Public Forecast Information Sharing in a Market with Competing Supply Chains

Abstract

Studying the operational motivation of a retailer to publicly announce his forecast information, this paper shows that by making forecast information publicly available to both his manufacturer and to the competitor, a retailer is able to credibly share his forecast information – an outcome that cannot be achieved by merely exchanging information within the supply chain. We model a market comprised of an incumbent supply chain facing the possible entry of a competing supply chain. In each supply chain, a retailer sources the product from a manufacturer, and the manufacturers must secure capacity prior to the beginning of the selling season. Due to the superior knowledge of the incumbent retailer about the consumer market, he privately observes a signal about the consumer's demand which may be high or low. We first confirm that the retailer cannot credibly share this forecast information only with his manufacturer within the supply chain, since regardless of the observed signal, the retailer has an incentive to inflate in order to induce the manufacturer to secure a high capacity level. However, when the information is also shared with the competitor, the incumbent retailer faces the trade-off between the desire to secure an ample capacity level and the fear of intense competition. By making information publicly available, it is possible to achieve truthful information sharing; an incumbent retailer observing a high forecast benefits from the increased capacity level to such an extent that he is willing to engage in intense competition to prove his accountability for the shared information. On the other hand, an incumbent retailer with a low forecast is not willing to engage in intense competition in exchange for the high level of capacity; thus, he truthfully reveals his low forecast to weaken competition. Moreover, we demonstrate that this public information sharing can benefit all the firms in the market as well as consumers. In addition, we show that compared to the advance purchase contract, all the firms except the incumbent manufacturer can be better-off using public information sharing under a simple wholesale price contract.

1 Introduction

Firms often decide to make some of their private forecast information publicly available. For example, in June 2012, Boeing released its 48th year Market Outlook.[1] In this report, Boeing forecasts more than $4 trillion market for new aircraft over the next 20 years with a significant increase in forecast deliveries. The topic of public disclosure of private information has received considerable attention in accounting (see, for example, Dye 1998 and 2001, Evans and Sridharan 2002), finance (Fishman and Hagerty 1995 and 2003), and marketing (Zhou and Zhu 2010). Although Boeing states that the purpose of the Market Outlook is also to help its ***suppliers*** to make informed decisions, little attention has been devoted thus far to the ***operational*** implications and firms' incentives in making private forecast information publicly available. Focusing on a firm's incentive to publicly share forecast information in an operational context, we pose the following question: what are a retailer's operational incentives to make forecast information available to all parties in the market, including potential competitors, as opposed to sharing information only with his manufacturer within the supply chain?

Although firms have implemented this method of public forecast sharing, the motivation to publicly reveal proprietary forecast information is not clear; when optimistic information about the future demand is shared, a potential entrant might update his beliefs about the market potential and consequently enter the market or increase the production level (Eliashberg and Robertson 1988, Robertson et al. 1995 and Kohli 1999). For example, in the market for mass disk storage systems, public announcement of optimistic market information provided by Storage Technology Corp. encouraged rival EMC to develop a similar product (Mohr et al. 2010). On the other hand, firms sometimes provide pessimistic forecast that results in weakened competition. Network equipment manufacturer, Aleton WebSystems Inc. revealed its production plans in order to deter its competitors from entering the same market (Mohr et al. 2010). In the latter case, the intriguing question is what is the credibility of these announcements, and under which conditions competitors may react to such announcements by leaving the market.

In this work, we present an analytical model that explains the motivation to publicly share information. We show that a retailer may voluntarily choose to share his forecast information publicly as a method to convey the credibility of the shared information and induce the manufacturer to invest in the appropriate capacity level. When the retailer is endowed with an optimistic forecast about the future demand, he is able to credibly share his private forecast information with the manufacturer and encourage the latter to set a high capacity level, by also sharing this information with a competing supply chain and incurring the cost of intensified competition. The outcome of increased capacity level cannot be achieved by merely sharing information within the supply chain by means of "cheap-talk", but it is the cost of intensified competition that makes the retailer being perceived as accountable for the shared information. We also explore the case in which the retailer is endowed with a pessimistic demand forecast. In this case, he is able to weaken competition by sharing his information publicly and incurring the cost of reduced capacity.

The value of information sharing within a supply chain has been a well-researched topic in operations management. Such research has emphasized its impact on operational effectiveness, such as improved inventory control, the alleviation of the bullwhip effect, and a better match of supply with demand (see Chen 2003 for an excellent survey). However, in spite of the clear benefits of information sharing within a supply chain, when the supply chain is comprised of independent profit-maximizing firms, their incentives

[1] See http://www.boeing.com/boeing/commercial/cmo/

for information sharing are often misaligned; that is, a firm within the supply chain can be worse-off sharing information truthfully than by misleading the other firms. In this case, firms may manipulate their forecast information opportunistically. This opportunistic forecast manipulation has been observed in many industries, including telecommunications, commercial aircraft, defense systems, and automotive industries (Cohen et al. 2003 and Oh and Ozer 2012). Aware of these incentives for forecast manipulation, firms that receive the information may not fully take the information provided by their partners into account, which can result in no information sharing at all. However, despite these incentives for information manipulation, empirical evidence suggests that firms are able to exchange information by informal talk and by using simple contracts such as the wholesale price contract (Arrow 1985, Desai and Srinivasan 1995, Bajari and Tadelis 2001, Iyer and Villas-Boas 2003, Cohen et al. 2003).

This paper studies how and when forecast information can be shared in a credible manner via informal talk under a simple wholesale price contract, by highlighting the role of making the information publicly available. We analyze a market with an incumbent supply chain, consisting of a retailer sourcing from a single manufacturer. The incumbent supply chain is facing possible entry into the market by a second supply chain, also comprised of a retailer and his manufacturer. Since the incumbent retailer has already been operating in the consumer market, he is able to privately observe a binary signal about uncertain consumer demand. The manufacturer must invest in capacity prior to observing the actual demand, and the private information observed by the retailer can guide the manufacturer in setting the appropriate capacity level. We first examine the ability of the incumbent retailer to share his forecast information with only his manufacturer, and demonstrate that meaningful information cannot be shared within the supply chain via informal communication, due to the retailer's incentive to inflate his forecast to induce the manufacturer to increase the capacity level (Ozer and Wei 2006).

As an alternative to the option of sharing information within the supply chain, we evaluate the implications of publicly announcing the demand forecast of the incumbent retailer. We show that when the forecast information is announced in this way, surprisingly, unverifiable forecast information can be shared truthfully via informal talk. By making forecast information publicly available when the market signal is good, the incumbent retailer can induce the incumbent manufacturer to build larger capacity, which benefits the retailer. However, it must also result in intensified competition level, which can hurt the incumbent retailer. This negative effect of the competition from the entrant can result in the incumbent retailer's information sharing being credible, and consequently in the truthful information sharing.

Specifically, we focus on two effects that arise when information is shared publicly: the capacity effect and the competition effect. The capacity effect describes the way in which the *manufacturer* updates her belief about the market condition and invests in a capacity level appropriate to the forecast information provided by the incumbent retailer. The competition effect describes the way in which the *entrant* retailer updates his belief about the attractiveness of the market and the production decision based on the shared information. When information is shared within the supply chain, the only effect is the capacity effect, which benefits the incumbent retailer regardless of the actual observed signal. As a result, the incumbent retailer cannot credibly share information within the supply chain. However, when information is shared publicly, both the capacity effect and the competition effect are present; the capacity effect incentivizes the retailer to inflate his forecast, whereas the competition effect incentivizes him to deflate his forecast. We characterize the conditions that guarantee truthful information sharing by making information publicly available. We find that a retailer who observes a high signal regarding the consumer market demand may engage in intensified competition.

In order to study the attractiveness of the option of publicly sharing forecast information as a mechanism to encourage the manufacturer to invest in the appropriate capacity level, we analyze another well-established option available to the incumbent retailer to share information with his manufacturer: the advance purchase contract. In this contract, the incumbent retailer commits in advance to purchase a minimum quantity regardless of the market realization. We compare the option of the incumbent retailer to share information by using the advance purchase commitment and his option to share information publicly, and demonstrate that when the signal accuracy is low, the retailer prefers to share information publicly rather than committing to purchase in advance.

2 Literature Review

Chen (2003) provides a detailed survey of the numerous benefits that firms can gain from sharing information among supply-chain members. Some of these benefits include the alleviation of the bullwhip effect, better matching of supply and demand and reduced inventory and capacity costs (Lee and Whang 2000, Toktay and Wein 2001, Aviv 2003 and Ozer 2003). However, most research in this stream does not consider strategic issues in information sharing within supply chains. Research in information sharing in a strategic context in supply chains can be classified into three categories depending on the supply-chain structure: (i) vertical information sharing between an informed and a less–informed party within a one-to-one supply chain; (ii) vertical and horizontal information sharing or information leakage within a supply chain with competition; and (iii) information sharing in a market with competing supply chains.

Vertical Information Sharing Within a One-to-One Supply Chain: The work in this stream of research focuses on vertical information sharing within a supply chain comprised of one upstream firm and one downstream firm. In order to overcome the problem of sharing information truthfully, researchers suggested employing sophisticated contracts, which include either a screening mechanism or a signaling game. In a screening mechanism, an uninformed firm moves first and designs a menu of contracts to offer to an informed firm within the supply chain. By choosing a specific contract from the well-designed menu of contracts, the informed party reveals its private information truthfully. Specifically, the private information can be the buyer's marginal cost (Ha 2001), the downstream retailer's holding-cost (Corbett and de Groote 2000), and the buyer's market size (Porteus and Whang 1999). In a signaling game, the firm with the superior information in the supply chain takes an action first, which conveys information to the uninformed party. In the operations management literature, Cachon and Lariviere (2001) study a signaling game, in which the manufacturer moves first by offering a commitment contract to the supplier. They demonstrate that this contract enables the manufacturer to reveal his private information truthfully; consequently, the supplier builds the capacity based on this information.

Although the above sophisticated mechanisms can align the incentives of the firms to share information truthfully, in reality, it has been observed that most of the information exchange is conducted voluntarily via informal communication without using the sophisticated mechanisms (Arrow 1985, Desai and Srinivasan 1995, Bajari and Tadelis 2001, Iyer and Villas-Boas 2003). As a result, researchers have studied alternative explanations of how independent firms can share information under a simple contract, such as the wholesale pricing, by means of "cheap talk."[2] Ren et al. (2010) analyze the effect of repeated interaction between firms

[2] *Cheap Talk* is defined as communication between the players of the game that has no direct effect on the players' payoffs (Crawford and Sobel 1982).

in the supply chain on the incentives to share information truthfully. Ozer et al. (2011) study the effect of trust and trustworthiness on the ability to share information by means of cheap talk. Finally, Chu et al. (2015) demonstrate that when a manufacturer takes multiple actions (setting capacity and a wholesale price) based on the received information from the retailer, truthful information sharing can be achieved in equilibrium. This paper adds to this line of work by offering a new mechanism for sharing information between a retailer and his manufacturer via informal talk under a simple wholesale price contract; in our case, the retailer, endowed with superior information, is able to achieve truthful information sharing with his manufacturer by sharing the information with the competing supply chain.

This paper is also related to the literature about the advance purchase contract. This paper suggests that a retailer can induce his manufacturer to invest in an ample capacity level by sharing information publicly, and we compare the performance of this setting to a scenario in which this result is achieved by using the advance purchase contract. A few papers, such as Cachon and Lariviere (2001), Cachon (2004), Ozer and Wei (2006) and Dong and Zhu (2007) examined the way the advance purchase contract influences the allocation of risk within the supply-chain and consequently the production quantity and supply-chain performance.

Information Sharing Within a Supply Chain With Competition: There has been great effort in the economics literature to study the incentives for horizontal information sharing between competing retailers (see, e.g., Li 1985, Gal-Or 1985 and 1986, Shapiro 1986, Raith 1996, Zhu 2004). This line of research adopts the perspective of the ex-ante incentives to share information. Li (2002), Zhang (2002) and Li and Zhang (2002) were among the first researchers to analyze the incentives to share information in a supply chain comprised of a single manufacturer selling to competing retailers. Li and Zhang (2008) study the effect of confidentiality on the incentives to share information in one-to-many supply chains, and Shin and Tunca (2010) explore the effect of auctions on information sharing. In addition, Anand and Goyal (2009) analyze the effect of information leakage on the incentives for information sharing and information acquisition with one upstream manufacturer and two competing downstream retailers. Kong et al. (2012) continue the work of Anand and Goyal (2009) to demonstrate that revenue-sharing contracts can solve the problem of information leakage. Shamir (2015) demonstrates how competing retailers can take advantage of information leakage in order to signal their private information to one another and establish a cartel. Shang et al. (2014) consider a many-to-one supply chain and demonstrate that a larger production diseconomies or more intense competition induces more information sharing within a supply chain. Our work reveals the role of horizontal competition of supply chains in achieving truthful information sharing between a retailer and his manufacturer.

Information Sharing Under Competing Supply Chains: Finally, this paper contributes to the recent literature on information sharing in a market with competing supply chains. Ha and Tong (2008) and Ha et al. (2011) analyze this framework to study incentives for information sharing within a supply chain, when a supply chain faces competition from another supply chain. We also study a setting in which one supply chain faces possible competition from an entrant supply chain. As opposed to Ha and Tong (2008) and Ha et al. (2011) who study the incentives for information sharing within a supply chain, we demonstrate that there are cases in which information can be shared between the supply chains. In addition, Zhou and Zhu (2010) study the effect of information transparency in a market in which both the retailers and the manufacturers face competition, and Guo et al. (2014) study information sharing issues in competing supply chains. One key difference between our paper and the above-mentioned papers is that we relax the assumption of truth-telling and allow the retailer to manipulate the shared information. We demonstrate that under this relaxed assumption, competition enables information sharing, which, in turn, can benefit all the parties within the supply chain.

While this paper is the first, to the best of our knowledge, that examines how public disclosure of information affects operational decisions of firms such as capacity investment, the study of public disclosure has received considerable attention in the fields of accounting and marketing. In accounting, Diamond (1985), Bushman (1991), Lundholm (1991), Alles and Lundholm (1993), Dye (1998), Fishman and Hagerty (1995), and Fishman and Hagerty (2003) examined the issue of public disclosure of information. An extensive survey of the literature in accounting about this topic can be found in Verrecchia (2001) and Dye (2001). In marketing, most of the research in this area is related to product development and product introduction. Researchers have examined the effect of announcing future introduction of new products on the ability to receive information from the customers (Mishra and Bhabra 2001), the effect on the existing products (Lee and O'Connor 2003), the effect on the competition (Rabino and Moore 1989, Robertson et al. 1995, Chesbrough and Schwartz 2007) and the effect on the firm's value (Chaney et al. 1991). In a recent paper, Ofek and Turut (2013) study the strategic aspects of truthful announcement of product development when a firm needs to weigh the trade-off between stimulation of future demand and the fear that a competitor would use these announcements to develop a similar product. Our paper differs from that of Ofek and Turut (2013) in a few key dimensions: in our model the retailer weighs the trade-off between capacity investment and potential competition, while Ofek and Turut examine the tension between competition and consumer demand. In addition, in our model, the retailer has other potential ways to share information with the manufacturer (such as using the advance purchase contract), and we evaluate the attractiveness of the public information-sharing method compared with the alternative. In the model of Ofek and Turut, the only information sharing channel available to the firm is to publicly announce its development plans.

3 The Model

We study a market consisting of (potentially) two competing supply chains. Each supply chain is comprised of a manufacturer selling an identical product to a single retailer.[3] The first supply chain is already working in the relevant market; hence, we denote its retailer and manufacturer as the *incumbents;* consequently, we use the index I to refer to the participants of this supply chain. In the second supply chain, the retailer considers whether to enter this market, and we denote the retailer and the manufacturer of this supply chain as *entrants* and use the index E to refer to the participants of this supply chain. Before the beginning of the selling season, the entrant retailer must decide whether to enter the market or to stay out of the market. If the entrant retailer decides to enter the market, he incurs a fixed cost F, which captures the investment cost of entering a new market (we later, in Section 8, relax the assumption of positive entry cost and explore a model without this cost). We denote the entrant retailer's decision by $a_E \in \{In, Out\}$.

If the entrant retailer decides to enter the market, the retailers compete in a Cournot fashion; if the entrant retailer decides to stay out of the market, the incumbent retailer is the sole seller of the product.

[3]The choice to model a market consisting of two supply chains is motivated by the observation of Johnson and Pyke (2000): "managers in nearly every industry have begun to realize that competition in the 21st century will no longer be firm against firm, but supply chain against supply chain."

The inverse demand function is:

$$p(\theta, q_I, q_E, a_E) = \begin{cases} \theta - q_I - q_E & \text{if } a_E = In; \\ \theta - q_I & \text{if } a_E = Out. \end{cases}$$

The random variable θ captures the potential size of the market and influences the entry decision of the entrant retailer. It can take the value of θ_H or θ_L, where $\theta_H > \theta_L > 0$. Thus, θ_H represents a scenario in which the demand for the product is high, whereas θ_L represents a low demand for the product.[4] Before having had the opportunity to observe any additional information about the market potential, it is common knowledge that:

$$\theta = \begin{cases} \theta_H & \text{with probability } \mu; \\ \theta_L & \text{with probability } 1 - \mu. \end{cases}$$

Since the incumbent retailer is more familiar with the consumer market than the entrant or the manufacturers, he can obtain some information about the value of θ, prior to the beginning of the selling season. This information is captured by the signal s, which can take the value s_h or s_l with the following probability:

$$\Pr(s_h|\theta_H) = \rho, \text{ and } \Pr(s_l|\theta_L) = \rho,$$

for some $\rho > 0.5$. Therefore, the signal that the incumbent retailer observes is always informative about the true state of the market.

