Anchoring Bias in Forecast Information Sharing in a Supply Chain

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Abstract

This paper investigates the behavioral aspects of decision making of retailers, in a supply chain, sharing private forecast information to suppliers. In a retailer-supplier setting, before the demand realization, the retailer shares the demand forecast followed by a "pull" wholesale price contract between a supplier and a retailer in which the inventory risk is borne by the supplier. In a one-shot interaction, the normative solution recommends that, in the equilibrium, the retailer inflates the demand and the supplier ignores the demand forecast. Hence, no credible demand forecast information is communicated. In this paper, we conjecture that, in the pull contract, the retailer deviates from the normative behavior due to the anchoring heuristic. We designed an experiment with human subjects to test this conjecture. We also study the extent of anchoring with different demand forecasts as anchors. Our experiment establishes the presence of anchoring in forecast information sharing.

1 Introduction

In a supply chain, there are multiple flows among different supply chain members. Information flow about demand forecast is one such critical flow which decides the success of a supply chain. Trust and credibility of the exchanged information is crucial for optimal decision making in a supply chain. However, there are instances where the information, especially about the demand forecast by the downstream agent, is inflated and leads to inefficiencies. For example: Ozer et al. (2011) cite Cisco— a major networking equipment supplier—had to write off US$2.1 billion in excess inventory because of inflated consumer forecasts; and, Ren et al. (2006) mention a case where American Airlines deferred the purchase of 54 Boeing aircrafts resulting in a loss of US $2.7 billion to Boeing.

These instances have motivated research in ensuring credible information sharing in supply chains. Cachon and Lariviere (2001) consider a supply chain with two players, a retailer (he) and a supplier (she). Before the demand realization, the retailer shares the demand forecast to the supplier. Based on the shared demand forecast, the supplier then builds capacity (upper

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information flow in Figure 1). After the capacity is built, the retailer observes realized demand and submits a final order. Finally, the supplier satisfies the minimum of capacity allocated and actual orders (lower information flow in Figure 1). This resembles a pull contract where the supplier acts as a newsvendor. In such a scenario, the retailer has an incentive to give the supplier an excessively optimistic initial demand forecast to ensure sufficient supply (reducing the supply risk). The supplier being aware of the retailer's incentive does not trust the shared demand forecast and allocates capacity which maximizes her profit. A similar analysis is done by Ren et al. (2006, 2010). With a linear price contract, they compute that, in the equilibrium of a one-shot game, the retailer inflates the demand and the supplier ignores the retailer's forecast. In other words, no credible demand forecast is communicated between the rational retailer and the rational supplier.

