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Supply Chain Configuration under Information Sharing

Mohammad Ali Kashefi¹

This paper examines the effect of information sharing on supply chain configuration where the market is characterized by demand uncertainty. A dynamic multi-stage game theoretic model with incomplete information is employed to capture the sequence of events. Our supply chain consists of two suppliers with exogenous wholesale prices and two retailers, the incumbent and the entrant, with asymmetric demand information. The informed incumbent prefers to conceal its private information from the entrant in order to reap more profits in the market. The channel of information flows is only through the first supplier and the incumbent can supply just from him, but the entrant is free to choose its proper supplier considering the point that the second supplier is uninformed. Our analytical model demonstrates that how the mean demand of the market, wherein our retailers compete, and its relation with the relative wholesale price of the suppliers play crucial roles in equilibrium determination. Our results show under which circumstances separation and pooling equilibria could occur in some range of demand variation. It is also shown that the entrant sometimes prefers to avoid information acquisition by choosing the second supplier and playing Cournot instead of Stackelberg which is more profitable for him in some occasions.

JEL Classification: C61, C72, D82, L13, L81, M11, Y40

Keywords: Information Sharing, Asymmetric Information, Supply Chain, Dynamic Game, Signaling Game, Demand Uncertainty, Strategic Information Management

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1. Introduction

Several industries and businesses follow differentiation strategies in order to attract the potential customers and overcome their rivals. Moreover proper implementation of this strategy requires a good knowledge of the market and sophistication of consumer demand which is costly and time-consuming. Hence access to private information about the actual demand of a specific market, particularly today, is a *competitive advantage* in competition that should be *managed* by CIOs. Controlling the channels of information leakage has become an important part of information management and business intelligence. Furthermore several competitors work with common players in their supply chain which potentially could share their economic information with their rivals-intentionally or unintentionally. Zhang and Li (2006) mentioned that several managers have concerns about the leakage of crucial information from suppliers to their rivals. This prospect leads to control over all signals that a competitor might ascribe from our ordinary course of business such as quantity ordering to common suppliers. Consequently information imperatives should be considered in our profit function and be treated strategically.

In this paper we explore the effect of information sharing on supply chain configuration in the market characterized with demand uncertainty. Indeed we examine how information considerations could affect the operational activities of firms. Our dynamic multi-stage supply chain signaling game includes four potential players, two suppliers (wholesalers) and two manufacturers (retailers), which will be configured based on informational and operational imperatives. At the beginning of the game, the first supplier which assumed to be the exclusive supplier of the incumbent (first retailer) decides whether to accept the entrant (second retailer) or not. Then the incumbent that have private information about market demand, places his quantity order strategically, while is aware of the first supplier's decision. Acceptance of the entrant implies that the incumbent could lose its competitive edge (private information). Hence the incumbent has strong incentive to conceal the updated information from the first supplier while ordering. At the third stage, the entrant chooses its proper supplier. If he chooses the first supplier (and the first supplier in stage one accepted him), the incumbent's order information will reveal to him. Finally both retailers compete on the quantity they launch to the market (Cournot duopoly competition). Price and profits are determined consequently.

This research contributes to the available outstanding literature in IO and strategic information management by studying the existence of a second supplier (with different wholesale price) on determination of the game's equilibria and further supply chain configuration. In fact it investigates analytically the effects of relative wholesale prices (of two suppliers) and demand uncertainty's elements on supply chain disposition. We have tried to equip all the agents of the game with crucial incentives to have interesting scenarios. Actually we model the incumbent's incentive of information sharing, the first supplier's incentive of information leakage and also the entrant's incentive for information acquisition and their effects on order quantities of retailers and acceptance

decision of first supplier which configure the supply chain. Four propositions and six Lemmas explicitly depict the results of this research which come out of the optimization problems of the game. Results show that how the additional second supplier affects the equilibria of the game and under some circumstance neutralizes the temptation of information acquisition. The results fill the gap of literature in this field. We also discuss about the scenario of exclusive supply contract (ESC) between the first supplier and the incumbent. Moreover the paper studies the effects of price differences between two suppliers. Several questions arise to answer in this study as for which constellations of demand uncertainty and wholesalers' relative price, the entrant chooses informed supplier and for which constellations of them, informed wholesaler accepts entrant's ordering? Is it possible for the incumbent to preclude information leakage? Does the entrant acquire information in equilibrium? What is the role of second supplier on the entrant's decision?

The remainder of this paper is organized as follows. In part 2 we briefly review the available related literature in IO and information management. Section 3 explains the basic general model and §4 deals with analysis and results. Finally, section 5 concludes this paper.

2. Literature Review

Several papers published in recent years have investigated the effect of information management on operation management. Indeed these studies focus on the trade-off between C-suits (CIO vs. COO²) of companies, the incentive of "minimum information leakage" versus the incentive of "maximum operational profits". The rationale behind these papers including ours is to model the incentives of all active agents in supply chain, wherein a company works, and try to optimize this *internal* trade-off considering all *external* strategic determinants.

Early papers on information sharing, studied the motivation of oligopolistic firms for information sharing. Gal-Or (1985), considering oligopolistic market characterized with demand uncertainty, concluded that no information sharing is the unique Nash equilibrium of the game. She modeled demand uncertainty with normal distribution function. Ziv (1993) designed a mechanism by which the firm will reveal the true value of its private information and this truthful revelation is its optimal reply. He showed that under some circumstances, information sharing's benefit is more than signaling costs.

Li (2002) pointed to two effects of vertical information sharing in two-level supply chain: direct and indirect effect. They showed that indirect effect (or leakage effect) motivates the retailers to conceal the demand information and reveal the cost information. Lee and Whang (2000) mentioned several examples of firms in supply chain that make profits by information sharing. They also empirically stated that the distribution of these benefits

² Chief Information Officer (CIO) vs. Chief Operation Officer (COO)

among players is asymmetric. Moreover different types of shared information were explained in their paper, e.g. inventory, sales, demand forecast, order status and production schedule. Our work deals with demand information.

Anand and Goyal (2009) *explicitly model firm's incentives to acquire, share and disseminate demand information, and their impact on order quantities and sale*. They consider one common supplier and two horizontally competing retailers. This seminal paper actually is the pillar of strategic information management. They have endogenized information acquisition decision of the incumbent retailer (with private information) in their model. Moreover their supply chain contains an exclusive supplier which our model tries to extend it to two suppliers with different wholesale prices.

Several scholars have contributed to this exquisite paper. Kong et al. (2012) study how the potential of revenue sharing contracts, which can be offered by supplier to two retailers, can favor information sharing through the supply chain and decline the destructive effects of information imperatives on operational one. In fact they have investigated the impacts of changing the wholesale price contract of Anand and Goyal (2009) to revenue sharing contract. They showed that this alteration motivates the supplier not always to leak the private demand information of the incumbent in equilibrium. This could result in higher benefits for all players of the supply chain even the uninformed entrant.

Özer et al. (2011) approached information sharing in supply chain considering cooperation and trust between different parties. They based their analytical model on laboratory findings that firms in supply chain cooperate even in the absence of contracts. Partial trust is also permitted in their model contrary to the available literatures. Ha et al. (2011) considered two competing supply chains each consists of one supplier and one retailer, with production technologies show diseconomies of scale. They show that information sharing benefits a supply chain under large production diseconomies, less intense competition, and less accurate information. For modeling diseconomies of scale they assume to have quadratic production cost. Two different types of competition (Bertrand & Cournot) are analyzed in this paper.

