Management Science

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

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David Godes

To cite this article:
David Godes (2017) Product Policy in Markets with Word-of-Mouth Communication. Management Science 63(1):267-278.
http://dx.doi.org/10.1287/mnsc.2015.2330

http://pubsonline.informs.org/journal/mnsc/

MANAGEMENT SCIENCE
Vol. 63, No. 1, January 2017, pp. 267–278
ISSN 0025-1909 (print), ISSN 1526-5501 (online)

Product Policy in Markets with Word-of-Mouth Communication

David Godes[a]

[a] Robert H. Smith School of Business, University of Maryland, College Park, Maryland 20742
Contact: dgodes@rhsmith.umd.edu (DG)

Received: June 6, 2013
Accepted: May 27, 2015
Published Online in Articles in Advance: May 11, 2016

https://doi.org/10.1287/mnsc.2015.2330

Abstract. We investigate the equilibrium relationship between product quality and word-of-mouth (WOM) communication. Specifically, we ask whether firms should optimally produce "better" products when consumers are more likely to exchange information. The critical moderating factor in our model is the nature of the communication and what its primary impact is. We first look at WOM that expands awareness of a product. We show that quality may either increase or decrease as WOM expands. The answer depends, in part, on the extent to which the expansion of WOM is one of scale alone or whether it also fundamentally changes the structure of communications. Next, we examine a model in which the primary impact of WOM is to help people to evaluate the utility provided by products with which they are already familiar. Our model suggests that more WOM in this context should always lead to higher-quality products. We demonstrate that the underlying driver of this result is that the elasticity of demand with respect to quality is increasing in the proportion of consumers who are informed about the product's quality. Taken together, the two models therefore suggest that the firm's optimal product-policy response to the growth in social interactions depends on both the content and the structure of the underlying conversations. Finally, we compare both WOM models to analogous models of advertising and demonstrate that the firm's optimal response to a decrease in advertising costs is quite different from that to an increase in WOM. The reason for these differences can be traced back to a fundamental distinction between advertising and WOM: although the former is optimized, the latter is far more random.

History: Accepted by J. Miguel Villas-Boas, marketing.
Supplemental Material: The online appendix is available at https://doi.org/10.1287/mnsc.2015.2330.

Keywords: marketing • product policy • economics • game theory and bargaining theory • social • word of mouth

> I think, on the Internet, word of mouth is more powerful than it has ever been before . . . . Everybody has an opinion and they share them. So in blogs, on social networking sites, by email, you can easily email 10 friends, text messages, and so on and so on. And so I think this is a very powerful and positive phenomenon for society, because I think in the past, if you are making a product, you would put . . . 70 percent of your attention, energy and dollars into shouting about the product, marketing the product, and 30 percent into building a great product. And so you could win with a mediocre product if you were a good enough marketer. And I think that is getting harder to do. That strategy—the balance of power is shifting away from companies and toward consumers . . . . [T]he right way to respond to this if you're a company is to say, "OK, I'm going to put the vast majority of my energy, attention and dollars into building a great product or service and put a smaller amount into shouting about it, marketing it, because I know if I build a great product or service, my customers will tell each other." —Jeff Bezos[1]

1. Introduction

Word-of-mouth (WOM) communication seems to account for an increasing role in consumer decisions.[2] We have witnessed exponential growth in terms of the volume, depth, and breadth of social interactions, particularly online.[3] These interactions have been shown to have a significant effect. For example, consumers buy books with higher ratings on Amazon (Chevalier and Mayzlin 2006) and attend movies with more-positive reviews (Chintagunta et al. 2010). Far less well understood, however, are the implications that the increase in the supply, and role, of social interactions may have for firms' strategies. A number of researchers have begun to address these topics from the perspective of the role of social interactions in fostering the promotion of the firm's products and services (Mayzlin 2006, Dellarocas 2006, Aral and Walker 2011). We argue here that the implications of the growth of social interactions go well beyond promotional considerations. We suggest that, as the above quote implies, the firm's product policy may also require reconsideration.

We ask two questions in this paper. First, what happens to optimal quality as social interactions increase? Should firms always offer better products when consumers interact more frequently? We analyze two

models, corresponding to two different operationalizations of what kind of information is transferred via social interactions. In the first model, WOM drives the amount of information in the market about the product's existence. We refer to this as "informative WOM." Conditional on knowing about the product, the customer knows the quality perfectly. We find that, as WOM expands the awareness of the product, optimal quality may either increase or decrease. The critical moderating factor is the extent to which the expansion of WOM leads to more-frequent social interactions for all, on one hand, or whether it affects the underlying structure of communication, resulting in different types experiencing greater or lesser degrees of awareness growth. Generally, we find that, in contrast to the above quote, (i) when WOM expands disproportionately among lower-taste consumers, optimal quality declines; and (ii) when WOM expands disproportionately among higher-taste customers, quality can either increase or decrease. We stress that, even when the awareness of higher-taste consumers expands more than that of lower-taste consumers, optimal quality may decline.

The second model we study focuses on the impact of persuasive WOM. Here, we assume that all consumers are aware of the product's existence but only some know its quality. The core result is that quality is always increasing in persuasive WOM. Although this may be consistent with one's ex ante intuition, it is critical to appreciate that the mechanism driving it may be somewhat less intuitive. Specifically, the result is not due to the firm's concern about potential sharing of negative experiences via WOM. It is driven by the fact that the higher the proportion of informed customers, the higher is the elasticity of demand with respect to chosen quality. This result demonstrates an interesting dichotomy between the commonly studied "direct social influence," where individuals' beliefs are impacted by information received from others, and what we term "indirect social influence." The latter reflects the impact of WOM on consumers who do not receive information from others but who nonetheless revise their beliefs about product quality as a result of the equilibrium impact on firm choices of the growth of WOM among other consumers. Put differently, as WOM spreads, there are consumers who may not hear from a friend about a product's quality but who nonetheless expect that product to be "better" because of the increase in overall WOM.

The second question we ask is whether the effects we predict with respect to WOM on quality choices would also obtain in a model of advertising. We find that, for both the informative and persuasive models, the differences are in fact substantial. This suggests that, from the firm's perspective, understanding whether consumers are informed or persuaded is insufficient; managers must also understand how these processes are being driven. In the informative context, in equilibrium, we find no link between changes in the cost of advertising and the quality of products. This is quite different from the WOM case and is because the firm's optimization of advertising ensures that the relative impact of advertising-driven awareness across customers of different types is equalized. Similarly, we find striking differences between the impact of persuasive WOM and persuasive advertising. Although an expansion of the former always leads to higher-quality products, a decrease in the cost of the latter may lead instead to an increase in quality. Again, the difference can be traced to the endogenous choice of advertising as compared with comparatively random WOM changes.

This paper offers a number of important contributions. Substantively, our results provide guidance to managers making quality decisions in a context characterized by a rapid expansion of WOM. Again, this recommendation—higher versus lower quality—will depend on (i) the underlying content of WOM conversations (do they primarily inform people about the existence of the product or about the value of its underlying attributes?); and (ii) for informative WOM, what is the distribution of awareness gains as WOM expands? As we show, this factor, in turn, is driven by the structure of the conversations. Who talks more to whom? For researchers, the paper also offers the important insight that any analysis of the strategic implications of social interactions needs to specify precisely what impact WOM has on the market: informative or persuasive. Of equal theoretical interest, we also demonstrate the intriguing result that WOM and advertising, two apparently equivalent mechanisms through which consumers may become informed or persuaded, may, in fact, have broadly divergent impacts on the firm's optimal choices, in this case product quality. Although it has been noted in the literature that the two channels may differ in terms of credibility, we are not aware of any similar finding to this.