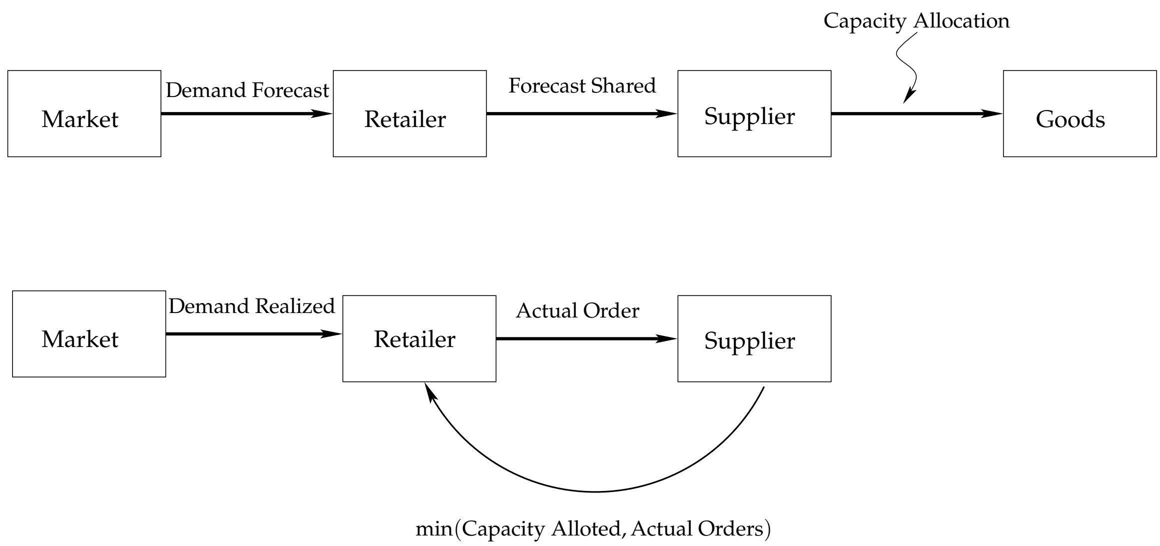

Figure 1: Flow of Information and Goods in the Supply Chain

To mitigate this problem, Cachon and Lariviere (2001) discuss a signaling game where the retailer, with real high demand forecast, credibly signals to the supplier by offering a side payment. This separates the retailer with real high demand forecast from the real low demand forecast. Ozer and Wei (2006) focus on signaling and screening games for credible demand forecast sharing. Ren et al. (2006, 2010) emphasize on infinitely repeated games to achieve the truthful forecast sharing. They consider linear price contracts; and, compute trigger and review strategies to credibly threaten the retailer from deviating from the truthful forecast sharing. Amit and Mehta (2010) provide a review on repeated games for supply chain coordination. For recent literature, we refer Ozer et al. (2011).

Recently, there is an increasing emphasize on behavioral operations management where the rationality assumption of the agents is relaxed. It is assumed that the agents use different heuristics in decision making which lead to biases from the optimal behavior. This approach is mainly descriptive as compared to the normative approach of the literature mentioned earlier; and, helps bridge the gap between theory and practice of operations management. Bendoly et al. (2006) and Loch and Wu (2007) provide comprehensive review of the literature in behavioral operations management.

In a supply chain, there may be various heuristics like framing effects, sunk costs, anchoring, representative heuristics, availability heuristic, dynamic inconsistency, etc. One early paper on behavioral operations management is Schweitzer and Cachon (2000) which studies biases in decision making in the newsvendor problem. In experimental settings, they observe that decision makers systematically deviate from the maximization of expected profits ("pull-to-centre effect"—ordering between the optimal orders and the average demand). They explain that such a behavior is consistent with the minimization of ex-post inventory error and the anchoring heuristic. Katok and Wu (2009) investigate three types of supply chain contracts: wholesale price, buyback, and revenue sharing contracts, in experimental settings. They observe that buyback and revenue sharing contracts perform better that the wholesale price contracts; however, their performance is not as good as in theory. They observe that the anchoring heuristic can explain the pull-to-centre effect with the wholesale price contract, but not with buyback and revenue sharing contracts. Ozer et al. (2011) analyze the effects of trust and cooperation, and its role in decision making was established through experimental evidence. They also probe changes in behavior and trust as a function of parameters like market uncertainty.

The wholesale price contracts considered in Katok and Wu (2009) are "push" contracts. Cachon (2004) consider three different types of wholesale price contracts: push, pull, and advance-purchase discounts. In the push contract, the retailer is the newsvendor and bears all the inventory risk. In the pull contract, the supplier is the newsvendor. Advance-purchase discount contract mixes both the push and the pull contracts where the inventory risk is shared by both the retailer and the supplier.

In this paper, we consider the "pull" wholesale price contract as in Cachon and Lariviere (2001). We conjecture that the retailer deviates from the optimal behavior of inflating demand forecast due to the anchoring heuristic. Under the pull contract, optimal behavior of inflating demand forecast is described in Cachon and Lariviere (2001); Ren et al. (2006, 2010); Ozer et al. (2011). Tversky and Kahneman (1974, p. 1128) originally define anchoring:

> "In many situations, people make estimate by starting from an initial value that is adjusted to yield the final answer. The initial value, or starting point, may be suggested by the formulation of the problem, or it may be the result of partial computation. In either case, adjustments are typically insufficient. That is, different starting points yield different estimates, which are biased towards the initial values. We call this phenomenon anchoring."

The contribution of this paper is to test our conjecture about the anchoring bias in forecast information sharing with the pull contract. We conduct an experiment to investigate anchoring. We also study the extent of anchoring with different demand forecasts as anchors. Our experiment establishes the presence of anchoring in forecast information sharing. Thus, there is some credible information transfer which improves the overall efficiency in the supply chain. This result can have important managerial implications.

