Multidimensional Bargaining and Inventory Risk in Supply Chains: An Experimental Study

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We study the impact of multidimensional bargaining and the location of inventory risk on the performance of a two-stage supply chain. We conduct a controlled human-subjects experiment where a retailer and supplier either interact through ultimatum offers or dynamically bargain over contract terms, including a wholesale price and, potentially, an order quantity. We also manipulate whether the risk associated with unsold inventory lies with the retailer or the supplier or is endogenously determined in the bargaining process. One key insight is that supply chain efficiency is significantly higher when the order quantity is included in the negotiation and that, contrary to the normative theory, this leads to a Pareto improvement whereby both the supplier and retailer earn higher profits. A second important result, also counter to the normative theory, is that the party incurring the cost of unsold inventory always earns a lower profit than their counterpart, regardless of the bargaining environment or inventory risk location. To explain these data, we posit that retailers and suppliers are affected by an anchoring bias and demonstrate that it can explain many of our results.

1. Introduction
Supply chain contracting is an important operations management topic that has attracted much attention in the literature (e.g., Cachon (2003, 2004), Özer and Wei (2006), Netessine and Rudi (2006)). Many of these studies assume a highly structured form of bargaining where one party makes an ultimatum offer to the other party, who then either rejects the proposal or accepts it and unilaterally sets an order quantity. In such a setting, it is known that wholesale price contracts do not coordinate the supply chain. Yet, previous work suggests that this efficiency loss may be an artifact of the underlying bargaining structure (Cachon 2004). Furthermore, supply chain contracts often include multiple terms, such as wholesale prices, order quantities, and which party will incur the cost of unsold inventory (“inventory risk”). Existing research indicates that this last term, the inventory risk location, may mean the difference between success and failure of a firm (Randall et al. 2002). In this work, we investigate alternative bargaining environments and study their impact on supply chain performance, from both a theoretical and an experimental perspective.
Cachon (2004) shows that the subgame perfect equilibrium of wholesale price contracts in a traditional ultimatum setting is Pareto dominated by alternative wholesale price contracts, which shift the inventory risk to the other party and involve a different quantity. Although the process by which this Pareto improvement is achieved is not modeled, it is clear that the scope of negotiations must expand to include other contract parameters beyond a wholesale price.

This result does not appear to be a theoretical curiosity, as our conversations with managers suggest that, when determining supply chain contracts, multiple terms may indeed be negotiated simultaneously. For instance, regarding inventory risk, retailers and suppliers often share inventory and point-of-sale data directly (Cachon and Fisher 2000), allowing a supplier of a product to manage the inventory and incur the cost of any unsold inventory, versus the retailer (Cachon and Fisher 1997). This is especially common in e-commerce, where the two parties may negotiate a contract which stipulates whether the retailer will purchase inventory themselves for resale or, alternatively, the supplier will be responsible for the inventory risk, and satisfy retailer demand through drop-shipping. Given this flexibility, a number of theoretical studies have shown that it is advantageous to be the party holding the inventory risk (Cachon 2004). On the other hand, anecdotal evidence indicates otherwise. For example, when we asked an executive of a large durable-goods manufacturing firm how they negotiate contract terms, he told us “[w]e want to push our inventory onto the retailers,” implying not only that the inventory risk is potentially included in the negotiation but also that they want to avoid the risk.

This discussion necessitates a study in which both inventory risk and bargaining are evaluated in conjunction, and brings us to our main research questions: (1) How does a more natural, unstructured, bargaining process compare with a structured ultimatum bargaining setting in terms of supply chain performance (e.g., channel efficiency, profits)? (2) In unstructured bargaining, does the inclusion of certain contract terms (e.g., order quantity and/or inventory location) affect supply chain performance? (3) Is inventory risk exposure beneficial or detrimental?

Because supply chain contracts are determined by human decision makers, in answering these questions we take both a theoretical and an experimental approach. A theoretical lens is useful in two ways. First, it can provide a set of clear benchmarks that are based on the standard assumption that decision makers are risk-neutral expected-profit maximizers. Second, once the normative benchmarks are identified, one can then consider how certain behavioral factors might affect these predictions, which can be used to generate formal hypotheses. For instance, many studies have shown that people may deviate from the normative benchmark in bargaining environments because
of risk aversion or a susceptibility to biases, such as anchoring. Once established, we can then administer a human-subjects experiment, which allows us to evaluate such behavioral hypotheses.

We first derive several predictions under the normative assumption of risk-neutral expected-profit maximizing decision makers. Our results provide equilibrium predictions for contract terms, such as wholesale prices and quantities, for the different bargaining settings that we consider and various inventory risk locations. For example, we show that in an unstructured bargaining environment where both the wholesale price and quantity are negotiated simultaneously, the supply chain should achieve 100% efficiency, irrespective of which party holds the inventory risk. Next, we consider how certain behavioral biases may affect these normative predictions. We then use these behavioral predictions to develop a set of experimental hypotheses.

