the firm's pricing decision is now affected both by not being able to condition on the expert opinion and by having to account for the marginal cost. The expected firm's profit is

$$E[\pi(n,p)] = \begin{cases} p - c, & \text{if } p \le \hat{q}_n - \frac{t}{4} \\ 1 \times (p-c) \times \text{Prob(pos.)} + \dfrac{V + \hat{q}_n - \frac{t}{4} - p}{V} \times (p-c) \times \text{Prob(neg.)}, & \text{if } \hat{q}_n - \frac{t}{4} < p \le \hat{q}_p - \frac{t}{4} \\ \dfrac{V + \hat{q}_p - \frac{t}{4} - p}{V} \times (p-c) \times \text{Prob(pos.)} + \dfrac{V + \hat{q}_n - \frac{t}{4} - p}{V} \times (p-c) \times \text{Prob(neg.)}, & \text{if } \hat{q}_p - \frac{t}{4} < p \le V + \hat{q}_n - \frac{t}{4} \\ \dfrac{V + \hat{q}_p - \frac{t}{4} - p}{V} \times (p-c) \times \text{Prob(pos.)} + 0, & \text{if } V + \hat{q}_n - \frac{t}{4} < p \le V + \hat{q}_p - \frac{t}{4} \\ 0, & \text{if } p > V + \hat{q}_p - \frac{t}{4}, \end{cases} \quad (23)$$

where Prob(pos.) is defined in Lemma 1, Prob(neg.) = 1 − Prob(pos.), and $\hat{q}_p$ and $\hat{q}_n$ are stated in Lemma 2.

The following proposition implies robustness of our main result to the model variation of this section.

Proposition 5. *When the product price cannot be conditioned on the expert opinion, the firm profit is maximized at $n = \frac{t}{2(1-u_0)}$ product variants. Moreover, this choice is strictly optimal if $q_0 > u_0$ and the marginal cost c is neither too large nor too small.*

Note that while the expression for the optimal price would be necessarily different from that in the main model (both because it cannot be conditioned on the expert opinion and because it has to depend on the cost), the expression for the optimal product variety turns out to be exactly the same, that is, the ability to adjust price may not matter for the product variety choice.

To understand the intuition for this result, recall that the intuition for the optimal variety choice in the main model was that the profit function was increasing in a mean-preserving spread of consumer beliefs (a belief updating has to be mean-preserving to be rational) due to the linear demand and the ability of the firm to adjust price based on consumer beliefs. Therefore, the firm was benefiting from the expert opinion being the most informative (the more information, the more consumers adjust their beliefs). In the current model variation, this effect still holds for a range of marginal costs, although for a slightly different reason: a mean-preserving spread of consumer beliefs is profit increasing if the cost is high enough to sometimes result in zero sales (given the optimal price), since sales cannot decrease below zero (which may happen in the case of a negative recommendation) but are strictly increasing in consumer beliefs in case of a positive recommendation (unless costs are so high that there are no sales under any condition). Thus, the firm still strictly benefits from the product variety that results in the best information in the marketplace under the following two conditions: 1) the cost is not too large, so that zero profit is not guaranteed, and 2) the cost is large enough to sometimes (given a negative recommendation) result in zero profit.

Note that if either of these conditions does not hold, then product variety does not matter: if the first condition is not satisfied, profits are always zero; if the second one is not satisfied, the expected profit does not depend on the expert opinion. The first condition can be easily interpreted for managerial guidance. It states that although a manager may be uncertain about the recommendation of the opinion leaders, that individual is expecting positive sales at least if they are good. The second condition may then be interpreted as saying that the higher the marginal cost, the more important it is to adjust the product variety. Furthermore, just as in the main model, it should be adjusted downward if the opinion leaders are more likely to like the product (i.e., if they are expected to have a lower acceptance threshold u_0) and upward otherwise.

5.5. Expert Opinion Depends on the Price

So far, we considered expert evaluation to be only driven by the product itself. Let us now consider the possibility that the expert opinion depends on the price, so that the lower the price, the higher the chance that the expert opinion is positive. Namely, suppose the expert opinion is positive if and only if the expert's product valuation net of price exceeds a certain threshold, that is, if $q - \min_j d(x_e, l_j) \cdot t - p > u_0'$. We use u_0' here instead of u_0 to indicate that due to the difference in the evaluation rules, there is no reason to expect this parameter to be the same across the two specifications. Assume the rest of the model setup is as in the previous section, that is, the firm faces marginal cost $c > 0$ and cannot change the price after the expert posts a product opinion.[12]