3. The Model

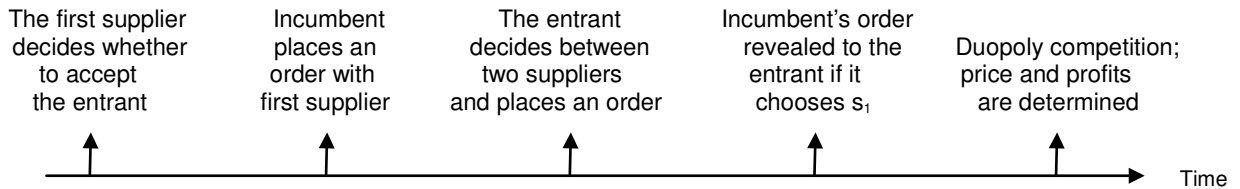
Inspired by Anand and Goyal (2009), consider a supply chain consisting of two retailers and two suppliers in which two retailers compete on the quantity they produce in a market characterized by demand uncertainty. One retailer is incumbent and due to long presence in the market has access to private information about demand. The other retailer is an uninformed entrant that is eager to realize the demand information. Based on some long-term contractual imperatives, incumbent restricted to supply its product from first supplier, but the entrant endogenously decides between two suppliers. Final product supplied from two different suppliers is assumed to be perfect substitutable. We index the four players- the incumbent, the entrant, the first supplier and the second

supplier, by i, e, s_1, s_2 respectively. All firms are risk neutral and aim to maximize their own expected profits.

Game Theoretic Model. According to Gibbons (1992) we study a dynamic (multi-stage) supply chain game of incomplete information between four players. More specifically speaking, a signaling game sequentially happens between retailers through their quantity ordering from suppliers.

Sequence of Events. The sequence of events is as follows: 1. The first supplier decides whether to accept entrant's potential order -which implies the leakage of demand information to it, or not; 2. The incumbent retailer (Stackelberg leader) - due to its private information about market demand, places an order with the first supplier, knowing that it will leak this information to the entrant (Stackelberg follower) if it accepts the entrant. Indeed the incumbent tries to strategically manage its private information via its ordering process. This might result in ordering distortion and supply chain inefficiency; 3. Then the entrant decides between two suppliers and places its order; 4. Here if the entrant chooses the first supplier then the incumbent's order information will be shared with it by s_1 , and finally 5. All ordered quantities are launched to the market, and price and profits are realized due to duopoly competition. (See figure 1)

Figure 1: The Sequence of Events



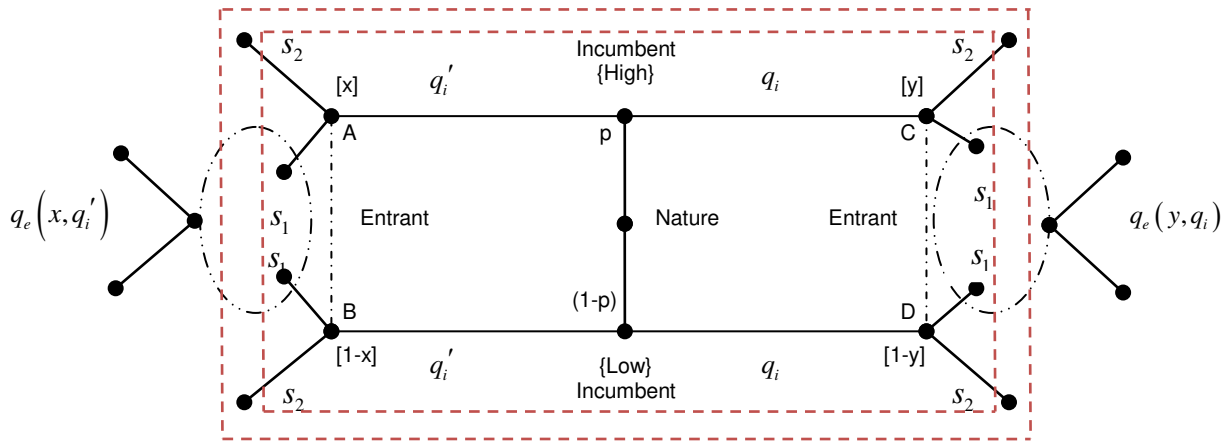
Demand Structure. We assume an inverse demand function that is linear and downward-sloping which implies that it arises from utility-maximizing behavior of customers with quadratic additively separable utility function (Singh and Vives (1984)). Uncertainty occurs in the intercepts of inverse demand function characterized specifically by $P(Q) = \tilde{A} - Q$ where $Q = q_i + q_e$ is the total quantity launched to the market by orders of both incumbent (q_i) and entrant (q_e). We assume a *binary support* for random variable \tilde{A} that can take two values: a high value A_H with probability p and a low value A_L with probability $(1-p)$ such that $0 < A_L < A_H$. We denote the mean demand by $\mu = pA_H + (1-p)A_L$. These priors are common knowledge between all players at the beginning of the game. We assume that the transactions between suppliers and retailers are governed by wholesale price contract. Wholesale price is assumed to be fixed exogenously and indexed by W_1 and W_2 for first and second suppliers respectively.

Also we assume that both suppliers have no capacity constraints to supply the retailers' orders and also we avoid partial ordering between suppliers. Consistent with Anand and Goyal (2009) also we consider $\theta = (A_H - W_1) / (A_L - W_1)$, as a proxy for demand uncertainty as showed by the coefficient of variation. Contrary to Anand and Goyal (2009) we do not normalize wholesale price to zero and therefore this price appears in the formulation of parameter θ .

Extensive Form Representation of the Signaling Game. In this setting the incumbent is the *sender* (informed agent), the entrant is the *receiver* (uninformed player), *type* space is $T = \{High, Low\}$ and $t \in T$ is a specific type of the sender, $m = q_i \in [0, \infty)$ is the *message* or signal that sender sends form a set $M(t)$, and $a = q_j \in [0, \infty)$ is the *action* or response that receiver chooses from a set $A(m)$. (See figure 2 and 3)

Solution Concept. Whereas we employ a dynamic game of incomplete information, Perfect Bayesian Nash Equilibria (PBNE) will be derived in terms of information and material flows. (Gibbons (1992))

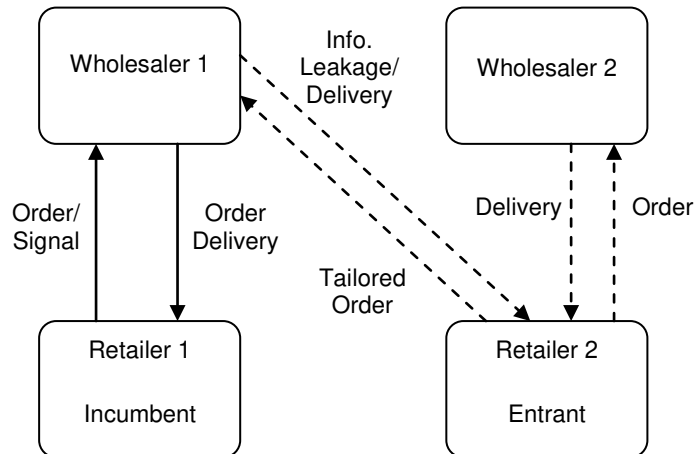
Figure 2: Extensive Form of Signaling Game



Contribution. This model is similar to that of Anand and Goyal (2009) with some alteration and extensions: First, another supplier s_2 is also available in the supply chain which could affect the decision making process of entrant and first supplier. Indeed we have eliminated the monopolistic role of first supplier. Second, following this extension, the entrant decision of choosing its proper supplier becomes endogenous variable in the model. Third, this setting assumes that incumbent receives demand signal, if any, by default, i.e. information acquisition is not a decision variable (contrary to Anand and Goyal (2009)) and finally, the decision to leak or not leak information is made ex-ante rather than ex-post by first supplier, i.e., before the demand signals is obtained (contrary to Anand and Goyal (2009)).