The next step is to conduct a controlled human-subjects experiment. We vary both the bargaining environment and the inventory risk location. For the bargaining dimension, we consider three levels: (i) structured ultimatum offers, coinciding with that of Davis et al. (2014), (ii) unstructured bargaining over the wholesale price, leaving the order quantity decision to the inventory risk holder, and (iii) simultaneous unstructured bargaining over the wholesale price and order quantity. For the inventory risk location, we also consider three variants: (i) exogenously imposed on the retailer, (ii) exogenously imposed on the supplier, or (iii) endogenously determined during bargaining.

Our experiment yields several insights. In response to our main research questions, we find the following: (1) moving from a structured ultimatum setting to one where the wholesale price is negotiated, supply chain efficiency does not increase, contrary to normative theory. (2) Comparing a bargaining environment where only the wholesale price is negotiated with one where both the wholesale price and order quantity are negotiated simultaneously, supply chain efficiency increases significantly, and considerably more than the normative theory predicts. Furthermore, this efficiency increase constitutes a Pareto improvement, with both retailer and supplier earning higher expected profits. Yet we also find that this bargaining environment, where both wholesale price and quantity are negotiated simultaneously, fails to achieve its normative predicted 100% efficiency. (3) Regardless of the inventory risk location and bargaining structure, it is always disadvantageous to be the party incurring the inventory risk, which is contrary to the normative theory in the unstructured bargaining environments. Additionally, we also find (4) allowing the inventory risk location to be negotiated does not affect agreed-upon terms and outcomes; (5) the number of terms included in the negotiation does not impact agreement rates; and (6) risk aversion can explain some comparative statics but fails to capture a level effect on wholesale prices.
While our experimental data contradict many of the normative theoretical predictions, many of the outcomes are consistent with our main behavioral hypothesis that retailers and suppliers are susceptible to an anchoring bias. Specifically, rather than fully exploiting one’s bargaining power to maximize expected profits, decision makers are anchored on salient reference points. For instance, when both wholesale prices and quantities are included in the negotiation, the inventory risk holder may anchor quantities towards mean demand, leading to supply chain efficiencies below the 100% prediction, which we see in our data. Similarly, when wholesale prices are anchored on a salient focal point, such as the midpoint between the supplier’s production cost and the retailer’s selling price, then inventory risk holders will not receive enough compensation for incurring the inventory risk, which is also consistent with our data. To further support our anchoring hypothesis, we conduct an additional treatment where we attempt to communicate the potential anchor point for wholesale prices to subjects. In this treatment, we find that wholesale prices are considerably closer to the normative predictions and that it is no longer disadvantageous to hold the inventory risk, thus coinciding with the standard theory. Last, we discuss other behavioral factors which one might expect to influence our data, such as loss aversion, regret, bounded rationality, and fairness, and illustrate how these are unlikely to be the main driver of our data, leaving anchoring as a plausible explanation for organizing our results.

2. Related Literature

Two streams of literature are most relevant to our study: supply chain contracting with alternative inventory risk allocations, and supply chain bargaining. The modeling literature on supply chain contracting is extensive. Many papers investigate how the allocation of inventory risk affects supply chain performance, usually in a setting where one party makes an ultimatum offer to another. For instance, Cachon (2004) compares wholesale price contracts where the retailer incurs the inventory risk, the supplier incurs the risk, and the two parties share the inventory risk. Netessine and Rudi (2006) also investigate inventory risk allocation. Specifically, they consider the context of e-retailers who decide which supply chain structure is best, and show which inventory risk allocation is optimal for different levels of demand variability, number of retailers, wholesale prices, and transportation costs. Kaya and Özer (2012) study a range of topics within supply chain contracting, including risk allocations under wholesale price, buy-back, revenue-sharing, quantity-flexible, and rebate contracts.

There have been a number of human-subjects experiments that investigate supply chain contracting. Most of these also focus on ultimatum offer settings, since they often aim to test the
predictions of theoretical models in such an environment. One example is Davis et al. (2014), who test the inventory risk allocation predictions from Cachon (2004). In some ways, our paper may be viewed as an extension of their work in that we use their setting as an initial baseline, and then consider a more natural, unstructured bargaining process. Other relevant behavioral supply chain studies are those which focus on testing the performance of coordinating contracts (e.g., Katok and Wu (2009), Donohue et al. (2016), Becker-Peth et al. (2013), Devlin et al. (2014)), how decomposing a task affects outcomes (Lee and Siemsen 2016), and the effect of setting multiple supply chain decisions jointly, versus sequentially (Ramachandran et al. 2016).

Recently, some behavioral operations papers have studied more natural bargaining processes in supply chain settings. Leider and Lovejoy (2016) test Lovejoy’s (2010) balanced-principal bargaining model, where all roles are played by human participants who can engage in chat box communication. Haruvy et al. (2016) use an experimental design where one of two parties in a two-stage supply chain can make repeated good faith offers, and the other player can reject offers until they choose to accept. Davis and Leider (2017) study capacity investment decisions in two-stage supply chains across a variety of contracts, in an unstructured bargaining environment.

We contribute to this literature by conducting a controlled laboratory experiment where humans interact through ultimatum offers or negotiate directly with each other in a multidimensional bargaining setting with back-and-forth offers and the ability to send limited feedback. Furthermore, we consider the inventory risk location along with different bargaining environments.

