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Many emerging technologies exhibit path-dependent demands driven by positive network feedback. Such network effects profoundly impact marketing strategists' thinking in today's network economy. However, the significant network externalities expected by many people often fail to materialize in the emerging technology market. We analyze this phenomenon in the context of a technology distribution channel. By studying cheap-talk strategies under information asymmetry, we show that incentive-compatible contracts are essential for achieving credible information transmission. In our model, the better-informed technology vendor has an incentive to inflate the retailer's ex ante belief of network externalities when a wholesale price contract is adopted. When properly termed revenue-sharing contracts are implemented, there are information-efficient cheap-talk equilibria where truthful information transmission is mutually beneficial. When the vendor's information is imperfect, even revenue-sharing contracts cannot guarantee credible information transmission if there is significant prior belief disparity between the vendor and the retailer. This study demonstrates how information-inefficient equilibria (e.g., information blockage) arise because of the conflict of interest or the conflict of opinion among channel members. It also explores the role of cheap talk in facilitating channel coordination.

Key words: behavioral game theory; channels of distribution; cheap-talk game; conflict of opinion; demand signaling; emerging technologies; network externalities; revenue sharing; strategic information transmission
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1. Introduction

The early stage of a technology's diffusion process usually plays a pivotal role in determining its fate in the future. In the market of emerging technologies, future demand for a technology is usually positively correlated with the size of its current user base. Prior theoretical research has suggested that such path-dependent demands for technologies are often caused by network effects (Katz and Shapiro 1985, 1994; Economides 1996). Network effects stem from the efficiency of a compatible product user base and the presence of significant technology switching costs. They usually lead to positive payoff externalities that make a technology adopter's return positively correlated with the number of users who have already adopted the same technology. Thinking of a technology's installed base as a network of adopters has significantly impacted marketing strategists' perceptions of the intertemporal dynamics of technology diffusion processes (e.g., Lee and O'Connor 2003). Some strategists came to believe that network externalities could justify preemptive business strategies like below-marginal-cost pricing in order to achieve first-mover advantages.

However, some researchers have argued that strong network externalities were much harder to find in the digital economy than most people thought. For example, Liebowitz (2002) reminds us:

> Many products that were involved in some way with e-commerce do not have even the slightest trace of network effects. Nevertheless, many business models applied to e-commerce were often based on unsupported and ultimately incorrect assumptions that ALL of e-commerce was subject to powerful network effects. How much of the recent Internet meltdown can be laid at the doorstep of these mistaken business strategies cannot be ascertained with any precision, but a substantial portion of the damage can certainly be attributed to them.

The fact that strong network effects often fail to materialize can sometimes be explained by traditional network economics models where people are assumed to be rational. In those models, a significant portion of network effects can be internalized by forward-looking technology sponsors and consumers with rational expectations, which makes strong path dependency difficult to observe ex post (Farrell and Klemperer 2004, Liebowitz and Margolis 1994).

Although the internalization of network effects provides a plausible explanation, it does not work well in cases where bogus network externalities (or at least highly imprecise projection of network externalities) persist and prevail. With the benefits of

market hindsight, we believe that the exaggerated network externalities may be the by-products of people's "irrational exuberance" of some emerging technologies like the Internet. After examining many failed Internet business strategies driven by the erroneous belief of strong network effects and significant switching costs, Porter (2001) describes this type of market distortion as an informational problem:

> Companies that have deployed Internet technology have been confused by distorted market signals, often of their own creation . . . . In the early stages of the rollout of any important new technology, market signals can be unreliable. New technologies trigger rampant experimentation, by both companies and customers, and the experimentation is often economically unsustainable. As a result, market behavior is distorted and must be interpreted with caution.

The emerging technology market's propensity to information-driven market distortions could be further exacerbated by the incentive problem of information sharing. This incentive problem arises because it is usually in technology vendors' best interest to claim significant network effects for their technologies (Padmanabhan et al. 1997). The marketing literature on channel coordination has offered abundant evidence of the incentive problem of demand information sharing (Chu 1992, Desai 2000, Lariviere and Padmanabhan 1997). We believe that the same incentive problem exists when channel members share their private information of network externalities, which affect future product demand.

Our paper studies the strategic transmission of information regarding network externalities in the context of a distribution channel composed of a technology vendor (the upstream firm) and an exclusive technology retailer (the downstream firm).[1] We consider a distribution channel with two periods and demand in the second period partially dependent on the realized sale in the first period. Both firms know that the market is subject to positive network feedback, but the technology vendor is better informed of the magnitude of the network externalities ex ante. The vendor may either have perfect knowledge of the network benefits or have an imperfect but informative signal (obviously the second scenario is a more realistic one). The vendor's information advantage regarding network externalities in our paper is justified by the fact that she has much more proprietary information of her *new* technology.[2]

Our analysis starts with a benchmark setting in which the distribution channel is treated as a vertically integrated firm facing downward-sloping demand curves in both periods. Because of the path-dependent demand caused by network feedback, the integrated firm will set the first-period price to maximize its total profits from the two periods. The well-known double-marginalization problem emerges when the vendor and retailer become independent and a wholesale price contract is used. We show that revenue-sharing contracts can easily coordinate the channel. We further prove that under very general conditions revenue-sharing contracts can accommodate arbitrary bargaining positions and that any wholesale price contract is Pareto-dominated by a continuum of revenue-sharing contracts.

The introduction of asymmetric information about network benefits opens the door for strategic information transmission. Unlike some recent studies that incorporate Spence-style signaling strategies, this paper examines the role of cheap talk in a sender-receiver game setting as discussed in Crawford (2003), Crawford and Sobel (1982), and Farrell and Rabin (1996). Under information asymmetry, wholesale price contracts not only cause the double-marginalization problem but also completely block information transmission between the two firms in our model. Because of the incentive incompatibilities caused by wholesale price contracts, the better-informed technology vendor always wants to induce the retailer to oversell in the first period by inflating his ex ante belief of the network externalities. Knowing the vendor's incentive to misinform him, the retailer will disregard the message (about network externalities) from her in equilibrium, which results in inefficient information blockage.

The channel coordination problems caused by misaligned incentives in our model should not surprise those marketing researchers who are familiar with the pioneering works in Jeuland and Shugan (1983), McGuire and Staelin (1983), and Shugan (1985). Using a cheap-talk game, our analysis suggests that properly termed revenue-sharing contracts make the "truth-telling and trust" strategy mutually beneficial when the vendor has perfect knowledge of the network externalities. The information transmission problem becomes more complicated when the vendor has an imperfect but informative signal about the network externalities. The equilibrium solution here requires both subgame perfection and sequential rationality. Because both firms' prior beliefs of the network benefits matter in Bayesian updating, even revenue-sharing contracts cannot guarantee credible information transmission if there is a significant conflict of opinion between the vendor and the retailer.

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[1] For pronominal clarity, the retailer is male and the technology vendor is female in this paper.

[2] Note that this argument generally does not apply to technologies with established sale records through which a downstream retailer may gain more private information about the magnitude of network externalities.

While the strategic implications of network externalities for the technology industry have been well studied (Shapiro and Varian 1999, Srinivasan et al. 2004, Sun et al. 2004), this study is unique in examining the issue of strategic exaggeration of network effects. Although it looks at this issue within the context of a technology distribution channel, it focuses on the strategic implications of imperfect information structure rather than the exotic contracting mechanisms that improve joint surplus. Unlike some recent vertical information-sharing models (e.g., Cachon and Lariviere 2001) that also emphasize the issue of information credibility, our study is innovative in introducing cheap talk (or voluntary disclosure as described in Stocken 2000) as an alternative to Spence-style signaling. We also extend our model to scenarios where imperfect private information and prior belief disparity coexist with asymmetric information.