Research Questions. This study is going to answer the following questions. For which constellations of demand uncertainty about \tilde{A} and wholesalers' relative price W_1/W_2 , entrant chooses informed supplier and for which constellations of them, informed wholesaler accepts entrant's ordering?

Figure 3: Potential Supply Chain Configuration



4. Analysis

As depicted in figure 1, the first supplier, the incumbent and the entrant, each, should choose among two decisions: the first supplier should decide whether to accept the entrant or not ('Accept' or 'Not Accept'), the incumbent's decision is its ordering strategy ('Separation' or 'Pooling')³, and finally the entrant's decision is to choose among two suppliers ('First Supplier' or 'Second Supplier'). Second supplier here will enter the game just in two cases: when the first supplier does not accept the entrant and so it must procure from the second supplier, or when the first supplier accepts the entrant but it is more profitable for it to choose the second supplier. Hence potentially we could have 8 different scenarios although some of them are infeasible or inefficient which are listed as follow:

³ *Pooling* strategy implies that both types of the incumbent order the same quantity from the supplier to conceal the leakage of demand information. By choosing *Separation* strategy the high-type incumbent and the low-type incumbent order separate amount of quantity based on different level of demand realization. Hence the supplier also becomes aware of the updated information.

Table 1: Potential Equilibria

	Scenario	Remark
1	(Accept, Separation, First Supplier)	-
2	(Accept, Separation, Second Supplier)	-
3	(Accept, Pooling, First Supplier)	-
4	(Accept, Pooling, Second Supplier)	Not Optimal for Incumbent
5	(Not Accept, Separation, First Supplier)	Infeasible
6	(Not Accept, Separation, Second Supplier)	-
7	(Not Accept, Pooling, First Supplier)	Infeasible
8	(Not Accept, Pooling, Second Supplier)	Not Optimal for Incumbent

As can be seen in table 1, we have potentially 4 equilibrium candidates which will be analytically discovered in next sections. Obviously when the first supplier decides not to accept the entrant it is not feasible to have two scenarios regardless of the incumbent's strategy (Scenarios 5 and 7). Moreover when the first supplier does not accept the entrant, there is no rational incentive for the incumbent to take the pooling strategy as it causes operational distortion while there is no channel for information leakage. Thus the 8th scenario is not optimal for the incumbent. Finally when the entrant chooses s_2 then separation will not be optimal for the incumbent and so the 4th scenario is ignored.

Incidentally the relationship between wholesale prices of two suppliers leads to clearer potential equilibria. Indeed if $W_1 \leq W_2$ then the first supplier offers lower wholesale price plus (weakly) higher information to the entrant which make him very attractive in the entrant's viewpoint. On the other hand if $W_1 > W_2$ then the second supplier offers lower price to the entrant but cannot add any updated information to the prior belief of the entrant while the first supplier is able to do that. In fact in this case there is a real trade-off between lower price and more information for the entrant which affects the incumbent's ordering strategy. The following table categorizes the remaining 4 scenarios:

Table 2: Potential Equilibria with Wholesale Price Consideration

2.1	If $W_1 \leq W_2$	Remark
1	(Accept, Separation, First Supplier)	-
2	(Accept, Separation, Second Supplier)	-
3	(Accept, Pooling, First Supplier)	-
4	(Not Accept, Separation, Second Supplier)	-

2.2	If $W_1 > W_2$	Remark
1	(Accept, Separation, First Supplier)	-
2	(Accept, Separation, Second Supplier)	-
3	(Accept, Pooling, First Supplier)	Not Optimal for Entrant
4	(Not Accept, Separation, Second Supplier)	-

As shown in above mentioned tables, if $W_1 \leq W_2$ and the first supplier accepts the entrant then the only incentive for the entrant to choose s_2 is the higher cost of information acquisition. In fact as it will be explained later, there is a threshold that affects the decision of the entrant between two suppliers. Here we have 4 equilibrium candidates.

Furthermore as depicted in table 2.2 if $W_1 > W_2$ then the only reason for the entrant to choose the first supplier is more precise demand information. So in the case of choosing pooling strategy by the incumbent there would be no rational incentive for the entrant to work with the first supplier, hence the 3rd scenario goes out. Here we have 3 equilibrium candidates.

For the sake of simplicity and tractability we impose two assumptions as below:

Assumption 1: If the first supplier accepts the entrant, it will leak the updated information.

Assumption 2: Wholesale prices are sufficiently high as both retailers (The incumbent and the entrant) will tend to sell all the received intermediate goods. This means that assembly costs of the retailers are low enough compared to W_1, W_2 .

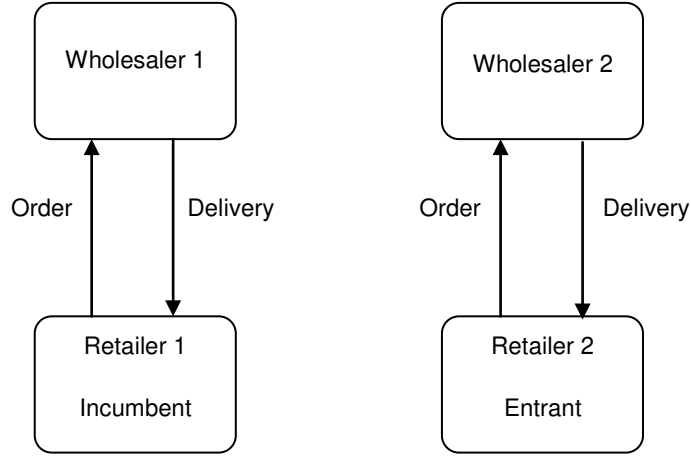
In the next section we consider the first supplier's decision as *given* in order to have a benchmark analysis in hand. For this purpose we assume that based on long term business relationship between the first supplier and the incumbent, there is *exclusivity* in contractual terms such that the first supplier commits not to leak the updated information to the entrant. Thus the first event in the game is solved beforehand. Details are as follow.

4.1. Exclusive Supply Contract

As benchmark analysis, we consider the existence of *exclusive supply contract* (Anand and Goyal (2009)). In this case the first supplier is precluded from information leakage to entrant based on some fixed contractual terms. That is the supplier makes an *ex ante* credible commitment not to leak the incumbent's order quantity to the entrant. Hence the incumbent, aware of this term, takes the *separation* strategy and has no concern upon truthful ordering. Moreover the entrant must procure its order from second supplier. Indeed the game between the incumbent and the entrant is a static simultaneous-move game with incomplete information in which the incumbent sends its order to first supplier and the entrant to the second one (See figure 4). The point is that

the incumbent at the ordering time knows the exact realization of demand while the entrant orders just based on his prior belief. Solving this game leads us to following results.