2 Experiment Design

We designed the experiment as a two agent supply chain game for human subjects to test for the prevalence of anchoring bias. In addition, we examine the variation in extent of anchoring with demand forecast information and time spent to make the decision. Each trial consists of two players, the supplier and the retailer who faces an uncertain seasonal demand for a certain product. The retailer, who is closer to the market, has additional information about the next season's demand. He passes on this demand forecast to the supplier, who prepares capacity to meet the demand. When the actual demand is realized, the supplier provides the goods as required by the retailer, to a maximum of the capacity she allotted. The retailer, however, can quote a value different from the demand forecast, and the supplier can allocate different from the one she receives.

The demand distribution is assumed to be uniform in the domain of $[50, 150]$. The supplier's capacity cost per unit and revenue per unit sales are fixed at $1 and $2 respectively. The retailer does not share capacity allocation cost and he receives $1 per unit sales. Unsold goods cannot be resold and have no scrap value. When the retailer is shown the demand forecast, it is mentioned that it is only an estimate and that actual demand may be different. However, it is not specified how the demand distribution changes given the knowledge of the forecast. The experiment is carried out for three different values of demand forecasts—low (75), medium (100), and high (125). Additionally, we have a control group in which the retailer does not receive any demand forecast information.

A total of 200 subjects, comprising of senior undergraduate, MBA and research students from Indian Institute of Technology Madras, were chosen for the experiment. They were allotted into two equally sized groups of suppliers and retailers and randomly matched. To ensure anonymity between retailers and suppliers, a small tutorial and the rules of the game were instructed to them separately. To ensure serious responses, monetary incentives were given for the retailer and the supplier who makes the maximum profit. The game was played online with each player being given a separate login username and password to prevent unauthorized access. In each trial, we recorded the information shared by the retailer to the supplier, the capacity allotted by the supplier and the time taken by each player to record his entry[1].

Normatively, the retailer should quote the maximum possible demand as his forecast, and

[1]Some of the data entered by the subjects were invalid and hence were ignored for the study.

the supplier should completely disregard the information he receives. However, in practice we expect some useful information sharing because we expect the retailer to anchor on the forecast of demand.

3 Results and Discussion

In this section, we analyze the experimental data entered by the retailer to verify the presence of anchoring bias. Table 3 presents the summary statistics for the retailers' reports. We find that the mean value quoted by the retailer increases with increase in demand forecast, while the standard deviation decreases. We now perform statistical tests on the experimental data obtained.

Table 1: Summary of Experimental Data

Demand Forecast	No demand forecast	Small(75)	Medium(100)	Large(125)
Mean Value quoted	119.50	104.73	118.64	133.21
Standard Deviation	26.65	26.61	22.26	15.78
No of valid samples	20	22	22	24

3.1 Presence of Anchoring Bias

We observe that the mean value quoted by the retailer seems to be correlated with the actual demand forecast. Since the underlying distribution of the values quoted by the retailers is unknown, we perform a non-parametric analysis on the data. We conduct the Wilcoxon signed rank test[2] samples indeed come from different distributions.

Hypothesis The probability distributions for the values quoted by the retailers are different for different demand forecasts.

In Table 2, we can see that for the cases of high, medium and low demand forecasts, we do not reject the hypothesis with a confidence of at least 97.28%. We reject the hypothesis that the distributions in the case of no demand forecast and medium (100) demand forecast with a confidence of 95.22%. The distributions for no demand and low (75) demand forecast is different with a confidence of 93.42%, and that for no demand forecast and high (125) demand forecast is different with a confidence of 99.96%.

Thus, the distributions for no demand forecast and medium (100) demand forecast seem to be similar. All other demand distributions are different with a confidence of at least 93.42%. Since the optimal value to be quoted by the retailer (150) is independent of the demand forecast, we propose anchoring bias as an explanation for this behavior. The value quoted by the retailer

[2] The Wilcoxon's signed rank test is used to determine if two sets of samples come from the same underlying distribution (Johnson, 2011).

seem to be anchored on the demand forecast. In the "no demand forecast" case, the value seems to be anchored on the mean demand (100), and hence the probability distributions for the no demand forecast case and the medium (100) demand forecast case are similar.