Our paper is directly related to channel coordination models that study product demand information sharing. Most of these models analyze demand information sharing in the framework of Spence-style signaling. Over the years we have seen some very successful development in the theoretical literature on channel demand signaling. The issue of demand signaling has been addressed in various channel contexts, including manufacturer-retailer, manufacturer-supplier, producer-consumer, and franchiser-franchisee. Wholesale prices, advertising, slotting allowance, and various types of fees have been studied as signaling devices in this literature (Chu 1992, Desai and Srinivasan 1995, Lariviere and Padmanabhan 1997, Desai 2000). Our study contributes to this literature by suggesting that channel members can sometimes use cheap talk to achieve credible information transmission. To emphasize the significance of cheap talk as an information-sharing option in channel coordination, our paper accentuates the major difference between cheap talk and signaling as described in Aumann and Hart (2003):

> Unlike "signaling," cheap talk (plain conversation) is "payoff-irrelevant;" there is no "credibility cost."... To be sure, that there is no credibility cost does not mean that there is no credibility; depending on the circumstances, the cheap talk may itself create positive motivation for players to believe each other.

The "credibility cost" of signaling mentioned above is the cost incurred when the informed player intentionally deviates from the first-best strategy in order to increase signal credibility. In terms of the signaling efficiency, cheap talk, if credibly conducted, is equivalent to free signaling. This observation is very interesting to the demand signaling literature where one important goal is to improve signaling efficiency.

The relevance of cheap talk to channel management also comes from its widespread application in the real business world. Cheap talk, in our opinion, may be one of the most primitive marketing tools that is still frequently used today. Many sophisticated channel contracts, although theoretically plausible, are rarely observed in the real business world. This is usually because of the significant costs of designing, implementing, and enforcing these contracts. Therefore, our study attempts to explore more efficient channel coordination mechanisms that jointly employ cheap talk and incentive contracts.

The next section of this paper presents a two-period model with path-dependent demand. Strategic information transmission between the two channel members is modeled as a cheap-talk game. We examine the implications of imperfect information and prior belief disparity in §3. Section 4 offers more discussions and concludes the paper. Detailed derivations and proofs are in the appendix.

2. Cheap-Talk Strategies for a Dyadic Channel

We consider a two-period model with path-dependent demand caused by network externalities. A technology vendor contracts with an exclusive retailer to sell a new technology. Such one-to-one relationships are commonly used in the marketing of emerging technologies. In both periods, the retailer faces downward-sloping demand curves, reasonable in that emerging technology markets usually exhibit some monopolistic features. Both firms are risk neutral, and they adopt a contract that governs both periods after observing the demand curve in the first period. The first-period inverse demand function observed by both firms is $p_1 = A - q_1$, where $p_1 \geq 0$.

We use θ to characterize the demand path dependency caused by positive network feedback. The inverse demand function in the second period is $p_2 = \tilde{A} + (\theta - 1)q_1 - q_2$, where $\tilde{A}$ does not depend on θ or q_1, $E(\tilde{A}) = A$, and the probability density function $f(\tilde{A})$ is everywhere positive within a support $[\underline{A}, \bar{A}]$. Therefore, the second-period demand depends on the realized sale in the first period. Note that $E(q_2) = \theta q_1$ if the sale prices are the same in the two periods, and we assume $\theta \geq 1$ because only nonnegative network effects are considered here.[3] We initially assume that both firms have perfect knowledge of θ in the first period. The vendor produces a new technology at a unit cost c ($c < A$), and the discount rate is set at zero for convenience.

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[3] Of course, we can use a demand autocorrelation process like AR(1) used in many studies of time-correlated demand to model the demand path dependency driven by the network feedback. However, the advantage of our model is that it recognizes the retailer's strategic pricing flexibility.

We first consider a benchmark case where one decision maker maximizes the expected profit of the integrated channel. This two-period optimization problem can be solved by backwards induction. The decision-maker's objective function in the second period given $\tilde{A} = \hat{A}$ is

$$\max_{q_2}[\hat{A} + (\theta - 1)q_1 - q_2 - c]q_2.$$

This concave function is maximized at $q_2^* = [\hat{A} - c + (\theta - 1)q_1]/2$, and the optimization problem in the first period thus becomes

$$\max_{q_1}(A - c - q_1)q_1 + \frac{1}{4}\int_{\underline{A}}^{\bar{A}}[\tilde{A} + (\theta - 1)q_1 - c]^2 f(\tilde{A})\,d\tilde{A}.$$

Simple mathematical manipulation shows that selling A (or equivalently $p_1 = 0$) in the first period is the best solution when $\theta \geq 2 + c/A$, which is quite intuitive because the decision maker will always maximize the first-period sales when path dependency is strong enough. So, to make things interesting, we assume $\theta \leq 2 + c/A$ in this model. This condition guarantees the existence of the following interior optimal solution:

$$\begin{cases} q_1^* = \dfrac{A - c}{3 - \theta}, \qquad p_1^* = A - \dfrac{A - c}{3 - \theta}, \\[2mm] E(\Pi_s^*) = \dfrac{(2 - \theta)(A - c)^2 + \int_{\underline{A}}^{\bar{A}}(\tilde{A} - c)^2 f(\tilde{A})\,d\tilde{A}}{(3 - \theta)^2}, \\[2mm] E(q_2^*) = q_1^*, \qquad E(p_2^*) = A + (\theta - 2)\left(\dfrac{A - c}{3 - \theta}\right) \geq p_1^*, \end{cases}$$

where $E(\Pi_s^*)$ is the maximum system expected profit. It is easy to see that q_1^* degenerates to the single-period optimum when there is no path dependency ($\theta = 1$). When $\theta > 1$, the optimal first-period sale is always greater than this single-period optimum because the decision maker oversells in the first period to take advantage of network externalities.

Next we analyze the decentralized case in which the retailer makes pricing decisions in both periods. The two firms sign a contract in the first period (after they observe the demand curve) to allocate the surplus. First we consider wholesale price contracts under which the technology vendor charges the retailer c' per unit purchased. The wholesale price depends on both firms' bargaining power. We let $c' \geq c$ so that the technology vendor will at least break even.

The appendix provides a detailed analysis of the double-marginalization problem and revenue-sharing contracting in this channel setting. The results of our analysis are consistent with the insights from the channel coordination literature. Specifically, our analysis demonstrates that, except for an extreme case

where the technology vendor sells at unit cost, wholesale price contracting, wherein different prices are allowed in the two periods, fails to coordinate the channel. It is well known that two-part contracts and revenue-sharing contracts can usually solve the double-marginalization problem. Under two-part contracts, the technology vendor sells at unit cost and charges the retailer a fixed side payment. It requires little math to see that such simple contracts can easily coordinate the distribution channel specified so far in our model. However, we pay much more attention to revenue-sharing contracts in this paper, and the reason will be discussed in the next section. Our analysis in the appendix further shows that, under perfect information, the two firms with arbitrary bargaining positions can always find some revenue-sharing contract that achieves channel coordination. In general, both firms are better off by adopting appropriate revenue-sharing contracts instead of using wholesale price contracts. These nice properties of revenue-sharing contracting allow us to use it as a vehicle to explore information transmission strategies under information asymmetry.

We now introduce information asymmetry by allowing only the technology vendor to know, or equivalently to receive a perfect signal of $\theta \in \{\theta^L, \theta^H\}$ in the first period. The retailer does not know whether $\theta = \theta^H$ or $\theta = \theta^L$ ($\theta^L < \theta^H$) in the first period, but has the following prior beliefs simply referred to as his prior:[4] $\Pr(\theta = \theta^H) = \rho$, $\Pr(\theta = \theta^L) = 1 - \rho$, $0 < \rho < 1$. It is easy to see that information transmission between the two firms will benefit the retailer in this case. However, it may not be the most advantageous policy for the better-informed vendor to truthfully reveal her proprietary information about θ to the retailer. The issues of incentives and credibility have been well articulated in prior research on channel information sharing. The focus of this section is not on costly signaling strategies or Hurwitze-style incentive-compatible mechanisms, but on cheap talk, which is a more commonly used communication strategy in the real world. In a cheap-talk game, the better-informed vendor can be viewed as a message sender who tries to send a message to the retailer. To model the strategic information transmission, we allow a cheap-talk stage in the first period of our model.