Figure 4: Supply Chain Configuration with Exclusivity



Proposition 1: Under exclusive supply contract between the first supplier and the incumbent (Non-Leakage), if $3A_L + 2(W_2 - 2W_1) \geq \mu$, then the order quantities of the high-type incumbent, the low-type incumbent and the entrant respectively are,

$$q_{iH}^{ESC} = \frac{1}{2}A_H - \frac{1}{6}\mu + \frac{1}{3}(W_2 - 2W_1), \quad q_{iL}^{ESC} = \frac{1}{2}A_L - \frac{1}{6}\mu + \frac{1}{3}(W_2 - 2W_1), \quad q_e^{ESC} = \frac{1}{3}(\mu - 2W_2 + W_1).$$

Moreover suppliers and retailers earn the following expected profits:

$$\pi_{s_1}^{ESC} = \frac{1}{3}(\mu - 2W_1 + W_2) \cdot W_1 \quad (\text{First Supplier})$$

$$\pi_{s_2}^{ESC} = \frac{1}{3}(\mu - 2W_2 + W_1) \cdot W_2 \quad (\text{Second Supplier})$$

$$\Pi_{iH}^{ESC} = \left[\frac{1}{2}A_H - \frac{1}{6}\mu + \frac{1}{3}(W_2 - 2W_1) \right]^2 \quad (\text{High type incumbent})$$

$$\Pi_{iL}^{ESC} = \left[\frac{1}{2}A_L - \frac{1}{6}\mu + \frac{1}{3}(W_2 - 2W_1) \right]^2 \quad (\text{Low type incumbent})$$

$$\Pi_e^{ESC} = \left[\frac{1}{3} (\mu - 2W_2 + W_1) \right]^2 \quad (\text{Entrant})$$

Proof: When due to contractual terms, the first supplier commits *ex ante* not to leak the updated demand information from incumbent to entrant, optimal order quantities results from solving a simultaneous-move game with incomplete information. Profit functions of high-type incumbent, low-type incumbent and entrant which should be maximized are as follows:

$$\Pi_{iH} = \max_{q_{iH}} (A_H - q_{iH} - q_e) q_{iH} - W_1 q_{iH}$$

$$\Pi_{iL} = \max_{q_{iL}} (A_L - q_{iL} - q_e) q_{iL} - W_1 q_{iL}$$

$$\Pi_e = \max_{q_e} (p \cdot (A_H - q_{iH} - q_e) q_e + (1-p) \cdot (A_L - q_{iL} - q_e) q_e) - W_2 q_e$$

Optimal order quantities are simply the answers of the first order conditions. Moreover $q_{iL}^{ESC} \geq 0$ is the participation constraint which guarantees the entry of incumbent and entrant to the market which results in $3A_L + 2(W_2 - 2W_1) \geq \mu$. This inequality also covers the price non-negativity condition that is $3A_L + 2(W_1 + W_2) \geq \mu$. Suppliers' profits can be calculated easily with equations $\pi_{s_1}^{ESC} = W_1 \cdot (p q_{iH}^{ESC} + (1-p) q_{iL}^{ESC})$ and $\pi_{s_2}^{ESC} = W_2 \cdot q_e^{ESC}$. Retailers' profits also have been obtained by plugging optimal quantities into profit functions as shown above. \square

Here the sequence of events is such that the first supplier based on exclusive contract with the incumbent does not accept the entrant's order which is common knowledge between all players. Due to that commitment, the incumbent truthfully reveals its order based on its updated demand information and so there is no operational distortion. The entrant afterwards has no other choice rather than doing business with second supplier. Finally after order delivery from suppliers, both retailers enter the market and compete on the amount of output. According to the first proposition, incumbent's order quantity depends on the actual realization of demand, posterior belief, which is known to it at ordering time while the entrant should maximize its expected profit and demand mean reveals in its optimal order quantity. In fact the entrant's ordering decision is based on his prior belief (demand mean). Here with the assumption of exclusivity, the incumbent does not encounter any informational distortion such that separation strategy and maximizing operational profit are in its interest.

4.2. Effect of Price Differences

Here we consider two different cases with respect to wholesale prices of the suppliers, establish the (dis)incentives of the players and seeking the equilibrium of the whole game.

4.2.1. The First Supplier Offers Lower Price ($W_1 \leq W_2$)

Under this price setting the entrant's incentives in choosing s_1 are lower wholesale price plus (weakly) higher information. Indeed even if the incumbent chooses pooling strategy, then the entrant can supply its goods with lower cost and its prior beliefs if it is accepted by s_1 . Actually there could be potentially two incentives for the entrant to choose the second supplier: First reason in working with s_2 could be the non-acceptance of s_1 and second one refers to the cost of information acquisition. As we will show in second proposition, under some circumstances it is more profitable for the entrant not to choose the first supplier and enter the market with its prior belief. In this case it can produce Cournot quantity instead of Stackelberg one.

On the other hand the first supplier's incentive is to deliver higher volume of intermediate goods to the retailers in order to maximize its profit. Hence acceptance of the entrant is in his interest. Moreover the incumbent's incentive in both demand states is to persuade the entrant that the demand is low to reach more profit in the market. Pooling strategy is an equipment of the incumbent to threat the s_1 not to accept the entrant. The question here is that how *credible* this threat is. Actually if the incumbent pools (the worst scenario for s_1 in this case), then how the sum of the orders of both retailers *in comparison with* the scenario of non-acceptance of the entrant by s_1 will be. The other point is that when demand variation is high, pooling strategy is too costly for the high-type incumbent. In fact if s_1 knows that the incumbent separates then he will always accept the entrant. As can be seen in following propositions and lemmas, the relative amount of the suppliers' wholesale price (W_1 / W_2) and mean demand μ play crucial roles here which could convince s_1 not to accept the entrant or could affect the entrant's decision in choosing among two suppliers and information acquisition.

4.2.1.1. Separating Equilibrium

Here we consider a potential equilibrium where the incumbent's order quantity depends on the demand states (High or Low). Thus if the first supplier accepts the entrant then the entrant will have perfect demand information as well prior to his ordering decision.⁴ Hence under this scenario a *Stackelberg* sequential move game with complete information occurs in which the incumbent is the leader and the entrant is the follower.

⁴ If the first supplier accepts the entrant then the entrant will access to the actual demand information and also cheaper goods. Since the incumbent orders first, so the entrant plays the role of the follower.