Similar to the main model, the probability of a positive expert opinion can be derived to be

$$\text{Prob(pos.)} = \begin{cases} 1, & \text{if } p < q_0 - u_0' - \dfrac{t}{2n} \\ \dfrac{t + 2n(q_0 - u_0' - p)}{2t}, & \text{if } q_0 - u_0' - \dfrac{t}{2n} \le p < \min\left\{1 - u_0' - \dfrac{t}{2n}, q_0 - u_0'\right\} \\ \dfrac{n(1 + q_0 - 2u_0' - 2p)}{t}, & \text{if } 1 - u_0' - \dfrac{t}{2n} \le p < q_0 - u_0' \\ \dfrac{1}{2}, & \text{if } q_0 - u_0' \le p < 1 - u_0' - \dfrac{t}{2n} \\ \dfrac{n(1 - u_0' - p)}{t}, & \text{if } \max\left\{1 - u_0' - \dfrac{t}{2n}, q_0 - u_0'\right\} \le p < 1 - u_0' \\ 0, & \text{if } p > 1 - u_0'. \end{cases} \tag{24}$$

As expected, the probability of a positive expert opinion decreases in the price. As a result, the consumers' expected product quality conditional on the positive expert opinion is

$$\hat{q}_p = \begin{cases} \dfrac{1 + q_0}{2}, & \text{if } p < q_0 - u_0' - \dfrac{t}{2n} \\ \dfrac{t + 2nq_0(q_0 - u_0' - p)}{t + 2n(q_0 - u_0' - p)}, & \text{if } q_0 - u_0' - \dfrac{t}{2n} \le p < \min\left\{1 - u_0' - \dfrac{t}{2n}, q_0 - u_0'\right\} \\ \dfrac{1 + q_0^2 - (u_0' + p)(1 + q_0)}{1 + q_0 - 2u_0' - 2p}, & \text{if } 1 - u_0' - \dfrac{t}{2n} \le p_0 - u_0' \\ 1, & \text{if } p \ge q_0 - u_0', \end{cases} \tag{25}$$

and conditional on the negative opinion, it is

$$\hat{q}_n = \begin{cases} q_0, & \text{if } p < 1 - u_0' - \dfrac{t}{2n} \\ \dfrac{t(1 + q_0) - 2n(1 + q_0^2 - (u_0' + p)(1 + q_0))}{2(t - n(1 + q_0 - 2u_0' - 2p))}, & \text{if } 1 - u_0' - \dfrac{t}{2n} \le p < q_0 - u_0' \\ \dfrac{(1 + q_0)t - 2n(1 - u_0' - p)}{2(t - n(1 - u_0' - p))}, & \text{if } \max\left\{1 - u_0' - \dfrac{t}{2n}, q_0 - u_0'\right\} \le p < 1 - u_0' \\ \dfrac{1 + q_0}{2}, & \text{if } p > 1 - u_0'. \end{cases} \tag{26}$$

Both of these expectations increase in p. This is because consumers observe the price and expect the expert to have formed the opinion using the same price. Therefore, a higher quality should be needed to compensate for a higher price to result in a positive recommendation. This means that a positive opinion implies a higher expected quality if the price is higher. Similarly, a negative opinion does not decrease the probability of the high quality as much in the case of a higher price as in the case of a lower price.

Substituting Equations (24), (25), and (26) in Equation (23), we obtain the firm's expected profit as a function of n and p, and then solve for the firm's optimal pricing and product variety decisions. Although the detailed analysis is relegated to the appendix, let us discuss here some intuition.

If the firm reduces the price, the probability of a positive expert review increases, but the consumers' expectation of quality conditional on the expert opinion (both positive and negative) decreases. This is a trade-off similar to the one coming from increasing the product variety. In addition to the informational effect of price, a price distortion from the one optimal without the informational effect results in a reduced profit due to the price's direct effect on the consumer demand. Hence, the firm would choose not to rely on the price distortion too much. We therefore have the following proposition.

Proposition 6. *Even when the expert opinion depends on price, the firm's profit is maximized at* $n^* = \frac{t}{2(1-u_0'-p^*)}$, *where* p^* *is the optimal price. Moreover, this variety is strictly optimal for some range of marginal costs.*

Note that $u_0' + p^*$ now serves the function of u_0 in the expression for the optimal product variety. This is intuitive, since $u_0' + p^*$ is the bar the product value (gross of price) now must clear to result in a positive expert opinion. Thus, the main result is conceptually robust to the possibility that the expert opinion depends on price.