Due to the long lead time for capacity building, in anticipation of the selling season, each manufacturer must secure capacity level K_i, $i \in \{E, I\}$, prior to observing the actual demand. Both manufacturers have an identical constant marginal production cost captured by c, and they both sell each unit, up to their capacity constraint, to their respective retailer, for the price of w.[5] The wholesale price w and the production cost c are assumed to be exogenous.[6] We further assume that $w < \theta_L$, such that even in the low demand state, it is profitable to produce the good.

The incumbent retailer can observe the signal s prior to the entry decision of the entrant retailer and prior to the manufacturers setting the capacity level. After the capacity levels have been determined, but before the retailers set their quantities, the value of θ is observed by all of the firms in the market. Therefore, before the actual selling season, all uncertainty in the market has been resolved. Due to the proximity of the incumbent retailer to the market, he can receive the signal s earlier. However, when the retailers decide the quantities that will be sold in the market, the uncertainty on the value of θ has been resolved, and hence, the incumbent retailer does not have any superior information to the entrant retailer. This modeling assumption captures an important element in markets subject to potential entry - when a potential entrant

[4] The use of a binary random variable to denote the potential market size is a simplification of reality. However, the use of the binary random variable allows us to present a relatively simple analysis while highlighting the main insights of the model. Similar assumptions are commonly used in models with asymmetric information. See, for example, Cachon and Lariviere (2001), Ha and Tong (2008), Anand and Goyal (2009) and Chu et al. (2015). Furthermore, in Section 8, we study a more general demand distribution.

[5] The assumption of identical production cost can be relaxed without qualitatively altering the results of the paper. We present the results when this assumption is relaxed in Section 8.2.

[6] The use of exogenous wholesale price is common in models with an endogenous capacity level and asymmetric information. Ozer and Wei (2006), Anand and Goyal (2009) and Ozer et al. (2011) are a few examples that make a similar assumption and use an exogenous wholesale price. In other papers that adopt the assumption that the wholesale price is endogenously determined, the capacity is usually determined exogenously (Ha and Tong 2008). Chu et al. (2015) provide an analysis of a supply chain in which both the capacity level and the wholesale price are determined endogenously.

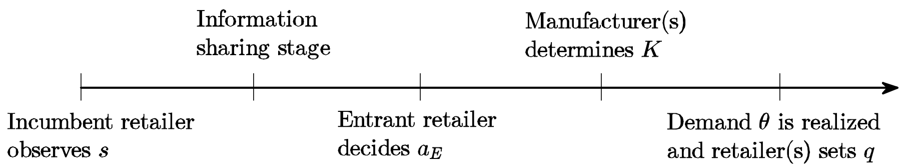

Figure 1: Sequence of Events

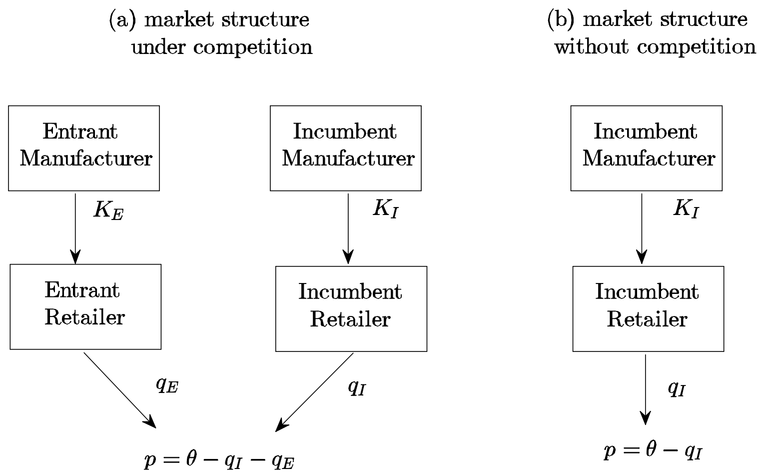

Figure 2: Market Structure: Panel (a) describes the market structure when the entrant retailer enters the market. Panel (b) presents the market structure when the entrant stays out of the market.

decides whether to enter a new market, he has inferior information compared to the firms that already operate in the market. This is modeled by the fact that the incumbent retailer can observe the signal s. However, once the entrant decides to join and compete in the new market and he invests in the necessary setup, the entrant retailer becomes more familiar with the market and the informational advantage of the incumbent fades away. We capture this aspect using the assumption that θ is observed by all the firms in the market before setting the sold quantities.

To be more explicit, the sequence of events is as follows: 1) The incumbent retailer observes the signal s. 2) Information is shared/not shared according to the different settings (explained below). 3) The entrant retailer decides whether to enter the market ($a_E = In$) or to stay out of the market ($a_E = Out$). 4) The incumbent manufacturer secures capacity K_I. If the entrant retailer chooses to enter the market, the entrant manufacturer also decides on her capacity level K_E. 5) Both retailers observe θ. If the entrant retailer chose to enter the market, both retailers choose the quantities q, i.e., q_I for the incumbent and q_E for the entrant. Otherwise, the incumbent retailer chooses the quantity q_I as a monopolist. Figure 1 also depicts the sequence of events in the model, and Figure 2 represents market structures for both cases of competition under entry and monopoly without entry. Note that under competition, each retailer orders from its own manufacturer as illustrated in panel (a) of Figure 2. When the incumbent retailer has more bargaining power, he may also order from the entrant manufacturer, which falls outside of the scope of this paper, but is an interesting future research to pursue.

The primary goal of this paper is to evaluate the incentives and ability of the incumbent retailer to share his private information with the different participants across the two supply chains. We focus on information sharing using cheap talk; that is, the incumbent retailer's private forecast information is neither contractible nor verifiable. Thus, the incumbent retailer can communicate this information only verbally, disclosing it to the different firms across the supply chains. In order to evaluate the ability and incentives of the incumbent retailer to share information, we compare three different settings: in the first scenario, denoted by $S1$, no information is shared between the incumbent retailer and the other firms in the market. This scenario serves as a benchmark for the performance of the firms in the market when no information is shared. In the second scenario, denoted by $S2$, we evaluate the possibility of the incumbent retailer to share information only with his manufacturer (i.e., information is shared only within the supply chain). Finally, in the third scenario, denoted by $S3$, the incumbent retailer shares his private information with all of the firms in the market (i.e., information is shared publicly).

When information is shared, since it is non-verifiable, upon observing s, the retailer decides to send a message m, which may differ from his observed value s. We denote the incumbent retailer's reporting strategy by $\sigma(s)$; that is, when the retailer observes the signal s, he reports the message $m = \sigma(s)$. When the other participants of the supply chain observe the incumbent retailer's message m, they also form a belief system about the value of s, conditional on the message m. The belief system is a probability measure, which we denote by μ_m.[7]

Upon observing θ, the incumbent manufacturer's capacity level K_I, the entry decision a_E of the competing retailer and the capacity of the competing manufacturer K_E, the incumbent retailer orders q_I units up to the capacity constraint of his manufacturer (K_I); the profit of the incumbent retailer is:

$$\pi_I(q_I|K_I, K_E, a_E, \theta) = (p(\theta, q_I, q_E, a_E) - w)\, q_I.$$

Denote by $q_I^*(K_I, K_E, a_E, \theta) \in \arg\max_{q_I \leq K_I} \pi_I(q_I|K_I, K_E, a_E, \theta)$ the optimal quantity of the incumbent retailer. Similarly, we denote the entrant retailer's profit in the following way:

$$\pi_E(q_E|K_E, K_I, a_E, \theta) = \begin{cases} (p(\theta, q_E, q_I, a_E) - w)\, q_E - F & \text{if } a_E = In; \\ 0 & \text{if } a_E = Out. \end{cases}$$

If the entrant retailer decides to enter the market, his profit is analogous to that of the incumbent retailer, except for the additional entry cost of F. We also denote by $q_E^*(K_E, K_I, a_E, \theta) \in \arg\max_{q_E} \pi_E(q_E|K_E, K_I, a_E, \theta)$ the optimal quantity decision of the entrant retailer when θ is known.

The incumbent manufacturer's profit in this market is denoted by:

$$\Pi_I(K_I|a_E) = q_I^*(K_I, K_E, a_E, \theta)w - cK_I.$$

The incumbent manufacturer must secure capacity prior to observing θ and based on his belief system μ_m. We denote the optimal capacity level of the incumbent manufacturer by $K_I^*(a_E) \in \arg\max_{K_I} E\,[\Pi_I(K_I|a_E)|\mu_m]$. The entrant manufacturer's profit is denoted by

$$\Pi_E(K_E|a_E) = \begin{cases} q_E^*(K_I, K_E, a_E, \theta)w - cK_E & \text{if } a_E = In; \\ 0 & \text{if } a_E = Out, \end{cases}$$

and the optimal capacity level of the entrant manufacturer is denoted by $K_E^*(a_E) \in \arg\max_{K_E} E\,[\Pi_E(K_E|a_E)|\mu_m]\,.$

As a solution concept to the model, we adopt the Perfect Bayesian Equilibrium, which is formally defined

[7] If information is not shared with a specific firm in the market, its belief system is identical to the prior belief.

as follows.

Definition 1 *(σ^*, a_E^*, K_I^*, K_E^*, q_I^*, q_E^*) defines a Perfect Bayesian Equilibrium if:*
(a) for a given a_E^*, K_I^*, K_E^*, and for a given q_j^*, $q_i^* \in \arg\max_{q_i \leq K_i} \pi_i(q_i|K_I, K_E, a_E, \theta)$ for $i \in \{E, I\}$, $i \neq j$.
(b) given σ^*, a_E^* and K_j^*, a manufacturer's capacity is determined, such that
$K_i^* \in \arg\max \ \ E[\Pi_i(K_i|a_E)|\mu_m]$ for $i \in \{E, I\}$, $i \neq j$.
(c) given σ^*, $a_E^* \in \arg\max_{a_E \in \{In, Out\}} \pi_E(q_E^*(a_E)|K_E^*(a_E), K_I^*(a_E), a_E, \theta)$.
(d) for any signal s, $\sigma^*(s) \in \arg\max_m \pi_I(q_I^*|K_I^*(m), K_E^*(m), a_E^*(m), \theta)$.
(e) if information is shared, the belief system of the recipients of the information μ_m is consistent; i.e., whenever possible, μ_m is updated using the Bayes' rule.

Definition 1 requires that within the sequence of the decisions made in this model, no firm has a unilateral profitable deviation from the strategy profile that determines the equilibrium. Condition (a) requires that given the entry decision and the capacity decisions of the manufacturers, both retailers choose the sold quantities that maximize their profit. Condition (b) suggests that given their available information, and the entry decision of the entrant retailer, both manufacturers determine the capacity level to maximize their profit. Condition (c) states that given his available information, the entrant retailer makes the entry decision to maximize his expected profit. Condition (d) implies that the incumbent retailer transmits the information strategically, taking the effect of his message on the entry and capacity decisions into account. Finally, condition (e) means that the belief of the recipients of the message is self-conforming. The recipients of the message update their belief using Bayes' rule given the incumbent retailer's equilibrium-reporting strategy.

Similar to other papers in the area of cheap-talk information sharing, we are interested in evaluating the degree to which information can be shared in equilibrium. We refer to an equilibrium in which the incumbent retailer always discloses his private information truthfully as an *informative equilibrium*. We define this equilibrium as follows:

Definition 2 *An **informative equilibrium** is an equilibrium (as defined in Definition 1) in which:*

$$\sigma^*(s) = s \text{ for every } s \in \{s_h, s_l\}.$$

In an informative equilibrium, the incumbent retailer finds it in his best interest to truthfully reveal his signal. In such an equilibrium, each recipient of the message uses this signal to update its belief about the status of the market. In an informative equilibrium, the recipient of the information updates its belief about the market condition in the following Bayesian manner:

$$\mu(s_i) = \Pr(\theta_H|s_i) = \begin{cases} \frac{\mu\rho}{\mu\rho + (1-\mu)(1-\rho)} & \text{if } s_i = s_h; \\ \frac{\mu(1-\rho)}{\mu(1-\rho)+(1-\mu)\rho} & \text{if } s_i = s_l. \end{cases}$$

Table 1 describes the information available to the different firms in the supply chain under the different settings we analyze.

4 Benchmark

This section is comprised of two parts; we first study, as a benchmark, the performance of the different firms when information is not shared. We then explore the possibility of the retailer to share information

	Incumbent Retailer	Incumbent Manufacturer	Entrant Supply Chain
Scenario $S1$	s	None	None
Scenario $S2$	s	m	None
Scenario $S3$	s	m	m

Table 1: Information available to the firms in the market in the different settings

within the supply chain.

4.1 Scenario $S1$: No-Information Sharing

We start our analysis assuming that no information is shared within the supply chain. Note that in this case, when information is not shared, the incumbent retailer has no advantage over the entrant retailer, if the latter decides to enter the market. The reason is that (i) in this setting, both manufacturers are endowed with the same information before setting their capacity levels; and (ii) prior to the retailers' decision about the sold quantities, all uncertainty in the market has been resolved. The next proposition provides a full characterization of the equilibrium under this setting.

Proposition 1 *There exist $F_1(\mu) > F_2(\mu)$, and $\overline{\mu}$ such that:*[8]
(a) If $F \geq F_1(\mu)$ or if $F_2(\mu) \leq F < F_1(\mu)$ and $\mu \leq \overline{\mu}$, then $a_E = out$ and

$$K_I = \begin{cases} \frac{\theta_H - w}{2} & \text{if } \mu \geq \overline{\mu}; \\ \frac{\theta_L - w}{2} & \text{if } \mu < \overline{\mu}; \end{cases}$$

(b) otherwise, $a_E = In$ and

$$K_I = K_E = \begin{cases} \frac{\theta_H - w}{3} & \text{if } \mu \geq \overline{\mu}; \\ \frac{\theta_L - w}{3} & \text{if } \mu < \overline{\mu}, \end{cases}$$

where $\overline{\mu} = c/w$,

$$F_1(\mu) = \mu\left(\frac{\theta_H - w}{3}\right)^2 + (1-\mu)\left(\frac{\theta_L - w}{3}\right)^2, \text{ and } F_2(\mu) = \mu\left(\theta_H - \frac{2\theta_L}{3} - \frac{w}{3}\right)\left(\frac{\theta_L - w}{3}\right) + (1-\mu)\left(\frac{\theta_L - w}{3}\right)^2.$$

This proposition presents two conditions that result in the potential entrant's decision not to enter the market. The first is that the entry costs are high, such that $F \geq F_1(\mu)$. $F_1(\mu)$ denotes the profit, excluding the entry cost, of the entrant retailer when he does not face capacity constraints. This condition suggests that even if the entrant retailer does not face any capacity constraints, the expected profit in the market does not recover his entry cost. The second condition ($F_2(\mu) \leq F < F_1(\mu)$ and $\mu \leq \overline{\mu}$) means that even when the entry costs are lower, if the prior belief that the market condition is high is relatively low (measured by $\mu < \overline{\mu} = \frac{c}{w}$), then the entrant decides to stay out of the market. The term $F_2(\mu)$ describes the profit, excluding entry cost, of the entrant retailer when he faces capacity constraints when the market demand is high. In this case, both manufacturers choose to invest in a low-capacity level, such that if the demand realization is high the retailers face capacity constraints. This capacity constraint lowers the entrant retailer's profit, which serves as a reason for the entrant retailer's decision to stay out of the market.

Note that when the entrant retailer stays out of the market, the incumbent manufacturer increases the capacity level from the low-monopoly level of $(\theta_L - w)/2$ to the high-monopoly level of $(\theta_H - w)/2$ if $\mu \geq \overline{\mu}$.

[8]Note that $(\theta_H - w)/(\theta_L - w) \geq 2$ implies $F_2 \leq F_1$.

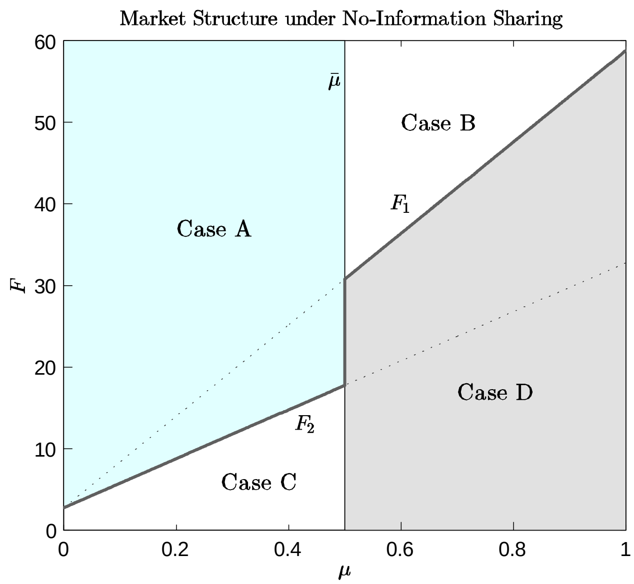

Figure 3: Possible market outcome when no information is shared as a function of the prior belief and the entry cost. Parameter values are: $\theta_H = 33$, $\theta_L = 15$, $w = 10$, $c = 5$, and $\rho = 0.8$.