For future references we establish the following lemma that states the optimal quantities of Stackelberg game for our mentioned inverse demand system. For brevity, the proof has been skipped.⁵

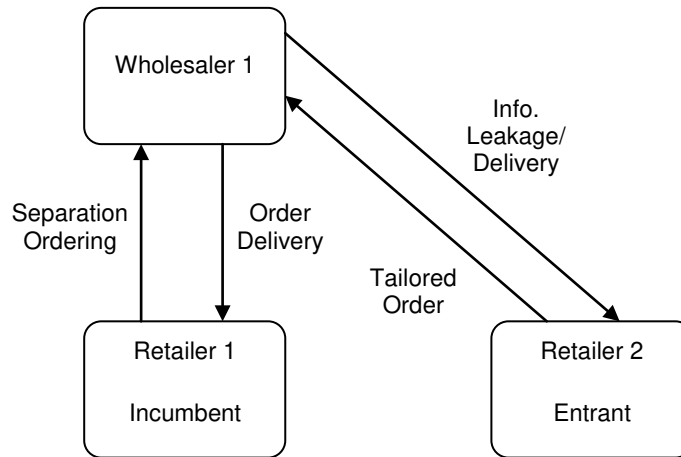
Lemma 1: If the first supplier s_1 accepts the entrant, the incumbent separates and the entrant chooses the first supplier s_1 , then the SPNE outcomes (quantities and profits) of the respected *Stackelberg game with complete information* are as follows:

$$q_i^{*Stackelberg} = (\tilde{A} - W_1) / 2 \quad ; \quad q_e^{*Stackelberg} = (\tilde{A} - W_1) / 4$$

$$\pi_i^{*Stackelberg} = (\tilde{A} - W_1)^2 / 8 \quad ; \quad \pi_e^{*Stackelberg} = (\tilde{A} - W_1)^2 / 16$$

Referring to figure 3, the supply chain configuration due to this scenario (Accept, Separation, First Supplier) can be depicted as the following figure.

Figure 5: Supply Chain Configuration of Lemma 1



As explained earlier in the separating equilibrium, the entrant has perfect demand information and realizes the demand state correctly. Consequently based on the figure 2, in the extensive form of the resulted game the entrant infers the realized demand, updates its prior belief and knows on which node of the signaling game stands.

In order to find the equilibrium, firstly we investigate the choice of entrant among two suppliers. Considering incentives, it is obvious that the entrant will choose more profitable supplier. Next Lemma describes the entrant’s decision.

⁵ The idea of putting this Lemma here is inspired by Anand and Goyal (2009). The detailed proof can be found in the technical appendix of Anand and Goyal (2009) and also several game theoretic books, i.e. Gibbons (1992).

Lemma 2: Under separation equilibrium and when $W_1 \leq W_2$, if $\mu \leq 8W_2 - 7W_1$ then the entrant will choose the first supplier s_1 . Otherwise it will choose the second supplier s_2 .

Proof: The entrant will choose s_1 if and only if $\Pi_e^{s_1} \geq \Pi_e^{s_2}$, otherwise it chooses the second supplier. As a matter of notation, $\Pi_e^{s_1}$ implies the entrant's profit by choosing the first supplier. If the entrant chooses the second supplier, regardless of the reason (Its own decision or non-acceptance of s_1), then its profit- based on proposition 1- is:

$$E(\Pi_e^{s_2}) = \left[\frac{1}{3} (\mu - 2W_2 + W_1) \right]^2$$

For calculating the expected $\Pi_e^{s_1}$, the entrant faces the following maximization problem based on its prior belief:

$$E(\Pi_e^{s_1}) = p \cdot \max_{q_{eH}} \left[(A_H - q_{iH}^* - q_{eH}) q_{eH} - W_1 \cdot q_{eH} \right] + (1-p) \cdot \max_{q_{eL}} \left[(A_L - q_{iL}^* - q_{eL}) q_{eL} - W_1 \cdot q_{eL} \right]$$

In order to solve the above optimization problem we need the optimal amount of the incumbent's quantity in both demand state. The expected profit of the entrant by choosing the first supplier is:

$$E(\Pi_e^{s_1}) = \left[\frac{1}{4} (\mu - W_1) \right]^2$$

Solving inequality $\Pi_e^{s_1} \geq \Pi_e^{s_2}$ leads us to the below result:

$$\mu \leq 8W_2 - 7W_1. \quad \square$$

Lemma 3: The first supplier always *accepts* the entrant, if separation equilibrium outcome occurs after acceptance.

Proof: Comparing the first supplier's profit in two cases (acceptance and non-acceptance) concludes the result. We have:

If the first supplier accepts the entrant, its profit is as follow:

$$\pi_{s_1}^{accept} = p \cdot (W_1 \cdot q_{iH}^* + W_1 \cdot q_{eH}^*) + (1-p) \cdot (W_1 \cdot q_{iL}^* + W_1 \cdot q_{eL}^*)$$

But in the case of non-acceptance we have:

$$\pi_{s_1}^{not-accept} = p \cdot (W_1 \cdot q_{iH}^*) + (1-p) \cdot (W_1 \cdot q_{iL}^*)$$

It is trivial to show that $\pi_{s_1}^{accept} \geq \pi_{s_1}^{not-accept}$. \square

According to above mentioned Lemmas, now, we are well equipped to establish the second proposition which describes the separation equilibrium. Before that, as in Anand and Goyal (2009), we should consider the entrant's belief as a part of PBNE. The entrant's belief structure is as follow:

$$\Pr_e(\tilde{A} = A_H) = \begin{cases} 1, & \text{if the first Supplier accepts and } q_i > q_{iL}^* \\ 0, & \text{if the first Supplier accepts and } q_i \leq q_{iL}^* \end{cases}$$

In separation strategy, the major incentive of the incumbent is to signal the entrant that the demand state is low. This could be beneficial when the difference between high and low demand states is *small enough* (this term is quantified via parameter $\theta = (A_H - W_1)/(A_L - W_1)$). Actually the incumbent tries to manage the entrant's belief. On the other hand, the entrant's belief is increasing in the order quantity of incumbent. This issue will appear as an *incentive compatibility constraint* in our optimization problem such that the high-type incumbent has an incentive to mimic the low-type. The inverse one is not reasonable. The following proposition characterizes the separation equilibrium. Here, capacities have been chosen by retailers, but quantities still not.

Proposition 2: A separating Perfect Bayesian Nash Equilibrium exists and is as follow:

i. If $\mu \leq 8W_2 - 7W_1$:

- The first supplier s_1 accepts the entrant.

- The incumbent orders:

$$q_{iH}^* = (A_H - W_1)/2, \text{ if demand is high}$$

$$q_{iL}^* = (A_L - W_1)/2, \text{ if demand is low and } \theta \geq 3$$

$$q_{iL}^* = \frac{2A_H - A_L - W_1 - \sqrt{(A_H - A_L)(3A_H - A_L) - 2W_1(A_H + A_L)}}{2}, \text{ if demand is low}$$

and $\theta < 3$

- The entrant chooses the first supplier s_1 and orders:

$$q_{eH}^* = (A_H - W_1)/4, \text{ if } \Pr_e(\tilde{A} = A_H) = 1$$

$$q_{eL}^* = (A_L - W_1)/4, \text{ if } \Pr_e(\tilde{A} = A_H) = 0 \text{ and } \theta \geq 3$$

$$q_{eL}^* = \frac{3A_L - 2A_H - W_1 + \sqrt{(A_H - A_L)(3A_H - A_L) - 2W_1(A_H + A_L)}}{4}, \text{ if } \Pr_e(\tilde{A} = A_H) = 0$$

and $\theta < 3$

Consistent with its belief that:

$$\Pr_e(\tilde{A} = A_H) = \begin{cases} 1, & \text{if the first Supplier accepts and } q_i > q_{iL}^* \\ 0, & \text{if the first Supplier accepts and } q_i \leq q_{iL}^* \end{cases}$$

ii. If $\mu > 8W_2 - 7W_1$:

- The first supplier s_1 accepts the entrant.