We first discuss the two firms' cheap-talk strategies under the wholesale price contracts. We assume that the technology vendor talks (or sends a message) to the retailer after they have agreed upon a wholesale price contract in the first period. After talking

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[4] This information structure is unrealistically simple and will be compared to the more general case with information imperfection in the next section.

with (or receiving the message from) the vendor, the retailer will make his first-period pricing decision, and all demand uncertainties will be resolved in the second period.[5] Proposition 1 shows that wholesale price contracts can completely block information transmission between the two firms due to incentive incompatibility.

PROPOSITION 1 (CHEAP TALK WITH WHOLESALE PRICE CONTRACTS). *Under asymmetric information and above-cost wholesale price contracts, the better-informed technology vendor always wants to inflate the retailer's ex ante belief of θ. Knowing the vendor's incentive to misinform him, a rational retailer will disregard the cheap-talk message in equilibrium.*

Given the vendor's incentive to inflate the retailer's belief of the network effects, the vendor always wants the retailer to believe that $\theta = \theta^H$. Therefore, the retailer will not believe what she says about θ and will instead use his own prior belief if he is rational. If by any chance the retailer's rationality is bounded (e.g., a credulous type) so that his belief can be inflated by the vendor's message, we may see a below-equilibrium technology price in the first period. Proposition 1 does not discuss the two-wholesale-price contract proposed in the previous section. Using different wholesale prices in the two periods may allow the vendor who knows $\theta = \theta^H$ to engage in costly signaling. For example, she may set the first-period wholesale price significantly below her cost and compensate it with a higher second-period wholesale price. Such a strategy could result in separating equilibria where the vendor who knows $\theta = \theta^L$ has no incentive to adopt the same contract. However, our analysis in the appendix has shown the weakness of the two-wholesale-price contracts. In addition, Spence-style signaling is generally costly, and separating equilibria are not always achievable. Even if there are contracts that guarantee credible signaling, they may not be flexible enough to accommodate various bargaining positions between the two channel members.

The equilibrium is still far from the first-best outcome when the retailer is rational and disregards the vendor's message as suggested in Proposition 1. Since strategic information transmission through cheap talk is completely blocked in equilibrium, the retailer has to make his pricing decision according to his less precise prior belief of the network externalities. Such an information blockage does not necessarily cause bogus network externalities, but it usually leads to highly imprecise projection of network externalities in the first period. If the information blockage occurs in many technology markets, we may see an information vacuum in downstream markets, and a little information about network effects could generate a huge impact on these technology markets. For example, the information leakage (or information externalities) caused by an individual firm's action may significantly alter the consensus belief of the network effects in these technology markets.[6] This type of market herd behavior under incomplete information has been explored in the informational cascade literature (Bikhchandani et al. 1998, Li 2004).

Many contracts that coordinate the distribution channel under full information may block strategic information transmission. For example, the two-part contracts discussed before can easily coordinate the distribution channel under full information, but the vendor has no incentive to let the retailer know the true value of θ because she always receives the fixed side payment. She may even have an incentive to inflate the retailer's prior through cheap talk if the side payment depends on the sale. Of course, the vendor may like to tell the retailer the true value of θ if the side payment directly depends on the retailer's profit. However, profit-dependent contracts are in general more costly to implement and to enforce than revenue-dependent contracts. Also, because revenue-sharing contracts have some nice properties, as shown in the appendix, they are the focus of our discussion in this paper.

PROPOSITION 2 (CHEAP TALK WITH REVENUE-SHARING CONTRACTS). *Under properly termed revenue-sharing contracts, there is an information-efficient cheap-talk equilibrium in which the technology vendor always tells the retailer the true value of θ, and the retailer always believes what he is told.*

It is important to point out that this "truth-telling and trust" equilibrium is not the unique cheap-talk equilibrium. Because the set of cheap-talk messages is usually very large, there are many other equilibria, and some of them are information efficient. For example, consider the "lying and reversal" equilibrium, in which the vendor always lies and the retailer always reverses what the vendor tells him. Although

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[5] Although all demand uncertainties are resolved in the second period, it is very difficult for the retailer to convince a court judge that the network externalities are high or low. The reason is that the demand changes caused by $\tilde{A}$ and θ are not differentiable as long as the support of $\tilde{A}$ is large enough to cover the possible effects of θ. This nonverifiability (by outsiders) makes it impossible or prohibitively costly to enforce contracts contingent on the realized value of θ, even though θ can be observed by the two channel members ex post, at least probabilistically. It is one of the fundamental assumptions of incomplete contract theory that the state of nature is observable (by insiders ex post) but not verifiable by outsiders (Hart and Moore 1999, Segal and Whinston 2002).

[6] To make this argument, we assume that people believe network effects are positively correlated across these technology markets. It is the case for many e-commerce technologies.

it looks absurd, this equilibrium is in fact information efficient in the sense that it guarantees credible information transmission. A well-known example of information-inefficient equilibrium is the so called "babbling equilibrium," in which the vendor always sends the retailer a meaningless message and the retailer always ignores the message (Farrell and Rabin 1996). It is easy to see that no firm can be better off by unilaterally deviating from such a babbling equilibrium. The issue of equilibrium selection emerges given the large number of cheap-talk equilibria. Fortunately, equilibrium coordination is trivial in this case, and even by Schelling's focal point argument, the equilibrium described in Proposition 2 seems to be the most plausible one.

The implications of Proposition 2 seem encouraging. As long as some incentive-compatible mechanisms like revenue sharing are implemented, cheap talk becomes self-policing and thus informative. The technology vendor's private knowledge of network effects can be credibly revealed to the retailer. Without information blockage, market distortions like bogus network externalities will not persist. However, the real business world is much more complicated than what our model depicts. For example, our model does not give the two firms the chance to select the contracting mechanisms prior to cheap talk. Otherwise, the better-informed technology vendor will seek informational rents in the bargaining process. She may enhance her bargaining power by threatening to adopt a contract that blocks credible information transmission. Therefore, ex post bargaining efficiency may not be attained.

Another real-world issue is whether the technology vendor should have perfect knowledge of θ in the first period. A more realistic assumption is to allow the vendor to receive an imperfect but informative signal of θ. This assumption may significantly affect the major results of our model if the two distribution channel partners have different prior beliefs of the network effects.

3. Cheap Talk and the Conflict of Opinion

So far, we have developed our model in an asymmetric information setting, where the technology vendor has perfect knowledge of θ. By implicitly treating θ as the vendor's type, the standard analytical techniques of Bayesian games can be directly applied. Most strategic information-sharing models also assume that one party has perfect information (especially when there is asymmetric information about one party's cost function). However, we believe that the technology vendor may not know the exact value of θ, a parameter used to characterize the demand path

dependency caused by network effects in our model. It is more likely for her to have some kinds of imperfect information of θ in the real world. To characterize this feature, we assume that the vendor receives an imperfect but informative binary signal S. This signal is completely informative (always reveals the true value of θ) with probability $\lambda \in (0, 1)$. It is an uninformative noise with probability $1 - \lambda$. We let

$$\Pr(S = \theta^H \mid S \text{ is noise}) = \Pr(S = \theta^L \mid S \text{ is noise}) = 1/2.$$

So, given a signal receiver's prior belief $\Pr(\theta = \theta^H) = \rho$, the following posterior beliefs (simply referred to as posteriors) can be obtained through Bayesian updating (we assume both distribution channel firms use Bayesian updating when they receive credible signals):

$$\eta^{S=\theta^H} = \Pr(\theta = \theta^H \mid S = \theta^H) = \frac{(1+\lambda)\rho}{2\rho\lambda - \lambda + 1},$$

$$\eta^{S=\theta^L} = \Pr(\theta = \theta^H \mid S = \theta^L) = 1 - \frac{(1+\lambda)(1-\rho)}{\lambda - 2\rho\lambda + 1}.$$

Note that the vendor has perfect information of θ when $\lambda = 1$. In this special case, we have $\eta^{S=\theta^H} = 1$ and $\eta^{S=\theta^L} = 0$ for all $0 < \rho < 1$. Therefore, we can see that both firms' priors play a more important role when imperfect private information coexists with asymmetric information. After receiving the imperfect signal, the vendor can report a binary signal to the retailer in the first period. Depending on her incentive, this cheap-talk signal may not be the signal she received (she may simply reverse the signal she received or randomize her signal between θ^H and θ^L).