This paper proceeds as follows: we review the relevant literature in the next section. In Sections 3 and 4, we present our models of informative and persuasive WOM, respectively. Then, in Sections 5.1 and 5.2, we compare the WOM results with the effect of exogenous shocks to the cost of informative and persuasive advertising. We conclude in Section 6 by discussing the limitations of our approach and suggestions for future research.

2. Relevant Literature

Our work relates to three streams of literature: (i) the impact of social interactions on firm decisions, (ii) quality choices by the firm, and (iii) network effects. Much of the earlier work on social interactions focused on

understanding the usefulness of the data such interactions make available (Kozinets 2002, Godes and Mayzlin 2004, Liu 2006, Chintagunta et al. 2010, Iyengar et al. 2011). More recent work has addressed opportunities available to the firm for influencing these interactions. Ryu and Feick (2007) show that the firm may use reward programs to encourage customer referrals. Godes and Mayzlin (2009) demonstrate that fostering recommendations from loyal customers may be less effective than fostering those from less loyal customers. Aral and Walker (2011) implements a large-scale field experiment and demonstrates the significant promotional impact of incorporating "viral features" into products. Mayzlin (2006) demonstrates that the influential power of social interactions may persist in equilibrium even while some firms manipulate these interactions. The current paper differs significantly from this stream in its focus on a distinct element of the marketing mix: product design choices. Two particularly closely related papers are Zhang (2010) and Villas-Boas (2004). Although the former studies a context with exogenous quality, one conclusion suggested by the research is that "optimal marketing strategies should take into account whether and how consumers learn from others" (Zhang 2010, p. 317). Indeed, one contribution of the current paper is to do precisely this. Villas-Boas (2004) analyzes the firm's optimal product line as a function of the firm's communication costs. In an extension, he also investigates a vertical differentiation setting comparing optimal product quality with and without communication costs. In some sense, one may see firm communication as being analogous to social interactions in that they both foster awareness of the firm's products. As we demonstrate in Sections 5.1 and 5.2, however, the predictions made by advertising models and WOM models may be markedly different.

Beginning with Moorthy (1988), the marketing literature has devoted considerable attention to product quality choices in a variety of contexts including endogenous information provision (Bhardwaj et al. 2008); two-dimensional quality (Vandenbosch and Weinberg 1995, Lauga and Ofek 2011); shocks to consumer transaction costs (Tyagi 2004); personalized pricing (Choudhary et al. 2005, Chen and Iyer 2002); personalized products (Zhang 2011); variations in consumer search cost for price information (Kuksov 2004); and the firm's ability to influence both quality and perceptions of quality (Iyer and Kuksov 2010). To our knowledge, prior research has not addressed the relationship between social interactions and product quality. Most closely related is Jiang and Yang (2015) who specify a two-period model of an experience good in which early consumers communicate true quality to later consumers. Their firm has unobservable efficiency and chooses price and quality endogenously. They find that the firm can signal its efficiency (and thus quality) in such a setting via price. Moreover, surprisingly, the high-efficiency firm chooses lower quality when its efficiency is known relative to when it is not. Both the model structure and, more importantly, the research focus of this paper differ from ours here. In particular, we study the impact of changes in customer information sharing on quality levels and how they compare with advertising. Jiang and Yang (2015), on the other hand, model such information sharing mainly as a way to facilitate an efficient firm's signaling of its quality choices.

Finally, some researchers (Besen and Farrell 1994, Katz and Shapiro 1994, Arthur 1989) have made the argument that, when network effects are strong, there is a possibility of a first mover dominating the market even when its product is not of the highest quality. To the extent that an increase in social interactions would be associated with more-pronounced network effects, these models would also predict the absence of a consistent and strictly positive relationship between quality and social interactions. The theory we propose is based on an entirely different process that does not contain network externalities (i.e., consumers derive no value from their network ties' adoptions) and thus should be seen as a complement to this stream of work.

3. Informative WOM

As suggested by Iyengar et al. (2011, p. 198), a key to understanding the impact of social interactions may lie in recognizing its context dependence. In particular, they note the importance of differentiating between social interactions that increase awareness, on one hand, and those that change consumers' evaluations of known products, on the other. As such, we address our core research question by explicitly recognizing these differences in the form of different models. In this section, we analyze a model in which WOM increases the proportion of consumers who are aware of a product. We model a monopolist firm selling a product with quality that is observable, conditional on awareness, which, in turn, is driven by WOM. We specify by $\theta \sim U[0,1]$ a consumer's type that captures the consumer's marginal value of quality.[4] Consumers buy the product iff they are aware of it and their utility exceeds the stated price:

$$U(\theta) = \theta Q - P.$$

We define an "awareness function" $A(\theta;\omega)$: $[0,1] \to [0,1]$ that is differentiable with respect to both parameters and characterizes the proportion of type θ consumers who are aware of the product's existence. The parameter ω captures WOM: when ω increases, this is meant to imply an increase in WOM. Our analysis proceeds as if $A(\theta;\omega)$ is common knowledge, although with no loss of generality one can think of the function as capturing the expected awareness of the

firm's product.[5] We do not consider the possibility that $A(\theta;\omega)$ is a function of the firm's choices of price and quality. That is, our approach here is opposite to that in the extant literature (Mayzlin 2006; Dellarocas 2006; Chen and Xie 2005, 2008; Godes 2012) where quality is assumed to be exogenous while the firm makes choices that impact social interactions. Here, we will assume that these social interactions are exogenous and study the optimal quality choices as a function of them. Given these assumptions, the sequence of the game proceeds as follows: (i) Nature chooses $A(\theta;\omega)$ and ω; (ii) the firm chooses price P and quality Q, conditional on these parameters; and (iii) consumers decide whether or not to buy.

We restrict $A(\theta;\omega)$ to be monotonic, which helps us to characterize a solution but is not necessary to obtain our results. A critical factor in the informative model is whether $A(\theta;\omega)$ is increasing or decreasing in θ. Are those with higher or lower valuations more likely to be aware of a product? Li and Hitt (2008) provide evidence that consumers with higher expected utility for a product will, on average, purchase the product earlier. Although not an exact mapping, Mitchell and Dacin (1996, p. 234) find that "experts," who might be expected to correspond to those with higher values of θ, "have much greater awareness and knowledge about the alternative models available in the market." More generally, we'd expect that in even the most basic model those consumers who will gain more utility from a product are likely to expend more resources on gathering information about it and thus will know more about the options available in the category. With this in mind, we proceed with the assumption that $A(\theta,\omega)$ is increasing in θ.[6]

We assume that the cost of quality is a variable cost.[7] Given our setup, the firm's objective function is

$$\Pi = \left(P - \frac{\gamma}{2}Q^2\right)\int_{P/Q}^{1} A(\theta;\omega)\,d\theta, \tag{1}$$

which it maximizes via its choice of P and Q. First-order conditions for optimal Q and P, respectively, are[8]

$$\frac{P}{Q^{*2}}\left(P - \frac{\gamma}{2}Q^{*2}\right)A\left(\frac{P}{Q^*}\right) = \gamma Q^*\int_{P/Q^*}^{1} A(\theta;\omega)\,d\theta, \tag{2}$$

$$\frac{1}{Q}\left(P^* - \frac{\gamma}{2}Q^2\right)A\left(\frac{P^*}{Q}\right) = \int_{P^*/Q}^{1} A(\theta;\omega)\,d\theta. \tag{3}$$