From the discussion prior to Proposition 6, one could be tempted to infer that the firm would not want to use the price as an instrument of affecting the expert opinion at all because changing price is costly (due to its direct effect on the demand), whereas changing variety is assumed not to be costly. But this is not exactly true because the effect of a price change on the probabilities of the positive and negative expert opinions are not exactly the same as the effect of a change in variety. In other words, the expert opinion is maximally informative when the firm uses both the price and the variety as instruments. Note also that if consumers have an increased direct utility when the assortment is larger (as in the model variation of Section 5.3) or the firm had additional per-variety cost (as in the model variation of Section 5.2), the variety adjustment to affect expert opinion would have a detrimental effect on profits, and some price adjustment is definitely optimal. This is because in the neighborhood of the optimal point, the cost of adjustment is quadratically small, and therefore, it would be optimal to adjust both variety and price.[13]

Of course, the earlier analysis assumed that the firm cannot secretly promote to the opinion leader (i.e., in a way unobserved to the rest of consumers), which is a possibility we discuss in the following section.

5.6. Independent Word of Mouth Versus Sponsored Influencer Marketing

Along with the traditional word of mouth now magnified (albeit at a cost of being less personal) by the ease of communication online, recent years have witnessed an increased popularity of another phenomenon called *sponsored influencer marketing*. For example, Schafer (2018) points out that unlike word of mouth marketing, which stands for creating and managing marketing environment to facilitate consumer-to-consumer information dissemination about a given company's products, influencer marketing increasingly refers to directly and actively promoting products to influencers, that is, people who are identified as having a large following, usually, based on some social media metrics.[14]

In another dichotomy, the Word of Mouth Marketing Association (WOMMA), a trade group founded in 2004 and acquired by the Association of National Advertisers in 2018) defines word of mouth marketing as all-inclusive, but splits it into organic and amplified (see Word of Mouth Marketing Association 2005). The first occurs when a customer is happy with a product and spreads the word without an active intervention from the firm, whereas the second is due to an active effort by the firm to affect word of mouth and ranges from developing consumer-to-consumer communication platforms to explicitly reaching out to influencers and possibly offering monetary compensation for positive reviews (a.k.a. sponsoring). Although the latter may have recently increased in popularity, according to the Federal Trade Commission (FTC), a clear disclosure of the financial connection is legally required in influencers' posts.

A decrease of sponsored influencers' impact on consumer beliefs due to the relationship disclosure may have not been very pronounced so far for two reasons. First, for a while, the practice of nondisclosure went under the radar of the FTC (Shin 2006). In fact, before around 2010, FTC attention was directed toward firms' rather than influencers' disclosures. However, recently, FTC started to take steps to more actively enforce influencer disclosures. In 2017, the FTC sent letters to a number of influencers stating that "any 'material connection' between an endorser and an advertiser . . . should be clearly and conspicuously disclosed" in all influencers' posts (including tweets), and it further mentioned "monetary payment or the gift of a free product" as examples of a material connection (see Federal Trade Commission 2017). Furthermore, not disclosing a relationship may be detrimental to both the influencer and the firm in the long run. As WOMMA puts it, "Attempting to fake word of mouth is unethical and creates a backlash, damages the brand, and tarnishes the corporate reputation" (Word of Mouth Marketing Association 2005, p. 2).

Second, since sponsored influencer posts are a relatively new phenomenon, many consumers perhaps have not yet learned to identify such short-hand disclosures as #sp (sponsored post) or #partner. However, if the practice of sponsoring continues, consumers are likely to learn those hashtags. When consumers can discern sponsored influencer marketing from independent (nonsponsored) word of mouth, it stands to reason that a firm would benefit from managing its marketing mix to best affect the second (independent) type of word of mouth, regardless of whether it engages in the first kind.

Moreover, the usefulness of sponsored influencer posts is based on the consumer belief that these posts at least to some extent reflect independent and truthful opinions. This could be because the digital influencers' popularity highly relies on their trustworthiness in the specific areas they cover, and they may not want to lose relevance.[15] One should also remember that many of these influencers are not professional marketers, and thus their motivation in posting reports may not be driven purely by the monetization of their influence over their followers. Therefore, in the long term, either influencers (on average) will have enough incentives to be (partially) truthful, perhaps due to other reviewers policing their posts, or due to firms' restraint coming from the concern that unduly high encouragement or payment could result in an influencer's viral post about unethical marketing tactics of that firm, or consumers will completely lose trust in opinion leaders they don't personally know and the word of mouth will revert to the old fashioned one. Either way, the ideas in our paper about influencing opinion leaders' opinions with a product selection also available to other consumers may apply. For example, the main model may be thought of as capturing the effect of an influencer's opinion when the influencer (consistently with that person's followers' expectations) has received the product for free. For example, even if an influencer never posts a negative opinion, if the influencer receives free products from various firms, a remark about or the use of a product would be interpreted as a positive recommendation, and an absence of those forms of communication could be interpreted as a negative recommendation. At the same time, although outside of the scope of the current paper, sponsored influencer marketing strategies is an interesting topic that warrants further research.