For the same condition, i.e., $\mu \geq \overline{\mu}$, if the entrant retailer decides to join the market, both manufacturers invest in the high-capacity level of $(\theta_H - w)/3$ (this is the high-capacity level adjusted to a market with competition). If $\mu < \overline{\mu}$, both manufacturers invest in the low-capacity level of $(\theta_L - w)/3$ - this is the low-capacity level adjusted to the market with competition between the supply chains. We summarize the four possible market outcomes under the benchmark in Table 2 and Figure 3. Case A describes the situation in which the entrant decides to stay out of the market and the incumbent manufacturer invests in the low-capacity level, while Case B describes the same decision of the entrant but when the incumbent manufacturer invests in the high-capacity level. Cases C and D describe the situation in which the entrant enters the market. In case C, both manufacturers invest in the low-capacity level of $(\theta_L - w)/3$, while in case D the prior belief μ is high enough such that both manufacturers invest in the capacity level of $(\theta_H - w)/3$.

We assume that $F_1(\mu) > F_2(\mu)$; this condition is equivalent to the condition that $\theta_H + w - 2\theta_L > 0$ or that $\Psi < 2$. It implies that the retailers are better-off when they do not face capacity constraints when the market demand is high. If this condition is not met, the retailers actually prefer being constrained by the capacity set by the manufacturers. In the latter case, the capacity constraints limit the ability of the retailers to compete by increasing the production quantity, and, thus, it results in higher retail prices and profit. This case can occur when the value of information, captured by Ψ, is relatively low, and then the negative effect to the retailers of competition outweighs the positive effect of the capacity expansion. When this is the case, an incumbent retailer has the incentive to actually inflate the observed signal in order to deter competition – an outcome that is usually not observed in practice. Due to this reason and the fact that we focus on the incentives for information sharing, we assume, throughout the paper, that the value of information is high ($\Psi \geq 2$).

4.2 Scenario $S2$: Private Information Sharing Within the Supply Chain

We now turn to examine the ability of the incumbent retailer to share his information privately with his manufacturer. Upon observing the signal s_i, $i \in \{l, h\}$, the incumbent retailer sends a message $m_i \in$

Case	F	μ	K_I	K_E	**entry decision**
A	$F > F_2(\mu)$	$\mu < \overline{\mu}$	$(\theta_L - w)/2$	0	out
B	$F > F_1(\mu)$	$\mu \geq \overline{\mu}$	$(\theta_H - w)/2$	0	out
C	$F \leq F_2(\mu)$	$\mu < \overline{\mu}$	$(\theta_L - w)/3$	$(\theta_L - w)/3$	in
D	$F \leq F_1(\mu)$	$\mu \geq \overline{\mu}$	$(\theta_H - w)/3$	$(\theta_H - w)/3$	in

Table 2: Market Structure and Capacity Investment with no-Information Sharing

$\{m_l, m_h\}$ about the value of the signal s_i. The report of the retailer is neither enforceable nor verifiable ex-post due to the noisy nature of the market demand. In order to evaluate the incentives of the incumbent retailer to reveal the true value of his signal, we use the following function to denote the interim profit of the incumbent retailer upon observing the signal s_i, sending the message m_j and taking the updating strategy μ_m of the manufacturer into account:

$$V(s_i, m_j) = E[\pi_I | s_i, m_j, \mu_m]. \tag{1}$$

Since it is impossible to enforce the retailer to truthfully reveal his private information, an informative equilibrium can be achieved only if the retailer finds it in his best interest to truthfully reveal his information for any signal realization. In particular, it implies that a necessary condition for achieving an informative equilibrium is that:

$$V(s_i, m_i) \geq V(s_i, m_j) \text{ for every } i \in \{l, h\} \text{ and } j \neq i. \tag{2}$$

The conditions given in (2) represent the incentive compatibility constraints of the incumbent retailer. These conditions suggest that the incumbent retailer is better-off sharing the message m_i (which means that the retailer announces that he has received the signal s_i) when observing the signal s_i, for $i \in \{l, h\}$. The next proposition evaluates the ability of the incumbent retailer to share his private information when information is shared only within the supply chain.

Proposition 2 *Assume that the incumbent retailer shares the information only with the incumbent manufacturer. Then:*
(a) If $\mu(s_l) \geq \overline{\mu}$ or if $\mu(s_h) \leq \overline{\mu}$, an informative equilibrium exists.
(b) Otherwise, an informative equilibrium does not exist. The unique equilibrium is the babbling equilibrium.

Proposition 2 demonstrates in part (a) that there are cases in which an informative equilibrium exists when information is shared within the supply chain. However, it is important to observe that in these cases the manufacturer behaves as though no information had been shared; that is, an informative equilibrium exists only if the information does not alter the behavior of the manufacturer. Specifically, the condition $\mu(s_l) \geq \overline{\mu}$ implies that without receiving any information, the manufacturer decides to invest in the high-capacity level, and he will continue to do so even when he receives a message from the retailer that the observed signal is low. The condition $\mu(s_h) \leq \overline{\mu}$ represents the opposite case..

In order to focus on the interesting parameter region, we define meaningful information as information that changes the behavior of the recipient. If meaningful information is shared in equilibrium, we refer to this equilibrium as an *influential* equilibrium, i.e., an influential equilibrium is an informative equilibrium (as defined in Definition 2) in which the secured capacity level of the incumbent manufacturer K_I^* satisfies $K_I^* \neq$

K_I^{S1}.[9] In an influential equilibrium, the capacity-level decision of the incumbent manufacturer is different from the capacity level when information is not shared. Under this equilibrium, the incumbent retailer truthfully reveals his information, and following this information sharing, the incumbent manufacturer changes his capacity level compared with the one in scenario $S1$, when information is not shared.

Although part (a) provides a positive result, it actually emphasizes the difficulty of sharing meaningful information when the information is shared only within the supply chain by cheap talk. Part (b) complements part (a) by stating that an influential equilibrium cannot be achieved. To understand the intuition of this result, note that the profit of the retailer is (weakly) increasing with the capacity level secured by the manufacturer. As a result, the retailer finds it in his best interest to report m_h, even after observing the signal s_l in order to induce the manufacturer to invest in the higher capacity level. However, taking these incentives of the retailer to inflate his demand forecast into account, the manufacturer ignores all of the information provided by the retailer and acts as if no information had been shared. Therefore, Proposition 2 shows that when information is shared only within the supply chain, an influential equilibrium cannot be achieved by means of cheap talk. Similar results about the ability to share forecast information via informal talk within the supply chain (although in different settings) were obtained by Ozer and Wei (2006), Ozer et al. (2011) and Shamir (2012). Since we study the ability of the incumbent retailer to share meaningful information, we focus on the ability to achieve an influential equilibrium in the reminder of this paper.

5 Scenario $S3$: Public Information Sharing Equilibrium

So far we obtained a negative result, i.e., the inability of the incumbent retailer to communicate his information only with the manufacturer when the information can alter the manufacturer's behavior. This section analyzes the way in which the exposure of the competing supply chain to the shared information affects the ability of the incumbent retailer to truthfully share his private information.

We reveal that there are cases in which the incumbent retailer can achieve meaningful information sharing by making this information publicly available. We show how by intensifying the competition between the supply chains, the incumbent retailer, who observes the signal s_h, is perceived as being accountable for the shared information, and thus can induce the manufacturer to invest in the high-capacity level, solving the problem highlighted in Proposition 2. In addition, we show that in an influential equilibrium, an incumbent retailer who observes the signal s_l, is able to credibly deter the competing supply chain from entering the market by simultaneously reducing the capacity level of his manufacturer.

The following Lemma assists in analyzing the possible outcome of an influential equilibrium achieved by publicly sharing information.

Lemma 1 *In an influential equilibrium, achieved by publicly sharing information, the unique outcome is:*
(a) When the incumbent retailer announces s_h, the entrant supply chain decides to enter the market, and both manufacturers invest in the high-capacity level of $(\theta_H - w)/3$.
(b) When the incumbent retailer announces s_l, the entrant supply chain decides to stay out of the market, and the incumbent manufacturer invests in the low-capacity level of $(\theta_L - w)/2$.

Lemma 1 suggests that the unique outcome of an influential equilibrium, achieved by publicly sharing information, is that when an incumbent retailer announces that he observed the high signal, the entrant

[9] The terminology, an influential equilibrium, has been introduced in the previous literature to denote the same concept in different contexts, see, e.g., Austen-Smith (1994 and 1995), Levy and Razin (2007), Allon and Bassamboo (2011) and Allon et al. (2011).

supply chain operates in the market, and both manufacturers invest in the high-capacity level appropriate for this market structure. However, if a retailer observes the low signal, the entrant supply chain decides to stay out of the market and the incumbent manufacturer invests in the low-capacity level for a monopoly supply chain. The intuition behind this Lemma is that an incumbent retailer has an incentive to report s_h only if this announcement results in a high capacity-level investment carried by his manufacturer, and this retailer is perceived as credible only if his announcement is followed by intense competition of the competing supply chain. The second part of the Lemma suggests that an incumbent retailer may have an incentive to truthfully report s_l, only if this announcement weakens the competition of the entrant supply chain (in particular, this announcement results in the decision of the competing supply chain to stay out of the market), and this retailer is perceived as being accountable for the shared information only if this information also results in reduced capacity level of his manufacturer.

In order to achieve meaningful information sharing, a retailer who observes the high signal should be better-off revealing this information than mimicking the retailer who observes the low signal. Similarly, a retailer who observes the low signal should be better-off revealing this information rather than mimicking the high type retailer. Based on Lemma 1, these conditions can be written as:

$$\mu(s_h)\left(\frac{\theta_H - w}{3}\right)^2 + (1-\mu(s_h))\left(\frac{\theta_L - w}{3}\right)^2 \geq \mu(s_h)\left(\theta_H - \frac{\theta_L}{2} - \frac{w}{2}\right)\left(\frac{\theta_L - w}{2}\right) + (1-\mu(s_h))\left(\frac{\theta_L - w}{2}\right)^2; \tag{IC$_{hl}$}$$

$$\mu(s_l)\left(\theta_H - \frac{\theta_L}{2} - \frac{w}{2}\right)\left(\frac{\theta_L - w}{2}\right) + (1-\mu(s_l))\left(\frac{\theta_L - w}{2}\right)^2 \geq \mu(s_l)\left(\frac{\theta_H - w}{3}\right)^2 + (1-\mu(s_l))\left(\frac{\theta_L - w}{3}\right)^2. \tag{IC$_{lh}$}$$

The condition given in (IC$_{hl}$) represents the incentive compatibility constraint of an incumbent retailer who observes a high signal. The Left-Hand Side (LHS) denotes this retailer's expected profit when he reports truthfully that he observed the high signal, and the Right-Hand Side (RHS) represents this retailer's profit when he reports falsely that he observed the low signal. Note that when the retailer reports that he observed the high signal, he does not face capacity constraints when demand is high, but he does suffer from intense competition in the market. On the other hand, if the retailer reports that he observed the low signal, he does not suffer from competition since the entrant supply chain decides to stay out of the market, but he faces capacity constraints when demand is high. Similarly, condition (IC$_{lh}$) represents the incentive compatibility constraint of an incumbent retailer who observes the low signal. The LHS denotes this retailer's profit when he reports his signal truthfully, and the RHS denotes his profit when he mimics the announcement of a retailer who observes the high signal.

The following proposition demonstrates the difference between the inability of the incumbent retailer to share meaningful information by using "cheap talk" when this information is shared within the supply chain (as was demonstrated in Proposition 2), and the ability of this retailer to truthfully communicate his information when the information is available also to the competing supply chain.

Proposition 3 *Meaningful information sharing, can be achieved if and only if the following conditions are satisfied:*

(a)

$$\frac{1}{4}\left(9+\sqrt{5\left(9+\frac{(1-\mu)(1-\rho)}{\mu\rho}\right)}\right) \leq \Psi \leq \frac{1}{4}\left(9+\sqrt{5\left(9+\frac{(1-\mu)\rho}{\mu(1-\rho)}\right)}\right), \tag{3}$$

where $\Psi = \frac{\theta_H - w}{\theta_L - w}$. *Or, equivalently,*

$$\frac{\max\left((4\Psi^2 - 18\Psi + 9)\mu,\, 5(1-\mu)\right)}{(4\Psi^2 - 18\Psi + 9)\mu + 5(1-\mu)} \leq \rho\,. \tag{4}$$

(b) $F_2(s_l) < F \leq F_1(s_h)$ *and* $\mu(s_h) \geq \overline{\mu} > \mu(s_l)$, *where*

$$F_1(s_h) = \mu(s_h)\left(\frac{\theta_H - w}{3}\right)^2 + (1-\mu(s_h))\left(\frac{\theta_L - w}{3}\right)^2;$$
$$F_2(s_l) = \mu(s_l)\left(\theta_H - \frac{2\theta_L}{3} - \frac{w}{3}\right)\left(\frac{\theta_L - w}{3}\right) + (1-\mu(s_l))\left(\frac{\theta_L - w}{3}\right)^2.$$

Proposition 3 demonstrates the striking difference between the retailer's ability to credibly share his information when information is shared publicly with his competitor, and the inability to do so when information is shared only within the supply chain (as was demonstrated in Proposition 2). The proposition characterizes the necessary and sufficient conditions that guarantee a retailer to be able to share his information truthfully. Part (a) suggests that the ability to satisfy the incentive compatibility constraints of the incumbent retailer (given by conditions IC_{hl} and IC_{lh}) depends on two main factors: (*i*) the precision of the observed signal (ρ) and (*ii*) a measure of the market variability, i.e., the distance between the market conditions during high demand and low demand.

Part (a) shows that the precision of the incumbent's signal should be high in order to achieve meaningful information sharing. The precision of the observed signal influences the ability to reach the desired equilibrium in two ways. First, when the incumbent retailer observes the high signal, he knows that by sharing information publicly he intensifies competition to the market in exchange for his manufacturer being able to secure a higher capacity level. In the state of high demand, the benefit to the incumbent retailer from the high capacity outweighs the cost of intense competition. However, if the realized demand is low, the incumbent retailer incurs the competition cost without enjoying the ample capacity level. As a result, the incumbent retailer is willing to share information publicly only if he believes there is a high probability that the realized demand will be high, following the signal s_h. Second, the precision of the observed signal also affects the incentive constraint of a retailer who observes the low signal. A retailer who observes the low signal, has an incentive to mimic the high-type retailer and induce the manufacturer to secure a high-capacity level if he believes that there is a high probability that the market condition will be high. As a result, a high-precision level relaxes the incentive constraint of the low-type retailer and makes it easier to reach an influential equilibrium.

The second factor that affects the ability to reach meaningful information sharing is the measure of market variability, i.e., the distance between $\theta_H - w$ and $\theta_L - w$. As a measure of this distance we use the parameter $\Psi = \frac{\theta_H - w}{\theta_L - w}$. The parameter Ψ can be viewed as a proxy to the amount of uncertainty existing in the market.[10] When the incumbent retailer reports that he observed a high signal, he knows that in an

[10] A similar parameter was used by Anand and Goyal (2009) and Chu et al. (2015) as a proxy for the demand uncertainty.

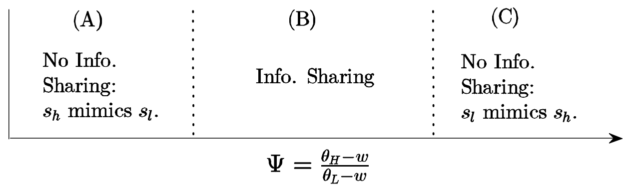

Figure 4: Influential information sharing equilibrium with respect to Ψ

influential equilibrium, it results in the entrant's decision leading to more intense competition, and the fact that his manufacturer will decide to invest in the higher capacity level. As discussed above, if the realized demand is low, this announcement results in a profit loss to the retailer. In order for this announcement to be profitable, the profit during the high-demand state must be high enough. This level can be achieved if the parameter Ψ is greater than the lower bound prescribed in part (a) of Proposition 3.

Interestingly, we find that in order to achieve an influential equilibrium, the measure Ψ should also be bounded from above, as illustrated in Figure 4. In an influential equilibrium, a retailer who observes the low signal should be better-off reporting truthfully that he observed the low signal than by mimicking the high-type retailer. However, if the profit the low-type retailer can gain from mimicking the high-type retailer is very high, which is the case when Ψ is very high, the low-type retailer will choose to manipulate the shared information. Therefore, in order to curb the incentives of the low type to mimic the high-type retailer, the profit in the high-demand state should also be bounded from above, as prescribed by Proposition 3. In settings of asymmetric information, there is usually a one-directional incentive to mimic the other type. In our case, both directional incentives matter, i.e., both of the incentive constraints of the high-type retailer mimicking the low type and the low type mimicking the high type play a role in determining the meaningful information-sharing region.

Note that as ρ increases, it is more likely to achieve meaningful information sharing; with an increase in ρ, the upper bound on the parameter Ψ that supports an influential equilibrium increases, and the lower bound on Ψ decreases. In other words, as ρ increases, the low-type retailer lowers his estimation that the market condition can be high; hence, he is less tempted to mimic the high-type retailer. Consequently, the upper bound on the possible parameter Ψ supporting the influential equilibrium increases. When $\rho = 1$, for example, the upper bound converges to infinity. In addition, as ρ increases, the high-type retailer has more confidence that the realized demand will be high; hence, he has higher tendency to accommodate intense competition in exchange for an increased capacity level secured by his manufacturer.