Combining these yields

$$P^* = \gamma Q^{*2}, \tag{4}$$

which implies that, in equilibrium, the cutoff type is γQ^*. Next, we substitute (4) into (2) and differentiate implicitly with respect to ω and solve for $\partial Q^*/\partial\omega$:

$$\frac{\partial Q^*}{\partial\omega} = \frac{\int_{\gamma Q^*} A_\omega(\theta)\,d\theta - (\gamma/2)Q^* A_\omega(\gamma Q^*)}{(\gamma/2)[3A(\gamma Q^*) + \gamma Q^* A_\theta(\gamma Q^*)]}. \tag{5}$$

We note that the denominator is positive by the second-order conditions. Substituting (4) into (3) and then into the numerator and rearranging, we can derive the following condition governing the relationship between WOM gains and optimal quality:

$$\frac{\partial Q^*}{\partial\omega} > 0 \iff \frac{\int_{\gamma Q^*} A_\omega(\theta)\,d\theta}{\int_{\gamma Q^*} A(\theta)\,d\theta} > \frac{A_\omega(\gamma Q^*)}{A(\gamma Q^*)}. \tag{6}$$

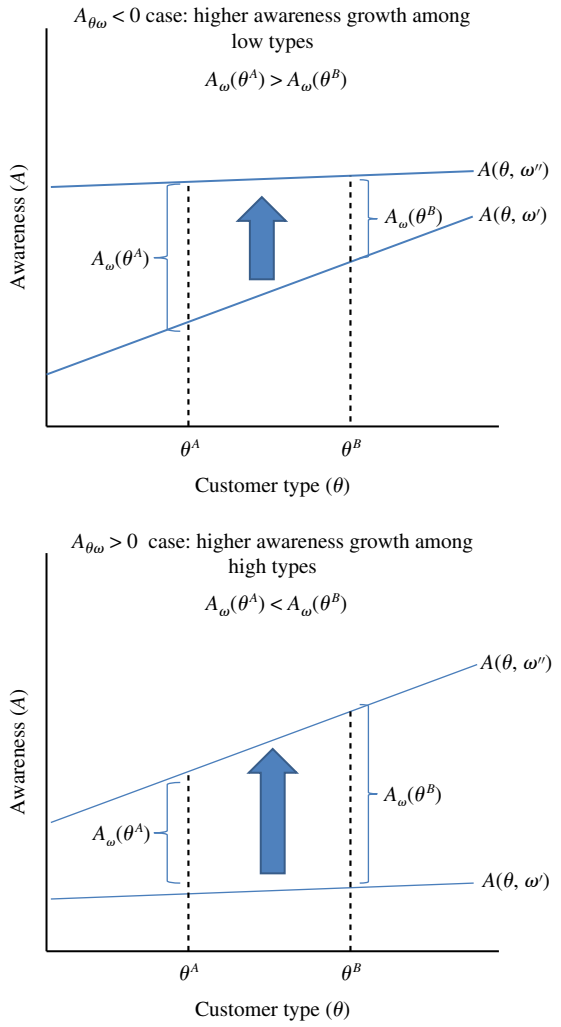
This condition suggests that optimal quality will increase in informative WOM if and only if the proportional gains in awareness among supramarginal customers (LHS) exceed the proportional gains in awareness at the margin (RHS). To be clear, this condition is more subtle than the simple conclusion that "should awareness gains be higher among high-taste consumers, then quality will increase" and vice versa. Specifically, (6) shows that one must normalize these awareness gains by the current status quo. These factors, the denominators in (6), reflect the current price level. As seen in (2) and (3), when awareness above the margin is high relative to at the margin, prices and qualities are high. In turn, this implies that even were it the case that $\int_{\gamma Q^*} A_\omega(\theta)\,d\theta > A_\omega(\gamma Q^*)$ (awareness gains above the margin are higher than those at the margin), we might still see quality decline as WOM expands; the high prices would render the marginal customers particularly valuable, warranting a drop in quality to attract them. The following proposition formalizes this intuition. Note that, since $A_\omega > 0$ for all types, $A_{\theta\omega} < 0$ implies that awareness gains are higher among lower types. See Figure 1 for a graphical representation of these curves.

Proposition 1. (i) *When $A_{\omega\theta} \le 0\ \forall\,\omega,\theta$ (when WOM increases the awareness levels of lower-taste customers more than higher-taste customers), optimal quality always declines in the level of WOM.*

(ii) *When $A_{\omega\theta} > 0\ \forall\,\omega,\theta$ (when WOM increases the awareness levels of lower-taste customers less than higher-taste customers), optimal quality may either increase or decrease. When $A_{\omega\theta}$ is high enough, optimal quality increases.*

Given the importance to our key result of the relative impact of informative WOM expansion on the awareness of high versus low types, we discuss the drivers of $A_{\omega\theta}$ via a simple example. Imagine there are two people, **H** (high type) and **L** (low type). Each individual is endowed with two characteristics: (a) μ^j, $j \in \{H,L\}$, the probability that they are informed exogenously about the existence of a product; and (b) τ^{jk}, $j,k \in \{H,L\}$, the probability each tells the other about the product, conditional on knowing about it. Imagine that $\mu^H = 0.5$, $\mu^L = 0.25$, and $\tau^{HL} = \tau^{LH} = 0.2$. These assumptions reflect the idea that higher-taste consumers may

Figure 1. (Color online) Shape of the Awareness Function



have more information. The quantity $A(H)$—the probability that H is aware—would then be calculated as follows:

$$A(H) = \mu^H + (1-\mu^H)\cdot\mu^L\cdot\tau^{LH} = 0.5 + 0.5\cdot 0.25\cdot 0.2 = 0.525.$$

The second term reflects the idea that those who are not exogenously informed might hear from others but only if those others both (a) are informed and (b) talk. In similar fashion, we can show that $A(L) = 0.325$. Now, what happens when WOM (τ^{jk}) expands? First, imagine the increase in such a way that the "structure" of conversations remains the same but the volume increases: $\tilde{\tau}^{jk} = \tau^{jk}(1+\delta)$. That is, we multiply all communication probabilities by a fixed constant. Allowing $\delta = 0.5$, then, we get the new awareness values as follows: $\tilde{A}(H) = 0.5 + 0.5\cdot 0.25\cdot 0.3 = 0.5375$, $\tilde{A}(L) = 0.25 + 0.75\cdot 0.5\cdot 0.3 = 0.3625$. Note that the awareness gains experienced by the high type ($0.5375 - 0.525 = 0.0125$) are lower than those experienced by the low type ($0.3625 - 0.325 = 0.0375$): when the structure of communication is held constant, an expansion of informative WOM will lead to disproportionate gains among lower-taste consumers. In the language of our model, $A_{\theta\omega} < 0$ and, thus, quality will always decline as long as the structure remains the same. This is because higher-taste consumers are more likely to know about the product, so the expansion in conversations is more likely to lead to redundant WOM the higher the taste profile: H is more likely to already know about the product when L is talking about it than vice versa. This leads us to a simple but interesting implication: a necessary condition for the expansion of informative WOM to lead to higher-quality products is that the expansion of WOM must fundamentally alter the structure of communication and not just the volume.[9] Moreover, this change in structure must be such that it implies that more people communicate disproportionately to higher types. In conclusion, in predicting the impact on product quality of an increase in informative WOM, we need to understand the extent to which the increase will also have an impact on the structure of social interactions.[10]

4. Persuasive WOM

In this section, we turn our focus to persuasive communication, which we define as that which changes consumers' evaluations of known products. Here, all consumers are aware of the product but may be uncertain as to its quality. Customer θ again experiences utility $U(\theta) = \theta Q - P$ for the product with $\theta \sim U[0,1]$, and the firm's variable cost of quality is again assumed to be $(\gamma/2)Q^2$ per unit produced and sold. We assume that all customers are aware of the product ($A(\theta) = 1\ \forall\ \theta$) but only some of them are informed about its quality. We define the differentiable function $F(\theta;\omega)$: $[0,1] \to (0,1)$ as the proportion of customers of type θ that are informed about the true value of Q. We assume that WOM will lead to an increase in F for all values of θ: $F_\omega(\theta) > 0$ for all θ. $F(\theta)$ may either increase or decrease in θ, unlike the informative model.[11] The firm chooses price P and quality Q as a function of the common-knowledge parameters $F(\theta;\omega)$ and γ. As before, $F(\theta;\omega)$ is a function of neither P nor Q. All consumers can observe P regardless of whether or not they observe Q.