6. Discussion and Conclusion

Nowadays, with the development of information technology and the growth of social media, it is increasingly easy for consumers to both post a comment or a picture of a product viewable by others and to notice whether somebody else uses or praises a product or a brand, making word of mouth and the effect of opinion leader recommendations on consumer purchase decisions more important than ever. However, in spite of the positive relationship between product choices and product quality, it can sometimes be difficult to interpret why a person likes a product. This is because in addition to product quality, the attitude toward the product is also influenced by the person's idiosyncratic preferences. Although valuation of quality may be shared by all consumers, the idiosyncratic consumer preferences are not. Moreover, as we argued in the introduction, in many instances product recommendations lack detailed explanations, and therefore, consumers may not be able to perfectly tease out the relevant information.

In this paper, we considered how product variety affects consumer inference of product quality from the opinion leader recommendations, and the consequences of these effects on the firm's profit and the optimal choice of product variety when consumers use opinion leader recommendations in their purchase decisions. Absent costs of variety, to increase profit, an intuitive solution is to increase product variety. With more alternatives available, it is more likely that the expert can find a variant that fits the expert's personal preference, and post a positive

Table 1. Summary of the Experimental Results

Panel A: Average Purchase Likelihood		
	No recommendation	Recommendation
Small variety	5.3684	7.8571
Large variety	7.3333	7.5263

Panel B: Estimation Results		
	Estimate	Standard error
Intercept	5.3684	0.4912
Recommendation dummy	2.4887	0.6779
Large variety dummy	1.9649	0.6779
Recommendation dummy × large variety dummy	−2.2957	0.9587

Note. All parameter estimates are significant at 2% level.

product opinion. Since consumers expect quality to be higher when the expert opinion is positive than when it is negative, they are willing to pay a higher price. From this perspective, an increased assortment size can benefit the firm. However, apart from the sentiment of the expert's post, the firm also needs to consider how the consumers' inference from the expert opinion is affected by the number of variants. When many product variants are available, consumers may expect an expert to find a better fit, and this consideration would then reduce consumer expectations of the product quality given either a positive or negative expert opinion. As a result, the consumer valuation may decrease, which could lead to a lower profit.

A prediction of our model is that when opinion leaders are more positively inclined (i.e., more likely to be happy with the product regardless of the exact quality they see), a firm should prefer to offer a smaller product selection. For example, the fact that Apple does not provide as many customization opportunities in iOS for iPhones as Android systems usually do could be seen as consistent with the previous prediction, since many opinion leaders like Apple products better and therefore, their positive recommendation threshold (u_0) derived from the value of the outside option (Android for iOS, and vice-versa) is lower for the iPhone.

One should note that an important condition of our main results is that consumers cannot perfectly separate the impact of product fit and product quality on the opinion leader recommendations. Although this is a reasonable assumption in many contexts, sometimes reviews are detailed enough for consumers to make this inference. For example, reviews by Consumer Reports, and some extensive online reviews would fall in the latter condition. In those situations, the negative effect of having a large number of product variants on consumer purchase decisions will be diminished.

Although we considered a number of variations of the main model and relaxed several assumptions, there are several other simplifying assumptions worth mentioning. One is that we have considered consumers uniformly distributed on a circumference. This assumption implies that there are no central or extreme preferences. In practice, the consumer preference space or the distribution of preferences is likely to be such that some consumers are more representative of the average consumer than others. Those that are more representative will find it easier to become opinion leaders. In other words, opinion leaders are likely to be more representative of the average consumer preference than a randomly chosen consumer. An implication of this is that to better satisfy opinion leaders, the firm may want to reposition more products toward more central preference locations and toward areas where the consumer preference distribution is denser than it would be without the opinion leader effects. At the same time, the conceptual results of the main model about the adjustments to the number of products is likely to be robust. This is because the effects of the number of products on the expected fit and therefore, on the consumer inference, remains (as far as the preference of all opinion leaders is not the same and precisely predictable).

Another simplifying assumption we made is that the expert has the same valuation of quality as uninformed consumers. If this is not so, the expert's judgements would be affected by that person's preference for quality. For example, if the expert values quality more, this would act as reducing the importance of fit in the expert's recommendations. In addition, if consumers do not know the expert's valuation of quality, this would add an extra uncertainty to the consumer inference, but there is no reason to expect that our main conceptual results would not hold.