We discuss our distribution channel model under two scenarios in this section: the common priors scenario ($\rho_V = \rho_R$) and the different priors scenario ($\rho_V \neq \rho_R$). The consideration of prior disparity allows our model to accommodate many real-world situations where the technology vendor and the retailer have different opinions of the network effects before any relevant information is revealed. The two parties' known conflict of opinion may significantly affect their channel strategies, and it is particularly applicable to the early stages of a new technology market. Some recent information economics studies also explicitly explore the impacts of prior disparity on people's decisions (Banerjee and Somanathan 2001, Piketty 1995).[7] The role of bounded rationality in cheap-talk games is studied in Crawford (2003).

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[7] See Aumann (1998) and Gul (1998) for an interesting discussion of John Harsanyi's common prior assumption in Bayesian games. Bob Aumann labels this assumption as the Harsanyi's doctrine. We fully agree with Ken Binmore and Faruk Gul that it should be defended as a working hypothesis rather than a doctrine.

All features of our model are common knowledge except S, observed only by the technology vendor.

Proposition 1 has shown that under above-cost wholesale price contracts, the better-informed technology vendor always has incentives to inflate the retailer's belief of θ. The following proposition suggests that this result holds under a more general scenario where the vendor's knowledge of θ is imperfect, and her prior may not be the same as the retailer's.

Proposition 3 (Cheap Talk with Wholesale Price Contracts and Imperfect Information). *Under asymmetric information and above-cost wholesale price contracts, the better-informed technology vendor always wants to inflate the retailer's ex ante belief of θ. Her incentive to misinform the retailer still exists when her knowledge of θ is imperfect, and her prior may not be the same as the retailer's.*

Because Proposition 1 is generalized by the above proposition, its implications that we discussed before are applicable here. Information transmission regarding network externalities is blocked in equilibrium because above-cost wholesale price contracts leave no room for incentive-compatible cheap talk. However, the technology vendor's imperfect knowledge of θ significantly complicates her cheap-talk strategies under revenue-sharing contracts. We first discuss a simpler scenario under which the vendor receives an imperfect signal, but her prior is still the same as the retailer's.

Proposition 4 (Cheap Talk with Revenue-Sharing Contracts and Imperfect Information: The Case of Common Priors). *Under properly termed revenue-sharing contracts, there is an information-efficient cheap-talk equilibrium in which the technology vendor always tells the retailer the imperfect signal S she received, and the retailer always believes what he is told.*

Thanks to common priors, the "truth-telling and trust" equilibrium still enables credible information transmission under imperfect information. However, under a more general scenario where the two firms have different priors, the existence of such an information-efficient equilibrium is not guaranteed any more. Lemma 5 shows that information transmission can be completely blocked under revenue-sharing contracts when the retailer's prior significantly differs from the vendor's.

Lemma 5. *Given the vendor's prior $\rho_V \in (0, 1)$, there are two thresholds $m(\rho_V, \lambda)$ and $n(\rho_V, \lambda)$ with the following three properties: (i) $0 < n < \rho_V < m < 1$; (ii) the vendor cannot credibly report signal S to the retailer when his prior $\rho_R \geq m$; and (iii) the vendor cannot credibly report signal S to the retailer when his prior $\rho_R \leq n$.*

Lemma 5 reveals an uncomfortable fact: Credible cheap talk may not be achieved under revenue-sharing contracts when there is significant prior disparity. This finding is consistent with what we learned from our daily experience: It is always difficult to communicate with someone whose opinions are significantly different from one's own. However, is credible cheap talk always possible when $n < \rho_R < m$? Proposition 6 shows that the credible cheap-talk range (n', m') is in fact much smaller than (n, m).

Proposition 6 (Cheap Talk with Revenue-Sharing Contracts and Imperfect Information: The Case of Different Priors). *Given the vendor's prior $\rho_V \in (0, 1)$, there are two thresholds $m'(\rho_V, \lambda)$ and $n'(\rho_V, \lambda)$ with the following two properties: (i) $n < n' < \rho_V < m' < m$, (ii) credible cheap talk is only possible when $\rho_R \in (n', m')$.*

Figure 1 depicts the credible cheap-talk range (n', m') in a typical setting. When $\rho_R = m'$, we have

$$E_V^{S=\theta^H}[q_1^*(\eta_R^{S=\theta^H}), \eta_V^{S=\theta^H}] = E_V^{S=\theta^H}[q_1^*(\eta_R^{S=\theta^L}), \eta_V^{S=\theta^H}],$$

and when $\rho_R = n'$ we have

$$E_V^{S=\theta^L}[q_1^*(\eta_R^{S=\theta^H}), \eta_V^{S=\theta^L}] = E_V^{S=\theta^L}[q_1^*(\eta_R^{S=\theta^L}), \eta_V^{S=\theta^L}].$$

As long as $\rho_R \in (n', m')$, the information-efficient "truth-telling and trust" equilibrium is plausible. Cheap talk is not credible because the vendor (the message sender) may be better off by misinforming the retailer when $\rho_R \notin (n', m')$. In the above proposition, we suggest that the credible cheap-talk range (n', m') depends on λ that is used in our model as
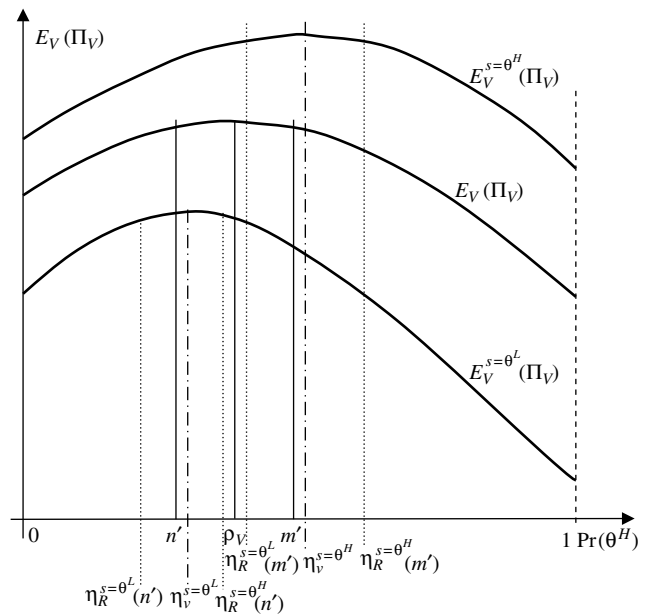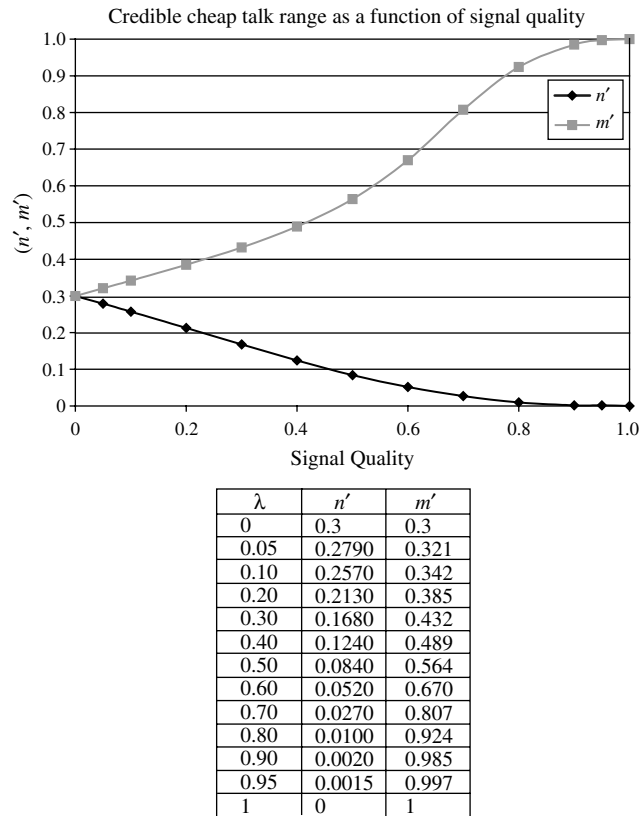
Figure 1 The Range of Credible Cheap Talk (n', m')