3. Theoretical Benchmarks

In this section we provide normative theoretical benchmarks for our study. We start with the traditional ultimatum offers model considered by much of the literature and then proceed to a model with unstructured bargaining over the wholesale price, but where the inventory risk holder unilaterally chooses the order quantity. Finally, we derive results when both the order quantity and wholesale price are simultaneously negotiated. In addition to the normative analysis, we provide a short discussion as to how these predictions may change when behavioral factors such as anchoring and risk aversion are present, and we use them to develop behavioral hypotheses and predictions.

For all settings, assume that demand, \( D \), is drawn uniformly from \([a,b]\) where \(0 \leq a < b < \infty\).\(^2\) Assume also that the supplier’s cost of production is \(c > 0\), the retailer’s selling price is \(p > c\),

\(^1\) There is also an extensive literature on bargaining in experimental economics. For a review, please see Kagel and Roth (1995) and Camerer (2003).

\(^2\) In our experiment, we assume that demand is drawn from the discrete uniform distribution on the set \(\{0, 1, \ldots, 100\}\). There are no qualitative differences between our discrete implementation and the continuous case.
and the retailer pays the supplier a wholesale price \( w \in [c, p] \) for each unit purchased. Denote by \( \pi_i^{RL}(\cdot) \) the expected profits for firm \( i \in \{r(\text{etailer}), s(\text{upplier})\} \) and inventory risk location \( RL \in \{r(\text{etailer}), s(\text{upplier})\} \). The disagreement payoff is 0 for both players, and there is full information of all cost and demand parameters.

3.1. Structured Bargaining: Ultimatum Offers

Suppose that one player makes an ultimatum wholesale price offer, \( w_{RL}^{RL} \), to the other player. If the offer is accepted, then the responding player unilaterally chooses an order quantity \( q_{RL}^{RL} \) and bears the risk of any unsold inventory. For both inventory risk locations one can solve for the subgame perfect equilibrium of these games. Depending on the inventory risk location, we can write each firm’s expected profit function as

\[
\text{Ret. Risk: } \pi_r^r = p - a \frac{\min\{q, x\} dx}{b - a} - wq; \quad \pi_r^s = (w - c)q
\]

\[
\text{Sup. Risk: } \pi_s^r = p - w \frac{\min\{q, x\} dx}{b - a} - wq; \quad \pi_s^s = w \frac{\min\{q, x\} dx}{b - a} - cq.
\]

Consider the case of retailer risk. The retailer’s optimal quantity is \( q_{RL}^{R}(w) = a + (b - a)(p - w)/p \). The supplier anticipates this quantity and chooses \( w \) to maximize its expected profits. With some work, one can obtain \( w_{RL}^{R} = (p + c)/2 + ap/(b - a) \). This generates inefficiency because \( w_{RL}^{R} > c \), which leads to an insufficient order quantity, relative to first-best. Finally, because (i) \( w_{RL}^{R} \geq (p + c)/2 \) and (ii) there is asymmetry of exposure to inventory risk, in the subgame perfect equilibrium, the supplier will earn strictly higher expected profits than the retailer.

Now consider the case of supplier risk. Given a wholesale price, the supplier chooses the quantity that maximizes its expected profit, which yields \( q_{RL}^{S}(w) = a + (b - a)(w - c)/w \). The retailer anticipates this order quantity and chooses the wholesale price to maximize its expected profits. An analytical solution is not feasible because the retailer’s first-order condition leads to a third-degree polynomial in \( w \). However, since the first-order condition is monotone in \( w \), there is a unique real root. Moreover, one can show that \( w_{RL}^{S} < (p + c)/2 \). The outcome here is also inefficient because \( w_{RL}^{S} < p \), leading the supplier to produce too little relative to first-best. Moreover, because \( w_{RL}^{S} < (p + c)/2 \), the retailer will earn strictly higher expected profits than the supplier.

We can summarize these results in the following proposition (see Appendix A for the proof):

**Proposition 1.** In the subgame perfect equilibrium of the structured bargaining game,
1. Under retailer risk, \( w_{\text{Ult}}^R = \frac{(p+c)}{2} + \frac{ap}{2(b-a)} \geq \frac{(p+c)}{2} > c \) and the supply chain is not coordinated.

2. Under supplier risk, \( w_{\text{Ult}}^S < \frac{(p+c)}{2} < p \) and the supply chain is not coordinated.

3. In both cases, the party holding the inventory risk earns a lower expected payoff than the party not holding the inventory risk.

3.2. Unstructured Bargaining

Our unstructured bargaining environment has no underlying extensive form, making predictions based on subgame perfect Nash equilibrium impossible. Therefore, we adopt the Nash bargaining solution as the basis for predictions (Camerer 2003, Ch. 4.1). Because the wholesale price is always negotiated, there are four cases to consider, depending on whether the order quantity is included in the negotiation or not, and whether the retailer or the supplier holds the inventory risk. Except as noted, we maintain the assumption that demand is uniformly distributed on \([a, b]\).