We have also assumed that the expert always posts the product evaluation. In practice, opinion leaders could be silent on many products. An absence of a recommendation may be interpreted as a negative opinion (the expert did not find it worthwhile to choose the product) or could be reducing the informativeness of the recommendations. One interesting possibility for future research is to consider how the uncertainties facing the expert before and after the purchase affect the likelihood of purchase and the likelihood of posting a review.

Although the effect of product variety on an expert's satisfaction with the chosen product may be intuitive, one may question whether consumers are sophisticated enough to discount a positive recommendation more when it is based on a choice from a larger variety. To provide some empirical validation to this prediction, we conducted a survey-based experiment using 80 subjects recruited through Amazon Mechanical Turk and paid \$2 each. We used a randomized two-by-two factorial between-subjects design to test whether a recommendation of a brand would indeed have a weaker effect on the buying propensity when the brand has a larger number of product versions. Specifically, we first showed the subjects a situation description in which we asked them to imagine that they are looking for a cashmere sweater as a Christmas gift for a friend, and they either have found an XYZ store's web page through a search for cashmere sweaters (Condition 1: no recommendation), or have heard a coworker opinion that she liked an XYZ's cashmere sweater and searched for the store online (Condition 2: recommendation). Following the situation description, a web page displayed the XYZ's "exclusive cashmere sweaters" with a short description of the product line, the price ($89.99), and a choice (pictures) of sweaters. In Condition I (small variety) there were only two sweaters, whereas in Condition II (large variety) there were 27 sweaters. We then asked subjects to rate their likelihood to buy on a scale of 0 to 10. Table 1 summarizes the results. As expected, the main effect of the recommendation on the purchase likelihood is positive. The main effect of the larger variety turned out to be positive as well, and, in line with our prediction, the interaction effect of larger variety and the recommendation is negative (all three effects are significant at 2% level). Thus, we believe this experiment provides some face validity to our assertion that consumers would discount a positive recommendation of a brand when the product variety within the brand is large.

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Appendix

Proof of Lemma 1. Note that $\min_j d(x_e, l_j)$ is distributed uniformly on $(0, \frac{1}{2n})$. If we denote the quality of the product by q, the probability of positive expert opinion conditional on the product quality is

$$\begin{aligned}\text{Prob(pos.}|q) &= \text{Prob}\left(q - \min_j d(x_e, l_j)\cdot t > u_0|q\right)\\ &= \text{Prob}\left(\min_j d(x_e, l_j) < \frac{q-u_0}{t}\right)\\ &= \begin{cases} 0, & \text{if } q \le u_0\\ \dfrac{2n(q-u_0)}{t}, & \text{if } 0 < n \le \dfrac{t}{2(q-u_0)}\\ 1, & \text{if } n > \dfrac{t}{2(q-u_0)} > 0.\end{cases}\end{aligned}$$

Therefore, the probability of a positive opinion is

$$\begin{aligned}\text{Prob(pos.)} &= \text{Prob(pos}|q=1)\cdot\text{Prob}(q=1)\\ &\quad + \text{Prob(pos}|q=q_0)\cdot\text{Prob}(q=q_0)\\ &= \frac{1}{2}\text{Prob(pos}|q=1) + \frac{1}{2}\text{Prob(pos}|q=q_0).\end{aligned}$$

If $q_0 > u_0$, we have

$$\begin{aligned}&\text{Prob(pos.)}\\ &= \begin{cases} \dfrac{1}{2}\times\dfrac{2n(1-u_0)}{t} + \dfrac{1}{2}\times\dfrac{2n(q_0-u_0)}{t}, & \text{if } n \le \dfrac{t}{2(1-u_0)}\\ \dfrac{1}{2}\times 1 + \dfrac{1}{2}\times\dfrac{2n(q_0-u_0)}{t}, & \text{if } \dfrac{t}{2(1-u_0)} < n \le \dfrac{t}{2(q_0-u_0)}\\ \dfrac{1}{2}\times 1 + \dfrac{1}{2}\times 1, & \text{if } n > \dfrac{t}{2(q_0-u_0)}\end{cases}\\ &= \begin{cases} \dfrac{n(1+q_0-2u_0)}{t}, & \text{if } n \le \dfrac{t}{2(1-u_0)}\\ \dfrac{t+2n(q_0-u_0)}{2t}, & \text{if } \dfrac{t}{2(1-u_0)} < n \le \dfrac{t}{2(q_0-u_0)}\\ 1, & \text{if } n > \dfrac{t}{2(q_0-u_0)}.\end{cases}\end{aligned}$$