Part (b) of Proposition 3 complements Lemma 1. Lemma 1 defines the unique possible outcome of an influential equilibrium, and part (b) of Proposition 3 characterizes the parameter region in which this unique outcome is achieved. Part (b) suggests that the entry cost should be bounded between $F_2(s_l)$ and $F_1(s_h)$, and the posterior belief about the market condition should be $\mu(s_l) < \overline{\mu} \leq \mu(s_h)$. The latter part suggests that upon learning that the observed signal is s_l the manufacturers will choose to invest in the low-capacity level, and that upon learning that the signal is s_h the manufacturers prefer to invest in the high-capacity level. The former part states that given low signal and low-capacity investment, the entrant retailer cannot cover his entry cost, and thus prefers to stay out of the market. However, in the case of high signal and high-capacity level, the entrant prefers to enter the market leading to intensified competition.

Figure 5 illustrates the results of Proposition 3 and depicts the possibility to share information as a function of the prior belief μ and the entry cost F. In region I, no influential equilibrium can be achieved

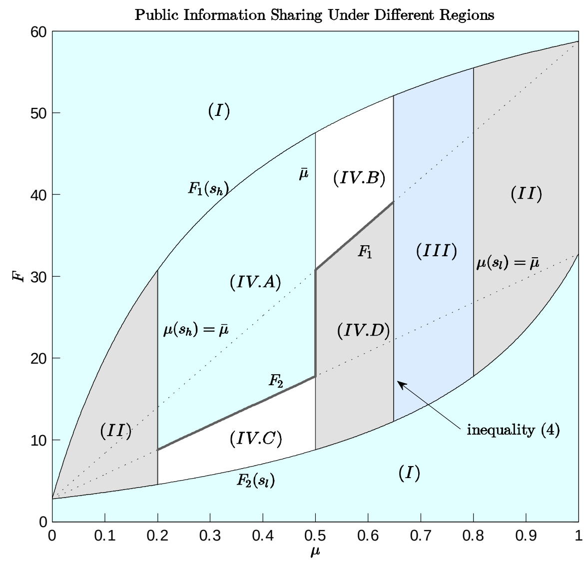

Figure 5: Equilibrium outcome and comparison with the benchmark case. Parameter values are the same as those given in Figure 3.

since either the entry costs are so high that even upon learning that the retailer observed s_h the entrant retailer decides to stay out of the market, or alternatively even when learning that the signal s_l was observed, the entrant retailer decides to enter the market. In both cases, the incentive compatibility constraints of the incumbent retailer (characterized in Proposition 3) are not satisfied. In region II, also, no influential equilibrium can be achieved; in this case, either the prior belief μ is too low such that even upon learning that the signal s_h was observed the incumbent manufacturer will not invest in the high-capacity level, or that the prior belief μ is too high such that even upon learning that the signal s_l was observed the incumbent manufacturer invests in the high-capacity level. Region III also describes a scenario in which no influential equilibrium can be achieved. In this case, the retailer with a high demand forecast is better off by mimicking the retailer with a low forecast; hence, his incentive constraint cannot be satisfied.

Region IV describes the area in which an influential equilibrium can be achieved, and it is divided into four cases according to the market outcome without information sharing (see Table 2 and Figure 3). Area IV.A describes the case in which without information sharing the entrant stays out of the market, and when information is shared he decides to enter the market. In addition, without information sharing, the incumbent manufacturer invests in the low capacity level, and she increases the capacity when learning that the observed signal is s_h. Area IV.B describes a case in which without information sharing, the entrant is out of the market, and upon learning that the observed signal is s_h, she decides to join the market. Area IV.C denotes the case in which the entrant retailer decides to join the market even when no information is shared. When the signal s_h is shared, the entrant supply chain increases the competition level compared with the case of no-information sharing by increasing the capacity level. When the signal s_l is shared, the entrant retailer alters his decision compared with the case of no-information sharing and he stays out of the market. Finally, area IV.D denotes the case in which without information sharing both supply chains operate in the market and invest in the high capacity level. In this case, information regarding the signal s_l serves to weaken competition – upon sharing s_l the entrant supply chain decides to stay out of market.

6 Implications of Public Information-Sharing

Section 5 presents the ability to share meaningful information by disclosing the shared information to both the incumbent manufacturer and the competing supply chain. In this section we analyze the implications of this influential equilibrium by comparing it with the equilibrium in which no information is shared that was analyzed in Section 4.1.[11]

First, consider the case in which the incumbent retailer observes the signal s_h. In this case, in an influential equilibrium, the competing supply chain operates in the market and both manufacturers invest in the high-capacity level. We denote this outcome as "intense competition equilibrium". In this equilibrium, the incumbent retailer is able to influence his manufacturer to invest in the high-capacity level by inducing the competing supply chain to intensify competition. This increase in the competition level can take two forms: either the entrant supply chain enters the market only upon learning that the incumbent retailer observed the high signal, or alternatively, if the entrant supply chain decided to enter the market even before observing the announcement of the incumbent retailer, this announcement results in an increase of the production quantity. Areas IV.A and IV.B in Figure 5 describe the case in which without information sharing the entrant supply-chain stays out of the market; upon announcing s_h, the entrant supply-chain decides to enter the market and both supply-chains invest in the high capacity level. Area IV.C in Figure 5 describes the case in which even without information sharing the entrant supply-chain operates in the market, but both supply-chains invest in the low capacity level; in this case, upon announcing s_h, both supply-chains choose to invest in the high capacity level.

The following Proposition describes the effect of information sharing on the profits of the different firms in the market upon observing the signal s_h.

Proposition 4 *Under the conditions of Proposition 3 when the incumbent retailer observes the signal* s_h*:*
(a) Information sharing hurts the incumbent retailer, compared with scenario $S1$*, if and only if* $F > F_1(\mu)$*, and* $\mu \geq \overline{\mu}$*.*
(b) Information sharing hurts the incumbent manufacturer, i.e., $E[\Pi_I^{S3}|s_h] < E[\Pi_I^{S1}|s_h]$*, if and only if*
(i) $F > F_2(\mu)$*,* $\mu < \overline{\mu}$ *and*

$$\frac{w-c}{w} \geq \frac{2(1-\mu(s_h))(\theta_H - \theta_L)}{2\theta_H - 3\theta_L + w},$$

or (ii) $F > F_1(\mu)$*, and* $\mu \geq \overline{\mu}$*.*
(c) The entrant retailer and the entrant manufacturer are better-off when information is shared.

While Proposition 3 demonstrates that it is possible to achieve an influential equilibrium by publicly sharing information, Proposition 4 shows that the competing supply chain always becomes better-off as a result of this information sharing, whereas the effect of information sharing on the profits of the incumbent retailer and the incumbent manufacturer is inconclusive.

Interestingly, there is a case in which the incumbent retailer is worse-off when information is shared. In this case, which corresponds to case B in Table 2 and area IV.B in Figure 5, without information sharing, the entrant supply chain decides to stay out of the market and the incumbent manufacturer invests in the high-capacity level of $(\theta_H - w)/2$. However, when information is shared, the entrant retailer updates his belief

[11] Alternatively, it is possible to think about this section as the comparison between the influential equilibrium and the babbling equilibrium which always exists, and results in no-information sharing.

	Setting $S1$		Setting $S3$	
	$c = 3.5$	$c = 4.9$	$c = 3.5$	$c = 4.9$
Incumbent retailer	125	125	144.44	144.44
Incumbent manufacturer	32.5	25.5	41.66	18.33
Entrant retailer	0	0	14.44	14.44
Entrant manufacturer	0	0	41.66	18.33

Table 3: Supply chains performance with and without public information sharing: The expected profits for the firms given that the incumbent retailer observed s_h. The parameter values are: $F = 92$, $w = 10$, $\theta_L = 20$, $\theta_H = 60$, $\mu = 0.3$ and $\rho = 0.7$.

about the market demand and decides to enter the market. Consequently, the incumbent manufacturer updates the capacity level to $(\theta_H - w)/3$ to reflect the new market structure. In this case, both effects, of intensifying competition and reducing the capacity level of the incumbent manufacturer, hurt the incumbent retailer compared with the setting in which no information is shared. In all other possible cases, information sharing benefits the incumbent retailer.

It is also interesting to note that the effect of information sharing on the profit of the incumbent manufacturer is inconclusive. In the first case described in part (b) and area IV.A in Figure 5, without information sharing, the entrant supply chain stays out of the market and the incumbent manufacturer invests in the low-capacity level for a monopoly market. When information is shared publicly, there are two effects: (i) The entrant retailer decides to enter the market (which makes the manufacturer worse-off due to the competition effect) and (ii) the incumbent manufacturer updates the belief about the probability of high demand realization and decides to invest in the high-capacity level appropriate to a market structure with competition (the capacity effect). Although the incumbent retailer experiences the same effects, there are cases in which, from the retailer's perspective, the competition effect is weaker than the capacity effect; thus, the incumbent retailer is better-off sharing information publicly. At the same time, from the incumbent manufacturer's perspective, the negative competition effect can be stronger than the positive capacity effect; thus, the incumbent manufacturer becomes worse-off when information is shared publicly and an influential equilibrium is achieved. The following numerical example in Table 3 illustrates this result. This example corresponds to a parameter region in which an influential equilibrium can be achieved. This table provides the expected profit of the firms in the market, given that the incumbent retailer observed s_h. In the first case, when $c = 3.5$, all parties across the two supply chains become better-off when information is shared. In the second case, when $c = 4.9$, the profit margin for the manufacturer $(w - c)/w$ is lower compared with the first case, which implies that the benefit of the capacity effect is lower compared with the first case. Hence, although information sharing can be achieved, the incumbent manufacturer becomes worse-off.

The second case described in part (b) is equivalent to the setting in which without information sharing, the entrant supply chain stays out of the market, and the incumbent manufacturer invests in the high-capacity level (case B in Table 2 and area IV.B in Figure 5). In this case, upon learning the signal s_h was observed, the entrant supply chain enters the market and the incumbent manufacturer lowers the capacity level compared with the case with no-information sharing. Thus, in this case, the manufacturer is worse-off when information is shared. As is shown in part (a), the incumbent retailer is also worse-off with information sharing.

Next, what is the impact of public information sharing on the consumer surplus? We denote the consumer surplus by CS.

Proposition 5 $E[CS^{S3}|s_h] > E[CS^{S1}|s_h]$, *i.e., meaningful information sharing makes the consumers better-off.*

Proposition 5 demonstrates that the consumers become better-off under an influential equilibrium compared with the case of no information sharing. As we noted above, achieving meaningful information sharing results in two effects: (i) the competition effect and (ii) the capacity effect. The former describes the fact that based on the shared information the entrant decides to enter the market or alternatively to increase the capacity level of the entrant supply chain, and the latter effect describes the fact that based on the shared information the total capacity in the market is higher compared with the case of no information sharing. Both of these effects result in higher quantity sold to the consumers and, thus, to an increase in consumer surplus.

We now turn to analyze the implications of the influential equilibrium when the incumbent retailer observes the low signal s_l. When the incumbent retailer observes s_l, in an influential equilibrium, the entrant supply chain stays out of the market and the incumbent manufacturer invests in the low-capacity level. We denote this equilibrium as "weakened competition". Under an influential equilibrium, when the observed signal is s_l, the incumbent retailer is able to convince the entrant supply chain to stay out of the market, since he is perceived as being accountable for the shared-information by inducing his manufacturer to invest in low-capacity level. Note that when information is shared only between the retailers, the unique equilibrium is the *babbling* equilibrium. In this case, regardless of the observed signal, the incumbent retailer prefers to tell the possible entrant that the observed signal is low in order to weaken competition. Being aware of the incumbent retailer's incentives to deflate the value of the observed signal, the entrant retailer ignores the message received from the incumbent retailer and acts as if no information had been shared. Interestingly, in this case of information sharing only between the retailers, it is the high-type retailer who wishes to mimic the low type in order to lower the competition level. Thus, to prove his accountability for the shared information, the low-type retailer must incur some cost that the high type cannot mimic – this cost is the low-capacity level secured by the incumbent manufacturer upon announcing s_l. By sharing the information with both the entrant retailer and the incumbent manufacturer, the low-type retailer is able to separate himself from the high-type retailer. Area IV.C in Figure 5 depicts the case in which without information sharing, the entrant supply-chain enters the market and invests in the low capacity level, and area IV.D depicts the case in which absent information sharing, the entrant supply-chain operates in the market and invests in the high capacity level. In both of these cases, upon learning that the observed signal is s_l, the entrant supply-chain decides to stay out of the market.

Then, who benefits from this information sharing? The next proposition evaluates the effect of information sharing on the profits of the different parties in the market compared with the case in which no information is shared (scenario $S1$).

Proposition 6 *In an influential equilibrium, when the incumbent retailer observes* s_l :
(a) The incumbent retailer is worse-off when information is shared if and only if $F > F_1(\mu)$, *and* $\mu \geq \overline{\mu}$.
(b) If and only if $F \leq F_1(s_l)$ *and* $\mu \geq \overline{\mu}$ *hold,* $E[\pi_E^{S3}|s_l] < E[\pi_E^{S1}|s_l]$, *i.e., information sharing makes the entrant retailer worse-off,*

where

$$F_1(s_l) = \mu(s_l)\left(\frac{\theta_H - w}{3}\right)^2 + (1-\mu(s_l))\left(\frac{\theta_L - w}{3}\right)^2.$$

(c) The entrant manufacturer is worse-off when information is shared if and only if $F < F_2(\mu)$ *and* $\mu < \overline{\mu}$.
(d) $E[\Pi_I^{S3}\,|s_l|] > E[\Pi_I^{S1}\,|s_l|]$, *i.e., information sharing benefits the incumbent manufacturer.*
(e) $E[CS^{S3}\,|s_l|] < E[CS^{S1}\,|s_l|]$, *i.e., the consumers are worse-off when information is shared.*

Part (a) suggests that it is possible for the incumbent retailer to be worse-off when the low-signal information is shared. This case occurs when absent information-sharing the entrant supply chain stays out of the market and the incumbent manufacturer invests in the high-capacity level (case B in Table 2 and area IV.B in Figure 5). When information about the signal s_l is shared, the outcome is that the competing supply chain is still out of the market, but the incumbent manufacturer lowers the capacity level, which hurts the incumbent retailer. In all other cases, the incumbent retailer benefits from information sharing. Note that Proposition 4 suggests that when observing the signal s_h the incumbent retailer is also worse-off sharing information under case B in Table 2 and better-off in all other cases. Consequently, if the incumbent retailer can commit ex-ante when to share information, he will choose information sharing in all cases except for case B in Table 2.

Part (b) demonstrates the fact that the entrant retailer can be worse-off when information is shared with him. Note that in Proposition 4 the entrant retailer is always better-off when information is shared. In the current case, if the low-forecast information is shared, the entrant manufacturer updates her belief about the market condition and decides to invest in the low-capacity level (conditioned on the entrant's decision to enter the market). Faced with this capacity constraint, the entrant retailer finds it in his best interest to stay out of the market and consequently earns zero profit. In contrast, under the conditions outlined in part (b) when information is not shared, the entrant manufacturer invests in the high-capacity level; knowing this manufacturer's behavior, the entrant retailer enters the market and earns positive profit, specifically when the entry costs are lower than $F_1(s_l)$. Part (c) demonstrates that the entrant manufacturer can also become worse-off when information is shared. In this case, without information sharing, the entrant supply chain operates in the market and the entrant manufacturer invests in the low-capacity level (area IV.C in Figure 5). This outcome provides the entrant manufacturer with a profit of $(w-c)(\theta_L - w)/3$. However, upon learning that the realized signal is s_l, the entrant retailer decides to stay out of the market and leaves his manufacturer with zero profit. Part (d) shows that the incumbent manufacturer is always better-off when information about s_l is shared. When this information is shared, the incumbent manufacturer understands that he should not be exposed to the risk of being left with unsold capacity. In addition, the entrant supply chain decides to stay out of the market, and thus market competition is weakened. Both of these effects work in favor of the incumbent manufacturer. This result contrasts with the result of Proposition 4, in which we find that it is possible for the incumbent manufacturer to become worse-off when information about s_h is shared. Finally, part (e) suggests that the consumers are worse-off when information about s_l is shared due to both the weakened competition and reduced capacity level in the market.

Table 4 summarizes the effect of meaningful information sharing equilibrium on the profit of the different firms in the market, compared with the case in which no information is shared. It is evident that the incumbent retailer is better-off under the meaningful information sharing equilibrium than no-information sharing equilibrium in all cases, but case B. Therefore, from an equilibrium selection perspective, if the incumbent retailer can commit in advance to when he will share information, information will be shared in

Case	incumbent retailer		incumbent manufacturer		entrant retailer		entrant manufacturer	
	$s = s_h$	$s = s_l$	$s = s_h$	$s = s_l$	$s = s_h$	$s = s_l$	$s = s_h$	$s = s_l$
A	↑	Indif.	↑ or ↓	Indif.	↑	Indif.	↑	Indif.
B	↓	↓	↓	↑	↑	Indif.	↑	Indif.
C	↑	↑	↑	↑	↑	↑	↑	↓
D	Indif.	↑	Indif.	↑	Indif.	↑ or ↓	Indif.	↑

Table 4: The effect of information sharing on the firms' profits compared with the no-information equilibrium. Note that "↑" implies that firms prefer information sharing, whereas "↓" means that they prefer no information sharing. In addition, "↑ or ↓" implies that the impact of information sharing on firms' profits is inconclusive, and "Indif." means that they are indifferent.

all cases, but case B.