3.2.1. Wholesale Price is Negotiated. Assume that the supplier and the retailer first negotiate \( w \). Then, given the agreed-upon wholesale price, the party that is exposed to risk chooses the order quantity to maximize its expected profits. Just as in the case of the structured bargaining setting, under retailer risk, the retailer will choose \( q_{\text{Neg}}^R(w) = a + (b-a)(\frac{(p-w)}{p}) \), while under supplier risk, the supplier will choose \( q_{\text{Neg}}^S(w) = a + (b-a)(\frac{(w-c)}{w}) \). Since we assume that the disagreement outcome is 0 for both players, the Nash bargaining solution is the wholesale price, \( w \), which maximizes the product of the retailer’s and supplier’s expected profits. In particular:

\[
\max_w \pi_{RL}^r(w, q_{RL}^r(w)) \cdot \pi_{RL}^s(w, q_{RL}^s(w)),
\]

s.t. \( c \leq w \leq p \),

where \( \pi_{RL}^i(w, q) \) are given in (1) and \( q_{RL}^i(w) \) is as above. In Appendix A we formally prove the following proposition:

**Proposition 2.** If \( a = 0 \), then when only the wholesale price is negotiated in an unstructured setting,

1. Under retailer risk, \( c < w_{\text{Neg}}^R = \frac{(p+3c)}{4} < \frac{(p+c)}{2} = w_{\text{Ult}}^R, q_{\text{Neg}}^R > q_{\text{Ult}}^R \) and the outcome is more efficient than the ultimatum setting. Since \( w_{\text{Neg}}^R > c \), the supply chain is not coordinated.

2. Under supplier risk, \( w_{\text{Neg}}^S = \) the real root of a third degree polynomial. Furthermore, \( p > w_{\text{Neg}}^S > \frac{(p+c)}{2} > w_{\text{Ult}}^S \). Therefore, \( q_{\text{Neg}}^S > q_{\text{Ult}}^S \) and the outcome is more efficient than the structured bargaining setting. The supply chain is not coordinated.

\(^4\)In addition to the proof, we also provide details of a numerical study showing that the results hold for \( a > 0 \) as well.
This proposition shows that moving to an unstructured setting where the wholesale price is negotiated, but the quantity is still unilaterally set by the inventory risk holder, should generate higher channel efficiency. The intuition is that, in an ultimatum setting, the party proposing the wholesale price has more bargaining power, which she can exploit to extract a more favorable wholesale price. However, the drawback of this favorable wholesale price is to increase the double marginalization problem, which generates inefficiency. In contrast, in the unstructured bargaining environment, the players have more equal bargaining power to determine the wholesale price. Thus the inventory risk holder achieves a more favorable wholesale price, which leads her to produce a higher quantity, which generates higher channel efficiency. Interestingly, however, as we will show presently, when only \( w \) is negotiated, the risk holder is predicted to earn higher expected profits than the non-risk holder (see Corollary 1).

3.2.2. Wholesale Price and Order Quantity are Negotiated. When both the wholesale price and order quantity are included in the negotiation, the Nash bargaining solution is the pair \((w, q)\) which maximizes the product of the retailer’s and supplier’s expected profits. In particular:

\[
\max_{w, q} \pi^{RL}_r(w, q) \cdot \pi^{RL}_s(w, q) \\
\text{s.t. } c \leq w \leq p \text{ and } a \leq q \leq b,
\]

where \(\pi^{RL}_i(w, q)\) are given by (1).

In this setting, one can solve for the Nash bargaining solution under both retailer and supplier risk. In Appendix A, we prove that Nash bargaining leads to

**Proposition 3.** When both the wholesale price and order quantity are negotiated in an unstructured setting,

1. Regardless of risk location, \( q^{RL}_{Neg \_wq} = a + (b - a)(p - c)/p \), the supply chain is coordinated and expected payoffs for the retailer and supplier are equalized.

2. Under retailer risk, \( w^{RL}_{Neg \_wq} = \frac{3ac^2 + ap^2 - 3bc^2 + 2bc + bp^2}{4(ac - bc + bp)} < \frac{p + c}{2} \), while under supplier risk, \( w^{RL}_{Neg \_wq} = \frac{p + c}{2} \).

Given the expressions, one can see that \( (p + c)/2 - w^{RL}_{Neg \_wq} > w^{RL}_{Neg \_wq} - (p + c)/2 > 0 \). That is, the wholesale price adjusts further from the midpoint between the selling price and the marginal cost, under retailer risk. The midpoint would represent the equal division in the absence of risk. However, due to the asymmetric presence of demand and inventory risk, the wholesale price must adjust

\footnote{The proof of Corollary 1 relies on our next result; hence, we delay our formal statement until the necessary tools to prove the result are given.}
from this midpoint to equalize expected payoffs. Under retailer risk, the retailer is exposed to both inventory and demand risk, while the supplier’s payoff is risk free. Therefore, to equalize expected payoffs, the wholesale price must move significantly to make up for this asymmetry in risk exposure. Under supplier risk, the supplier faces both demand and inventory risk, while the retailer faces demand risk. Therefore, the asymmetry in risk exposure is less, so the wholesale price adjusts less.

If we specialize to the case of \( a = 0 \), comparing this setting, where both the wholesale price and quantity are negotiated, to one where only the wholesale price is negotiated, then we can also show that \( w^R_{Neg-w} = w^R_{Neg-wq} \), while \( w^S_{Neg-w} > w^S_{Neg-wq} \). This leads to the following corollary:

**Corollary 1.** If \( a = 0 \), then when only the wholesale price is negotiated, the inventory risk holder earns a higher expected payoff than the party not holding the inventory risk.