Figure 2   **The Range of Credible Cheap Talk** (n', m') **as a Function of Signal Quality** λ

Credible cheap talk range as a function of signal quality

λ	n'	m'
0	0.3	0.3
0.05	0.2790	0.321
0.10	0.2570	0.342
0.20	0.2130	0.385
0.30	0.1680	0.432
0.40	0.1240	0.489
0.50	0.0840	0.564
0.60	0.0520	0.670
0.70	0.0270	0.807
0.80	0.0100	0.924
0.90	0.0020	0.985
0.95	0.0015	0.997
1	0	1

Note. $\theta^H = 2$, $\theta^L = 1.5$, and $\rho_V = 0.3$.

a measure of signal quality or information quality in general. Corollary 7 shows how the quality of the vendor's signal affects the credible cheap-talk range.

COROLLARY 7. *For* $\lambda \in (0, 1)$ *and vendor's prior* $\rho_V \in (0, 1)$, *we have*: (i) $\partial n'(\rho_V, \lambda)/\partial \lambda < 0$, $\partial m'(\rho_V, \lambda)/\partial \lambda > 0$; (ii) $\lim_{\lambda \to 1} n'(\rho_V, \lambda) = 0$, $\lim_{\lambda \to 1} m'(\rho_V, \lambda) = 1$; *and* (iii) $\lim_{\lambda \to 0} n'(\rho_V, \lambda) = \rho_V$ *and* $\lim_{\lambda \to 0} m'(\rho_V, \lambda) = \rho_V$.

Figure 2 shows the result of a numerical example in which we let $\theta^H = 2$, $\theta^L = 1.5$, and $\rho_V = 0.3$. It allows readers to see the results of Corollary 7 in an intuitive way. The figure suggests that the credible cheap-talk range will expand as the quality (or precision) of the vendor's signal improves. Interestingly, this finding is also consistent with what we learned from our daily experience: The message from a party with better or more authoritative information source tends to be persuasive to more people. The credible cheap-talk range degenerates to an empty set when it is common knowledge that the signal received by the vendor is purely random noise. When it is common knowledge that the vendor receives a perfect signal, we have the perfect information scenario discussed in Proposition 2, where the vendor's prior does not matter.

In the business context of our model, the analytical results of this section suggest that information blockage between the two firms is not only a problem of wholesale price contracts. In the real business world, information imperfections and the conflict of opinion abound. Therefore, credible cheap talk is sometimes unachievable even under revenue-sharing contracts. For example, the technology vendor cannot credibly transmit her signal of network effects through cheap talk when there is notable distance between her beliefs and the retailer's beliefs of the network benefits. As a result, those technology retailers with strong opinions of the network externalities will not believe what they are told by the vendors even though it is common knowledge that the vendors are better informed. Consequently, there are presumably two types of market failure. When the retailers' beliefs of network benefits are systematically greater than those of the technology vendors (e.g., this may be caused by the irrational exuberance of emerging technologies), they may price too aggressively in the first period because of the bogus network externalities sustained by information blockages. When the retailers' beliefs are systematically less than those of the technology vendors (e.g., this may happen in economic recession or after a technology bubble bursts), they may price too conservatively in the first period based upon their pessimistic beliefs that may also be sustained by information blockages.

4.   Discussions and Conclusion

This paper studies cheap-talk strategies in the context of a technology distribution channel. It contributes to the marketing literature by suggesting that information transmission problems along distribution channels could boost or sustain erroneous beliefs of network externalities. Our analysis shows that rational technology vendors have incentives to claim bogus network effects to exploit credulous retailers. It also demonstrates why channel members under information asymmetry may not reach information-efficient equilibria due to information blockages. One potentially interesting extension of our model is to investigate the market of competing (incompatible) technologies. Under this scenario, retailers must consider both competitive dynamics[8] and network feedback when they make pricing decisions. Knowing that the first-period sale is crucial to deter competing technologies and to ignite positive network feedback, technology

[8] Dynamic competition in the emerging technology market is recently studied in Ofek and Sarvary (2003). Shaffer and Zettelmeyer (2002) analyze a multiproduct distribution setting where third-party information provision and channel competitive dynamics interact.

vendors may have stronger incentive to inflate retailers' belief of network benefits, which makes credible cheap talk even more difficult to achieve.

Our analysis can also be extended to more dynamic channel settings where contract renegotiation is modeled. It is known that contract renegotiation and ex post bargaining often distort the incentives for ex ante information transmission (Farrell and Gibbons 1995, Wernerfelt 2004). However, complicated contracting mechanisms may not be the best choice for channel coordination in this more general setting. Recent development in the incomplete contract literature has justified the use of simple and noncontingent contracts in various holdup settings (Bernheim and Whinston 1999, Segal and Whinston 2002). For example, Bernheim and Whinston (1999) demonstrate why it is often optimal to leave even verifiable parameters unspecified in contracts subject to renegotiation. Some insights from these studies, in our opinion, can be applied in future studies that investigate the relationship among cheap talk, contract renegotiation, and channel contractual incompleteness.

One major insight of our study is that cheap talk, if appropriately backed by incentive-compatible mechanisms, can coordinate a channel. Although we use revenue sharing as an example of the incentive-compatible mechanism for cheap talk, we do not intend to overstate its applicability for other channel settings. Revenue sharing has its inherent limitations, which may partially explain why it is not often adopted in some industries (Cachon and Lariviere 2005). Moreover, revenue sharing may not provide the right incentive for credible cheap talk in many complicated situations. Sometimes the administrative costs of revenue sharing make it inferior to some other mechanisms. Therefore, the objective of our analysis is not to show that revenue sharing works in this particular model, but to demonstrate why it is important for channel members to adopt incentive-compatible mechanisms that facilitate strategic information transmission.

We want to point out that, under the common prior scenario, there are many types of incentive contracts that can coordinate the dyadic channel described in our model. However, we hesitate to say that these contracts are equivalent. The reason is that these contracts, because of their administrative costs and other transaction costs, usually have significant differences in terms of their efficiencies in the real business world. For example, wholesale contracts, although they often fail to coordinate channels, incur little administrative cost, which may partially explain its popularity in the real business world. Generally speaking, complicated contracts are more expensive to draft and to enforce than simple ones. Furthermore, with asymmetric information, simple contracts are frequently better than complicated contracts in situations where contractual incompleteness can be used as a signaling device (Spier 1992). Because of the cost advantage of cheap talk over complicated contracts, we believe that more fresh insights will emerge from future studies that extend our cheap-talk game by explicitly modeling the channel-contracting costs.

