Information sharing behavior under supply uncertainty

1. INTRODUCTION

One of the common assumptions when modeling forecast sharing between a buyer and his suppliers is that uncertainty originates from the demand side (Cachon & Lariviere 2001, Özer et al. 2011). However, certain industries, e.g., aerospace, behave differently. Products like airplanes and military vehicles require significant investments to develop and manufacture and they are produced in low quantities. In order to reduce the associated financial risk, significant advance ordering has become a standard business practice in these industries. So, effectively there is little demand uncertainty as evidenced by the fact that aerospace companies only monitor the backlog of (confirmed) orders. This backlog is often measured in terms of years of production. As of February 2014, Boeing has a backlog of more than 5,000 aircrafts equivalent to almost 8-9 years of production; Airbus also shows a similar pattern (CAPA 2014).

However, the above does not mean that these industries are immune to operations-related risks. Many of these products are complicated and involve numerous components and subassemblies. So, the assembler (e.g., Boeing or Pratt & Whitney) has to deal with a large number of suppliers. For example, Boeing 787 has 45 major Tier-1 suppliers (Boeing 2014). So, these systems face considerable *risks on the supply side* because of problems in terms of delays, disruptions, cancellations, changes in costs, etc. (refer to Cachon and Lariviere 2001, Nolan and Kotha 2005, and Greising & Johnsson 2007 for details). In such scenarios, it is the assembler (henceforth termed buyer) who is in touch with all suppliers and has the most up-to-date information about system-wide supply side risks; the suppliers individually only know about their own problems. It is then up to the assembler to decide how much of this private information to share with the suppliers and the suppliers then decide what to do with this information. For example, Greising and Johnson (2007) identify that one of Boeing's key suppliers, Spirit, produced significantly less than their original schedule "at Boeing's request;" Boeing reduced its firm production orders from its original production schedule due to supply uncertainty from other suppliers.

Information sharing in a decentralized supply chain has been a part of operations management literature for some time. But, most such papers deal with a buyer sharing forecasts about demand uncertainties with his suppliers. In this context, most early research generally assumed that the buyer truthfully shares his demand forecast. However, Cachon and Lariviere (2001) show that while optimal supply chain coordination requires truthful sharing by the buyers, they still have incentives to inflate. Since suppliers know of the buyer's incentive, they are motivated not to trust the forecast. Subsequently, a significant stream of literature has developed in this area. Of particular interest for us are Özer and Wei (2006) and Özer et al. (2011). The former analytically proves that under a price-only contract any forecast cannot be credibly shared and develops two contracts enabling credible forecast sharing. The latter uses a behavioral framework to reveal a number of insights about forecast sharing (by the buyer) and capacity building (by the suppliers) behaviors in the face of demand uncertainty. In the context of such information sharing behavior, a number of issues come into play. The principal among them are: i) whether the information being shared is just cheap talk (i.e., costless, nonbinding, non-verifiable messages that may affect the receiver's beliefs (Farrell & Rabin, 1996)) or is there some really valuable information, and ii) how much does the receiver believe the information being shared and how does this affect the provider's sharing behavior (Erat and Gneezy 2012, Gneezy et al. 2013).

Research Questions

The main goal of this paper is to again use a behavioral framework to understand forecast sharing and capacity building behaviors in the context of a decentralized supply chain, but when *the primary source of uncertainty is from the supply side and the buyer is sharing information about potential supply side risks with the suppliers*. This change in the source of uncertainty has a profound effect on the problem since it changes the whole framing. Tversky and Kahneman (1981) introduce the concept of framing decisions and demonstrate that rewording an objectively identical decision focusing on either gains or losses significantly changes the preference of choices. As we show below, compared to previous research on forecast sharing with demand uncertainty, supply uncertainty negatively reframes the problem by focusing on losses.