- The incumbent orders:

$$q_{iH}^* = \frac{1}{2}A_H - \frac{1}{6}\mu + \frac{1}{3}(W_2 - 2W_1) \quad , \text{ if demand is high}$$

$$q_{iL}^* = \frac{1}{2}A_L - \frac{1}{6}\mu + \frac{1}{3}(W_2 - 2W_1) \quad , \text{ if demand is low}$$

- The entrant chooses the second supplier s_2 and orders:

$$q_e^* = (\mu - 2W_2 + W_1)/3, \text{ consistent with its belief that } \Pr_e(\tilde{A} = A_H) = p$$

Proof: We use Lemmas 1-3 in our calculation. The proof is similar to that of Anand and Goyal (2009), adjusted to our model with two suppliers.

Part One: Based on Lemma 2 we know that under which circumstances the entrant will choose among two suppliers. So if $\mu \leq 8W_2 - 7W_1$ the entrant chooses the first supplier s_1 . Also in Lemma 3 we have shown that the first supplier always accepts the entrant. Hence under separation strategy, the incumbent determines its order quantity by simultaneously solving the following maximization problem:

The low-type incumbent solves:

$$\Pi_{iL} = \max_{q_{iL}} (A_L - q_{iL} - q_{eL}^*(q_{iL}))q_{iL} - W_1 \cdot q_{iL}$$

$$\text{Such that } (A_H - q_{iL} - q_{eL}^*(q_{iL}))q_{iL} - W_1 \cdot q_{iL} \leq (A_H - W_1)^2 / 8$$

And the high-type incumbent solves:

$$\Pi_{iH} = \max_{q_{iH}} (A_H - q_{iH} - q_{eH}^*(q_{iH}))q_{iH} - W_1 \cdot q_{iH} \quad (\text{Unconstrained})$$

Note: The low-type incumbent has not any incentive to mimic the high-type one, while the high-type tries to convince the entrant that the demand state is low. Thus the maximization problem of the low-type incumbent has a constrained which guarantees that off-equilibrium profit is not higher than equilibrium profit. (Incentive Compatibility Constraint)

Moreover the entrant faces the following maximization problem:

$$q_{eL}^*(q_{iL}) = \arg \max_{q_{eL}} (A_L - q_{iL} - q_{eL})q_{eL} - W_1 \cdot q_{eL} = (A_L - q_{iL} - W_1) / 2$$

$$q_{eH}^*(q_{iH}) = \arg \max_{q_{eH}} (A_H - q_{iH} - q_{eH})q_{eH} - W_1 \cdot q_{eH} = (A_H - q_{iH} - W_1) / 2$$

Considering $\theta = (A_H - W_1)/(A_L - W_1)$, the rest of the proof for part one is similar to Anand and Goyal (2009). In our proof the wholesale price appears in calculation and change the final order quantity.⁶

Part Two: Based on Lemma 2 we know that if $\mu > 8W_2 - 7W_1$ then the entrant chooses the second supplier. This choice does not update the prior belief of the entrant. The proof of this part is similar to the proof of proposition 1. In this scenario although the first supplier accepts the entrant, information acquisition is not valuable for the entrant and it prefers to enter the market using its prior belief. \square

As can be seen in proposition 2, when demand variation is high enough, here $\theta \geq 3$, it is too costly for the incumbent to manipulate its order quantity. Truthful revelation of the demand state is in his interest. Thus if the entrant chooses the first supplier, the real demand state will be transferred thereafter. Indeed when $\theta \geq 3$ the difference between high and low demand realization is as so high such that the high type incumbent avoids mimicking the low type. In this case if the entrant procures from s_1 then the game will be the Stackelberg with complete information as discussed in Lemma 1.

On the other hand, when demand variation is low enough, here $\theta < 3$, it is valuable for the incumbent to manipulate its ordering to convince the entrant upon low demand realization. The point is that the entrant is also aware of this thinking and behaves strategically. So when demand is high, the high type incumbent orders truthfully as before but the low type incumbent should ensure the entrant that demand is really low. Hence the incumbent should order a quantity strictly less than $q_{iL}^* = (A_L - W_1)/2$ to convince the entrant that the demand is low. Otherwise the entrant might infer $q_{iL}^* = (A_L - W_1)/2$ as an ordering of the high type incumbent mimicking low type. Thus when demand state is low and $\theta < 3$, then the low type incumbent prefers to order $q_{iL}^* = \left[\left(2A_H - A_L - W_1 - \sqrt{(A_H - A_L)(3A_H - A_L) - 2W_1(A_H + A_L)} \right) / 2 \right] < \left[(A_L - W_1) / 2 \right]$.

The other issue is the existence of the threshold which determines the choice of entrant among two suppliers. As shown in Lemma 2, the entrant will not choose the first supplier if $\mu > 8W_2 - 7W_1$. This implies that information acquisition for the entrant is a strategic decision and entering the market with prior belief could be his best reaction. Indeed when $\mu > 8W_2 - 7W_1$ the entrant produces based on Cournot which is higher compared to Stackelberg follower. Also it can sell its product with higher price which concludes higher benefit. But the incumbent (as potential Stackelberg leader) and the first supplier face the opportunity cost of not having the entrant in their desirable supply chain configuration as shown in figure 5. By considering the condition $\mu > 8W_2 - 7W_1$, the first supplier can leverage the choice of entrant by decreasing its wholesale price W_1

⁶ The proof of the first part is very similar Anand and Goyal (2009, Technical Appendix). Here contrary to them, based on different modeling and the existence of second supplier, we consider positive wholesale prices which slightly affect the results.

(which we take it exogenous in the model). Indeed by decreasing the wholesale price W_1 the range of choosing s_1 by the entrant expands which could be profitable for s_1 .

4.2.1.2. Pooling Equilibrium

In this subsection we consider a potential equilibrium where the incumbent chooses pooling strategy such that the incumbent's order quantity is independent of demand state. Hence the entrant cannot update his prior belief. Indeed, here, the only reason for the entrant in choosing s_1 is the lower wholesale price of it in comparison with s_2 , that is $W_1 \leq W_2$.

As it was discussed in table 2.1, under pooling equilibrium, the first supplier already has accepted the entrant. In fact if s_1 does not accept the entrant then there will be no incentive for the incumbent to pool. So (Not Accept, Pooling, Second Supplier) will not happen in equilibrium as it is not optimal for the incumbent. Moreover as we have shown in proposition 2, when the difference between high and low demand realization is high enough ($\theta > 3$), then it is too costly for the incumbent to pool and mimic the other type. Hence pooling equilibrium is feasible for smaller range of θ which will be determined precisely later. So the question is that under which circumstances the first supplier accepts the entrant when the threat of pooling is credible. Following lemma deals with this situation.

Lemma 4: Under the pooling equilibrium, if $\mu \leq 2A_L - W_1$ then the first supplier s_1 *accepts* the entrant. Otherwise it will reject the entrant.