7 Advance Purchase vs. Public Information Sharing

Scenario $S3$ describes the way public information sharing can remedy the problem of credible information sharing among supply-chain members. The problem of credible information exchange within a supply chain was studied extensively in the past. A popular solution is to use a signaling game to convey the credibility of the shared information. Some papers that adopt this method include Cachon and Lariviere (2001), Cachon (2004), Ozer and Wei (2006), Dong and Zhu (2007). In setting $S2$, we showed that when the prior belief regarding the market demand is low, the manufacturer is not willing to accept the risk of investing in an ample capacity level. The papers mentioned above discuss the way the advance purchase contract allows the retailer and the manufacturer to allocate the risk in the supply-chain in such a way that the manufacturer is willing to increase the capacity level. In this section we compare between the public information sharing mechanism and the use of advance purchase as a signaling game. Under the advance purchase contract, a retailer commits to purchase a minimum quantity, regardless of the realized demand. In this case, a retailer with a high demand forecast is able to commit to purchase in advance a quantity that cannot be mimicked by a retailer who observes low demand forecast, and, thus, can separate himself from the retailer with low forecast. We first briefly provide the analysis of the advance purchase contract and then compare its performance with the option to share information publicly.

In order to effectively compare between the two mechanisms that result in information sharing, for the analysis of the advance purchase contract, we focus on the parameter region in which sharing information is influential, i.e., the shared information alters the actions of the receivers; specifically, in our setting, we examine the case in which in the absence of information sharing, the manufacturer invests in the low-capacity level, and when information is shared truthfully, the manufacturer invests in the high-capacity level.[12] We further focus our analysis on the case in which without information sharing, the entrant supply chain stays out of the market.[13] In the advance purchase contract, the timeline is as follows: first, after

[12] In all other parameter regions, the solution to this signaling game under the advance purchase contract is as follows. If the incumbent manufacturer invests in the high capacity level even when no information is shared, then there is a pooling equilibrium in which both types of retailers commit to order the same amount $q^{adv} \in [0, (\theta_L - w)/2]$. There is no need for the high-type retailer to separate himself from the low type, since even without this separation the manufacturer invests in the high capacity level.

[13] In this case, as will be shown later, the cost of public information sharing is the highest, because following public information sharing, the market becomes from a monopoly supply chain to two competing supply chains.

obtaining his demand forecast signal s_i, $i \in \{h, l\}$, the retailer commits to purchase at least $q^{adv}(s_i)$ units from the manufacturer at a wholesale price w, regardless of the realized market condition. Second, based on the retailer's advance purchase commitment, the manufacturer updates her belief about the market status and builds up the capacity K $(\geq q^{adv})$ accordingly. Finally, the market condition θ is realized, and the retailer decides how much to order $q \in [q^{adv}, K]$ from the manufacturer.

Since we investigate the forecast information sharing via this advance purchase contract, we focus on separating equilibria. Note that to achieve a separating equilibrium, a retailer who observes the signal s_i must be better-off by committing to the quantity $q^{adv}(s_i)$ than to any other possible quantity. In our search for separating equilibria, we refine our equilibria using the intuitive criterion (Cho and Kreps 1987). In a separating equilibrium that satisfies the intuitive criterion, a retailer who observes the low signal commits in advance to purchase at most the quantity $q^{adv}(s_l) = (\theta_L - w)/2$.[14] In addition, a retailer who observes the high signal commits to purchase the minimum amount that makes the low-type retailer indifferent to mimicking him; specifically, $q^{adv}(s_h)$ should be the minimum quantity satisfying the following condition:

$$\mu(s_l)\left(\theta_H - \frac{\theta_L}{2} - \frac{w}{2}\right)\left(\frac{\theta_L - w}{2}\right) + (1-\mu(s_l))\left(\frac{\theta_L - w}{2}\right)^2 \geq \\ \mu(s_l)\left[\pi^{adv}(\theta_H, q^{adv}(s_h))\right] + (1-\mu(s_l))\left[\pi^{adv}(\theta_L, q^{adv}(s_h))\right], \quad (5)$$

where

$$\pi^{adv}(\theta_i, q^{adv}) = \max_{q \leq K} \left((\theta_i - q - w)q - w(q^{adv} - q)^+\right), \quad i \in \{H, L\}. \quad (6)$$

Condition (5) represents the incentive compatibility constraint of a retailer observing a low signal when the advance purchase quantity of a retailer observing the high signal is given by $q^{adv}(s_h)$. The LHS denotes the expected profit of the retailer when he signals the manufacturer that he has observed the low signal. In this case, the manufacturer invests in the low-capacity level of $(\theta_L - w)/2$, and the retailer faces capacity constraints when the realized demand is high. The RHS denotes the expected profit of the retailer when he mimics the advance purchasing behavior of the high-type retailer. In this case, the manufacturer invests in the high-capacity level of $(\theta_H - w)/2$.[15] In this case, the retailer benefits from the high-capacity level if the demand is high, but when the realized demand is low, the retailer needs to pay for the advance purchase units that exceed the quantity he would have bought in the absence of the advance purchase contract. The next Lemma characterizes the separating equilibrium.

Lemma 2 *In the separating equilibrium that satisfies the intuitive criterion, a retailer who observes a high signal commits to purchase the following quantity:*

$$q^{adv}(s_h) = \begin{cases} \frac{\theta_L - w + \sqrt{\frac{\mu(s_l)}{1-\mu(s_l)}}(\theta_H - \theta_L)}{2}, & \text{if } \frac{\sqrt{\frac{\mu(s_l)}{1-\mu(s_l)}}(\theta_H - \theta_L)}{2} \leq \frac{w}{2}; \\ \frac{\mu(s_l)}{1-\mu(s_l)}\frac{(\theta_H - \theta_L)^2}{4w} + \frac{\theta_L}{2} - \frac{w}{4}, & o/w, \end{cases} \quad (7)$$

[14] Under the intuitive criterion, the low-type retailer does not incur any costs that are associated with the advance purchase. In any realization of the market demand, for the given wholesale price w, the low-type retailer purchases at least $(\theta_L - w)/2$ units. Therefore, in a separating equlibrium that satisfies the intuitive criterion, he does not commit to purchase a higher amount.

[15] Note that we assume that in equilibrium, the high-type retailer does not commit to order more than $(\theta_H - w)/2$ in advance. Therefore, the manufacturer will produce this amount when he believes that the retailer has observed the signal s_h. The reason for this choice is that any separating equilibria in which the high-type retailer orders more than $(\theta_H - w)/2$ in advance are Pareto dominated by a pooling equilibrium in which both possible retailer types order $(\theta_H - w)/2$.

and the manufacturer builds the following capacity:

$$K = \begin{cases} \frac{\theta_H - w}{2} & \text{if } q^{adv} \geq q^{adv}(s_h); \\ \frac{\theta_L - w}{2} & \text{if } q^{adv} < q^{adv}(s_h). \end{cases}$$

Lemma 2 describes the minimum amount a retailer who observes the high signal should commit to purchase, in order to convey to the manufacturer the credibility of his shared information. There are two different cases to consider. In the first case, it is sufficient to commit to purchase a quantity that is less than $\theta_L/2$ in order to establish the separating equilibrium. In this case, even if the realized demand is low, the retailer sells all the advance purchased units at the retail market. In the second case in which $\theta_L/2 \leq q^{adv}(s_h) \leq (\theta_H - w)/2$, if the realized demand is low, the retailer sells less than the advance purchased units such that some units are left unsold when the realized demand is low.

Note that using the advance purchase contract, the incumbent retailer can credibly communicate with his manufacturer, without inviting competition. Is it always better for the retailer? Specifically, if the incumbent retailer can choose between the advance purchase contract and public information-sharing, which communication mechanism would he choose? Moreover, what is the difference between the two mechanisms– the advance purchase contract and the public information sharing–with respect to the profits of the different parties in the two supply chains and the effect on the consumers? The next proposition compares the effect of sharing information by using the advance purchase mechanism (a signaling game) and the option of the incumbent retailer to share information publicly.

Proposition 7 *(a)* $E[\pi_I^{S3}] \geq E[\pi_I^{adv}]$ *if*
(i) $q^{adv}(s_h) < (\theta_H - w)/2$, *and*

$$\frac{5}{36}\left(\mu(s_h)(\theta_H - w)^2 + (1-\mu(s_h))(\theta_L - w)^2\right) \leq (1-\mu(s_h))\frac{\mu(s_l)}{1-\mu(s_l)}\left(\frac{\theta_H - \theta_L}{2}\right)^2; \tag{8}$$

or (ii) $q^{adv}(s_h) \geq (\theta_H - w)/2$, *and*

$$\frac{5}{36}\left(\mu(s_h)(\theta_H - w)^2 + (1-\mu(s_h))(\theta_L - w)^2\right) \leq (1-\mu(s_h))\left[\left(\frac{\theta_L - w}{2}\right)^2 - \left(\frac{\theta_L^2}{4} - w\left(\frac{\theta_H - w}{2}\right)\right)\right].$$

(b) $E[\Pi_I^{adv}] > E[\Pi_I^{S3}]$, *i.e., the incumbent manufacturer is better-off under the advance purchase contract than under the public information sharing;*
(c) $E[\pi_E^{adv}] < E[\pi_E^{S3}]$ *and* $E[\Pi_E^{adv}] < E[\Pi_E^{S3}]$, *i.e., both the entrant retailer and the entrant manufacturer are worse-off under the advance purchase contract than under the public information sharing;*
(d) $CS^{S1} < CS^{adv} < CS^{S3}$, *i.e., the consumers are worse-off under the advance purchase contract, compared with the public information sharing.*

Part (a) presents an important result of this study; after showing that it is possible to achieve truthful forecast information sharing via cheap talk, we also demonstrate that in certain cases, the incumbent retailer prefers public information sharing to using sophisticated signaling games, i.e., the advance purchase contract. This result can explain the popular use of a simple contract and an informal talk as a method to share information in supply chains, which was discussed in Section 2. The LHS of (8) represents the cost of the incumbent retailer in intense competition, relative to the symmetric information case. The loss of the incumbent retailer due to competition is given by:

$$\mu(s_h)\left((\frac{\theta_H - w}{2})^2 - (\frac{\theta_H - w}{3})^2\right) + (1-\mu(s_h))\left((\frac{\theta_L - w}{2})^2 - (\frac{\theta_L - w}{3})^2\right). \qquad (9)$$

Under symmetric information, the incumbent retailer induces the manufacturer to set the high-capacity level, and the retailer's profit under market condition θ_i is given by $(\theta_i - w)^2/4$. When the retailer shares information publicly, he also induces the manufacturer to increase the capacity level, but he simultaneously invites competition to the market. As a result, under competition, the profit of the incumbent retailer in market condition θ_i is given by $(\theta_i - w)^2/9$. Condition (9) is equivalent to the LHS of (8). The RHS of (8) represents the cost that an incumbent retailer, who observes the signal s_h, incurs under the advance purchase contract. The second condition given in part (a) states that if $q^{adv}(s_h)$ is higher than $(\theta_H - w)/2$, the separating equilibrium is dominated by a pooling equilibrium in which both types of incumbent retailers order the quantity $(\theta_H - w)/2$. In this case, we compare the profits under the equilibrium in which information is shared publicly to the pooling equilibrium. For example, when $\theta_H = 15.5$, $\theta_L = 9$, $w = 6.9$, $\mu = 0.36$ and $\rho = 0.6$, the incumbent retailer prefers to share information publicly than using the signaling game. However, for the same parameter region, when ρ is increased to 0.8, the incumbent retailer would prefer to use the advance purchase contract over the option to share information publicly.

Part (b) states that the incumbent manufacturer is better-off under the advance purchase contract than when information is shared publicly. When information is shared publicly, due to the competition effect, the manufacturer invests in the capacity level of $(\theta_H - w)/3$. However, under the advance purchase contract, since the manufacturer sells to the sole retailer in the market, she is able to increase the capacity level to $(\theta_H - w)/2$. In addition, in the advance purchase contract, when the realized demand is low, the manufacturer does not sell only the $(\theta_L - w)/2$ units to the retailer, but he sells a higher quantity of $q^{adv}(s_h)$. The fact that the retailer commits to purchase a minimum number of units reduces the risk that the manufacturer has to face upon observing a low-demand realization; thus, this mechanism makes her better-off compared with the option of sharing information publicly.

Part (c) discusses the effect of the advance purchase contract on the performance of the entrant supply chain. In the absence of information sharing, the entrant supply chain chooses to stay out of the market, and receives zero profit. When information is shared publicly, the entrant supply chain finds it beneficial to enter the market. Therefore, the entrant supply chain prefers public information sharing over the advance purchase contract. Part (d) discusses the effect of the advance purchase contract compared with public information sharing on the consumer surplus. When information is shared publicly, as was demonstrated in Proposition 5, the consumers are better-off than when information is not shared, due to the fact that public information sharing results in an increased capacity level and increased competition. Proposition 7 states that the consumers prefer the public information sharing over the use of the advance purchase contract. Under the latter, there is a monopoly seller with lower total capacity compared with the public information-sharing case. The proposition also states that between no-information sharing, that was studied in setting $S1$ and the advance purchase contract, the consumers prefer the advance purchase contract, since it results in a larger sold quantity when demand is high, due to the increased capacity effect. In addition, the advance purchase contract results in a higher quantity sold when demand realization is low, compared with the no information-sharing scenario, since the retailer commits to a minimum quantity which is higher than the quantity sold in setting $S1$.

We further discuss the effect of the signal's precision on the decision of the incumbent retailer, i.e., whether to choose the public announcement or the advance purchase in the following proposition.

Proposition 8 *As the precision of the signal increases (ρ), the attractiveness of the advance purchase contract increases compared with the public information sharing option, i.e.,*

$$\frac{\partial \left(E[\pi_I^{adv}] - E[\pi_I^{S3}]\right)}{\partial \rho} \geq 0.$$

As the precision of the signal increases (captured by the parameter ρ), an incumbent retailer observing the low signal has lower incentive to try and mimic a retailer observing the high signal. As a result, the quantity the high-type retailer needs to commit to purchase in advance decreases, and thus the advance purchase contract becomes more attractive. This can be seen from examining Equation (7) and observing that the advance purchase quantity is decreasing in $\mu(s_l)$ (which decreases in ρ). At the same time, as ρ increases, it is more likely that the entrant will decide to join the market upon learning that the retailer has observed the signal s_h. Furthermore, the cost to the retailer of choosing the public information sharing compared with the symmetric case given in Equation (9) is increasing in ρ. Therefore, as the precision of the signal increases we predict that the retailer will choose to share information within the supply chain, by choosing the advance purchase contract, over the option to publicly reveal the observed signal. Interestingly, this result is aligned with the example of Boeing. The Market Outlook that Boeing publishes every year is an aggregated forecast for the next 20 years - a forecast which is in nature less accurate. Boeing also states that the Market Outlook is "*long-term forecast.*" At the same time, Boeing does not choose to publicly announce its short-term forecast, a forecast which is characterized by a higher precision level.

8 Extensions

The model we have studied highlights the operational value of making forecast information publicly available to both the manufacturer and the competitor - the fact that the information is made available simultaneously to both the competitor and the manufacturer allows the incumbent retailer to convey his credibility and prove that he is accountable for the shared information. In this section, we explore the applicability of our results to more general settings by relaxing a few of our main assumptions. In Section 8.1, we consider asymmetric wholesale prices, such that the incumbent retailer purchases a unit for the wholesale price of w_I, while the entrant retailer purchases the unit for the wholesale price of w_E. Then, in Section 8.2 we relax the assumption of strictly positive entry cost, symmetric production costs and an entrant supply chain. We consider zero entry cost, asymmetric production costs, and the entrant as an integrated firm. In Section 8.3 we discuss the applicability of our results to a more general demand distribution.

8.1 Asymmetric Wholesale Prices

To illustrate our main findings in a concise way, we have analyzed the model with symmetric wholesale prices. In this subsection, we extend our analysis to the asymmetric wholesale price case and show that our insights remain valid. The analysis of the asymmetric case also allows us to present an interesting finding about the effect of an increased wholesale price on the profit of the retailer.