If $q_0 \le u_0$, on the other hand, we have

$$\begin{aligned}\text{Prob(pos.)} &= \begin{cases} \dfrac{1}{2}\times\dfrac{2n(1-u_0)}{t} + \dfrac{1}{2}\times 0, & \text{if } n \le \dfrac{t}{2(1-u_0)}\\ \dfrac{1}{2}\times 1 + \dfrac{1}{2}\times 0, & \text{if } n > \dfrac{t}{2(1-u_0)}\end{cases}\\ &= \begin{cases} \dfrac{n(1-u_0)}{t}, & \text{if } n \le \dfrac{t}{2(1-u_0)}\\ \dfrac{1}{2}, & \text{if } n > \dfrac{t}{2(1-u_0)}.\end{cases}\end{aligned}$$

This completes the proof of Lemma 1. □

Proof of Lemma 2. First, we derive the case of $q_0 > u_0$. By Bayes' theorem, the probability that the product quality is high conditional on a positive expert opinion is

$$\begin{aligned}\text{Prob}(q=1|\text{pos.}) &= \frac{\text{Prob(pos.}|q=1)\cdot\text{Prob}(q=1)}{\text{Prob(pos.)}}\\ &= \frac{1}{2}\cdot\frac{\text{Prob(pos.}|q=1)}{\text{Prob(pos.)}}.\end{aligned}$$

By substituting in it with the expressions obtained in the proof of Lemma 1, we have

$$\begin{aligned}&\text{Prob}(q=1|\text{pos.})\\ &= \begin{cases} \dfrac{1}{2}\times\dfrac{\frac{2n(1-u_0)}{t}}{\frac{n(1+q_0-2u_0)}{t}}, & \text{if } n \le \dfrac{t}{2(1-u_0)}\\ \dfrac{1}{2}\times\dfrac{1}{\frac{t+2n(q_0-u_0)}{2t}}, & \text{if } \dfrac{t}{2(1-u_0)} < n \le \dfrac{t}{2(q_0-u_0)}\\ \dfrac{1}{2}\times\dfrac{1}{1}, & \text{if } n > \dfrac{t}{2(q_0-u_0)}\end{cases}\end{aligned}$$

$$= \begin{cases} \dfrac{1-u_0}{1+q_0-2u_0}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ \dfrac{t}{t+2n(q_0-u_0)}, & \text{if } \dfrac{t}{2(1-u_0)} < n \le \dfrac{t}{2(q_0-u_0)} \\ \dfrac{1}{2}, & \text{if } n > \dfrac{t}{2(q_0-u_0)}. \end{cases}$$

As a result, the expected product quality conditional on a positive opinion is

$$\begin{aligned}
\hat{q}_p &= 1 \cdot \mathrm{Prob}(q=1|\mathrm{pos.}) + q_0 \cdot \mathrm{Prob}(q=q_0|\mathrm{pos.}) \\
&= 1 \cdot \mathrm{Prob}(q=1|\mathrm{pos.}) + q_0 \cdot (1-\mathrm{Prob}(q=1|\mathrm{pos.})) \\
&= \begin{cases} 1 \times \dfrac{1-u_0}{1+q_0-2u_0} + q_0 \times \left(1-\dfrac{1-u_0}{1+q_0-2u_0}\right), & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ 1 \times \dfrac{t}{t+2n(q_0-u_0)} + q_0 \times \left(1-\dfrac{t}{t+2n(q_0-u_0)}\right), & \text{if } \dfrac{t}{2(1-u_0)} < n \le \dfrac{t}{2(q_0-u_0)} \\ 1 \times \frac{1}{2} + q_0 \times \left(1-\frac{1}{2}\right), & \text{if } n > \dfrac{t}{2(q_0-u_0)} \end{cases} \\
&= \begin{cases} \dfrac{1+q_0^2-u_0(1+q_0)}{1+q_0-2u_0}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ \dfrac{t+2nq_0(q_0-u_0)}{t+2n(q_0-u_0)}, & \text{if } \dfrac{t}{2(1-u_0)} < n \le \dfrac{t}{2(q_0-u_0)} \\ \dfrac{1+q_0}{2}, & \text{if } n > \dfrac{t}{2(q_0-u_0)}. \end{cases}
\end{aligned}$$