Given the setup, the firm's profits in this model differ slightly from (1) and are given by

$$\Pi = \left(P - \frac{\gamma}{2}Q^2\right)\left[\int_{P/Q}^{1} F(\theta;\omega)\,d\theta + \int_{P/E[Q]}^{1} [1 - F(\theta;\omega)]\,d\theta\right]. \tag{7}$$

The first (second) term in the brackets represents the demand from the informed (uninformed) customers. The informed customers make their purchase decisions based on the actual quality of the product whereas

the uninformed customers form an expectation based on the equilibrium. We identify the best perfect Bayes equilibrium (PBE) of this game at which the firm maximizes (7) via its choice of P and Q subject to the information structure and equilibrium conditions.

The unique challenge facing the firm here is that some customers are informed, while others are not. The equilibrium requires that the uninformed customer believes the firm's claims about quality, which, in turn, implies that the uninformed customer must believe that the firm will not be strictly better off by deviating. Interestingly, here, only the informed customers observe a deviation; the uninformed customers do not. Thus, the crucial distinguishing aspect of this problem is that the uninformed customers' purchase choices are not a function of selected quality. Nonetheless, their purchases (fixed, with respect to Q) need to be considered in the optimization process.[12] In particular, the firm, in announcing quality level $\tilde{Q}$, must find it optimal to produce quality level $\tilde{Q}$ conditional on the fact that the uninformed customers, in equilibrium, will purchase conditional on the announcement being true.[13] This intuition is formalized in the following lemma, which characterizes the optimal PBE for the firm.

Lemma 1. (a) *In any perfect Bayes equilibrium of this model, the firm announces quality $\tilde{Q}$ and must choose to produce quality level $Q^* = \tilde{Q}$ that satisfies the following condition*:

$$Q^*(\tilde{Q}) = \arg\max_{Q}\left(P - \frac{\gamma}{2}Q^2\right)\left[\int_{P/Q}^{1} F(\theta;\omega)\,d\theta + D_u(\tilde{Q})\right], \tag{8}$$

where $D_u(\tilde{Q}) \equiv \int_{P/\tilde{Q}}^{1}[1 - F(\theta;\omega)]\,d\theta$ is uninformed customer demand.

(b) *The equilibrium that maximizes profits requires further that*

$$P^* = \arg\max_{P}\left(P - \frac{\gamma}{2}Q^{*2}\right)\left(1 - \frac{P}{Q^*}\right).$$

(c) *This equilibrium exists for all admissible values of $F(\theta)$ and γ.*

It is important to appreciate that the characterization presented in Lemma 1 is more than simply a statement of the generic requirements for a PBE. In particular, (8) reflects the unique quality-selection problem in this context. Mechanically, as shown in the proof, one finds Q^* by taking the first-order condition of (8) with respect to Q and then imposing the constraint that $Q^* = \tilde{Q}$. With respect to off-path beliefs, note that only price deviations are relevant since the informed customers have no uncertainty and the uninformed customers do not observe quality. When uninformed customers observe some $\tilde{P} \neq P^*$, then, we need to specify their beliefs about quality. There will always be off-path beliefs to ensure that the firm does not do strictly better through such a deviation. Indeed, as shown in the proof, a simple and reasonable example of such a belief would be that the consumer, upon observing some $\tilde{P} \neq P^*$, does not increase expectations about quality. The following proposition states the main result that, in equilibrium, quality always increases in WOM.

Proposition 2. *In the equilibrium presented in Proposition 1, for any admissible $F(\theta;\omega)$ and γ, optimal quality is always strictly increasing in persuasive WOM ω. Moreover, this holds for any equilibrium choice of P.*

Several comments are in order. First, although the result may be consistent with one's ex ante belief (i.e., quality should increase as persuasive WOM increases), the mechanism behind it may not be. Specifically, the intuition has nothing to do with the firm "fooling" customers or with the firm's decreasing ability to do so as WOM spreads. Instead, our result is driven by the fact that, as WOM spreads, creating more informed and fewer uninformed customers, the sensitivity of demand with respect to quality increases. This is because informed customers respond to produced quality whereas uninformed customers do not. The latter react only to announced, or expected, quality in equilibrium. Second, note that this result holds regardless of the relative WOM gains across θ. Specifically, even if WOM gains are higher at lower values of θ, optimal quality will increase. The intuition for this comes from the fact that, relative to the full-information case, the firm is underproducing quality because of its inability to make a credible commitment to the uninformed customers. For every customer that becomes informed as a result of WOM, the firm is able to commit to higher quality since demand elasticity with respect to quality strictly increases. That commitment effect is bolstered as long as the measure of informed customers increases, regardless of where the increase occurs.

Finally, combined with the results in the previous section, we have identified two distinct paths of social influence: direct social influence and indirect social influence. The former occurs as a function of those interactions that result in the exchange of information among individuals about the existence and/or value of products. This is what the literature has typically defined as social influence. At the same time, there is also "indirect social influence" occurring in the persuasive model, which we define as changes in consumers' evaluations of the product due to expected changes in firm's actions. As information spreads, the firm changes its strategy, which results in an effect on consumers who were not recipients of any new information.

5. Advertising vs. WOM

To this point, we've analyzed the impact on the firm's product policy of the exogenous expansion of social interactions, which, in turn, results in an increase in awareness of, or evaluation of, existing products. Of course, there are other channels besides social interactions through which these processes occur. In particular, firms invest heavily in an effort to accomplish both of these tasks via advertising. It is worth considering, then, whether we might find the same effects for advertising as we have for WOM. Would an exogenous decrease in the cost of advertising (the analog of an exogenous expansion in WOM) yield similar results as those we have found? Perhaps surprisingly, we find that the answer may be no. We address this question as we did above, looking first at a model of informative advertising and then at a model of persuasive advertising.

5.1. Informative Advertising

Consider a simple model in which there are no interactions among consumers and all consumer awareness is driven by firm-created messages that we call "advertising." The primary distinction here is that the firm chooses $S(\theta) = A(\theta)$ endogenously. We assume consumers differ in terms of their receptiveness, or attentiveness, to firm communications such that higher types are more likely to become aware as a function of these firm actions,

$$A(\theta) = p(\theta)V(\theta), \quad p_\theta(\theta) > 0, \tag{9}$$

where $V(\theta)$ is the firm's chosen level of communication to type θ and $p(\theta)$ reflects the probability that a consumer of type θ will notice or recall the firm's message.[14] We thus model the firm's use of targeted advertising though the same result obtains in a model of untargeted advertising.[15] The firm's choice of advertising to type θ – $V(\theta)$ comes at a convex cost $(c/2)V^2(\theta)$ such that it gets increasingly more costly to communicate with the remaining unreached consumers of type θ. The motivation for this assumption is that there exists a great deal of unobservable fragmentation in consumer usage of media. Although it may be straightforward to communicate to, say, 50% of the market, reaching the next 10% and the next 10% becomes harder and harder. The objective function then becomes

$$\Pi = \left(P - \frac{\gamma}{2}Q^2\right)\left[\int_{P/Q}^{1} p(\theta)V(\theta)\,d\theta\right] - \frac{c}{2}\int_{P/Q}^{1} V^2(\theta)\,d\theta.$$