In this analysis we focus on a corresponding case in which when the incumbent retailer observes the high signal he is increasing the competition level in the market to convey his accountability for the shared

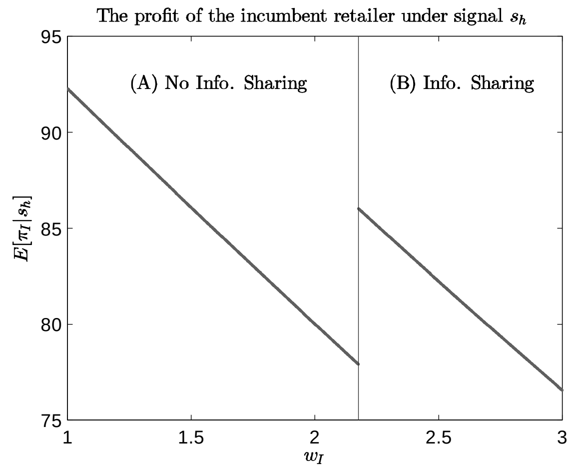

Figure 6: The effect of the incumbent retailer's wholesale price on his profit. Parameter values are: $\theta_H = 30$, $\theta_L = 10$, $w_E = 5$, $c = 0.1$, $\mu = 0.5$, $F = 30$, and $\rho = 0.8$.

information. We further assume that since the incumbent supply chain already operates in the market, it is more efficient, such that $w_I \leq w_E$. Specifically, the parameter region can be written as

$$F_1' < F < F_1'(s_h),\ \ \mu < \frac{c}{w_I} \text{ and } \mu(s_h) \geq \frac{c}{w_I}\,, \tag{10}$$

where

$$F_1' = \mu\left(\frac{\theta_H - 2w_E + w_I}{3}\right)^2 + (1-\mu)\left(\frac{\theta_L - 2w_E + w_I}{3}\right)^2, \text{ and}$$
$$F_1'(s_h) = \mu(s_h)\left(\frac{\theta_H - 2w_E + w_I}{3}\right)^2 + (1-\mu(s_h))\left(\frac{\theta_L - 2w_E + w_I}{3}\right)^2.$$

Similar to the discussion in Section 5, the conditions given in (10) suggest that without information sharing, the entrant decides to stay out of the market, and the incumbent manufacturer invests in the low-capacity level. Upon sharing information, the conditions suggest that the entrant finds the market attractive enough to enter, and the incumbent manufacturer invests in the high-capacity level. Based on these conditions we present the corresponding result to Proposition 3:

Proposition 9 *Under the region presented in Equation (10), meaningful information sharing can occur, if and only if*

$$\rho \geq \frac{\max((1-\mu)\Phi,\, \mu)}{\mu + (1-\mu)\Phi}\,, \tag{11}$$

where

$$\Phi = \frac{9(\theta_L - w_I)^2 - 4(\theta_L - 2w_I + w_E)^2}{4(\theta_H - 2w_I + w_E)^2 - 9(2\theta_H - \theta_L - w_I)(\theta_L - w_I)}\,.$$

Even when the wholesale prices are different, Proposition 9 suggests that the main message of the paper is kept - it is possible to reach an influential equilibrium by publicly sharing information. Similar to Proposition 3, this result is possible if the signal of the incumbent retailer is accurate enough. The intuition behind this result is also very similar to the discussion that follows Proposition 3.

In addition, this analysis allows us to explore the effect of the incumbent's wholesale price on the profit of the incumbent retailer. Figure 6 shows the effect of increasing the incumbent's wholesale price w_I while keeping w_E fixed. The figure demonstrates that an increase of the wholesale price has two effects; the first effect is the reduction in the profit margin the retailer receives from selling one unit of the product - this effect naturally hurts the retailer. However, an increase in the wholesale price can also affect the ability to share information. The region (A) in Figure 6 corresponds to a wholesale price which is low, and thus no information can be shared (this is the region in which $\mu(s_h) < \frac{c}{w_I}$). In this case, even upon learning that the signal is high, the manufacturer does not choose to invest in the high-capacity level and no information can be shared. However, as the wholesale price increases into region (B), it becomes possible to reach an influential equilibrium and information can be shared. Therefore, when evaluating the effect of an increased wholesale price on the retailer's profit, we need to take into account also its effect on the ability to share information. Figure 6 suggests that it is possible that the latter effect, of having the ability to exchange information, can dominate the former effect of the reduction in the profit margin; in this case an increase in the wholesale price can actually benefit the retailer.[16]

8.2 Entrant as a Firm with No Entry Cost and Asymmetric Production Costs

In this subsection we relax the following assumptions we adopted in the main model; first, we assume that the entry costs are zero ($F = 0$). Second, we relax the assumption of the symmetric production costs; the entrant firm has a fixed marginal cost of c_E for producing one unit of the product, while the production cost of the incumbent manufacturer is denoted by c_I which can be different from c_E. Third, we consider the entrant as a firm instead of a supply chain. The unit wholesale price the manufacturer charges the incumbent retailer is denoted, as in the previous section, by w_I. The entrant firm and the incumbent manufacturer must decide on the production quantity prior to observing the actual demand.

We focus our analysis on a parameter region in which upon learning that the incumbent retailer observed the high signal, both the entrant firm and the incumbent manufacturer increase the capacity levels compared to no information-sharing case. Specifically, the parameter region is as follows:

$$\begin{gathered}\mu < \overline{\mu} \leq \mu(s_h)\,,\ \text{and}\\ \mu\left(\theta_H - \tfrac{2\theta_L}{3} + \tfrac{w_I}{3}\right) + (1-\mu)\left(\tfrac{\theta_L + w_I}{3}\right) < c_E \leq \mu(s_h)\left(\tfrac{\theta_H}{2} - \tfrac{\theta_L}{6} + \tfrac{w_I}{3}\right) + (1-\mu(s_h))\left(\tfrac{\theta_L + w_I}{3}\right)\,.\end{gathered} \tag{12}$$

We show, in the next proposition, when an influential equilibrium can exist within this parameter region.

Proposition 10 *In the parameter region given in (12), an influential equilibrium exists if the following set of conditions is satisfied:*

$$\begin{aligned}&\mu(s_h)\left(\frac{\theta_H}{2} - \frac{\theta_L}{6} - \frac{2w_I}{3}\right)^2 + (1-\mu(s_h))\left(\frac{\theta_L - 2w_I}{3}\right)^2\\ &\qquad \geq \mu(s_h)\left(\theta_H - \frac{\theta_L}{2} - \frac{w_I}{2}\right)\left(\frac{\theta_L - w_I}{2}\right) + (1-\mu(s_h))\left(\frac{\theta_L - w_I}{2}\right)^2\,,\ \textit{and}\end{aligned} \tag{13}$$

[16] We thank the ananymous reviewer for suggesting this direction of analysis.

$$\mu(s_l)\left(\theta_H - \frac{\theta_L}{2} - \frac{w_I}{2}\right)\left(\frac{\theta_L - w_I}{2}\right) + (1-\mu(s_l))\left(\frac{\theta_L - w_I}{2}\right)^2$$
$$\geq \mu(s_l)\left(\frac{\theta_H}{2} - \frac{\theta_L}{6} - \frac{2w_I}{3}\right)^2 + (1-\mu(s_l))\left(\frac{\theta_L - 2w_I}{3}\right)^2. \quad (14)$$

Proposition 10 demonstrates that even when relaxing the assumptions discussed above, an influential equilibrium exists. Conditions (13) and (14) correspond to conditions (IC_{hl}) and (IC_{lh}) in Section 5; that is, they represent the incentive compatibility conditions of the incumbent retailer. Constraint (13) is for an incumbent retailer who observes the high signal, and constraint (14) is for an incumbent retailer who observes the low signal. However, there are a few differences between the incentive constraints (IC_{hl}) and (IC_{lh}) in Section 5 and (13) and (14) in Proposition 10. The fact that the entrant is a firm and not a supply chain implies that when the entrant decides the quantity to sell in the market, he views the capacity investment as a sunk cost, and thus at this stage, the entrant enjoys a lower marginal cost (of zero) compared with the cost of w_I incurred by the incumbent retailer. This difference allows the entrant to be more aggressive at this stage. The second difference is that at the capacity setting stage the incumbent manufacturer and the entrant firm have asymmetric costs. This asymmetry results in different capacity levels.

When we combine these two effects, it is not clear whether it is easier to satisfy the incentive constraints of the incumbent retailer compared with the analysis of Proposition 3. If the capacity cost of the entrant is high relative to that of the incumbent manufacturer,[17] it is possible that the effect of competition will be lower than the one in Proposition 3, and thus it will be easier to satisfy the incentive constraints of the incumbent retailer. However, if the capacity cost of the entrant is similar to that of the incumbent manufacturer, the effect of the aggressive quantity setting in the last stage of the game can prevent the incumbent retailer from announcing truthfully that he observed the high signal; thus, in this case, it is harder to reach an influential equilibrium compared with the analysis of Section 5.

8.3 General Distribution

In the main model we assumed that the market can take only two possible outcomes: either the market demand is high (captured by the outcome of θ_H), or alternatively it is low (captured by the notation θ_L). We now explore the implications of our results to more general distributions.

We assume that the market can take n possible outcomes, each denoted by θ_i, and for each i and j where $i > j$, we have that $\theta_i > \theta_j$ (i.e., θ_i represents a better market condition than θ_j). We further assume that the incumbent retailer can observe an informative signal about the market outcome, with a precision of ρ, such that:

$$\Pr(s_i|\theta_i) = \rho, \text{ for every } i.$$

Upon observing the signal s_i, it is possible to establish the posterior probability of the market outcome. This posterior probability is denoted by:

$$\mu_i(s_j) = \Pr(\theta = \theta_i|s_j).$$

Similar to the main analysis, we are interested in analyzing whether it is possible to achieve an influential

[17] It is reasonable to assume that the incumbent manufacturer, who specializes in this area, has a lower capacity cost than the entrant who sets the capacity and also sells to the consumer market.

equilibrium. In an influential equilibrium in a market with n possible states the incumbent retailer chooses to truthfully reveal his observed signal for any signal realization, and this announcement alters the behavior of the firms in the market for each signal announcement. We call this equilibrium *full influential equilibrium* (the word full stands for the fact that the firms in the market react differently for any signal). In a truthful information sharing equilibrium, i.e., in a full influential equilibrium, the following incentive constraints of the incumbent retailer must be satisfied:

$$\sum_{i=1}^{n} \mu_i(s_j)\pi_I(q_I|K_I(s_j), K_E(s_j), a_E(s_j), \theta_i) \geq \sum_{i=1}^{n} \mu_i(s_j)\pi_I(q_I|K_I(s_k), K_E(s_k), a_E(s_k), \theta_i), \text{ for every } j \text{ and } k \neq j. \quad (15)$$

The set of incentive constraints represented in (15) includes $n \times (n-1)$ individual incentive constraints. It suggests that for each signal realization s_j the incumbent retailer must be better-off revealing truthfully that he observed s_j than announcing that he has observed a different signal. The following proposition demonstrates the difference between the case of the two point distribution and the more general case.

Proposition 11 *For any $n > 2$, full influential equilibrium does not exist.*

Proposition 11 suggests that there is a difference between the ability to share information in the case of the two point distribution and the more general case. For any distribution with more than two possible states it is impossible to achieve the full influential equilibrium. The underlying reason behind this result is as follows: assume there are two states s_i and s_j, and for both of these states the entrant retailer decides to enter the market, but the incumbent manufacturer sets a higher capacity level for state s_j. In this case, even when observing the state s_i, the incumbent retailer has an incentive to announce that the signal is actually s_j. Because the entrant retailer is in the market anyway, the incumbent retailer cannot increase the level of competition by announcing s_i, but by announcing s_j he induces the manufacturer to increase the capacity level. In a similar way, if there are two signal states, in both of them the entrant decides to stay out of the market, but the manufacturer sets different capacity levels for these states, the incentive of the incumbent retailer will be to induce the manufacturer to set a higher capacity level. Equipped with this negative result we define a weaker form of information sharing, which we call partial influential equilibrium. In a partial influential equilibrium, the incumbent retailer is able to share some of his information with the firms in the market. We next define the properties of such an equilibrium.

Proposition 12 *In a partial influential equilibrium:*
(a) if the entrant retailer chooses to enter the market when the signal is s_j or higher, the incumbent manufacturer sets the same capacity level for all states s_j or higher;
(b) if the entrant retailer chooses to stay out of the market when the signal is s_j or lower, the incumbent manufacturer sets the same capacity level for all states s_j or lower.

Proposition 12 suggests that partial influential equilibrium is a hybrid equilibrium between an influential equilibrium and a babbling equilibrium. In the partial influential equilibrium, the incumbent retailer is able to alter the decisions of the firms in the market since for states s_1 through s_i, the entrant stays out of the market and the manufacturer builds the low capacity level, while for states s_j through s_n, the entrant joins the market and the manufacturer builds a high capacity level. At the same time, this equilibrium also has the properties of babbling equilibrium in the sense that the firms in the market regard any message between s_1 and s_i and between s_j and s_n in the same way.

In summary, although for a general distribution, the incumbent retailer has detailed information about the market outcome (he can observe n possible signals), the level of information that can be shared in the market does not increase.

9 Concluding Remarks

In this paper we study the effect of making information publicly available in a market characterized by uncertain demand drawn from a binary distribution and comprised of an incumbent supply chain and a potential entrant supply chain. We demonstrate how the incumbent retailer with superior forecast information is able to credibly share his information by making information publicly available. We also emphasize that the ability to credibly share information originates from the fact that multiple firms receive the shared information; when information is shared privately within the supply chain, the incumbent retailer has an incentive to manipulate the shared information in order to secure ample capacity. However, when the information is shared with the competitor as well, the incumbent retailer considers the trade-off between the desire to secure ample capacity, and the fear of intense competition. The primary result of our paper is that by making information publicly available, it is possible to achieve separation between a retailer observing a high demand forecast and the retailer who observes the low demand forecast; that is, a retailer with a high forecast benefits from the increased capacity level to such an extent that he is willing to accommodate competition in order to prove his accountability for the shared information. On the other hand, a retailer with a low forecast, although he benefits from an increased capacity level, is not willing to accommodate competition in exchange for the high capacity level; thus, he also truthfully reveals his forecast in order to weaken competition.

We also compare the mechanism for achieving truthful information sharing by making information publicly available to a more traditional signaling game - the advance purchase contract, in which information is shared only within the incumbent supply chain. In the signaling game, in order to prove his accountability to the shared information, the retailer commits to a minimum purchase quantity regardless of the realized demand. We demonstrate that there are cases in which the incumbent retailer prefers to share information publicly to committing to a minimum purchase. In addition, making information publicly available makes the competing supply chain and the consumers better-off compared with the signaling game.

The incentives of firms to share information publicly have received considerable attention in finance, accounting and marketing literature. However, to the best of our knowledge this is the first paper in operations management that studies the incentives of firms to share forecast information publicly. We hope that it will stimulate new avenues of research on the operational effects of making forecast information publicly available.

Appendix A- Proofs of main Propositions and Lemmas

Proof of Proposition 1.

(i) The entrant retailer is out of the market: Assume first that the entrant retailer decided to stay out of the market. In this case, if $\theta = \theta_L$, the unconstrained monopoly quantity is $q = \frac{\theta_L - w}{2}$. Since this is the worst possible market condition and $w > c$, the incumbent manufacturer will not invest in lower capacity than $\frac{\theta_L - w}{2}$ (under both market conditions, the manufacturer will be able to sell at least this amount). If $\theta = \theta_H$, and the entrant retailer decided to stay out of the market, the unconstrained monopoly will sell $q = \frac{\theta_H - w}{2}$. If the manufacturer decided to secure a lower capacity level, it must be that $K_I = \frac{\theta_L - w}{2}$. We showed that the incumbent manufacturer will not invest in a lower capacity than $\frac{\theta_L - w}{2}$, and any strategy of the manufacturer which results in capacity level $\frac{\theta_L - w}{2} < K_I < \frac{\theta_H - w}{2}$ is dominated by the strategy to invest in the capacity level of $\frac{\theta_H - w}{2}$ or $\frac{\theta_L - w}{2}$. Therefore, the constrained retailer will sell $q_I = \frac{\theta_L - w}{2}$, and earn $\pi_I = \left(\theta_H - \frac{\theta_L}{2} - \frac{w}{2}\right)\left(\frac{\theta_L - w}{2}\right)$. Finally, note that by investing in the capacity level of $\frac{\theta_H - w}{2}$, the manufacturer earns $\Pi_I = w\left[\mu\left(\frac{\theta_H - w}{2}\right) + (1-\mu)\left(\frac{\theta_L - w}{2}\right)\right] - c\,\frac{\theta_H - w}{2}$, and he earns $\Pi_I = (\frac{\theta_L - w}{2})(w - c)$ if he invests in the capacity level of $\frac{\theta_L - w}{2}$. Finally, it is straightforward to verify that the incumbent manufacturer prefers to invest in the high capacity level if $\mu \geq \overline{\mu}$.