Consider a supply chain consisting of a buyer and multiple suppliers operating under a price-only contract. We focus on a particular supplier *S*. The buyer purchases components from *S* at a unit wholesale price *w*. The buyer also buys required components from other suppliers. He then assembles the product and sells them at a per unit retail price *r*. The buyer's demand is a constant *D*. However, she faces uncertainty on the supply side. Specifically, suppose the maximum shortfall (relative to *D*) incurred by the suppliers, other than *S*, is represented by the random variable *U* with cumulative distribution function G (public information). The buyer orders from *S* after receiving certain private information about *U,* while S builds her capacity based on *G*. *S*'s unit capacity and production costs are c_K and *c*, respectively. If there is no supply uncertainty, *S* would build a capacity of *D*. But, because of *U*, he might decide to build less than *D*; suppose *S* builds a capacity of *K* = (*D* – *d*). The buyer wants this capacity *K* to be always greater than the realized supply from the other suppliers. Meanwhile, *S* needs to balance the costs of building too much capacity with too little while deciding on *K*, like in a newsvendor problem. (1) below shows the expected profit functions for the buyer and the supplier *S*, respectively, while (2) gives the optimal capacity decision for supplier *S*.

$$\prod^B = (r-w)D - (r-w)\,E_U\,max(d,U)\,,\ \prod^S = (w-c)D - c_K K - (w-c)E_U\,min(K, D-U) \quad (1)$$

$$K = D - d^S \ where\, d^S = G^{-1}\left(\frac{w-c-c_K}{w-c}\right) \quad (2)$$

Contrast the above with a standard selling-to-a-newsvendor problem where there is no supply uncertainty, but the buyer's demand is represented by the random variable D_n. Equations (3) show the profit functions for the two parties in that case where K_n is the supplier's capacity decision.

$$\prod^B = (r-w)\,E_{D_n}\,min(K_n, D_n),\ \prod^S = (w-c)E_{D_n}\,min(K_n, D_n) - c_K K_n \quad (3)$$

If the uncertainties *U* and D_n are identical, then the problem facing supplier *S* is objectively the same in both cases. However, the formulations differ in terms of framing as described below.

In the former case (i.e., with supply uncertainty), the profit functions for both channel partners are *negatively framed* because they start with certain gains if the constant demand is completely satisfied and face only *uncertain losses* due to their decisions and supply uncertainty. Specifically, the buyer starts with certain profits of $(r-w)D$ and faces uncertain losses of $(r-w)E_U \max(d, U)$, while the supplier starts with certain profits of $(w-c)D - c_K K$ and faces uncertain overcapacity losses of $(w-c)E_U \min(K, D-U)$. In the latter case, the buyer's and the supplier's profit functions contain *uncertain* *gains*. While the buyer's profit function could be labeled as *positive framing* because the buyer faces only uncertain gains, the supplier's profit function contains both uncertain gains and losses. Consequently, we term the traditional selling-to-a-newsvendor problem as *standard framing*.

In the above context, we would like to address the following four research questions. The first one deals with the effect of framing on the decisions of the two channel partners.

i) How does the supplier's capacity decision and the buyer's information sharing about uncertainty compare between the two framing scenarios?

The second one deals with how the information shared is perceived by the supplier. Since the buyer faces no losses due to overcapacity, any forecast that the buyer shares about demand/supply uncertainty can be thought of as cheap talk by the supplier. So, we would like to study:

ii) How does the buyer's information sharing about the uncertainty compare to the supplier's expectation of the buyer's behavior?

It is also important to note that firms often simultaneously operate as buyers and suppliers in their supply chains. So, in the context of information sharing an important issue relates to:

iii) How do the behaviors of the players compare when they are buyers versus when they are suppliers?

The above research questions address the issue of framing and information sharing behavior. However, it is well-known from previous research that any random number by itself can generate anchoring effects (Tversky & Kahneman 1974), that is, the supplier might anchor her decision on the numerical message by the buyer even when she knows that the message is a totally random number. Our last research question relates to this anchoring effect.

iv) How much of the buyer's forecast message is just an anchor for the supplier's capacity decision and how much of it does the supplier treat as private information?

2. RESEARCH HYPOTHESES

In this section we present the hypotheses based on the above research questions. Our first hypothesis deals with the supplier's capacity decision. It is based on Schweitzer and Cachon (2000) who suggest that negative framing of the newsvendor problem would lead to an increase in the order quantity from the supplier (i.e., her capacity) due to prospect theory developed by Kahneman and Tversky (1979).