We first inspect the first-order conditions for Q^* in this model:[16]

$$Q^*\int_{\gamma Q^*} p(\theta)V(\theta)\,d\theta - \frac{\gamma Q^{*2}}{2}p(\gamma Q^*)V(\gamma Q^*) + \frac{c}{2}V^2(\gamma Q^*) = 0. \tag{10}$$

The first two terms represent the standard margin-share trade-off and the third term represents the saved advertising expense as quality increases. Note that, for exogenous advertising, we would indeed find that quality would decrease when advertising costs decrease, just as our WOM results might suggest.[17] However, of course, advertising is chosen endogenously. Solving for optimal advertising implies

$$V^*(\theta) = \begin{cases} c^{-1}\left(P - \frac{\gamma}{2}Q^2\right)p(\theta), & \theta \in \left(\frac{P}{Q}, 1\right); \\ 0, & \text{otherwise.} \end{cases} \tag{11}$$

Note that, when advertising cost c declines, the level of advertising-induced awareness increases more for higher types than lower types, as one would expect: $V^*_{c\theta} < 0$. In turn, we substitute (11) into (10) to yield

$$\frac{\gamma Q^{*2}}{2c}\int_{\gamma Q^*} p^2(\theta)\,d\theta - \frac{\gamma^2 Q^{*4}}{4c}p^2(\gamma Q^*) + \frac{\gamma^2 Q^{*4}}{8c}p^2(\gamma Q^*) = 0, \tag{12}$$

where it is clear that c plays no role in the firm's choice of quality, because it simply shifts the LHS of the equation. Simply put, changes in the cost of advertising effect a rebalancing of advertising expenditures across types such that the relative impact of the three forces in (12) remains unchanged.

Although awareness and differences in awareness levels across consumer types ultimately drive the firm's quality choices, the manner in which WOM and advertising drive awareness is fundamentally distinct: advertising is chosen optimally whereas WOM, or at least a substantial component of WOM, is more random. Shocks to WOM effect imbalances in the relationship between the awareness of marginal and supramarginal consumers, which the firm addresses with changes to its product quality. However, shocks to the advertising market are addressed via changes to advertising, which acts as a buffer against product quality choices. Because WOM is not optimized, or is less well optimized compared with advertising, changes in awareness levels that arise as a result of these different mechanisms have very different implications for optimal product design.

5.2. Persuasive Advertising

We now shift our attention to the impact of firm-driven persuasive messages. To keep the model as close as possible to that presented in Section 4, we focus on advertising that can credibly communicate the true quality of the product. For digital products, for example, the firm's ability to provide credible "samples" has improved over time. Similarly, in some product categories (pharmaceuticals, for example), there exist regulations that enforce the veracity of claims made via

advertising messages. Thus, those receiving the messages can be reasonably assured that they know the true quality.

We present a complete analysis of this model in the online technical appendix and cover only the salient factors here. We again specify $(c/2)V(\theta)^2$ to be the advertising cost. As we demonstrate in the online technical appendix, we can restrict our analysis to equilibria in which $V(\theta) = 1$ and the firm advertises only to a connected set of customers defined by $[\underline{\theta}, \bar{\theta}]$.[18] Recall that in the persuasive WOM case, the firm's investment in quality was limited by the measure of informed customers who provided a commitment device for the firm. Here, the key difference is that the firm chooses (via its selection of $(\underline{\theta}, \bar{\theta})$) the measure of informed customers. In an advertising equilibrium, the profit function the firm optimizes is the following:

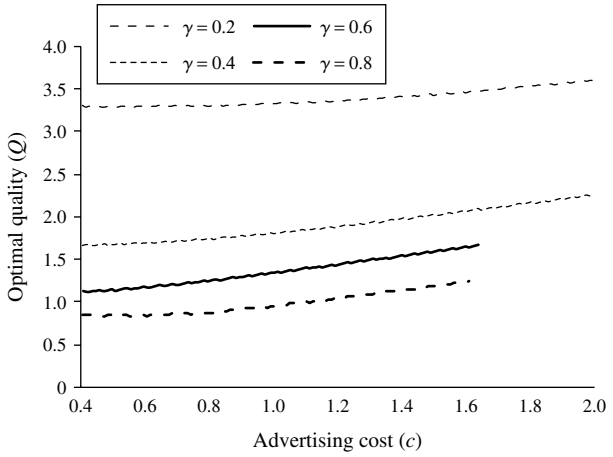
$$\max_{\{P,Q,\bar{\theta},\underline{\theta}\}} \left(P - \frac{\gamma}{2}Q^2\right)\left(1 - \frac{P}{Q}\right) - \frac{c}{2}(\bar{\theta} - \underline{\theta})$$
$$\text{s.t. } \underline{\theta} = \frac{P}{Q}, \quad \bar{\theta} \geq \frac{P}{Q} + \frac{\gamma Q^2(1 - P/Q)}{2P - c}.$$

The constraint on $\bar{\theta}$ (derived in the online technical appendix) ensures that the firm commits to advertising to a sufficient measure of customers that the uninformed can infer that quality is at the level Q because a deviation to a lower quality would be unprofitable. This is simply the endogenous analog of the commitment power with which the firm was endowed exogenously in the WOM context. Conditional on this constraint being satisfied, not only will all informed customers $\theta \in (\underline{\theta}, \bar{\theta})$ buy in equilibrium but so, too, will all $\theta \in (\bar{\theta}, 1)$. This follows from the fact that if type θ' knows the quality and makes a purchase, then any customer of type $\theta'' > \theta'$ will also purchase. Since the firm will never advertise more than it has to, the $\bar{\theta}$ constraint holds strictly and we can rewrite the problem as an unconstrained maximization:

$$\max_{\{P,Q\}} \left(P - \frac{\gamma}{2}Q^2\right)\left(1 - \frac{P}{Q}\right) - \frac{c}{2}\cdot\frac{\gamma Q^2(1 - P/Q)}{2P - c}.$$

This model does not lend itself to a straightforward unambiguous analytical solution. Our main objective is simply to assess whether WOM is equivalent to advertising in its impact on quality, which is simple to ascertain via numerical analysis. Figure 2 presents equilibrium quality levels for different values of c and γ. One sees immediately the difference between the advertising case and the WOM case. Although an increase in the volume of persuasive WOM always increases quality, an analogous decrease in the cost of persuasive advertising may have the opposite effect—lower quality.[19] The intuition for this result is an interplay between the direct effect and the strategic effect. On one hand, a decrease in advertising costs, for given quality and price, decreases the amount of advertising because the firm has less incentive to deviate and thus it is able to reduce the costly commitment device by informing fewer customers while still maintaining its credible claim of $\tilde{Q}$. The strategic effect, however, dominates in most regions in Figure 2: When c decreases, the firm optimally adjusts the cutoff P/Q downward by cutting both price and quality. When it is cheaper to reach customers, the firm wants to expand its market, implying a drop in quality (and price). The critical takeaway is that, as in our comparison of informative WOM and informative advertising, because the firm endogenously chooses persuasive advertising levels, we may get very different predictions for the impact of advertising, on one hand, and WOM, on the other, on equilibrium quality levels.