Proof: Similar to the proof of Lemma 3, comparing the first supplier's profit in two cases (acceptance and non-acceptance) concludes the result. We have:

If the first supplier accepts the entrant, its profit is as follow:

$$\pi_{s_1}^{accept} = W_1 \cdot (q_{ip}^* + q_{ep}^*)$$

q_{ip}^* and q_{ep}^* can be calculated based on the proof of the next proposition. To be mentioned here, we have:

$$q_{ip}^* = A_L - (\mu + W_1) / 2$$

$$q_{ep}^* = (3\mu - 2A_L - W_1) / 4$$

By plugging these two quantities into the profit function of the first supplier we reach:

$$\pi_{s_1}^{accept} = (W_1 / 4)(\mu + 2A_L - 3W_1) \quad (*)$$

But in the case of non-acceptance we have:

$$\pi_{s_1}^{not-accept} = p \cdot (W_1 \cdot q_{iH}^*) + (1-p) \cdot (W_1 \cdot q_{iL}^*)$$

Separation quantities of the incumbent can be obtained from proposition 2, so here we get:

$$\pi_{s_1}^{not-accept} = (W_1 / 2)(\mu - W_1) \quad (**)$$

By comparing (*) and (**) we conclude:

$$\pi_{s_1}^{accept} \geq \pi_{s_1}^{not-accept} \text{ iff } \mu \leq 2A_L - W_1. \quad \square$$

As corollary of above mentioned Lemma it can be stated that the probability of accepting the entrant by s_1 is *decreasing* with respect to the probability of high demand realization p . (The proof is simply achieved by limit the inequality when p tends to zero)

Now we should find out range of quantity in which the incumbent has incentive to pool. As we discussed before, the low type incumbent has no incentive to mimic the high type. Hence the optimal quantity of the low type incumbent in pooling equilibrium determines the upper bound of (or maximum amount of) the pooling interval (q_{iP}^{\max}). On the other hand the high type incumbent has reasonable incentive to mimic the low type and conceal the real demand state, but the question is that '*down to which amount?*' Indeed the high type incumbent pools when it would make more profit than the case of ordering a high enough quantity which can reveal his type to the entrant. Thus the minimum order quantity that the high type incumbent prefers to pool determines the lower bound of (or minimum amount of) the pooling interval (q_{iP}^{\min}). Obviously the lower bound should be smaller or equal to the upper bound of the interval. This trivial condition specifies the range of θ in which pooling equilibrium exists.

In pooling equilibrium, the belief structure of the entrant which is an essential part of the PBNE determination, based on Anand and Goyal (2009), is as follow:

$$\Pr_e(\tilde{A} = A_H) = \begin{cases} 1, & \text{if the first Supplier accepts and } q_i > q_{iP}^{\max} \\ p, & \text{if the first Supplier accepts and } q_{iP}^{\min} \leq q_i \leq q_{iP}^{\max}, \text{ or} \\ & \text{if the first Supplier does not accept} \\ 0, & \text{if the first Supplier accepts and } q_i < q_{iP}^{\min} \end{cases}$$

Next Lemma formalizes the above mentioned discussion:

Lemma 5: A pooling equilibrium, if exists, should belong to the interval $[q_{iP}^{\min}, q_{iP}^{\max}]$ where:

$$\begin{cases} q_{iP}^{\max} = A_L - (\mu + W_1) / 2 \\ q_{iP}^{\min} = A_H - (\mu + W_1) / 2 - (1/2) \sqrt{(A_H - \mu)(3A_H - \mu) - 2W_1(A_H + \mu)} \end{cases}$$

Proof: The upper bound of the interval will be determined by the optimal order quantity of the low type incumbent because the low type never prefers to pool on a quantity more than q_{iP}^{*L} . In fact if he orders more than this optimal quantity, the entrant might ascribe it as a high demand realization signal which is not favorable for the incumbent. For finding q_{iP}^{*L} we have to solve the following maximization problem:

$$\Pi_{iL}^P = \max_{q_{iP}} \left(A_L - q_{iP} - q_{eP}^*(q_{iP}) \right) \cdot q_{iP} - W_1 \cdot q_{iP}$$

Since the entrant cannot realize the exact demand state, he should stick to his prior and solve the following optimization problem:

$$\Pi_e^P = \max_{q_{eP}} \left(p \cdot (A_H - q_{iP} - q_{eP}) \cdot q_{eP} + (1-p) \cdot (A_L - q_{iP} - q_{eP}) \cdot q_{eP} \right) - W_1 \cdot q_{eP}$$

First-Order-Conditions lead us to the optimal quantity of the entrant and also low type incumbent which specifies the *upper* bound of the interval in Lemma 5. Both optimal quantities are shown below:

$$q_{eP}^*(q_{iP}) = (\mu - q_{iP} - W_1) / 2$$

$$q_{iP}^{\max} = q_{iP}^{*L} = A_L - (\mu + W_1) / 2$$

Plugging the optimal quantity of the low type incumbent q_{iP}^{*L} into the entrant's equation reach us to: $q_{eP}^* = (3\mu - 2A_L - W_1) / 4$

In order to find out the lower bound of the interval we should consider the incentive of the high type incumbent who prefers to mimic the low type to affect the entrant's order. Indeed the high type incumbent will pool as long as the profit of pooling dominates the profit of truthful revelation. So the high type incumbent solves the following inequality:

$$\left(A_H - q_{iP} - q_{eP}^*(q_{iP}) \right) \cdot q_{iP} - W_1 \cdot q_{iP} \geq \underbrace{\max_{q_{iH} > q_{iP}} \left(A_H - q_{iH} - q_{eH}^*(q_{iH}) \right) \cdot q_{iH} - W_1 \cdot q_{iH}}_{(A_H - W_1)^2 / 8}$$

After some manipulation on the inequality and find out the two roots of the resulted formula will get us to the lower bound of the interval as below:

$$q_{iP}^{\min} = A_H - (\mu + W_1) / 2 - (1/2) \sqrt{(A_H - \mu)(3A_H - \mu) - 2W_1(A_H + \mu)} \quad \square$$

Existence condition of a pooling equilibrium is similar to Anand and Goyal (2009) and will be got by solving the inequality $q_{iP}^{\min} \leq q_{iP}^{\max}$. The alterations are the positive amount of wholesale price- which changes the formulation of θ such that $\theta = (A_H - W_1) / (A_L - W_1)$ - and also the threshold (Shown in Lemma 2) after which the entrant chooses the second supplier. Working with the second supplier leads to separation equilibrium.

Lemma 6: The pooling equilibrium *exists* if demand uncertainty proxy parameter θ and mean demand μ obey the following inequalities simultaneously:

$$\theta \leq (3 + 2p - p^2) / (1 + 4p - p^2) \text{ where } p \text{ is the probability of high demand realization;}$$

And

$\mu \leq \min\{(8W_2 - 7W_1), (2A_L - W_1)\}$ which causes that first, s_1 accepts the entrant and second, the entrant chooses the first supplier s_1 .

Otherwise there is no pooling equilibrium and the incumbent prefers to separate its ordering.