Table 2: Wilcoxon Signed Rank Test

Parameter	75 vs 100	100 vs 125	75 vs 125	75 vs No Forecast	100 vs No Forecast	125 vs No Forecast
Mean	242	264	264	220	220	240
Std. Dev.	42.60	45.48	45.48	39.71	39.71	26.46
Z value	-2.23	-2.21	-3.46	1.84	-0.063	-3.57
Sig. level	0.0258	0.0272	0.0006	0.0658	0.9522	0.0004
Confidence	97.42%	97.28%	99.94%	93.42%	4.78%	99.96%

3.2 Measuring the Extent of Anchoring

Anchoring is present in each of the cases that we have considered, but its extent may be different in each of them. Thus, anchoring can be studied for several "anchors", the demand forecasts. Let o be the normative value to be followed by the retailer, a be the anchor and v be the value he shares. We define Anchoring Index A as,

$$A = \frac{o - v}{o - a}$$

If we assume that anchoring causes a proportional deviation from normative behavior, then acts as a measure of the strength of anchoring. Here, the optimal value o is 150 (Cachon 2001). In Table 3, we show the variation of the anchoring index with various anchors. We find that the extent of anchoring seems to increase with the increase in demand forecast. In other words, the value quoted by the retailer is strongly correlated with the true demand forecast.

Table 3: Extent of Anchoring

Demand Forecast	Small (75)	Medium(100)	Large(125)
Mean Value quoted	104.73	118.64	133.21
Mean Anchoring Index	0.60	0.63	0.67

3.3 Anchoring versus time taken for decision making

Since we also measure the time taken by the retailers to determine the value which they quote, we find how it influences the shared data. We find that there is a positive correlation between anchoring index and time for decision making (see Table 4). In other words, as people spend more time to decide the value of the shared forecast, the extent of anchoring tends to increase.

Table 4: Correlation between Anchoring Index and Time taken

Demand Forecast	Small (75)	Medium (100)	Large (125)
Correlation Coefficient	0.027	0.181	0.193

4 Conclusions

Credible information flow about demand forecast is critical in deciding the success of a supply chain. There is an increasing focus on the research in ensuring credible information sharing in supply chains. Normative results show that when the supplier has to borne the inventory risk (like in the "pull" wholesale price contract), in the equilibrium, the retailer inflates the demand and the supplier ignores the demand forecast (Cachon and Lariviere, 2001; Ren et al., 2006, 2010). Hence, no credible demand forecast information is communicated.

Due to lower descriptive power of normative models, there is an increasing emphasis on behavioral operations management where the assumption of rationality is relaxed. Katok and Wu (2009) and Ozer et al. (2011) discuss behavioral issues in the context of supply chain. Katok and Wu (2009) investigate three types of supply chain contracts: wholesale price, buyback, and revenue sharing contracts, in experimental settings. They observe that buyback and revenue sharing contracts perform better that the wholesale price contracts; however, their performance is not as good as in theory. They observe that the anchoring heuristic can explain the pull-to-centre effect with the wholesale price contract, but not with buyback and revenue sharing contracts. They consider "push" wholesale price contracts where the retailer borne the inventory risk. Ozer et al. (2011) analyze the effects of trust and cooperation, and its role in decision making was established through experimental evidence. They also probe changes in behavior and trust as a function of parameters like market uncertainty.

In this paper, we conjecture that, in the pull wholesale price contract, the retailer deviates from the normative behavior due to the anchoring heuristic. We designed an experiment with human subjects to test this conjecture. We also study the extent of anchoring with different demand forecasts as anchors. Our experiment establishes the presence of anchoring in forecast information sharing. We find that the extent of anchoring seems to increase with the increase in demand forecast. We also observe that as people spend more time to decide the value of the shared forecast, the extent of anchoring tends to increase.

Future research may include the suppliers' response to the shared demand forecast by the retailers. The analysis can be extended to repeated interactions. We use uniform distribution for future demand. The paper can be extended for different distributions of future demand.

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