(ii) The entrant retailer is in of the market: Assume now that the entrant retailer is in the market. First note that it is a dominated strategy for each manufacturer to invest in a capacity level lower than $\frac{\theta_L - w}{3}$. If the demand is low, retailer i can sell at least $\frac{\theta_L - w}{3}$ if he has enough capacity. If the capacity constraint of the competing retailer is binding when demand is low, then the retailer can sell even higher quantity. Now assume that the demand is high. In this case again note that a retailer can sell at least $\frac{\theta_L - w}{3}$. Therefore, each manufacturer will invest in a capacity level of at least $\frac{\theta_L - w}{3}$.
Now assume that one of the manufacturers has invested in a capacity level higher than $\frac{\theta_L - w}{3}$. Since this manufacturer can use the capacity level above $\frac{\theta_L - w}{3}$ only with probability μ, it implies that a manufacturer finds it in his best interest to do so only if $\mu \geq \frac{c}{w}$. However, due to the symmetry in the parameters of the problem, if one manufacturer finds it to be in his best interest to invest in a higher capacity than $\frac{\theta_L - w}{3}$, so will the other manufacturer. In this case, if both manufacturers invest in higher capacity than $\frac{\theta_L - w}{3}$, it can be verified that in equilibrium the capacity investment level will be $\frac{\theta_H - w}{3}$. ■

Proof of Proposition 2. For part (a), in order to achieve a truthful information sharing equilibrium, the following condition must be satisfied:

$$V(s_i, m_i) \geq V(s_i, m_j) \text{ for every } i \in \{l, h\} \text{ and } j \neq i.$$

Note that if $\mu(s_l) \geq \overline{\mu}$, regardless of the shared information, the manufacturer always invests in the high capacity level. Also note that if $\mu(s_h) < \overline{\mu}$, regardless of the shared information, the manufacturer always invests in the low capacity level. Therefore, the shared information has no effect on the actions of the manufacturer. As a result, truthful information sharing is supported as an equilibrium.
For part (b), note that the retailer's profit function is (weakly) increasing with the capacity of the manufacturer. The profit of the retailer is increasing for $K \leq \frac{\theta_H - w}{2}$, and it is constant in the capacity level for $K > \frac{\theta_H - w}{2}$. As a result, the retailer has an incentive to induce the manufacturer to invest in high-capacity level. The retailer can do so, if the manufacturer believes him, by announcing that the observed signal is high. Consequently, since both the high-type retailer and the low-type retailer always announce that they observed a high signal, it is impossible to reach an informative equilibrium. ■

Proof of Lemma 1. Let us denote the possible outcome following **truthful** information sharing by the following mapping $(s_h; s_l) \to ((K_I(s_h), K_E(s_h)); (K_I(s_l), K_E(s_l)))$, where the first term describes the capacity level of each manufacturer following the signal s_h, and the second term describes the capacity level of each manufacturer following the signal s_l. First assume that $K_I(s_h) = K_I(s_l)$, which means that

regardless of the observed signal, the incumbent retailer does not change his capacity decision, then if $K_E(s_h) \neq K_E(s_l)$, the incumbent retailer has an incentive to weaken the competition level and when information is shared in a strategic manner, the retailer would announce s_l, regardless of the observed signal. Anticipating this behavior, the firms in the market ignore the message of the incumbent retailer. Therefore the outcome $K_I(s_h) = K_I(s_l)$ cannot occur in an influential equilibrium.
Now assume that when information is shared truthfully, $K_E(s_h) = K_E(s_l)$ and $K_I(s_h) \neq K_I(s_l)$. These conditions imply that regardless of the observed signal, the entrant supply chain chooses the same capacity level. In this case, the incumbent retailer has an incentive, regardless of the observed signal to induce the manufacturer to increase the capacity level. As a result, when information is shared in a strategic manner, the incumbent retailer would announce s_h regardless of the actual signal realization. Anticipating this behavior, the firms in the market ignore the announcements of the retailer and no meaningful information sharing equilibrium can be achieved. Therefore the outcome $K_E(s_h) = K_E(s_l)$ cannot occur in an influential equilibrium.
The conclusion from the argument so far is that in an influential equilibrium the following two conditions should hold: $K_E(s_h) > K_E(s_l)$ and $K_I(s_h) > K_I(s_l)$. In addition, by symmetry when the entrant supply chain operates in the market, the capacity level of this supply chain equals the capacity level of the entrant supply chain. Therefore, it must hold that $K_E(s_h) = K_I(s_h)$. Combining it with the fact that $K_I(s_h) > K_I(s_l)$, the conclusion is that $K_E(s_h) = K_I(s_h) = (\theta_H - w)/3$; when the incumbent retailer announces s_h, the entrant supply chain operates in the market, and both supply chains invest in the high capacity level.
The last case we need to eliminate is that when s_l is shared, the entrant supply chain also operates in the market and invests in the low capacity level of $(\theta_L - w)/3$. Assume to the contrary that this case is feasible, then the incentive constraints to achieve influential information sharing would be:

$$\mu(s_h)\left(\frac{\theta_H - w}{3}\right)^2 + (1-\mu(s_h))\left(\frac{\theta_L - w}{3}\right)^2 > \mu(s_h)\left(\theta_H - \frac{2\theta_L}{3} - \frac{w}{3}\right)\left(\frac{\theta_L - w}{3}\right) + (1-\mu(s_h))\left(\frac{\theta_L - w}{3}\right)^2; \tag{IC$_{hl}$}$$

$$\mu(s_l)\left(\theta_H - \frac{2\theta_L}{3} - \frac{w}{3}\right)\left(\frac{\theta_L - w}{3}\right) + (1-\mu(s_l))\left(\frac{\theta_L - w}{3}\right)^2 < \mu(s_l)\left(\frac{\theta_H - w}{3}\right)^2 + (1-\mu(s_l))\left(\frac{\theta_L - w}{3}\right)^2. \tag{IC$_{lh}$}$$

The first term is the incentive compatibility constraint of the high type retailer and the second one is the incentive compatibility constraint for the low type retailer. The LHS of the first constraint states that when announcing s_h, both supply chains operate in the market and invest in the capacity level of $\frac{\theta_H - w}{3}$. The RHS of this constraint suggests that when announcing s_l both supply chains operate in the market and invest in the capacity level of $\frac{\theta_L - w}{3}$. Note that after simple manipulation, these conditions reduce to the conditions that $\left(\frac{\theta_H - w}{3}\right)^2 > \left(\theta_H - \frac{2\theta_L}{3} - \frac{w}{3}\right)\left(\frac{\theta_L - w}{3}\right)$, and that $\left(\frac{\theta_H - w}{3}\right)^2 < \left(\theta_H - \frac{2\theta_L}{3} - \frac{w}{3}\right)\left(\frac{\theta_L - w}{3}\right)$, which naturally cannot happen simultaneously, and contradicts the assumption that even when observing s_l the entrant supply chain operates in the market.
As a result, the only possible outcome, is the one outlined in Lemma **1.** ■

Proof of Proposition 3. (a) For an influential equilibrium to be supported, the following conditions must be met:

$$\mu(s_h)\left(\frac{\theta_H - w}{3}\right)^2 + (1-\mu(s_h))\left(\frac{\theta_L - w}{3}\right)^2 \geq \mu(s_h)\left(\theta_H - \frac{\theta_L}{2} - \frac{w}{2}\right)\left(\frac{\theta_L - w}{2}\right) + (1-\mu(s_h))\left(\frac{\theta_L - w}{2}\right)^2; \tag{IC$_{hl}$}$$

$$\mu(s_l)\left(\theta_H - \frac{\theta_L}{2} - \frac{w}{2}\right)\left(\frac{\theta_L - w}{2}\right) + (1-\mu(s_l))\left(\frac{\theta_L - w}{2}\right)^2 \geq \mu(s_l)\left(\frac{\theta_H - w}{3}\right)^2 + (1-\mu(s_l))\left(\frac{\theta_L - w}{3}\right)^2. \tag{IC$_{lh}$}$$

We first look at the first incentive constraint, which can be re-written in the following manner:

$$\mu(s_h)\left[\left(\frac{\theta_H-w}{3}\right)^2-(\theta_H-w)\,(\frac{\theta_L-w}{2})+(\frac{\theta_L-w}{2})^2\right]-\frac{5}{36}\,(1-\mu(s_h))\left[(\theta_L-w)^2\right]\geq 0. \qquad (16)$$

Dividing Equation (16) by $(\theta_L-w)^2$, we obtain equation (16) can be expressed in the following manner as a function of $\Psi=\frac{\theta_H-w}{\theta_L-w}$:

$$\mu(s_h)\left[\frac{1}{9}\Psi^2-\frac{\Psi}{2}+\frac{1}{4}\right]-\frac{5}{36}(1-\mu(s_h))\geq 0,$$

or alternatively:

$$\frac{1}{9}\Psi^2-\frac{\Psi}{2}+\frac{1}{4}-\frac{5}{36}\frac{(1-\mu(s_h))}{\mu(s_h)}\geq 0.$$

Note that as ρ becomes higher, the last term becomes smaller; hence, a solution to this equation will exist. In addition, we need to show that a solution to the second incentive constraint exists for the same parameter region. Following the same technique, the incentive constraint of the low-type retailer can be written as:

$$-\frac{1}{9}\Psi^2+\frac{\Psi}{2}-\frac{1}{4}+\frac{5}{36}\frac{(1-\mu(s_l))}{\mu(s_l)}\geq 0.$$

If ρ is high enough, the last term is also very large, and guarantees a solution to the above inequality.
(b) The conditions outlined in part (b) of the proposition characterize the parameter region that was described in Lemma **1** as the unique possible outcome of an influential equilibrium. ■

Proof of Proposition 4. (a) We need to consider a few possible settings when information is not shared. We follow the 4 possible scenarios according to Table 2.
(i) In case A, the incumbent is a monopoly but operates with low capacity level. Note that the retailer's profit when information is not shared, is identical to the LHS of Equation (IC_{hl}). By the conditions of Proposition 3**,** the retailer is better-off announcing truthfully his private information than receiving the LHS of Equation (IC_{hl}), which is his profit when no information is shared. Thus, satisfying the incentive compatibility constraints for the incumbent retailer, also guarantees that he is better-off when information is shared compared with the case in which no information is shared
(ii) In case B, the incumbent is a monopoly and operates in the market with high capacity level. Clearly information sharing results in competition and capacity level of $(\theta_H-w)/3$, which is a lower capacity level compared with the case of no-information sharing. Therefore, in this case the incumbent retailer is worse-off when information is shared.
(iii) In case C, without information sharing the profit of the incumbent retailer is given by

$$\mu(s_h)\left[\left(\theta_H-\frac{2\theta_L}{3}-\frac{w}{3}\right)\left(\frac{\theta_L-w}{3}\right)\right]+(1-\mu(s_h))\left(\frac{\theta_L-w}{3}\right)^2,$$

which is clearly less than the expected profit of this retailer when information is shared upon observing s_h which is $\mu(s_h)\left(\frac{\theta_H-w}{3}\right)^2+(1-\mu(s_h))\left(\frac{\theta_L-w}{3}\right)^2$.
(iv) In case D, the incumbent retailer is indifferent between sharing and not-sharing information.
(b) (i) in case A, the profit of the incumbent manufacturer when information is not shared is given by $E[\Pi_I^{S1}|s_h]=\left(\frac{\theta_L-w}{2}\right)(w-c)$. When information is shared publicly, the profit of the incumbent manufacturer is given by

$$E[\Pi_I^{S3}|s_h]=\mu(s_h)\left[\left(\frac{\theta_H-w}{3}\right)(w-c)\right]+(1-\mu(s_h))\left[\left(\frac{\theta_L-w}{3}\right)w-c\left(\frac{\theta_H-w}{3}\right)\right].$$

In this case, the market is characterized by competition, and the manufacturer produces the high level quantity for this market. The manufacturer is better-off when information is shared, if and only if:

$$\left(\frac{\theta_L - w}{2}\right)(w-c) \leq \mu(s_h)\left[\left(\frac{\theta_H - w}{3}\right)(w-c)\right] + (1-\mu(s_h))\left[\left(\frac{\theta_L - w}{3}\right)w - c\left(\frac{\theta_H - w}{3}\right)\right],$$

which can be written as

$$\left(\frac{\theta_L - w}{2}\right)(w-c) \leq w\left[\frac{\mu(s_h)\theta_H + (1-\mu(s_h))\,\theta_L}{3} - \frac{w}{3}\right] - c\left(\frac{\theta_H - w}{3}\right).$$

After some additional manipulation, we then obtain

$$\frac{w-c}{w} \geq \frac{2(1-\mu(s_h))(\theta_H - \theta_L)}{2\theta_H - 3\theta_L + w}.$$

(ii) In case B, the incumbent manufacturer is also worse-off since absent information sharing there is high capacity investment and monopoly, while with information sharing there is competition in the market.
(iii) The incumbent manufacturer is better-off when information is shared if the following condition holds:

$$\mu(s_h)\left[\left(\frac{\theta_H - w}{3}\right)(w-c)\right] + (1-\mu(s_h))\left[\left(\frac{\theta_L - w}{3}\right)w - c\left(\frac{\theta_H - w}{3}\right)\right] > \left(\frac{\theta_L - w}{3}\right)(w-c).$$

This condition is satisfied since $\mu(s_h) \geq \overline{\mu}$.
(iv) In this case, the incumbent manufacturer is indifferent between sharing information and no-information sharing.
(c) In cases A and B, the entrant retailer and the entrant manufacturer earn zero profit when information is not shared. However, when information is shared, the entrant retailer updates his belief about the market condition and finds it beneficial to join the market, since he expects to earn positive profit. Therefore, the entrant retailer is better-off when information is shared publicly. Also, when the entrant retailer joins the market, the entrant manufacturer earns positive profit, compared with the case of no-information sharing when he earns zero profit. The analysis of cases C and D is the same as for the incumbent supply chain due to symmetry. ■

Proof of Proposition 5. Similar to Proposition **4,** we compare the outcome of information sharing to the 4 possible cases without information sharing. Note that the consumer surplus in market state θ_i is given by $\frac{(\theta_i - p)q}{2}$. The consumer surplus is increasing in q since $\frac{dCS}{dq} = \frac{(\theta_i - p)}{2} - \frac{\partial p(q)}{\partial q}\frac{q}{2}$, and $\frac{\partial p(q)}{\partial q} < 0$. In cases A and B, information sharing results in a higher quantity sold in the market. The same holds for case C. In case D, there is no difference in the sold quantities, so the consumers are better-off when information is shared. ■

Proof of Proposition 6. (a) For case A, the incumbent retailer is indifferent between information sharing and no information. For case B, the incumbent retailer prefers no-information sharing since in this case he is a monopoly seller with high capacity level. Note that case D is equivalent to the profit of the incumbent retailer when he reports s_h. Since in equilibrium the incumbent retailer prefers to report s_l, the incumbent retailer prefers information-sharing over no-information sharing. In case C, the profit of the incumbent retailer is even lower than the profit of the incumbent retailer in case D when no information is shared. Therefore, in case C, the incumbent retailer prefers information-sharing.
(b) Note that in cases A and B, even without information-sharing, the entrant retailer chooses to stay out of the market. As a result, the entrant retailer is indifferent between information-sharing and no information in cases A and B. In case C, without information sharing the entrant manufacturer invests in the low capacity level, and the entrant retailer believes, based on the prior, that he can recover the entry costs.

However, based on the shared information, he updates his belief and understands that he cannot recover the entry cost – therefore, in this case he is also better-off. In case D, without information-sharing, the entrant manufacturer invests in a high capacity-level, and with information-sharing, the entrant manufacturer is willing to invest only in the low capacity level, and as a result the entrant retailer chooses to stay out of the market, The conditions in the Proposition characterize the case in which the entrant retailer is better-off staying in the market with high capacity level over staying out of the market due to the low capacity level.
(c) In cases A and B, the entrant supply chain is out of the market with and without information sharing, such that the entrant manufacturer is indifferent between sharing information and no-information sharing. In case C, without information sharing, it is clear that the entrant manufacturer is earning strictly positive profit when no information is shared, and thus the entrant manufacturer prefers no-information sharing in this case. In case D, when information is shared the entrant manufacturer earns zero profit. When information is not shared, the entrant manufacturer earns, given the signal s_l :

$$\mu(s_l)\left(\frac{\theta_H - w}{3}\right)(w-c) + (1-\mu(s_l))\left[\left(\frac{\theta_L - w}{3}\right)w - c\left(\frac{\theta_H - w}{3}\right)\right]$$

(d) In case A, the incumbent manufacturer is indifferent between information-sharing and no-information sharing. In case B, without information-sharing and with information sharing, the incumbent supply chain is a monopoly. Without information-sharing, the incumbent manufacturer invests in the high capacity level, and he decides to invest in the low capacity level following the information revealed to him. Therefore, the incumbent manufacturer prefers information-sharing. In case D the profit of the incumbent manufacturer without information-sharing is given by

$$\begin{aligned}
&\mu(s_l)\left(\frac{\theta_H - w}{3}\right)w + (1-\mu(s_l))\left(\frac{\theta_L - w}{3}\right)w - \left(\frac{\theta_H - w}{3}\right)c \\
\leq &\,\overline{\mu}\left(\frac{\theta_H - w}{2}\right)w + (1-\overline{\mu})\left(\frac{\theta_L - w}{2}\right)w - \left(\frac{\theta_H - w}{2}\right)c \\
= &\left(\frac{\theta_L - w}{2}\right)(w-c),
\end{aligned}$$

where the last expression denotes the profit of the incumbent retailer when information is shared. In case C, there is competition in the market without information-sharing, while with information sharing there is no competition, and clearly $\left(\frac{\theta_L - w}{2}\right)(w-c) > \left(\frac{\theta_L - w}{3}\right)(w-c)$.
(e) In case A, the consumers are indifferent between information sharing and no-information sharing. In case B, without information sharing there is a monopoly in the market with high capacity, while with information-sharing there is a monopoly with low capacity level, which makes the consumers worse-off. In cases C and D, without information sharing there is higher level of capacity in the market and competition. With information sharing, there is no competition and lower level of capacity. ■

Proof of Lemma 2. The first part of the lemma is derived by solving for Equation (5), for the case in which $\pi^{adv}(\theta_i, q^{adv}) = \frac{(\theta_L - w)}{2}$. This is the profit of the retailer when the demand is low and he has committed to a quantity lower than $\frac{\theta_L}{2}$. The second part of the lemma is derived by solving for the Equation (5) when the retailer's profit in a state with low demand is given by $\pi^{adv}(\theta_i, q^{adv}) = \frac{\theta_L^2}{4} - wq^{adv}$. Note that this is the retailer's profit when he commits to purchase more than $\frac{\theta_L}{2}$. In this case, not all units are sold to the consumer. ■

Proof of Proposition 7. For part (a), under the symmetric information setting, the profit of the incumbent retailer, who observes the signal s_h, is given by $\mu(s_h)(\frac{\theta_H - w}{2})^2 + (1-\mu(s_h))(\frac{\theta_L - w}{2})^2$. The LHS of Equation (8) denotes the loss to the incumbent retailer, relative to the symmetric case, due to sharing information publicly. The RHS of Equation (8) denotes the loss to the incumbent retailer, relative to the symmetric case, from using the advance purchase option. It is possible to verify that the set of parameters that satisfy this condition is not empty.