The intuition for this result is as follows. First, under retailer risk, the wholesale price is the same when either \( w \) is negotiated or \((w,q)\) is negotiated. However, in the former case, the retailer can choose the order quantity to maximize her expected profits. Since expected profits are equalized when \((w,q)\) is negotiated, this implies that the retailer earns more than the supplier when only \( w \) is negotiated. Second, under supplier risk, the supplier actually receives a more favorable wholesale price when only the wholesale price is negotiated. Moreover, the supplier can also optimize the order quantity when only \( w \) is negotiated; hence, we can conclude that the supplier earns more than the retailer. Before proceeding, note that Tables A.1(b) and A.2(b) in Appendix A provide numerical evidence that Corollary 1 can be expected to hold for \( a > 0 \).

**3.3. Endogenous Risk Location**

From a risk-neutral, rational point of view, the fact that expected profits between the retailer and supplier are equalized when \((w,q)\) is negotiated means that it does not matter who holds the inventory risk. On the other hand, from Corollary 1, when only \( w \) is negotiated, the inventory risk holder earns a higher expected profit. As discussed above, this is because they now have a say in determining the wholesale price as part of the negotiation, but they maintain sole control over the order quantity, which leads to a second-mover advantage.

**3.4. Alternative Behavioral Benchmarks**

While the standard risk-neutral expected-profit maximizing theory provides baseline benchmarks for our study, these normative predictions may not be confirmed once we incorporate human decision makers. Here, we briefly highlight some behavioral issues that are likely to arise in this setting, based on prior research. We then develop a set of behavioral hypotheses and predictions which detail how outcomes may differ from the normative theory, if such biases are present. We will comment on additional behavioral explanations for our data in Section 7.
3.4.1. Anchoring on Focal Points. Focal points have been shown to serve as anchors which
 can affect negotiated outcomes. For example, Gächter and Riedl (2005), Bolton and Karagözoglu
 (2016) and others show how historical norms can create “moral property rights” which influence
 negotiated outcomes. In addition, Roth and Malouf’s (1979) pioneering work on binary lottery
 games show how two focal points – equal expected monetary payoffs or equal division of lottery
 tickets – become more or less salient depending on the information structure.

While we do not manipulate historical norms, there may be focal points with respect to the
 wholesale price and quantity, when included in the negotiation. Regarding the wholesale price,
 \( \frac{p+c}{2} \) represents a plausible focal point because it is the midpoint between two salient endpoints:
 the supplier’s cost, \( c \), and the retailer’s selling price, \( p \). Also, in the absence of risk, \( \frac{p+c}{2} \) equalizes
 payoffs. When the order quantity is included in the negotiation, there are two natural focal points:
 the mean demand, \( \frac{a+b}{2} \), and the quantity which maximizes channel efficiency, \( a + (b-a)\left(\frac{p-c}{p}\right) \).

The former is likely to be salient for the inventory risk holder, while the latter is likely to be salient
 for the non-risk holder because her expected profits are strictly increasing in \( q \).

We can use this discussion to formulate a set of behavioral hypotheses which predict how out-
comes may differ from the normative benchmarks, if an anchoring bias is present. Let ‘Ult’ represent
the structured bargaining environment with ultimatum offers, ‘Neg-W’ represent the unstruc-
tured bargaining setting where only the wholesale price is negotiated, and ‘Neg-WQ’ represent the
unstructured bargaining environment where both the wholesale price and quantity are negotiated.

In terms of supply chain efficiency, the normative theory outlined in the previous subsections
predicts efficiency to satisfy: \( \text{Ult} < \text{Neg-W} < \text{Neg-WQ} = 100\% \). However, anchoring suggests
that players may not fully exploit their bargaining power because the anchor, rather than profit
maximization, influences decisions. As a result, when comparing Ult and Neg-W, the difference in
wholesale prices may be smaller than the normative theory predicts. Moreover, in both settings,
the inventory risk holder has unilateral control over the order quantity (which is the main driver
of channel efficiency). Combined, these factors suggest that the difference in efficiency between
Ult and Neg-W will be negligible. Comparing Neg-W with Neg-WQ, in the latter case the non-
risk holder has partial agency over the order quantity. This player is likely anchored on a higher
quantity, which should have the effect of increasing the negotiated order quantity and, hence,
increasing efficiency.\(^7\) This brings us to the following behavioral hypothesis:

\(^6\) When the quantity is not negotiated and is set unilaterally, it is unlikely that these focal points for \( q \) play a role;
instead, the focal points are likely mean demand and the quantity that maximizes the risk holder’s expected profit
(consistent with the ‘pull-to-center’ effect observed in newsvendor studies).

\(^7\) Assuming the critical fractile of the integrated supply chain is greater than \( \frac{1}{2} \).
Hypothesis 1 (Efficiency). For both retailer and supplier risk, channel efficiency satisfies \( \text{Ult} = \text{Neg-W} < \text{Neg-WQ} < 100\% \).