In our model, only the cheap-talk strategies between the technology vendor and the retailer are considered. It could be an interesting study to consider the scenario under which the technology vendor can talk to both the retailer and his customers (technology buyers). One interesting issue in this setting is communication discipline (Farrell and Gibbons 1989). For instance, the technology vendor's public talk with technology buyers may affect her ability to convey information to the retailer. The information externality generated by cheap talk may also affect the beliefs of complementary product producers who may impact market dynamics because of indirect network feedback (Basu et al. 2003, Gupta et al. 1999). These potential effects may function as disciplining devices on cheap talk.

We explore the role of cheap-talk strategies as an alternative to costly Spence-style signaling strategies in channel coordination. Our analysis suggests that cheap talk can be an effective tool in informing or misinforming business partners. With a better understanding of the channel cheap-talk strategies, marketing researchers can explore new coordination mechanisms in which cheap talk and contractual incentive provisions can be jointly employed. Because our model only considers two possible states of θ, cheap talk is either perfectly informative or not at all informative. Readers should be aware that, as shown in Crawford and Sobel (1982), cheap talk could become partially informative if we consider a continuum of θ with some coarser information structure. In addition, business partners, as the name suggests, are usually not enemies or competitors, as modeled in some recent strategic information transmission games (Crawford 2003, Hendricks and McAfee 2005). Therefore, lying may not be a wise move because it hurts a reputation that, as discussed in Banks et al. (2002), could be very valuable for long-term channel relationships. However, it is a reasonable strategy for the technology vendor in our model because it is hard for the retailer to verify her cheap-talk message to a third party (e.g., a court) ex post. Moreover, the gains from boosting current sale may overwhelm the potential damage to a reputation in the emerging technology market, where survival is the first priority.

It is worth noting that the reputation effects could play a more important role in facilitating truth telling when a channel relationship involves multiple technologies. For example, long-term reputation is much

more valuable when two channel members collaborate on marketing multiple new products over time. Another example is that a large established technology vendor (with many technology products) contracts with many small retailers to sell its new technologies. In these cases, vendors have stronger incentives to build a good reputation because they want to collaborate with their channel members to market other technologies in the future. Therefore, new insights may emerge if we analyze these cases in a repeated game setting where self-enforced relational contracts are usually viable (Baker et al. 2002, Gibbons 2005, Levin 2003).

Our model further investigates the plausibility of credible cheap talk under scenarios where imperfect private information and prior disparity coexist with asymmetric information. Our analysis suggests that channel members with different prior beliefs may not be able to convey information credibly, as in the common prior case. Given the technology vendor's prior, there is a credible cheap-talk range, and credible cheap talk is only feasible when the retailer's prior is within that range. This credible range widens as the quality of the vendor's signal improves. These results show that information blockages are much easier to form in the real business world than what the traditional theories suggest. We believe that the introduction of prior belief disparity to the channel literature could result in fruitful debate among marketing researchers. The conflict of interest problem has been thoroughly studied in the vertical contractual relation literature. However, coordination problems frequently arise because of the conflict of opinion. We address this issue by relaxing John Harsanyi's common prior assumption in channel coordination games. This generalization underscores the difficulty of information transmission between channel members whose prior beliefs differ significantly.

The latest development in game theory suggests that there might be some remedies for the credibility problem caused by the prior belief disparity. For example, as suggested by Aumann and Hart (2003), protracted exchanges of messages (long cheap talk) could make a conversation more informative. In our model, a cheap-talk strategy with partial revelation could make partial information transmission possible. The better-informed technology vendor can partially reveal her private information by sending her message through a jointly observable noisy channel that always transmits the correct information with a certain probability. Of course, this is not a perfect solution because only a part of the private information can be credibly conveyed. Moreover, this cheap-talk strategy requires the availability of a jointly observable noisy channel, which is not assumed in our analysis. Nevertheless, we think that this is one promising

direction for future studies of cheap-talk strategies under prior belief disparity.

Our study is only an early attempt to examine the role of cheap talk in affecting emerging technology market dynamics and in facilitating channel coordination. We will be very glad if some researchers find it not cheap talk, and further explore the relevant business and technological issues in the near future.

Acknowledgments

Appendix. Detailed Derivations and Proofs

Double-Marginalization Problem

With any wholesale price $c' \geq c$, the retailer's decision is very similar to that of the decision maker in the benchmark case. The following optimal solution can be similarly derived by backwards induction:

$$
\begin{cases}
q_1^* = \dfrac{A - c'}{3 - \theta}, & p_1^* = A - \dfrac{A - c'}{3 - \theta}, \\[2mm]
E(\Pi_R^*) = \dfrac{(2 - \theta)(A - c')^2 + \int_{\underline{A}}^{\bar{A}} (\tilde{A} - c')^2 f(\tilde{A})\, d\tilde{A}}{(3 - \theta)^2}, \\[2mm]
E(q_2^*) = q_1^*, & E(p_2^*) = A + (\theta - 2)\left(\dfrac{A - c'}{3 - \theta}\right),
\end{cases}
$$

where $E(\Pi_R^*)$ is the retailer's maximum expected profit. The vendor's expected profit can be shown as $E(\Pi_V^*) = 2(c' - c)q_1^*$. Comparing this solution with the benchmark solution, we have

$$
E(\Pi_s^*) - [E(\Pi_R^*) + E(\Pi_V^*)]
$$

$$
= \frac{(c' - c)[(2 - \theta)(2A - c - c') + E(2\tilde{A} - c - c')]}{(3 - \theta)^2}
$$

$$
- \frac{2(A - c')(c' - c)}{3 - \theta}
$$

$$
= \frac{(c' - c)[(2A - c - c') - 2(A - c')]}{3 - \theta} = \frac{(c' - c)^2}{3 - \theta} \geq 0.
$$

Therefore, we know that with any wholesale price $c' > c$, the channel's total expected profit is less than the maximum system expected profit $E(\Pi_s^*)$. If $c' = c$, the channel's total expected profit is equal to $E(\Pi_s^*)$. Now we let c_1 and c_2 denote the two wholesale prices used in the first and the second period, respectively. Backward induction yields the following optimal solution:

$$
q_1^* = \frac{(\theta - 1)(A - c_2) + 2(A - c_1)}{(\theta + 1)(3 - \theta)}, \qquad E(q_2^*) = \frac{A - c_2 + (\theta - 1)q_1^*}{2}.
$$

To achieve $E(\Pi_s^*) = E(\Pi_R^*) + E(\Pi_V^*)$, the following group of equations must be satisfied:

$$\begin{cases} \dfrac{(\theta-1)(A-c_2)+2(A-c_1)}{(\theta+1)(3-\theta)} = \dfrac{A-c_1}{3-\theta}, \\[2mm] \dfrac{A-c_2+(\theta-1)q_1^*}{2} = \dfrac{A-c_1}{3-\theta}. \end{cases}$$

Solving it yields $c = c_1 = c_2$. Therefore, the channel's total expected profit is still less than the maximum system expected profit $E(\Pi_s^*)$ when two different wholesale prices are used in the two periods.

Revenue-Sharing Contracting

Consider the following revenue-sharing contracts: The retailer shares the distribution channel revenue with the technology vendor. Let $\alpha \in (0, 1)$ be the fraction of revenue the retailer keeps. The technology vendor earns $1 - \alpha$ of the revenue and also charges the retailer αc per unit purchased. Note that the contract becomes the unit-cost wholesale price contract if we allow $\alpha = 1$. The retailer's objective function in the second period given $\tilde{A} = \hat{A}$ is

$$\max_{q_2} \alpha[\hat{A} + (\theta-1)q_1 - q_2 - c]q_2.$$

This concave function is maximized at $q_2^* = [\hat{A} - c + (\theta-1)q_1]/2$. Therefore, for any $\alpha \in (0, 1]$, we have $E(\Pi_s^*) = E(\Pi_R^*) + E(\Pi_V^*)$. Because $\alpha E(\Pi_s^*) = E(\Pi_R^*)$, we know that for arbitrary bargaining positions (assume the existence of the disagreement point that allows both firms to walk away without losing anything if they fail to reach an agreement) the two firms can agree upon a revenue-sharing contract that splits the surplus with some α (to be precise we need to include the degenerated revenue-sharing contract with $\alpha = 0$).