Proof: By solving $q_{iP}^{\min} \leq q_{iP}^{\max}$ (As done in Anand and Goyal (2009)) we reach the first inequality of θ . The second inequality on μ has been proven in Lemma 2. \square

The following proposition characterizes the pooling equilibrium when $W_1 \leq W_2$:

Proposition 3:

- If $\mu \leq \min\{(8W_2 - 7W_1), (2A_L - W_1)\}$ & when $\theta \leq (3 + 2p - p^2) / (1 + 4p - p^2)$, a pooling Perfect Bayesian Nash Equilibrium exists and is as follow:

- I. The first supplier s_1 accepts the entrant.
- II. The incumbent orders: $q_{iP}^* = A_L - (\mu + W_1) / 2$
- III. The entrant chooses the first supplier s_1 and orders: $q_{eP}^* = (3\mu - 2A_L - W_1) / 4$
Consistent with its belief that:

$$\Pr_e(\tilde{A} = A_H) = \begin{cases} 1, & \text{if the first Supplier accepts and } q_i > q_{iP}^{\max} \\ p, & \text{if the first Supplier accepts and } q_{iP}^{\min} \leq q_i \leq q_{iP}^{\max}, \text{ or} \\ & \text{if the first Supplier does not accept} \\ 0, & \text{if the first Supplier accepts and } q_i < q_{iP}^{\min} \end{cases}$$

$$\text{where } q_{iP}^{\min} = A_H - (\mu + W_1) / 2 - (1/2) \sqrt{(A_H - \mu)(3A_H - \mu) - 2W_1(A_H + \mu)}$$

- Otherwise, If $\mu \leq \min\{(8W_2 - 7W_1), (2A_L - W_1)\}$, $\theta \leq (3 + 2p - p^2) / (1 + 4p - p^2)$ or both does not hold, there is no pooling equilibrium and firms behave as proposition 2.

Proof: Proofs of Lemmas 2, 4, 5 and 6, actually lead us to the outcomes of this proposition. \square

As shown in proposition 3, when the incumbent chooses pooling equilibrium (and it exists), the entrant obtains no additional demand information and should stick to its prior. The point is that this pooling should be beneficial for the incumbent. This issue is determined by the condition on θ . Indeed when θ is high it is too costly for the high type incumbent to mimic the low type and separation will occur.

The other important point is preconditions for existence of pooling equilibrium. In fact information acquisition should be profitable for the entrant which is captured by $\mu \leq 8W_2 - 7W_1$. Moreover the first supplier accepts the entrant as long as the profit he would make from acceptance (besides the threat of pooling strategy) dominates the choice of non-acceptance. This also causes to impose a restriction on mean demand that is $\mu \leq 2A_L - W_1$. Hence $\mu \leq \min\{(8W_2 - 7W_1), (2A_L - W_1)\}$ is the necessary condition for existence of any pooling equilibrium.

4.2.2. The Second Supplier Offers Lower Price ($W_2 < W_1$)

Under this pricing regime, the only incentive of the entrant for choosing s_1 is its potential updated information. It implies that if the incumbent pools on its quantity ordering, then the entrant will choose the cheaper wholesaler in equilibrium. As we have shown in table 2.2, if $W_1 > W_2$ we could have potentially three possible equilibria where in two cases, the first supplier accepts the entrant and the incumbent separates. Hence the exact equilibrium will be determined by the decision choice of the entrant among two wholesalers. Whereas the second supplier offers more attractive price, we have a real trade-off for the entrant between higher levels of demand information (which could be obtained by choosing s_1) and lower price of the product (which is offered by s_2). This decision will configure our supply chain. Also as we have explained in Lemma 3, under separation, the first supplier s_1 always accepts the entrant (in equilibrium). Hence only two equilibrium candidates remain. As significant calculations have been done so far, we go directly to state the result.

Proposition 4: If $\mu \leq 8W_2 - 7W_1$ and $0.875 \leq \frac{W_2}{W_1} \leq 1$, then in equilibrium, the first supplier s_1

accepts the entrant, the incumbent separates and the entrant prefers s_1 . The optimal quantities of the players and the belief structure of the entrant are as stated in the first part of proposition 2. Otherwise if one or both of above mentioned conditions does not hold, then in equilibrium, the first supplier s_1 accepts the entrant, the incumbent separates and the entrant chooses the second supplier s_2 that offers lower price. The optimal quantities of the players and the belief structure of the entrant are as stated in the second part of proposition 2.

Proof: The proof is similar to the methods we have followed in Lemmas 1-3 and proposition 2. The added condition on the relative amount of wholesale prices stems

from the fact that $W_1 > W_2$ which causes the imposition of inequality $0 \leq \mu \leq 8W_2 - 7W_1$. In previous subsection as $W_1 \leq W_2$, the mean demand was always positive but here in order to have non-negative mean demand we should have $0 \leq 8W_2 - 7W_1$. This leads us to a condition on wholesale prices $\frac{7}{8} = 0.875 \leq \frac{W_2}{W_1} \leq 1$. \square

As expresses in proposition 4, when the entrant has access to a supplier with lower price, the range of relative wholesale price W_2 / W_1 is more restricted. In fact if the price of s_2 is much lower than s_1 such that the condition $0.875 \leq (W_2 / W_1)$ would not hold, then the entrant will ignore the updated demand information and work with the second supplier.

5. Conclusion

In this paper we presented a model to investigate the strategic effects of information sharing on supply chain configuration with vertical structure. We considered a typical supply chain containing two suppliers (wholesalers) that could potentially supply intermediate (final) goods to two manufacturers (retailers), an incumbent and an entrant. The incumbent is assumed to do business only with the first supplier (potential channel of information leakage from incumbent to entrant) while the entrant is free to choose its supplier strategically. A dynamic multi-stage game of incomplete information between these four economic agents was employed: The first supplier starts the game by his decision upon (none) acceptance of the entrant followed by the quantity order decision of the incumbent, then the entrant decides between two suppliers and places his order (considering their wholesale price and updated information) and finally, both retailers play a Cournot duopoly game on the amount of quantity they launch to the market characterized by demand uncertainty. Our model contributed to the literature in IO and strategic information management by considering a second supplier which gives a degree of freedom to the entrant in choosing its supplier. Methodologically, a signaling game was applied to model the strategic interactions of players. Hence, Perfect Bayesian Nash Equilibrium (PBNE) has been derived in terms of information and material flows.

We showed that how the difference between wholesale prices W_1, W_2 , the elements of mean demand $\mu = p \cdot A_H + (1 - p) \cdot A_L$, and also the range of demand variation $\theta = (A_H - W_1) / (A_L - W_1)$, select an equilibrium from the set of candidates. Moreover it was demonstrated that information acquisition is not always desirable for an uninformed entrant and how the entrant prefers to trade off between price and information, playing Cournot or Stackelberg. Furthermore existence of pooling equilibrium for sufficiently small demand variation confirms the significant role of strategic information management whereby the incumbent is able to keep its competitive advantage and

preclude the leakage of information. Add a second supplier to the seminal model of Anand and Goyal (2009), actually empowers us to involve the first supplier more actively. This extension gives the entrant an opportunity to choose its own supplier endogenously. In addition, the existence of pooling equilibrium besides the separation one implies that more accurate demand information (in the form of lower θ) enables the incumbent to conceal its private information while less accuracy leads to truthful ordering and neutralize the asymmetric dominance.

Our model dealt with exogenous wholesale prices which restrict the role of suppliers. Further research can endogenize the pricing of suppliers in the model. Indeed price competition between two suppliers makes the research more interesting and realistic. Moreover we imposed a restriction on choice of the incumbent between suppliers which can be released in oncoming works. Partial supply also can be investigated. Finally for the sake simplicity we avoided to examine the level of information quality which is worth examining.

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