Turning to inventory risk (which is tied to the distribution of profits), recall that the normative theory predicts that (a) the inventory risk holder will earn less than their counterpart in Ult, more than their counterpart in Neg-W, and the same as their counterpart in Neg-WQ, and (b) when the inventory risk location is endogenously determined in Neg-W and Neg-WQ, both players should weakly prefer to hold the inventory risk. While past research suggests that inventory risk holders will be worse off in the Ult treatment,\(^8\) if players are anchored on a wholesale price of \( \frac{p+c}{2} \), players in both Neg-W and Neg-WQ may not fully exploit their bargaining power when determining the wholesale price in the negotiation. Consequently, in these treatments, inventory risk holders may also be predicted to suffer. That is, it is disadvantageous to hold inventory risk. Hence we have

Hypothesis 2 (Inventory Risk). (a) Across all treatments, the inventory risk holder will earn less than their counterpart. (b) When the inventory risk location is negotiated in Neg-W and Neg-WQ, both players prefer to avoid the inventory risk.

Last, anchoring may also play a role in the bargaining process itself. A large literature in negotiations (e.g., Galinsky and Mussweiler (2001)) shows that first offers also serve as strong anchors, with the negotiated outcome often falling midway between the players’ opening offers; i.e., initial offers are positively correlated with agreements. Thus if inventory risk holders do not make a strong initial offer due to an anchoring bias, while the non-risk holders make an aggressive opening offer, it will further support the possibility that holding inventory risk is detrimental. The fact that inventory risk holders face an unfavorable wholesale price, makes it unlikely that they will agree to or choose to set the quantity at the channel optimum, which suggests that anchoring may hurt efficiency as well.

Hypothesis 3 (Initial Offers). Agreed outcomes are positively correlated with initial offers.

3.4.2. Risk Aversion. Several studies have also noted roles for risk aversion in explaining deviations from normative theoretical predictions. In Appendix A.4 we generate detailed predictions under risk aversion, here we summarize for when both terms are negotiated. First, with respect to the order quantity, risk aversion predicts a negative relationship between the order quantity and the

\(^8\) For the Ult setting, wholesale prices would have to be set in a way that is inconsistent with anchoring for the risk holder to earn higher profits than their counterpart. For instance, given our experimental parameters, in Ult supplier risk, the wholesale price would have to be roughly 10 for this to occur, whereas anchoring would predict it to be between 6 (the normative prediction) and 9 (the midpoint between \( c \) and \( p \)).
strength of risk aversion. Second, regarding the wholesale price, risk aversion makes the following predictions (i) under supplier risk, as the supplier becomes more risk averse, the wholesale price becomes less favorable for the supplier; (ii) under retailer risk, there is a non-linear relationship between the wholesale price and the retailer’s level of risk aversion. Third, in terms of whether it is advantageous to hold the inventory risk, the predictions for risk aversion are nuanced, although it is generally the case that as the retailer becomes less risk averse, she is more likely to take the inventory risk. To determine whether risk aversion drives our experimental results, we will directly compare our data with these predictions (Section 5.4).

4. Experimental Design

In all treatments, subjects were assigned to the role of supplier or retailer and the roles were fixed for the duration of the experiment. In each period a retailer and a supplier were randomly paired and had to determine contract terms for a product that the retailer could sell for a price \( p = 15 \) per unit and that the supplier could produce at a cost of \( c = 3 \) per unit. The demand for the product was a random draw from the discrete uniform distribution on \( \{1, 2, \ldots, 100\} \), where actual demand was unknown at the time of contracting.

The experiment consisted of a \( 3 \times 3 - 1 \) between-subjects design (please refer to Table 1 for a summary of our design). The first dimension manipulated the bargaining environment, and the second dimension manipulated the inventory risk location. Under all three bargaining environments we had two inventory risk variations which exogenously specified that either the retailer or the supplier would bear the risk of unsold inventory, yielding six treatments. In addition, for the two unstructured bargaining environments, we considered a third inventory risk variation where the inventory risk location, retailer or supplier, was endogenously determined. We refer to these three inventory risk scenarios as Retailer Risk (RR), Supplier Risk (SR) and Endogenous Risk (ER).

Structured Bargaining: Ultimatum Offers (Ult). In the Ult setting, one player would make an ultimatum wholesale price offer, \( w \in [3, 15] \), which the responder could either accept or reject. If the offer was rejected, both players would receive a payoff of zero. If the offer was accepted, the responder – who bears inventory risk – would set the quantity, \( q \). Random demand would then be realized and the players would receive feedback that included realized profits.

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</table>

Table 1: Experimental Design and Number of Subjects
Unstructured Bargaining: Wholesale Price is Negotiated (Neg-W). In the Neg-W treatments, each retailer/supplier pair was given five minutes to negotiate a wholesale price (and, in the ER version, the location of the inventory risk). During the negotiation, retailers and suppliers were permitted to make offers at any time, and to make as many offers as they wished. If the pair was unable to reach an agreement after five minutes, then bargaining would end and the players would receive a payoff of zero. If the pair reached an agreement – which occurred when one player accepted the other player’s most recent offer – then the player bearing the inventory risk would unilaterally set an order quantity, \( q \). Following this, demand would be realized and players would receive feedback that included realized profits.