Figure 2. Lower Ad Costs May Lower Quality



6. Conclusion and Discussion

We investigate the impact on the firm's optimal provision of quality of an exogenous shift in WOM. Our approach is to consider separately informative WOM, which expands awareness about a product, and persuasive WOM, which informs people about the quality of a known product. When informative WOM grows, we find that, unless the WOM expansion results in a specific restructuring of interactions such that people are likely to communicate more with higher types, the firm's optimal quality will decline. When persuasive WOM grows, we find this will always lead to higher-quality products. In equilibrium, an expansion of persuasive WOM leads to a demand curve that is more sensitive to produced quality, leading to higher-quality production. This model incorporates both direct social influence (where the sharing of information among individuals changes their willingness to pay) and indirect social influence (where the expanded interactions also impact those who do not receive more information from others via the impact of these interactions

on the firm's actions). We then perform an analysis with respect to the cost of advertising and find that the impact of a decrease in advertising costs may, surprisingly, yield diametrically opposite results compared with WOM. Although a growth in informative WOM may increase or decrease quality, a drop in informative advertising costs has no effect on optimal quality. On the other hand, although a growth in persuasive WOM always leads to increased quality, we show that a drop in persuasive advertising costs may lead instead to a decline in quality. We trace the different impact on quality of WOM as compared with advertising to the fact that the latter is chosen optimally whereas the formally is, relatively speaking, random.

The most significant managerial implication of our results is that we link directly and, to our knowledge, for the first time, the firm's product decisions to the level of WOM in the marketplace. The optimal response to such an environmental shock depends both on the content (informative versus persuasive) and the structure of the expanded interactions. Importantly our analysis also highlights the fact that WOM and advertising, although on the surface analogous channels through which customers acquire information, have very different (in some cases, opposite) associations with the firm's choice of quality.

Our analysis is, of course, not without limitations. We focus exclusively on a monopolist throughout the paper. It would be useful to extend this inquiry to a competitive setting. Although this is likely to offer significant new insights, the informative model will need to deal with issues surrounding joint versus firm-specific awareness. As has been discussed in the rapidly expanding WOM literature, the firm today has more impact than ever over the volume (and, perhaps, type) of WOM surrounding its product. Thus, one might imagine that allowing in our model for the firm to effect the WOM shift endogenously may yield new insights. In particular, it would be interesting to assess the extent to which the persuasive WOM results persist in light of the potential for endogenous firm manipulation. That is, one might find interesting the combination of our approach here with the context studied by Mayzlin (2006). Another fruitful area in which to extend this work would be to allow for a strategic customer. Particularly in business-to-business markets, one could easily imagine contexts in which customers endogenously expand their networks in an effort to garner power over the firm and, in part, its product policy.

We do not consider the potentially important role of dynamics in our model. Although we look at the impact of WOM on quality, the explicit and simultaneous consideration of the impact that the firm's choice of quality may have on future WOM would make for an intriguing extension. One might imagine the potential for a mutually reinforcing WOM-quality relationship in which the firm decreases quality as WOM expands in order to appeal to a broader audience. This, in turn, might lead to more WOM among lower types, which would lead to even lower-quality products and so on. Coupled with a competitive model, this might argue for the prediction that, as WOM expands, we may end up with more and more vertical (quality) differentiation between firms. Another way to enrich the firm's set of decision variables would be to allow the firm to offer multiple products and to investigate the impact of WOM changes on the optimal product line design. As a final limitation, although we consider separately the impact of WOM and advertising, it would be an interesting exercise to consider their joint impact on the firm's choice of quality.

Besides extending the model to a broader, more general setting it would also be interesting to study the relationship between quality and WOM empirically. Given that our results are largely contingent on the type of WOM in effect—informative or persuasive—it would be important to address this empirical question: which is more likely/prevalent in a given setting? More fundamentally, we suspect that testing the focal relationship would offer a significant contribution to the literature.

Acknowledgments

The author is grateful to Dina Mayzlin, J. Miguel Villas-Boas, and seminar participants at the University of Pittsburgh, University of Houston, Northwestern University, University of Southern California, 2015 Product and Service Innovation Conference, Washington University, Rice University, and the Massachusetts Institute of Technology, as well as an anonymous associate editor and three reviewers for comments on previous versions of this paper. Financial support from the Center for Digital Thought and Strategy at the University of Maryland is gratefully acknowledged. The usual disclaimer applies.

Appendix

Proof of Proposition 1. (i) Assume that $A_{\theta\omega} \le 0$ and that optimal quality is increasing in WOM. From (6), this implies that

$$\frac{\int_{\gamma Q^*} A_\omega(\theta)\,d\theta}{A_\omega(\gamma Q^*)} > \frac{\int_{\gamma Q^*} A(\theta)\,d\theta}{A(\gamma Q^*)}.$$

However, since $A_{\theta\omega} \le 0$, we know that $A_\omega(\gamma Q^*) \ge A_\omega(\theta)$ $\forall\, \theta > \gamma Q^*$, which, in turn, implies that

$$\int_{\gamma Q^*} A_\omega(\theta)\,d\theta \le \int_{\gamma Q^*} A_\omega(\gamma Q^*)\,d\theta = (1-\gamma Q^*)A_\omega(\gamma Q^*)$$
$$\Leftrightarrow \frac{\int_{\gamma Q^*} A_\omega(\theta)\,d\theta}{A_\omega(\gamma Q^*)} \le (1-\gamma Q^*). \qquad (13)$$

Now, since $A_\theta > 0$, we know that $A(\gamma Q^*) < A(\theta)\ \forall\, \theta > \gamma Q^*$ and therefore

$$\int_{\gamma Q^*} A(\gamma Q^*)\,d\theta = (1-\gamma Q^*)A(\gamma Q^*) < \int_{\gamma Q^*} A(\theta)\,d\theta$$
$$\Leftrightarrow \frac{\int_{\gamma Q^*} A(\theta)\,d\theta}{A(\gamma Q^*)} > (1-\gamma Q^*).$$

Combined with (13), this implies that $\int_{\gamma Q^*} A_\omega(\theta)\,d\theta / A_\omega(\gamma Q^*) < \int_{\gamma Q^*} A(\theta)\,d\theta / A(\gamma Q^*)$, which contradicts the premise that quality is increasing per (6), proving the claim.

(ii) First, note that, by part (i), when $A_{\omega\theta} = 0$, it will always be the case that quality strictly decreases in WOM ($\partial Q^*/\partial\omega < 0$). This implies that there will exist a region in which $A_{\omega\theta} > 0$ and $\partial Q^*/\partial\omega < 0$. Now we investigate what happens when $A_{\omega\theta} \gg 0$. Assume that this is the case and that optimal quality is decreasing in WOM. From (6), this implies that

$$\frac{\int_{\gamma Q^*} A_\omega(\theta)\,d\theta}{A_\omega(\gamma Q^*)} < \frac{\int_{\gamma Q^*} A(\theta)\,d\theta}{A(\gamma Q^*)}$$
$$\Leftrightarrow A(\gamma Q^*)\int_{\gamma Q^*} A_\omega(\theta)\,d\theta < A_\omega(\gamma Q^*)\int_{\gamma Q^*} A(\theta)\,d\theta.$$

Now, fix the RHS. The idea is to keep overall awareness ($\int_{\gamma Q^*} A(\theta)d\theta$) constant but just vary the sensitivity of the slope of the awareness function with respect to WOM (i.e., A_ω). Since the LHS is monotonically increasing in $A_{\omega\theta}$, we can arbitrarily increase it until a contradiction is found. □

Proof of Lemma 1. (a) The firm chooses three quantities: Q^*, $\tilde{Q}$, and P^*, or produced quality, announced quality, and price, respectively. Firm profits are

$$\Pi(P,Q) = \left(P - \frac{\gamma}{2}Q^2\right)\left[\int_{P/Q}^{1} F(\theta;\omega)\,d\theta + D_u(\tilde{Q})\right], \qquad (14)$$

where D_u is the demand of the uninformed customers, who will buy based on their expectation of quality (i.e., $\tilde{Q}$):

$$D_u(\tilde{Q}) \equiv \int_{P/\tilde{Q}}^{1} [1 - F(\theta;\omega)]\,d\theta. \qquad (15)$$

Again, we reiterate that D_u is not a function of produced quality Q^*. To see that there is no profitable deviation, on one hand, by definition, the firm could not be better off given existing beliefs by changing quality. Again, this is a profit-maximizing choice. More importantly, note that off-path beliefs do not come into play with respect to quality since (i) uninformed customers do not observe quality and thus wouldn't form off-path beliefs and (ii) informed customers know the true quality and, thus, for them there is no asymmetry of information.