On the other hand, if the expert opinion is negative,

$$\begin{aligned}
&\mathrm{Prob}(q=1|\mathrm{neg.}) \\
&= \frac{\mathrm{Prob}(\mathrm{neg.}|q=1) \cdot \mathrm{Prob}(q=1)}{\mathrm{Prob}(\mathrm{neg.})} \\
&= \frac{1}{2} \cdot \frac{1-\mathrm{Prob}(\mathrm{pos.}|q=1)}{1-\mathrm{Prob}(\mathrm{pos.})} \\
&= \begin{cases} \dfrac{1}{2} \times \dfrac{1-\dfrac{2n(1-u_0)}{t}}{1-\dfrac{n(1+q_0-2u_0)}{t}} = \dfrac{t-2n(1-u_0)}{2(t-n(1+q_0-2u_0))}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ 0, & \text{if } n > \dfrac{t}{2(1-u_0)}, \end{cases}
\end{aligned}$$

and

$$\begin{aligned}
\hat{q}_n &= 1 \cdot \mathrm{Prob}(q=1|\mathrm{neg.}) + q_0 \cdot (1-\mathrm{Prob}(q=1|\mathrm{neg.})) \\
&= \begin{cases} 1 \times \dfrac{t-2n(1-u_0)}{2(t-n(1+q_0-2u_0))} + q_0 \times \left(1-\dfrac{t-2n(1-u_0)}{2(t-n(1+q_0-2u_0))}\right), & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ 1 \times 0 + q_0 \times (1-0), & \text{if } n > \dfrac{t}{2(1-u_0)} \end{cases} \\
&= \begin{cases} \dfrac{t(1+q_0)-2n(1+q_0^2-u_0(1+q_0))}{2(t-n(1+q_0-2u_0))}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ q_0, & \text{if } n > \dfrac{t}{2(1-u_0)}. \end{cases}
\end{aligned}$$

Similarly, if $q_0 \le u_0$,

$$\mathrm{Prob}(q=1|\mathrm{pos.}) = 1,$$
$$\hat{q}_p = 1,$$

$$\begin{aligned}
&\mathrm{Prob}(q=1|\mathrm{neg.}) \\
&= \begin{cases} \dfrac{1}{2} \times \dfrac{1-\dfrac{2n(1-u_0)}{t}}{1-\dfrac{n(1-u_0)}{t}} = \dfrac{t-2n(1-u_0)}{2t-2n(1-u_0)}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ 0, & \text{if } n > \dfrac{t}{2(1-u_0)}, \end{cases}
\end{aligned}$$

and

$$\begin{aligned}
\hat{q}_n &= \begin{cases} 1 \times \dfrac{t-2n(1-u_0)}{2t-2n(1-u_0)} + q_0 \times \left(1-\dfrac{t-2n(1-u_0)}{2t-2n(1-u_0)}\right), & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ 1 \times 0 + q_0 \times (1-0), & \text{if } n > \dfrac{t}{2(1-u_0)} \end{cases} \\
&= \begin{cases} \dfrac{(1+q_0)t-2n(1-u_0)}{2(t-n(1-u_0))}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ q_0, & \text{if } n > \dfrac{t}{2(1-u_0)}. \end{cases}
\end{aligned}$$

This completes the proof of Lemma 2. □

Proof of Proposition 1. We can derive the first-order derivative of $E[\pi(n)]$ with respect to n as follows.

If $q_0 > u_0$,

$$\frac{dE[\pi(n)]}{dn} = \begin{cases} \dfrac{(1-q_0)^4 t}{16(t-n(1+q_0-2u_0))^2(1+q_0-2u_0)V}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ -\dfrac{(1-q_0)^2(q_0-u_0)t}{4(t+2n(q_0-u_0))^2 V}, & \text{if } \dfrac{t}{2(1-u_0)} < n \le \dfrac{t}{2(q_0-u_0)} \\ 0, & \text{if } n > \dfrac{t}{2(q_0-u_0)}. \end{cases}$$

If $q_0 \le u_0$, on the other hand,

$$\frac{dE[\pi(n)]}{dn} = \begin{cases} \dfrac{(1-q_0)^2(1-u_0)t}{16V(t-n(1-u_0))^2}, & \text{if } n \le \dfrac{t}{2(1-u_0)} \\ 0, & \text{if } n > \dfrac{t}{2(1-u_0)}. \end{cases}$$

The relationship between $E[\pi(n)]$ and n stated in the first part of Proposition 1 can be proved since $\frac{dE[\pi(n)]}{dn} > 0$ if $n \le \frac{t}{2(1-u_0)}$, $\frac{dE[\pi(n)]}{dn} < 0$ if $\frac{t}{2(1-u_0)} < n \le \frac{t}{2(q_0-u_0)}$, and $\frac{dE[\pi(n)]}{dn} = 0$ otherwise.