Hypothesis 1. The supplier increases her capacity in negative framing compared to standard framing.

Our next two hypotheses relate to the information sharing behavior of the two chain partners. Note that cheap talk motivates the buyer to lie to S about supply problems of other suppliers. Specifically, the buyer would like to underreport any supply problems. In recent research, Gneezy et al. (2013) find that lying behavior is positively correlated to the belief that the lie will be followed, even at the cost of the liar. That is, lying by an information provider reduces when the receiver more closely follows the lie. In our context, if we collect the belief of the buyer about what the supplier will do, we can define *information distortion* (on the part of the buyer) as the difference between the buyer's message about the supply problems and his belief about what the supplier will do. In other words, information distortion is the amount by which the buyer is lying. To match, we can define *compensation action* (on the part of the supplier) as the difference between the buyer's message and the supplier's actual action. So, compensation action is the amount by which the supplier follows the buyer's lie. Therefore, we can test whether buyer's lying is positively correlated to how closely the lie is followed by the supplier.

Hypothesis 2. The buyer's information distortion about supply risk is positively correlated to the supplier's compensation action for the distortion.

While the above hypothesis connects the behaviors of the two chain partners, our next hypothesis focuses on how framing affects deceptive behavior. Unfortunately, there is little extant research in this area. Laine et al. (2013) find evidence that honesty is positively connected with risk aversion. In prospect theory, positive framing increases risk-adverse behavior, and negative framing increases risk-seeking behavior (Kahneman & Tversky, 1979). Therefore dishonesty, in this case information distortion by the buyer, should be associated more with risk-seeking behavior and by extension negative framing.

Hypothesis 3. The buyer distorts her information more in negative framing versus standard framing.

Except for pure retailers, firms in supply chains simultaneously operate as buyers and suppliers receiving information from downstream customers and providing information to upstream suppliers. It is interesting to measure the differences in behavior with respect to information sharing depending on whether someone is a supplier or a buyer. If subjects are consistent, then subjects should distort the information they share by the same amount by which they compensate for such distortion.

Hypothesis 4(a). Subjects distort information playing as buyers by the same amount as they compensate for information distortion playing as suppliers.

On the other hand, decades of research has established that people tend to evaluate themselves better than an average peer (refer to Guenther and Alicke 2010 for details). This better-than-average effect could affect information sharing behavior. If subjects are affected by lying aversion, then being 'better' aligns with honesty. Therefore, one would expect a subject's compensation action for distortion to be greater than their own information distortion, because the subject expects to be more honest and distort information less than their average peer.

Hypothesis 4(b). Subjects distort information less playing as buyers than they compensate for the distortion playing as suppliers.

Lastly, note that, at its base a shared message by the buyer is simply a number. We know that anchoring unconsciously affects human behavior. Therefore, we should expect that suppliers follow such messages, even when they know the number is completely random.

Hypothesis 5. The supplier relies on the shared information even when it is a completely random number.

We propose that shared information consists of two distinct component effects in addition to individual preferences: an anchoring effect and an effect due to information asymmetry. By measuring the strengths of the two effects, we can then compare the impact of anchoring and information asymmetry on supplier behavior.

3. EXPERIMENTAL DESIGN

In this section, we describe the experimental setting that is used to test the above hypotheses. Our setting presents subjects with a set of decisions that objectively model the financial incentives and information asymmetry as described above without using the setup of buyers, suppliers, and information sharing about supply risk. This context-free description is similar to Kremer et al (2010) and facilitates minimization of changes to the game/instructions between standard and negative framing.

Our 2-player base game consists of the following two stages. The original range for (supply) uncertainty in the game has a uniform distribution with a range of 400. In the *first stage*, Player 1 acting as the buyer receives private information about the uncertainty reducing its range by 75% to 100. Based on this information, Player 1 decides what numerical message (representing supply risk information) to send to Player 2 and also predicts how Player 2 will act (i.e., what number she will choose representing the amount of capacity to build). In *stage two*, upon receiving the numerical message of Player 1, Player 2 acting as the supplier decides on a number (representing the amount of capacity to build) attempting to maximize her profit and also guesses what Player 1 received as private information. After the second stage, both players receive the summary of decisions for the game and their individual profits.