Although the above establishes that the proposed choice of quality is an equilibrium, we also claim that there is no other possible equilibrium choice of quality. To see this, imagine that, contrary to the lemma, the firm chooses a level of quality that does not maximize (14), given that D_u is simply a constant in the maximization. Analogous to the preceding discussion, the firm could always do strictly better by moving to the profit-maximizing level; additionally and again, off-path beliefs do not come into play since (i) the uninformed customers never know they are off path and (ii) informed customers only care about the true quality, which they observe.

(b) Since, in equilibrium, all customers above the cutoff will buy, that this maximizes profits is true by construction. To see that this choice of price is an equilibrium with appropriately chosen beliefs, there is of course no profit benefit to cutting price. What about raising prices from P^* to $P' > P^*$? By construction, if there is no change in uninformed customers' beliefs about quality upon seeing P', profit in this deviation will be strictly lower:

$$\left(P' - \frac{\gamma}{2}Q^{*2}\right)\left[\int_{P'/Q^*}^{1} F(\theta;\omega)\,d\theta + \int_{P'/Q^*}^{1} [1 - F(\theta;\omega)]\,d\theta\right]$$
$$< \left(P^* - \frac{\gamma}{2}Q^{*2}\right)\left[\int_{P^*/Q^*}^{1} F(\theta;\omega)\,d\theta + \int_{P^*/Q^*}^{1} [1 - F(\theta;\omega)].\,d\theta\right].$$

The only way for this to be profitable would be for $E[Q\,|\,P'] > Q^*$: for uninformed customers to believe that quality is higher now that price has been chosen off path. Thus, it is sufficient for us to assume that so long as one's beliefs about quality do not increase upon seeing an off-path price—if, for example, off-path prices are uninformative with respect to quality inferences—then this price is, indeed, an equilibrium.

(c) To see that this equilibrium always exists, we simply derive it. This is accomplished first by maximizing (14) with respect to Q (holding $\tilde{Q}$ constant) and then imposing the equilibrium condition $\tilde{Q} = Q^*$.

First-order conditions for optimal quality are

$$-\gamma Q^*\left[\int_{P/Q^*} F(\theta;\omega)\,d\theta + \int_{P/\tilde{Q}} (1 - F(\theta;\omega))\,d\theta\right]$$
$$+ \left(P - \frac{\gamma}{2}Q^{*2}\right)\frac{P}{Q^{*2}}F\left(\frac{P}{Q^*};\omega\right) = 0. \qquad (16)$$

Second-order conditions for a unique maximum are

$$-\gamma\left[\int_{P/Q} F(\theta;\omega)\,d\theta + \int_{P/\tilde{Q}} (1 - F(\theta;\omega))\,d\theta\right] - \gamma\frac{P}{Q}F\left(\frac{P}{Q}\right)$$
$$-\left(P - \frac{\gamma}{2}Q^{*2}\right)\left[\frac{P}{Q^3}F\left(\frac{P}{Q}\right) - \frac{P^2}{Q^4}F_\theta\left(\frac{P}{Q}\right)\right] \le 0.$$

We assume that this holds, which will be the case, for example, as long as F is not "too steep."

Imposing the equilibrium condition $Q^* = \tilde{Q}$ on the first-order conditions yields the following:

$$\gamma Q^*\left[1 - \frac{P}{Q^*}\right] = \left(P - \frac{\gamma}{2}Q^{*2}\right)\frac{P}{Q^{*2}}F\left(\frac{P}{Q^*};\omega\right). \qquad (17)$$

To find the optimal price, we differentiate (14) with respect to P:

$$\left[\int_{P^*/Q}^{1} F(\theta;\omega)\,d\theta + \int_{P^*/\tilde{Q}}^{1} (1 - F(\theta;\omega))\,d\theta\right]$$
$$-\left(P^* - \frac{\gamma}{2}Q^2\right)\left[\frac{1}{Q}F\left(\frac{P^*}{Q};\omega\right) + \frac{1}{\tilde{Q}}\left[1 - F\left(\frac{P^*}{\tilde{Q}};\omega\right)\right]\right] = 0.$$

Second-order conditions for a unique maximum are

$$-\frac{2}{Q}F\left(\frac{P}{Q}\right)-\frac{2}{\tilde{Q}}\left(1-F\left(\frac{P}{\tilde{Q}}\right)\right)-\left(P^*-\frac{\gamma}{2}Q^2\right)\left[\frac{1}{Q^2}F_\theta\left(\frac{P}{Q}\right)-\frac{1}{\tilde{Q}^2}F_\theta\left(\frac{P}{\tilde{Q}}\right)\right]\le 0,$$

which holds as long as $|F_{\theta\theta}(\theta)|$ is not too high. For example, if F is linear, this condition collapses to $-(2/Q)F(P/Q)-(2/\tilde{Q})(1-F(P/\tilde{Q}))\le 0$, which always holds.

This demonstrates that the equilibrium quality level is unique under these conditions. To show that it always exists within the permissible range of the parameter space, we apply to the first-order conditions for price the equilibrium condition $Q^*=\tilde{Q}$ to yield

$$Q\left(1-\frac{P^*}{Q}\right)=\left(P^*-\frac{\gamma}{2}Q^2\right)\iff P^*=\frac{Q+(\gamma/2)Q^2}{2}, \quad (18)$$

which we then substitute back into (17). After substitution and simplification, the RHS becomes

$$\left(P-\frac{\gamma}{2}Q^{*2}\right)\frac{P}{Q^{*2}}F\left(\frac{P}{Q^*};\omega\right)\Bigg|_{P=P^*}=\left[\frac{1}{4}-\frac{\gamma^2}{16}Q^{*2}\right]F\left(\frac{1}{2}+\frac{\gamma Q^*}{4}\right),$$

and the LHS is

$$\gamma Q^*\left(1-\frac{P}{Q^*}\right)\Bigg|_{P=P^*}=\frac{\gamma Q^*}{2}\left[1-\frac{\gamma Q^*}{2}\right].$$

Thus, we are looking for a solution to the following:

$$\left[\frac{1}{4}-\frac{\gamma^2}{16}Q^{*2}\right]F\left(\frac{1}{2}+\frac{\gamma Q^*}{4}\right)=\frac{\gamma Q^*}{2}\left[1-\frac{\gamma Q^*}{2}\right]\iff F\left(\frac{1}{2}+\frac{\gamma Q^*}{4}\right)=\frac{4\gamma Q^*}{2+\gamma Q^*}. \quad (19)$$

As $Q^*\to 0$, the RHS vanishes but $F(\theta)>0$ for all θ. On the other hand, as $Q^*\to 2/\gamma$ (the maximum value to ensure that $P/Q\le 1$), the RHS approaches 2. Thus, by continuity, since $F\in(0,1)$, a solution exists. □

Proof of Proposition 2. We start with the implicit expression for the optimal quality from (19)

$$(2+\gamma Q)F-4\gamma Q=0, \quad (20)$$

where we've simplified by rearranging and omitting the argument to F. Note that the argument is $P/Q=\frac{1}{2}+(\gamma/4)Q$. Now, we implicitly differentiate (20) with respect to ω and rearrange, which yields:

$$\frac{\partial Q^*}{\partial\omega}=\frac{F_\omega(2+\gamma Q^*)}{\gamma(4-F)-(2+\gamma Q^*)(\gamma/4)F_\theta}>0.$$

To appreciate the sign of the inequality, note that (a) $F_\omega>0$ by assumption and (b) the denominator is positive under the held assumption (providing us the sufficient conditions for a unique global optimum) that F_θ, if positive, is not too high.