For any above-cost wholesale price contract or the more general two-price contract described above, we know $E(\Pi_s^*) > E(\Pi_R^*) + E(\Pi_V^*)$. Therefore, it must be Pareto-dominated by a continuum (α^L, α^H) of revenue-sharing contracts where $0 < \alpha^L < \alpha^H < 1$.

PROOF OF PROPOSITION 1. Without knowing θ in the first period, the retailer has to maximize his expected profit based upon his prior ρ and the wholesale price $c' > c$. His second-period profit is maximized at $q_2^* = [\hat{A} - c' + (\theta-1)q_1]/2$ given $\tilde{A} = \hat{A}$, and the optimization problem in the first period thus becomes

$$\max_{q_1} (A - c' - q_1)q_1 + \frac{q_1^2}{4}E(\theta-1)^2 + \frac{q_1}{2}[E(\theta)-1](A-c')$$
$$+ \frac{1}{4}\int_{\underline{A}}^{\bar{A}} [\tilde{A}-c']^2 f(\tilde{A})\,d\tilde{A}.$$

It is easy to find that the second-order derivative is still negative, so the optimal first-period sale is

$$q_1^* = \frac{[E(\theta)+1](A-c')}{4-E(\theta-1)^2} = \frac{[\rho\theta^H+(1-\rho)\theta^L+1](A-c')}{4-\rho(\theta^H-1)^2-(1-\rho)(\theta^L-1)^2}.$$

Therefore, we have $\partial q_1^*/\partial\rho > 0$. In addition, we know $\partial E(q_2^*)/\partial\rho > 0$ and $E(\Pi_V^*) = (c'-c)[q_1^* + E(q_2^*)]$, so we have $\partial E(\Pi_V^*)/\partial\rho > 0$. Thus, for any prior and above-cost wholesale price, the technology vendor always wants to inflate

the retailer's belief of θ through cheap talk. Knowing the vendor's incentive to misinform him, a rational retailer will disregard the vendor's message in equilibrium. Q.E.D.

PROOF OF PROPOSITION 2. Consider the revenue-sharing contracts discussed in this appendix. The "truth-telling and trust" equilibrium seems intuitive given $E(\Pi_V)/E(\Pi_R) = (1-\alpha)/\alpha$. Specifically, we need to prove that both firms have no incentive to deviate from their equilibrium cheap-talk strategies if they believe that the other party will play the equilibrium strategy.

Suppose that the vendor knows the retailer will always trust her under revenue-sharing contracts; she will not want to lie. The reason is, if she lies, the retailer will make an inaccurate pricing decision in the first period and thus earn a suboptimal profit, which will reduce the vendor's profit because $E(\Pi_V)/E(\Pi_R) = (1-\alpha)/\alpha$. (Note that this fixed fraction does not depend on truthful information transmission because all revenue-sharing-relevant parameters like the unit cost are common knowledge in our model.) By the same reasoning, we can show that the retailer does not have any incentive not to trust the vendor (and make his pricing decision accordingly) if he knows that the vendor will tell him the truth. Q.E.D.

PROOF OF PROPOSITION 3. Denote ρ_R as the retailer's prior. Proposition 1 suggests that

$$q_1^* = \frac{[E(\theta)+1](A-c')}{4-E(\theta-1)^2} = \frac{[\rho_R\theta^H+(1-\rho_R)\theta^L+1](A-c')}{4-\rho_R(\theta^H-1)^2-(1-\rho_R)(\theta^L-1)^2},$$

and we thus have $\partial q_1^*/\partial\rho_R > 0$. In addition, we know that the vendor's prior matters with imperfect information. Because

$$E(q_2^*, \eta_V) = \frac{A-c'+[\eta_V(\theta^H-1)+(1-\eta_V)(\theta^L-1)]q_1^*}{2},$$

where η_V is the vendor's posterior, and $E(\Pi_V^*, \eta_V) = (c'-c)\cdot[q_1^* + E(q_2^*, \eta_V)]$, we have $\partial E(\Pi_V^*, \eta_V)/\partial\rho_R > 0$. Therefore, the better-informed technology vendor always wants to inflate the retailer's prior of θ. Her intention to misinform the retailer does not depend on her prior nor whether or not her knowledge of θ is imperfect. Information blockage still exits in equilibrium. Q.E.D.

PROOF OF PROPOSITION 4. Consider the revenue-sharing contracts discussed in this appendix. The "truth-telling and trust" equilibrium described in Proposition 2 still seems reasonable here given $E(\Pi_V)/E(\Pi_R) = (1-\alpha)/\alpha$. (This equation still holds because the two firms have common priors and they both use Bayesian updating to generate their posteriors.) The argument we used in the proof of Proposition 2 shows that this equilibrium cheap-talk strategy is mutually beneficial and no party can gain with unilateral deviation. Q.E.D.

PROOF OF LEMMA 5. Under revenue-sharing contracts, as discussed above, the retailer's optimization problem in the first period can be derived by backward induction as (α is ignored in the proof when it is irrelevant)

$$\max_{q_1} (A - c - q_1)q_1 + \frac{q_1^2}{4}E_R(\theta-1)^2 + \frac{q_1}{2}[E_R(\theta)-1](A-c)$$
$$+ \frac{1}{4}\int_{\underline{A}}^{\bar{A}} [\tilde{A}-c]^2 f(\tilde{A})\,d\tilde{A}.$$

Because we consider different priors, we use $E_R(\cdot)$ to denote expectations with respect to the retailer's belief. Therefore, if the retailer does not receive any signal from the vendor, he sets his optimal first-period sale at

$$q_1^*(\rho_R) = \frac{[E_R(\theta)+1](A-c)}{4 - E_R(\theta-1)^2}$$

$$= \frac{[\rho_R\theta^H + (1-\rho_R)\theta^L + 1](A-c)}{4 - \rho_R(\theta^H-1)^2 - (1-\rho_R)(\theta^L-1)^2},$$

so we have $\partial q_1^*/\partial \rho_R > 0$. The vendor's expected profit function based upon her posterior can be derived as

$$E_V[q_1^*(\rho_R), \eta_V]$$

$$= (A - c - q_1^*)q_1^* + \left(\frac{q_1^*}{2}\right)^2 [\eta_V(\theta^H-1)^2 + (1-\eta_V)(\theta^L-1)^2]$$

$$+ \frac{q_1^*}{2}[\eta_V\theta^H + (1-\eta_V)\theta^L - 1](A-c) + \frac{1}{4}\int_{\underline{A}}^{\bar{A}}[\tilde{A}-c]^2 f(\tilde{A}) d\tilde{A}.$$

Note that her expected profit function is a concave quadratic function of q_1^*. We first prove property (ii). Given the following Bayesian updating equations

$$\eta^{S=\theta^H} = \Pr(\theta = \theta^H \mid S = \theta^H) = \frac{(1+\lambda)\rho}{2\rho\lambda - \lambda + 1},$$

$$\eta^{S=\theta^L} = \Pr(\theta = \theta^H \mid S = \theta^L) = 1 - \frac{(1+\lambda)(1-\rho)}{\lambda - 2\rho\lambda + 1},$$

we have $\lim_{\rho\to 1}\eta^{S=\theta^L} = 1$ and $\partial\eta^{S=\theta^L}/\partial\rho > 0$. Therefore, for any given $\rho_V \in (0, 1)$, there is a threshold m that satisfies $\eta_R^{S=\theta^L}(m) = \eta_V^{S=\theta^H}(m)$ and $\eta_R^{S=\theta^L} > \eta_V^{S=\theta^H}$ for all $\rho_R > m$. Under this condition, the vendor always wants to reduce the retailer's posterior because $\partial q_1^*/\partial\rho_R > 0$, and her expected profit function is a concave quadratic function of q_1^*. Therefore, she cannot credibly report her signal S to the retailer when $\rho_R \geq m$, because in equilibrium he will not believe what she reports due to conflicting incentives. The proof of property (iii) is similar. Bayesian updating equations suggest that, for any given $\rho_V \in (0, 1)$, there is a threshold n that satisfies $\eta_R^{S=\theta^H}(n) = \eta_V^{S=\theta^L}(n)$ and $\eta_V^{S=\theta^L} > \eta_R^{S=\theta^H}$ for all $\rho_R < n$. It is easy to see that the vendor always wants to inflate the retailer's posterior through cheap talk under this condition. Therefore, credible information transmission is also blocked.   Q.E.D.