Unstructured Bargaining: Wholesale Price and Order Quantity is Negotiated (Neg-WQ). As with Neg-W, in Neg-WQ each retailer-supplier pair was given five minutes to negotiate, but in these treatments they negotiated a wholesale price and order quantity (and, in the ER version, the location of inventory risk). If the pair was unable to reach an agreement after five minutes, then bargaining would end and the players would receive a payoff of zero. If the pair reached an agreement – which occurred when one player accepted the other player’s most recent offer – the contract would be implemented and payoffs would be determined following the realization of demand.

Discussion of Treatments. In all treatments, to reduce complexity, we provided subjects a decision support tool. They could enter hypothetical values for \( w \), \( q \) (and the inventory risk location in the ER treatments) into the tool, which would generate a graph showing the profit for both players as a function of demand. In addition, in the Neg-WQ treatments, subjects could generate the same graph for the most recent offer received by clicking a “test offer” button.

In the unstructured bargaining treatments, subjects were able to provide feedback about the most recent offer. In particular, they could “reject” any of the proposed terms through a button for each contract term, which they could click at any time for the most recent offer received. This feedback would then be displayed on the proposer’s screen. Note that a subject could later accept the offer even if they voiced displeasure with it, so long as a revised offer was not received. We chose to allow this type of feedback in order to replicate a more realistic bargaining process, while simultaneously enabling us to objectively track offers and feedback. Finally, we note that offers were also unrestricted in the sense that they were not required to improve upon their previous offer, and that only the most recent offer could be accepted. We opted for the former because we did not want to suggest to subjects what defines a better offer, while the latter keeps bargaining relatively simple.
For our unstructured bargaining treatments, note that the wholesale price is always negotiated. We chose this based on anecdotal evidence. For instance, a director of a large manufacturing firm told us that they always negotiate strictly on price and never commit to an order quantity. On the other hand, there is evidence of other contracts that are based on tiered pricing, in that the wholesale price affects the quantity, and vice versa, such that both terms are negotiated together.\footnote{There are other variants that one could consider for treatments, such as letting dyads negotiate the quantity and/or inventory risk, given a fixed wholesale price. While our aim is to consider unstructured settings where the wholesale price is always included, we hope that future work considers such extensions.}

In total, subjects participated in 7 rounds, with random rematching between rounds. For each treatment, we ran three sessions, each of which had between 12 and 16 subjects, for a total of 338 subjects (recall Table 1).\footnote{One of the Ult sessions had eight subjects, and another 10. This was due to low show-up rates. However, these treatments essentially serve as a baseline that replicates the work of Davis et al. (2014).} Sample instructions and software screenshots are available upon request.

Post-Experiment Risk Elicitation. After all rounds, subjects participated in a risk elicitation task where they decided between a series of 50-50 binary lotteries. One lottery was fixed from question to question; the other lottery was more risky (and the payoff if the ‘good’ state occurred increased from question to question). Subjects were paid for one randomly selected lottery question. Finally, because Dohmen et al. (2011) show that it often has better explanatory power to explain risky behavior, we asked subjects: “How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?” Responses were recorded on an 11 point scale, with higher numbers indicating more willingness to take risks.

| Table 2 | Normative Predictions Given our Experimental Parameters |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                | Retailer Risk (RR) | Supplier Risk (SR) |
| Channel Efficiency (%) | Ult | Neg-W | Neg-WQ | Ult | Neg-W | Neg-WQ |
| Retailer Expected Profit | 75 | 93.75 | 100 | 85.94 | 98.50 | 100 |
| Supplier Expected Profit | 120 | 270 | 240 | 337.5 | 224.58 | 240 |
| Wholesale Price (w) | 240 | 180 | 240 | 75 | 248.24 | 240 |
| Order Quantity (q) | 9 | 6 | 6 | 6 | 10.07 | 10 |
|                     | 40 | 60 | 80 | 50 | 70.21 | 80 |

Note 1: The endogenous risk (ER) treatments yield the same predictions as those above, depending on whether the inventory risk lies with the retailer or supplier, in the Neg-W and Neg-WQ treatments.

In addition to testing our behavioral hypotheses and predictions, we are also interested in determining how the normative theory compares with our experimental data. In Table 2, we report predictions for our experimental parameters assuming risk-neutral expected-profit maximizers.
Depending on how risk is allocated in the ER treatments, the predictions are identical to either the SR or RR predictions for the same bargaining structure; hence they are omitted.

The experimental software was programmed in z-Tree (Fischbacher 2007), and all sessions took place in the laboratory of a private university in the United States. Sessions took 80 minutes on average, with average earnings of $31, where subjects were compensated for all rounds of decisions.

5. Outcome Results

We present our experimental results in two sections. We first focus on outcomes — specifically, efficiency, expected profits and contract terms. Section 6 discusses bargaining process details.

An overview of our results on outcomes is as follows: first, in all treatments, roughly 85% of dyads successfully reached an agreement (no statistical differences). Therefore, we present the average outcomes conditional on an agreement and explore the determinants of agreements later. Second, we observed broad support for our anchoring hypotheses. Specifically, players do not fully exploit the bargaining power they have, which leads to small and insignificant differences between Ult and Neg-W, whereas including the order quantity in the negotiation leads to higher order quantities and more efficient outcomes. Furthermore, in all bargaining structures, it is disadvantageous to hold the inventory risk, despite the normative prediction that it is strictly or weakly better to do so in Neg-W and Neg-WQ. Finally, we found little evidence of experience effects in any treatment; thus we include all rounds of decisions in our analysis. For all hypothesis tests reported, we take the session average as the unit of independent observation, and regressions use standard errors which have been corrected for clustering at the session level.