We now show that the same qualitative result holds even if the firm implements an equilibrium in which it chooses a price different from that which maximizes profits. We emphasize that, regardless of how the price is set, as was shown in the proof of Lemma (1), the quality must be found the same way (by maximizing quality, holding constant the demand from the uninformed customers). Thus, we return to the expression for equilibrium quality (see (17)). We will refer to the price in this equilibrium as $\tilde{P}$:

$$-\gamma Q^*\left[1-\frac{\tilde{P}}{Q^*}\right]+\left(\tilde{P}-\frac{\gamma}{2}Q^{*2}\right)\frac{\tilde{P}}{Q^{*2}}F\left(\frac{\tilde{P}}{Q^*};\omega\right)=0. \quad (21)$$

The associated second-order conditions with general price are

$$-\gamma\left[\int_{P/Q}F(\theta;\omega)\,d\theta+\int_{P/\tilde{Q}}(1-F(\theta;\omega))\,d\theta\right]-\gamma\frac{\tilde{P}}{Q}F\left(\frac{\tilde{P}}{Q}\right)-\left(\tilde{P}-\frac{\gamma}{2}Q^{*2}\right)\left[\frac{\tilde{P}}{Q^3}F\left(\frac{\tilde{P}}{Q}\right)-\frac{\tilde{P}^2}{Q^4}F_\theta\left(\frac{\tilde{P}}{Q}\right)\right]\le 0,$$

which again holds for F_θ not too high. We now implicitly differentiate (21) with respect to ω (noting that $\tilde{P}$ is not a function of ω) and rearrange:

$$\frac{\partial Q^*}{\partial\omega}=\frac{((\tilde{P}-(\gamma/2)Q^{*2})(\tilde{P}/Q^{*2})F_\omega)}{\gamma(1-\tilde{P}/Q^*)+(\tilde{P}-(\gamma/2)Q^{*2})[(\tilde{P}/Q^{*3})F(\tilde{P}/Q^*)-(\tilde{P}^2/Q^{*4})F_\theta(\tilde{P}/Q^*)]}>0.$$

The sign follows from the second-order conditions (denominator), evaluated at the equilibrium point, and the fact that $F_\omega>0$. □

Endnotes

[1] Source: *Charlie Rose Show*, July 28, 2010, Interview of Jeff Bezos (transcript).

[2] For example, Nielsen's 2013 Global Trust in Advertising Report finds that 84% of respondents trust a "recommendations from others." This is higher than the 78% reported in 2007 and higher than all other forms of advertising (source: 2013 Global Trust in Advertising Report, summary report accessed March 14, 2015, http://www.slideshare.net/iabmexico/global-trust-in-advertising-report-nielsen-2013).

[3] The number of reviews on Yelp, for example, has grown from under 1 million in 2006 to over 36 million in 2013. On Twitter, the average number of daily tweets has grown by 8 *million percent* from 2007 to 2013. Facebook has grown from approximately 50 million users in 2007 to nearly 700 million in 2013 (*sources*: respectively, http://www.yelp.com/about, http://www.mediabistro.com/alltwitter/twitter-400-million-tweets_b23744 and http://newsroom.fb.com/Key-Facts; all accessed March 13, 2013).

[4] In the online technical appendix (available as supplemental material at https://doi.org/10.1287/mnsc.2015.2330), we demonstrate that the main results from both the informative and persuasive models persist with a general distribution of types.

[5] See the online technical appendix for a more detailed discussion of this issue.

[6] See the online technical appendix for a micromodel that yields this as an equilibrium outcome of consumers' endogenous investments in awareness building.

[7] Of course, in reality, the creation of all products and services requires the expenditure of both fixed and variable costs. As we

show in the online technical appendix, when costs are fixed, an expansion of either informative or persuasive WOM always leads to higher-quality products.

[8] Second-order conditions for global concavity in Q in order to ensure an internal and unique optimum are $(P-(\gamma/2)Q^2)A_\theta(P/Q)P/Q+[(\gamma/2)Q^2+3P]A(P/Q)\geq 0\ \forall P,Q$. It is clear that this holds for all $A_\theta \geq 0$ as is our assumption. Were we to relax this assumption, allowing for those consumers with lower types to be more aware, the condition would still hold as long as A were not "too steep." Similarly, second-order conditions for P are $(P-(\gamma/2)Q^2)A_\theta(P/Q)+2QA(P/Q)\geq 0\ \forall P,Q$. This, again, always holds for $A_\theta > 0$.

[9] For example, in this case, were we to allow $\tilde{\tau}^{LH}=0.5$ while keeping $\tilde{\tau}^{HL}=0.3$, then the impact on the awareness of H of an expansion in WOM would be higher than the impact on L.

[10] Although we show the necessity of a structural change for $A_{\omega\theta}>0$ only in a simple example, we can demonstrate the result far more generally. For simplicity of exposition, this has not been presented in the paper but is available from the authors.

[11] Sufficient conditions for second-order conditions to hold are that (a) $F_\theta < k_1, k_1 > 0$ and (b) $|F_{\theta\theta}| < k_2$.

[12] In other words, ignoring the second term in the brackets in (7) would not yield an equilibrium quality level.

[13] As an example, imagine that $P=1$, $F(\theta)=0.5\ \forall\theta$, and $\gamma=0.3$. Were the firm to simply maximize (7) by assuming that, in equilibrium, the uninformed customer knows the quality is Q and, thereby, substituting $E[Q]=Q$, then the equation simplifies to $(1-(0.3/2)Q^2)[1-1/Q]$ which is mazimized at $Q^*\approx 1.68$. However, if the firm announces $\tilde{Q}=1.68$, then it solves the following in choosing Q^*:

$$Q^*=\arg\max_Q\left(1-\frac{0.3}{2}Q^2\right)\left[0.5*\left(1-\frac{1}{Q}\right)+0.5*\left(1-\frac{1}{1.68}\right)\right],$$

which yields $Q^*\approx 1.47$ and is thus not an equilibrium.

[14] As seen in (12), the assumption that $p_\theta > 0$ is not at all critical. It mainly serves to yield an upward-sloping awareness function. This, in turn, allows us to maintain consistency with the WOM model analyzed above.

[15] See the online technical appendix for a formal model of untargeted advertising.

[16] Note that here, as in the model of informative WOM, $P^*=\gamma Q^{*2}$.

[17] It is easy to show from (6) that a "flat" increase in WOM such that $A_\omega(\theta)=A_\omega\ \forall\theta$ always yields lower quality.

[18] We also restrict our attention to $p(\theta)=1$ since no equilibria exist for $p(\theta)<1$. To see why, imagine such an equilibrium existed for type θ'. In such a case, the off-path belief for customers of type θ' who see no advertising must, in equilibrium, be the same as those who saw the advertising. As such, the firm will always deviate to zero advertising.

[19] Note that a decrease in quality caused by a decrease in advertising costs, the analog to an exogenous upward shift in WOM, is seen in Figure 2 as an upward-sloping line.

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