PROOF OF PROPOSITION 6. We first consider the case where $\rho_R > \rho_V$. If the vendor receives a signal $S = \theta^L$, she will always tell the retailer her true signal θ^L. To see this, recall from Lemma 5 that $\partial q_1^*/\partial\rho_R > 0$, and the vendor's expected profit is a concave quadratic function of q_1^*. Therefore, for all $\rho_R > \eta_V^{S=\theta^L}$ we have $\partial E_V[q_1^*(\rho_R), \eta_V]/\partial\rho_R < 0$. The vendor has no incentive to misinform the retailer because in this case $\eta_R^{S=\theta^H} > \rho_R > \eta_R^{S=\theta^L} > \eta_V^{S=\theta^L}$. If she receives a signal $S = \theta^H$, she may not want to tell the retailer her true signal θ^H. Lemma 5 has shown that cheap talk will be blocked when $\eta_R^{S=\theta^L} \geq \eta_V^{S=\theta^H}$. However, we always have $\eta_R^{S=\theta^H} > \eta_V^{S=\theta^H} > \eta_R^{S=\theta^L}$ when ρ_R is sufficiently close to ρ_V (note that this means $\rho_R - \rho_V < m$). Define $G(\rho_R - \rho_V) = E_V[q_1^*(\eta_R^{S=\theta^H}), \eta_V^{S=\theta^H}] - E_V[q_1^*(\eta_R^{S=\theta^L}), \eta_V^{S=\theta^H}]$. This function is continuous and monotonically decreasing in $\rho_R - \rho_V$ when $\rho_R - \rho_V \in [0, m]$. Because $G(0) > 0$ and $G(m) < 0$, we know

that there is an $m' < m$ that satisfies $G(m') = 0$. When $m' > \rho_R > \rho_V$, there is a "truth-telling and trust" equilibrium as described in Propositions 2 and 4. When $\rho_R \geq m' > \rho_V$, the vendor always has incentives to misinform the retailer and the retailer knows that, which makes credible cheap talk impossible.

Next we consider the case where $\rho_R < \rho_V$. Similarly, it is easy to see that the vendor will truthfully report her signal to the retailer when $S = \theta^H$. When $S = \theta^L$, define $W(\rho_V - \rho_R) = E_V[q_1^*(\eta_R^{S=\theta^L}), \eta_V^{S=\theta^L}] - E_V[q_1^*(\eta_R^{S=\theta^H}), \eta_V^{S=\theta^L}]$. This function is continuous and monotonically decreasing in $\rho_V - \rho_R$ when $\rho_V - \rho_R \in [0, \rho_V - n]$. Because $W(0) > 0$ and $W(\rho_V - n) < 0$, we know that there is an $n' > n$ that satisfies $W(\rho_V - n') = 0$. Combining both cases and Proposition 4, we know that for a given $\rho_V \in (0, 1)$ there are two thresholds $m'(\rho_V, \lambda)$ and $n'(\rho_V, \lambda)$ with the following two properties: (i) $n < n' < \rho_V < m' < m$; (ii) credible cheap talk is only possible when $\rho_R \in (n', m')$.   Q.E.D.

PROOF OF COROLLARY 7. Recall from Lemma 5 that the vendor's expected profit is a concave quadratic function of q_1^*, so the equilibrium equation for $\rho = m'(\lambda)$ is

$$2q_1^*[\eta_V^{S=\theta^H}(\lambda)] = q_1^*[\eta_R^{S=\theta^H}(\rho, \lambda)] + q_1^*[\eta_R^{S=\theta^L}(\rho, \lambda)].$$

Differentiating the equation totally, we get

$$2\frac{\partial q_1^*}{\partial\eta}\frac{\partial\eta^{S=\theta^H}}{\partial\lambda} = \frac{\partial q_1^*}{\partial\eta}\left(\frac{\partial\eta^{S=\theta^H}}{\partial\rho}\frac{\partial m'}{\partial\lambda} + \frac{\partial\eta^{S=\theta^H}}{\partial\lambda}\right)$$

$$+ \frac{\partial q_1^*}{\partial\eta}\left(\frac{\partial\eta^{S=\theta^L}}{\partial\rho}\frac{\partial m'}{\partial\lambda} + \frac{\partial\eta^{S=\theta^L}}{\partial\lambda}\right).$$

Therefore, we have

$$\frac{\partial m'}{\partial\lambda}\left(\frac{\partial\eta^{S=\theta^H}}{\partial\rho} + \frac{\partial\eta^{S=\theta^L}}{\partial\rho}\right) = \frac{\partial\eta^{S=\theta^H}}{\partial\lambda} - \frac{\partial\eta^{S=\theta^L}}{\partial\lambda}.$$

Because $\partial\eta^{S=\theta^H}/\partial\rho > 0, \partial\eta^{S=\theta^L}/\partial\rho > 0, \partial\eta^{S=\theta^H}/\partial\lambda > 0$, and $\partial\eta^{S=\theta^L}/\partial\lambda < 0$, we know $\partial m'/\partial\lambda > 0$. Similarly, the equilibrium equation for $\rho = n'(\lambda)$ is

$$2q_1^*[\eta_V^{S=\theta^L}(\lambda)] = q_1^*[\eta_R^{S=\theta^H}(\rho, \lambda)] + q_1^*[\eta_R^{S=\theta^L}(\rho, \lambda)].$$

Total differentiation and rearrangement yield

$$\frac{\partial n'}{\partial\lambda}\left(\frac{\partial\eta^{S=\theta^H}}{\partial\rho} + \frac{\partial\eta^{S=\theta^L}}{\partial\rho}\right) = \frac{\partial\eta^{S=\theta^L}}{\partial\lambda} - \frac{\partial\eta^{S=\theta^H}}{\partial\lambda},$$

so we have $\partial n'/\partial\lambda < 0$.

For properties (ii) and (iii), we only give the proof for the case of m'. The proof for the case of n' is very similar and thus omitted here. First notice that $\lim_{\lambda\to 1}\eta_V^{S=\theta^H} = \lim_{\lambda\to 1}\eta_R^{S=\theta^H}(m') = 1$. Therefore, $\partial q_1^*/\partial\rho_R > 0$ and the equilibrium equation for $\rho = m'(\lambda)$ suggest that $\lim_{\lambda\to 1}\eta_R^{S=\theta^L}(m') = 1$ (note that this result seems counterintuitive, but remember that m' also depends on λ). Because $m' > \eta_R^{S=\theta^L}(m')$, we prove $\lim_{\lambda\to 1}m' = 1$. Next notice that $\lim_{\lambda\to 0}\eta_V^{S=\theta^H} = \lim_{\lambda\to 0}\eta_R^{S=\theta^L}(m) = \rho_V$ and $\lim_{\lambda\to 0}m = \lim_{\lambda\to 0}\eta_R^{S=\theta^L}(m)$. We know $\lim_{\lambda\to 0}m' = \rho_V$ because $\rho_V < m' < m$.   Q.E.D.

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