In order to gain additional insight regarding the parameter region in which the public information sharing equilibrium outperforms the separating equilibrium, we can express Equation (8) in the following manner:

$$\frac{5}{9}\left[\mu(s_h)\left(\theta_H - w\right)^2 + \left(1-\mu(s_h)\right)\left(\theta_L - w\right)^2\right] - \left(1-\mu(s_h)\right)\frac{\mu(s_l)}{1-\mu(s_l)}\left(\theta_H - \theta_L\right)^2 \leq 0$$

$$\frac{5}{9}\left[\mu(s_h)\left(\theta_H - w\right)^2 + \left(1-\mu(s_h)\right)\left(\theta_L - w\right)^2\right] - \left(1-\mu(s_h)\right)\frac{\mu(s_l)}{1-\mu(s_l)}\left(\theta_H - w + w - \theta_L\right)^2 \leq 0$$

$$\frac{5}{9}\left[\frac{\mu(s_h)}{\left(1-\mu(s_h)\right)}\left(\theta_H - w\right)^2 + \left(\theta_L - w\right)^2\right] - \frac{\mu(s_l)}{1-\mu(s_l)}\left[(\theta_H - w)^2 + (\theta_L - w)^2 - 2(\theta_H - w)(\theta_L - w)\right] \leq 0.$$

Using the fact that $\frac{(\theta_H - w)}{(\theta_L - w)} = \Psi$, the equation above can be expressed as

$$\Psi^2\left[\frac{5}{9}\frac{\mu(s_h)}{(1-\mu(s_h))} - \frac{\mu(s_l)}{1-\mu(s_l)}\right] + \Psi\frac{2\mu(s_l)}{1-\mu(s_l)} + \left(\frac{5}{9} - \frac{\mu(s_l)}{1-\mu(s_l)}\right) \leq 0$$

$$\Psi^2\left[\frac{5}{9}\frac{\mu\rho}{(1-\mu)(1-\rho)} - \frac{\mu(1-\rho)}{(1-\mu)\rho}\right] + \Psi\frac{2\mu(1-\rho)}{(1-\mu)\rho} + \left(\frac{5}{9} - \frac{\mu(1-\rho)}{(1-\mu)\rho}\right) \leq 0.$$

This expression relates between the value of information, captured by Ψ, and the cases in which the public information sharing equilibrium outperforms the separating equilibrium.
If $q^{adv}(s_h) > (\theta_H - w)/2$, then the separating equilibrium is Pareto dominated (from the retailer's perspective) by a pooling equilibrium in which both types of retailers order the quantity $(\theta_H - w)/2$. The second set of conditions given in part (a) refers to this case.

For part (b), in the symmetric case, the profit of the incumbent manufacturer is given by $\mu(s_h)(\frac{\theta_H - w}{2})(w - c) + (1-\mu(s_h))\left[(\frac{\theta_L - w}{2})w - (\frac{\theta_H - w}{2})c\right]$. The profit of the incumbent manufacturer is higher in the symmetric case than in the public information sharing (due to the competition effect). However, in the advance purchase the profit of the incumbent manufacturer is higher than the symmetric case, since he is able to sell more units when demand is low.

For part (c), in the advance purchase, the entrant supply chain decides to stay out of the market, while we showed that in the public information sharing they decide to enter the market and earn a positive profit.

For part (d), in the advance purchase option, the consumers are purchasing from a monopoly retailer, which makes them worse-off, compared with the public information sharing. ■

Proof of Proposition 8. From Equation (7) it is possible to see that $q^{adv}(s_h)$ is decreasing in $\mu(s_l)$ which in turn is decreasing in ρ. Therefore, the advance purchase quantity is decreasing in the precision of the signal. In the public information sharing setting, the effect of introducing competition is independent of the signal accuracy. ■

Proof of Propositions 9 and 10. The proof is similar to that of Proposition 3 with additional algebra, and hence is omitted for brevity. ■

Proof of Proposition 11. Assume that there are $n = 3$ possible states, denoted by θ_L, θ_M and θ_H. First assume that the entrant decides to stay out of the market in state θ_L and state θ_M (where $\theta_M > \theta_L$). In this case, according to the definition of full influential equilibrium, the manufacturer needs to set different capacity levels for state θ_M and state θ_L. However, in this case the incumbent retailer has an incentive to always report θ_M and not θ_L.

Now assume that the entrant decides to enter the market for states θ_M and θ_H. Upon observing the signal s_h, the incentive compatibility constraint of a retailer observing the signal s_h and not reporting s_m

is given by:

$$\mu_h(s_h)\left[\frac{\theta_H - w}{3}\right]^2 + \mu_m(s_h)\left[\frac{\theta_M - w}{3}\right]^2 + \mu_l(s_h)\left[\frac{\theta_L - w}{3}\right]^2$$
$$> \mu_h(s_h)\left[\frac{\theta_H - 2\theta_M - w}{3}\right]\left[\frac{\theta_M - w}{3}\right] + \mu_m(s_h)\left[\frac{\theta_M - w}{3}\right]^2 + \mu_l(s_h)\left[\frac{\theta_L - w}{3}\right]^2,$$

which can be reduced to

$$\left[\frac{\theta_H - w}{3}\right]^2 > \left[\frac{\theta_H - 2\theta_M - w}{3}\right]\left[\frac{\theta_M - w}{3}\right].$$

However, upon observing the signal s_m, the incentive compatibility constraint of this retailer to not announce s_h is given by:

$$\mu_h(s_m)\left[\frac{\theta_H - 2\theta_M - w}{3}\right]\left[\frac{\theta_M - w}{3}\right] + \mu_m(s_m)\left[\frac{\theta_M - w}{3}\right]^2 + \mu_l(s_m)\left[\frac{\theta_L - w}{3}\right]^2$$
$$> \mu_h(s_m)\left[\frac{\theta_H - w}{3}\right]^2 + \mu_m(s_m)\left[\frac{\theta_M - w}{3}\right]^2 + \mu_l(s_m)\left[\frac{\theta_L - w}{3}\right]^2,$$

which is reduced to

$$\left[\frac{\theta_H - w}{3}\right]^2 < \left[\frac{\theta_H - 2\theta_M - w}{3}\right]\left[\frac{\theta_M - w}{3}\right],$$

and provides a contradiction for the ability to reach a full influential equilibrium. ■

Proof of Proposition 12. The proof to this proposition is a direct result of Proposition 11:
For part (a), by the proof of Proposition 11, when the entrant decides to enter the market for states s_i or higher, it is impossible to have two different capacity levels. Therefore, to support an equilibrium, the capacity level must be identical for all the states in which the entrant decides to join the market.

For part (b), as seen in Proposition 11, for all the states in which the entrant decides to stay out of the market, the incumbent has an incentive to induce the manufacturer to increase the capacity level. Therefore, in equilibrium the manufacturer must set a uniform capacity level for all of these states. ■

Appendix B- Analysis of the Separating Equilibrium

In this appendix we provide a rigorous analysis of the separating equilibrium that is studied in Section 6.

Preliminaries

In a signaling game, we denote by T the type space for the party that holds the private information, with $t \in T$. This party takes an action a from a set of possible actions $A(t)$. The uninformed party, having seen the action, updates his belief about the type t of the informed party; we use $\mu(a)$ to denote the updated belief of the uninformed party about the type of the informed party. Following this updated belief, the uninformed party also chooses an action r from the set $R(a, \mu(a))$.

This notation translates to our case, in the following manner. The informed party is the incumbent retailer, and the type space is $T = \{low, high\}$, where *low* denotes a retailer that observed the low signal s_l and *high* denotes the case in which the retailer observed the high signal s_h. The action space is the advance purchase quantity, such that $a = q^{adv} \in [0, \infty) = A(t)$. In our case, the uninformed party is the incumbent manufacturer, who updates her belief about the retailer's type; the action of the incumbent manufacturer is the capacity level she sets, $K \in [0, \infty) = R(a)$.

Consistent with games of incomplete information, "Nature" moves first by choosing the type of the incumbent retailer. Nature draws a high type s_h with the following probability:

$$\Pr(s_h) = \Pr(s_h|\theta_H)\Pr(\theta_H) + \Pr(s_h|\theta_L)\Pr(\theta_L) = \mu\rho + (1-\mu)(1-\rho),$$

and the low type retailer s_l with the complement probability.

Note that we focus on the separating equilibrium for the parameter region that satisfies the following conditions:

$(A1)$ $\mu < \overline{\mu}$

$(A2)$ $\mu(s_h) \geq \overline{\mu}$.

The first assumption states that without committing to purchase in advance, the manufacturer invests in the low capacity level of $(\theta_L - w)/2$. If this assumption is not satisfied, then the retailer has no incentive to communicate his private information, since when $\mu \geq \overline{\mu}$ the manufacturer invests in the high capacity level any way regardless of the advance purchase quantity. In this case, the pooling equilibrium, in which both types do not commit to purchase in advance, Pareto-dominates any separating equilibria.

The second assumption suggests that when information is communicated, the manufacturer invests in the high capacity level upon inferring that the retailer observed the signal s_h. If this assumption is not satisfied the retailer has no incentive to commit to purchase in advance, since this commitment cannot change the capacity investment level of the manufacturer.

Another rationale that guides us in focusing on the parameter region characterized by assumptions $(A1)$ and $(A2)$ is that we aim to compare two mechanisms that induce the manufacturer to invest in the high capacity level: the public information sharing and the advance purchase mechanism. In Section 5 we focused on the *influential* equilibrium for the case of public information sharing, and in order to be consistent, we also focus on the *influential* equilibrium (i.e., an equilibrium that alters the behavior of the incumbent manufacturer) when studying the advance purchase equilibrium.

The Separating Equilibrium

In a pure strategy equilibrium, the advance purchased quantities $q^{adv}(s_h)$ and $q^{adv}(s_l)$ must serve as a solution to the following problems:

$$\max_{q^{adv}(s_h)} \mu(s_h)\pi^{adv}(\theta_H, q^{adv}(s_h)) + (1-\mu(s_h))\pi^{adv}(\theta_L, q^{adv}(s_h)), \quad \text{and} \tag{17}$$

$$\max_{q^{adv}(s_l)} \mu(s_l)\pi^{adv}(\theta_H, q^{adv}(s_l)) + (1-\mu(s_l))\pi^{adv}(\theta_L, q^{adv}(s_l)) \tag{18}$$

subject to:

$$\mu(s_l)\left(\theta_H - \frac{\theta_L}{2} - \frac{w}{2}\right)\left(\frac{\theta_L - w}{2}\right) + (1-\mu(s_l))\left(\frac{\theta_L - w}{2}\right)^2 \geq$$
$$\mu(s_l)\left[\pi^{adv}(\theta_H, q^{adv}(s_h))\right] + (1-\mu(s_l))\,\pi^{adv}(\theta_L, q^{adv}(s_h)); \tag{19}$$

$$\mu(s_h)\pi^{adv}(\theta_H, q^{adv}(s_h)) + (1-\mu(s_h))\,\pi^{adv}(\theta_L, q^{adv}(s_h)) \geq$$
$$\mu(s_h)\left(\theta_H - \frac{\theta_L}{2} - \frac{w}{2}\right)\left(\frac{\theta_L - w}{2}\right) + (1-\mu(s_h))\left(\frac{\theta_L - w}{2}\right)^2, \tag{20}$$

where

$$\pi^{adv}(\theta_i, q^{adv}(s_j)) = \max_{q\leq K}((\theta_i - q - w)q - w(q^{adv}(s_i) - q)^+) \text{ for } i \in \{H, L\}, \text{ and } j \in \{h, l\}.$$

Equation (19) denotes the incentive compatibility constraint of a retailer observing the signal s_l. The LHS describes the expected profit of this retailer when he chooses the advance purchased quantity $q^{adv}(s_l)$. In this case, the manufacturer invests in the low capacity level, and thus this retailer faces capacity constraint when the realized demand is high. The RHS denotes the profit of this retailer when he mimics the high type retailer and chooses the advance purchase quantity of $q^{adv}(s_h)$. Equation (20) describes the incentive compatibility constraint of a retailer observing the signal s_h. Finally, Equations (17) and (18) denote the profit of each retailer given the advance purchase quantity.

The program above suggests that the retailer's actions are best-response to what he knows based on the signal he observes, and what he conjectures the manufacturer will do based on his advance purchase quantity. In this equilibrium, the manufacturer updates her belief about the state of demand based on the advance purchase quantity and invests in capacity level to maximize her profit.

Constraint (20) is not binding in equilibrium since only the low-type retailer has an incentive to mimic the high type. Therefore, the optimization problem for the high type reduces to the following problem:

$$\max_{q^{adv}(s_h)} \mu(s_h)\pi^{adv}(\theta_H, q^{adv}(s_h)) + (1-\mu(s_h))\pi^{adv}(\theta_L, q^{adv}(s_h)) \tag{21}$$

subject to:

$$\mu(s_l)\left(\theta_H - \frac{\theta_L}{2} - \frac{w}{2}\right)\left(\frac{\theta_L - w}{2}\right) + (1-\mu(s_l))\left(\frac{\theta_L - w}{2}\right)^2 \geq$$
$$\mu(s_l)\left[\pi^{adv}(\theta_H, q^{adv}(s_h))\right] + (1-\mu(s_l))\left[\pi^{adv}(\theta_L, q^{adv}(s_h))\right].$$

The high-type retailer maximizes his profit subject to the incentive compatibility constraint of the low-type retailer. The Lagrangian for the above formulation is given by the following formulation:

$$\mathcal{L}(q^{adv}(s_h), u) = \max_{q^{adv}(s_h)} \left[\begin{array}{c} \mu(s_h)\pi^{adv}(\theta_H, q^{adv}(s_h)) + (1-\mu(s_h))\pi^{adv}(\theta_L, q^{adv}(s_h)) \\ +u\left(\begin{array}{c} \mu(s_l)\left(\theta_H - \frac{\theta_L}{2} - \frac{w}{2}\right)\left(\frac{\theta_L - w}{2}\right) + (1-\mu(s_l))\left(\frac{\theta_L - w}{2}\right)^2 \\ -\mu(s_l)\left[\pi^{adv}(\theta_H, q^{adv}(s_h))\right] - (1-\mu(s_l))\left[\pi^{adv}(\theta_L, q^{adv}(s_h))\right] \end{array}\right) \end{array}\right].$$

Solving this problem, we get that for the parameter region we focus, the unconstrained solution (i.e., $u = 0$) is not feasible, since the low-type retailer has always an incentive to mimic the high-type retailer for $q^{adv}(s_h) \in [0, \frac{\theta_L - w}{2}]$. Also note that the high-type retailer's profit is decreasing in the advance purchase quantity for any $q^{adv}(s_h) \geq \frac{\theta_L - w}{2}$. Therefore, the high-type retailer is searching to commit for the minimum amount $q^{adv}(s_h)$ that will make the low-type retailer indifferent between mimicking him and ordering any amount $q^{adv}(s_l) \in [0, \frac{\theta_L - w}{2}]$.

There are two cases we need to consider: (i) $q^{adv}(s_h) \in [\frac{\theta_L - w}{2}, \frac{\theta_L}{2}]$, and (ii) $q^{adv}(s_h) > \frac{\theta_L}{2}$. In the first case, when the realized demand is low, the retailer sells all the units he committed to purchase in advance. In the second case, the retailer commits to purchase such a high quantity that when the demand is low, the retailer prefers not to sell all the units.

Solving the incentive compatibility constraint of the low-type retailer provides, for the first case, the following solution:

$$q^{adv}(s_h) = \frac{\theta_L - w + \sqrt{\frac{\mu(s_l)}{1-\mu(s_l)}}(\theta_H - \theta_L)}{2},$$

and this solution is possible only when $\left(\sqrt{\frac{\mu(s_l)}{1-\mu(s_l)}}(\theta_H - \theta_L)\right)/2 \leq w/2$. When the first case is not feasible, the retailer needs to commit to purchase a higher quantity. Solving for the incentive compatibility constraint for the low-type retailer, for the second case, provides the solution:

$$q^{adv}(s_h) = \frac{\mu(s_l)}{1-\mu(s_l)} \frac{(\theta_H - \theta_L)^2}{4w} + \frac{\theta_L}{2} - \frac{w}{4}.$$

Therefore, the solution to the advance purchase quantity separating equilibrium is given by:

$$q^{adv}(s_h) = \begin{cases} \frac{\theta_L - w + \sqrt{\frac{\mu(s_l)}{1-\mu(s_l)}}(\theta_H - \theta_L)}{2}, & \text{if } \frac{\sqrt{\frac{\mu(s_l)}{1-\mu(s_l)}}(\theta_H - \theta_L)}{2} \leq \frac{w}{2}; \\ \frac{\mu(s_l)}{1-\mu(s_l)} \frac{(\theta_H - \theta_L)^2}{4w} + \frac{\theta_L}{2} - \frac{w}{4}, & o/w; \end{cases}$$

$$q^{adv}(s_l) \in [0, \frac{\theta_L - w}{2}];$$

$$K = \begin{cases} \frac{\theta_H - w}{2} & \text{if } q^{adv} \geq q^{adv}(s_h); \\ \frac{\theta_L - w}{2} & \text{if } q^{adv} < q^{adv}(s_h). \end{cases}$$

Note that this equilibrium also satisfies the Intuitive Criterion (Cho and Kreps 1987).

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