As for the optimal number of product variants, we know that if $q_0 > u_0$, $E[\pi(n)]$ is first increasing in n, then decreasing in n, and then constant in n. Thus, the maximal value of $E[\pi(n)]$ is achieved at $n = \frac{t}{2(1-u_0)}$. If $q_0 \le u_0$, on the other hand, $E[\pi(n)]$ is first increasing in n and then constant in n. As a result, the maximal value of $E[\pi(n)]$ is achieved if $n \ge \frac{t}{2(1-u_0)}$.

This completes the proof of Proposition 1. □

Proof of Corollary 1. This corollary immediately follows from the optimal number of variants stated in Proposition 1. □

Endnotes

[1] Another difference between recommendations from family and friends and those from the online influencers is that online influencers may be "sponsored" by the firm, an issue we will return to in Section 5.6.

[2] From the authors' interview with Xiaohui (Alex) Xu on April 8, 2019.

[3] Note that this result is not due to the uninformed consumers valuing fit since in the main model, they are unable to choose a product which fits them better.

[4] We assume consumer heterogeneity over v to generate a continuous downward sloping demand: consumer heterogeneity over fit we define later would not lead to downward sloping demand in the main model because we assume consumers do not observe this value prior to purchase. Alternatively, one can consider consumer heterogeneity over the value of quality. This alternative assumption leads to conceptually similar results but more complex analytical expressions.

[5] Using Salop's circular preference space instead of Hotelling's unit interval allows us to avoid the technical complications associated with considering consumers located closer to the center versus closer to the end of the preference space.

[6] According to Ogawa and Piller (2006), the new product failure rates often reach 50% or greater, suggesting that manufacturers of new products have limited knowledge about the average consumer valuation.

[7] Also note that to consider consumer quality inference and consumer demand, we need not assume that the price or the number of product variants is chosen optimally. However, we specify the rules of these decisions in order to be able to make managerially relevant recommendations about how the number of product variants optimal for the firm should be adjusted in view of the uninformed consumers' quality inference from the expert's opinion.

[8] The integer-constrained choice of n will be the nearest integer above or below the unconstrained one. Careful consideration of the integer constraints and the results that depend on when the value of n jumps from below to above or vice-versa do not appear to be insightful.

[9] When $q_0 \le u_0$ and $n_h^* \ge \frac{t}{2(1-u_0)}$, we may also have separating equilibria where the low-quality firm is always identified as the low type and thus does not have strictly positive incentive for mimicry. However, as we discuss later, the equilibrium profits are the same.

[10] If $q_0 \le u_0$, $E[\pi(n)|q=1]$ is maximized when $n \ge \frac{t}{2(1-u_0)}$, where the expert opinion will always be positive for the high-quality firm and negative for the low-quality firm. If $q_0 > u_0$, on the other hand, $E[\pi(n)|q=1]$ is maximized at $n = \frac{t}{2(1-u_0)}$, where the expert opinion will always be positive for the high-quality firm and sometimes be negative for the low-quality firm.

[11] If $q_0 \le u_0$, $E[\pi(n)|q=q_0]$ is maximized at $n=0$ ($n=1$ under the integer constraint). If $q_0 > u_0$, on the other hand, $E[\pi(n)|q=q_0]$ is maximized at $n=0$ or $n \ge \frac{t}{2(q_0-u_0)}$ ($n \ge \frac{t}{2(q_0-u_0)}$ under the integer constraint). We can think of the $n=0$ case as the one where n is too small to satisfy the expert even if $q=1$, and the $n \ge \frac{t}{2(q_0-u_0)}$ case as the one where n is large enough so that the expert is satisfied even if $q = q_0 > u_0$.

[12] In this setup, since the total demand from the opinion leaders is assumed to be negligible, allowing full flexibility in varying price to the expert and other consumers would amount to the firm having complete control over expert evaluations, and is therefore not realistic. If the expert knows that consumers in the audience would face a different price, the expert should at least try to factor the price paid out of the evaluation.

[13] Another reason for optimality of price adjustment is the integer constraint on the product variety, which would make setting the exact optimal (noninteger) variety impossible, and therefore, the informational effect would need to be fine-tuned through price.

[14] Technically, this is also not really a new phenomenon, but could be thought of as a variation of a referral program (Godes 2012).

[15] For example, Shi and Wojnicki (2014) point out that although extrinsic (monetary) incentives increase opinion leaders' referrals, the reason opinion leaders are willing to respond to monetary incentives is that they have developed a reputation for intrinsically (based on their own opinion) motivated referrals. The argument is that although intrinsically motivated (organic) referrals increase the social capital of an opinion leader, externally incentivized ones (compensated by the firms) decrease it. It then follows that compensation to incentivize opinion leaders' positive recommendations cannot replace organic recommendations, but rather the latter ones are essential for the former ones to have an effect.

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