Subjects randomly and anonymously play both roles for 30 games per session in groups of 8 subjects who are randomly drawn from the participant pool that is maintained by the experimental economics laboratory of a university research center in Canada. The payment is based on performance with the average payment of $30 per subject for a session of two hours. The ranges of the original uncertainty (400) and that of the private uncertainty for Player 1 (100) are constant for all subjects, while the specific range of the private uncertainty randomly fluctuates within the range of the original uncertainty from game to game. The financial incentives (costs, revenues) of both players are common knowledge.

We develop four different treatments depending on framing (negative and standard) and critical ratios (high and low). Specifically, the instructions in the negative framing provide certain profits and all risks were in terms of losses, while standard framing balance risks of profits and losses like in a selling-to-a-newsvendor problem. For the critical ratio treatment, Player 1's profit per unit remains constant, while the financial incentives of Player 2 are modified to emulate critical ratios of 25% and 75%. There are 32 subjects for three treatments and 40 subjects for the fourth one.

Another 32 subjects test anchoring in a single stage game with the financial incentives of low critical ratio and standard framing. These subjects play the role of Player 2 receiving random messages (that they are told were random messages) from data collected in the equivalent treatment in the two player game. Otherwise, this game is identical to the base game.

4. RESULTS

In this section we provide the results of our analysis based on the data collected. We develop general linear models (Greene, 2003; Wickens & Keppel, 2004) to model behavior and treatment effects.

H1: *We find suppliers (Player 2) build significantly (p<0.1%) higher capacities in negative framing*. This result confirms Schweitzer and Cachon (2000) hypothesis about the effect of framing on newsvendor order quantities and application of prospect theory.

H2: *We find significant (p<0.1%) positive correlation between the buyer's information distortion and the supplier's compensation action*. This result aligns with the recent research into lying behavior, which posits that the liar decreases the amount of lying, the more the liar believes that the lie will be followed (Erat and Gneezy 2012, Gneezy et al. 2013)

H3: *We find no support that negative framing increases information distortion*. In fact, negative framing significantly (p<0.1%) *decreases* information distortion. This suggests that buyers perceive more (less) honesty as risk averse (risk-seeking) behavior. Given Laine et al. (2013) results to the contrary, our result indicates that the connection between honesty and risk might depend on the context.

H4: We find that the alignment of subject's information distortion and their compensation action for that distortion depend on critical ratio and framing.

Specifically, for standard framing with high critical ratio and negative framing with low critical ratio, we find significant support for H4(a). That is, in those scenarios a subject's information distortion as a buyer is consistent with his compensation action playing as supplier.

However, in the other two treatments, we find significant (p<0.3%) support for H4(b), such that a subject's information distortion as a buyer is consistently less than their compensation action playing as a supplier. Therefore, in these two scenarios, subjects appear to be significantly affected by the better-than-average effect causing them to compensate for information distortion more than they distort information themselves.

H5: Analyzing the anchoring treatment data, we find *suppliers significantly (p<0.1%) rely on random messages*. When we combine the anchoring treatment with its equivalent two player game treatment, we find that supplier's decisions is affected by the buyer's messages as per the following: 1/6 is due to anchoring effects, 1/3 is due to the effects of information asymmetry, and ½ is due to individual preferences. This result confirms the power of the anchoring effect of numbers and finds that its strength is half that of information asymmetry.

Concluding Discussion: Our study has three managerial implications for industries that are dominated by supply uncertainty. First, supply managers who send numerical orders to suppliers using EDI (Electronic Data Interchange) or other automated methods can be reasonably assured that suppliers will deliver their orders without much discount due to anchoring effects. Second, customer-facing managers with experience managing suppliers may operate with a bias causing them to overcompensate for any communicated supply risk. These two implications provide strategic incentives for managers of buyer firms not to share any information about potential supply problems with suppliers. However, even if managers share potential risk with their suppliers, negative framing effects significantly pull supplier capacity decisions toward buyer's preferences and away from supplier's optimal decision as modeled by the selling-to-a-newsvendor problem.

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