Our main results on bargaining outcomes are presented in Table 3 and Figure 1. The table reports \( p \)-values of tests of the normative theoretical point predictions for a number of metrics, while Figure 1, in three panels, reports average channel efficiency, order quantities and wholesale prices for each bargaining structure and inventory risk setting. Note that the data from the ER treatments are included into the relevant retailer/supplier risk cells/bars, depending on the agreed-upon allocation of inventory risk. We discuss the ER treatments in detail in a later subsection.

5.1. Comparisons to Point Predictions

Before discussing our behavioral hypotheses, we briefly mention the results of tests of the normative theoretical point predictions, reported in Table 3. For the Neg-W and the Neg-WQ treatments, we reject the normative point predictions for channel efficiency, wholesale price, and order quantity at the 5% level; we also reject one or both of the normative point predictions for retailer/supplier expected profits. For the Ult RR treatment, we fail to reject the normative point predictions for
Figure 1 Summary of Results (Conditional on an Agreement)

(a) Expected Profits & Efficiency

Note: The numbers inside each bar are the average expected profits by role. The numbers above each bar are the average supply chain efficiency for each treatment.

(b) Order Quantity

Note 1: $p$-values are from non-parametric trend tests using the session average as the unit of observation. $p$-values between two bars are from Mann-Whitney rank sum tests that adjacent treatments are identical.

Note 2: The direction of the arrows indicates the comparative static according to the normative benchmark.

(c) Wholesale Price

Note 1: $p$-values are from Mann-Whitney rank sum tests that adjacent treatments are identical using the session average as the unit of observation.

Note 2: The direction of the arrows indicates the comparative static according to the normative benchmark.
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### Table 3

*p*-values of Tests of Normative Theoretical Point Predictions (Conditional on an Agreement)

<table>
<thead>
<tr>
<th></th>
<th>Retailer Risk (RR)</th>
<th>Supplier Risk (SR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ult</td>
<td>Neg-W</td>
</tr>
<tr>
<td>Channel Efficiency (%)</td>
<td>1.000</td>
<td>0.028</td>
</tr>
<tr>
<td>Retailer Expected Profit</td>
<td>1.000</td>
<td>0.046</td>
</tr>
<tr>
<td>Supplier Expected Profit</td>
<td>0.593</td>
<td>0.345</td>
</tr>
<tr>
<td>Wholesale Price (<em>w</em>)</td>
<td>0.593</td>
<td>0.046</td>
</tr>
<tr>
<td>Order Quantity (<em>q</em>)</td>
<td>0.285</td>
<td>0.028</td>
</tr>
</tbody>
</table>

Note 1: Data from the ER treatments are pooled into the relevant Neg-W and Neg-WQ treatment depending on how inventory risk was allocated in the agreement.

Note 2: *p*-values are generated from two-sided Wilcoxon signed-rank tests with the session average as the unit of independent observation.

Note 3: For each of the Ult treatments, we have 3 independent samples. Therefore, the strongest possible rejection of a null hypothesis is at the 10.9% level. All other treatments have 6 independent samples.

all five metrics (in all cases, *p* > 0.285). For the Ult SR treatment, for 4 of 5 metrics we reject at *p* = 0.109. While this is not significant at the 10% level, with only three independent sessions, this is the strongest possible rejection. Thus, it is plausible that behavior is significantly different from the normative benchmarks in this treatment as well.

It is also worth mentioning the direction of the differences from the normative theory, which can be seen in Figure 1. For instance, in all of the unstructured bargaining treatments, Neg-W and Neg-WQ, efficiency and the order quantity are lower than the normative theoretical predictions. Also, in line with anchoring, note that when quantities are negotiated, Neg-WQ, observed quantities are between 50 and 80 (60.77 and 63.77). Similarly, turning to the wholesale price, all the deviations from the normative theory are consistent with anchoring. For example, in Ult SR, the wholesale price of 7.21 is greater than the normative prediction of 6 (and less than 9), while in the Neg-W and Neg-WQ treatments, the wholesale prices of 9.19 and 9.21 are significantly less than the normative predictions of 10.07 and 10, respectively (as well as being greater than 9).

### 5.2. Comparisons Across Treatments

We now turn to comparisons across treatments, with emphasis on testing our behavioral hypotheses on efficiency and inventory risk. We organize the discussion around a series of results.

**Result (Efficiency)** *In support of Hypothesis 1, efficiency is the same between Ult and Neg-W, and is significantly higher in Neg-WQ. Furthermore, Neg-WQ fails to achieve 100% efficiency.*

Support for this result is illustrated in Figure 1(a). For the retailer risk conditions, channel efficiency is 73.61%, 74.91% and 90.64% for Ult, Neg-W and Neg-WQ, respectively. A rank sum test cannot reject that Ult and Neg-W have the same efficiency (*p* = 1.000), while the same test strongly rejects that Neg-W and Neg-WQ have the same efficiency (*p* = 0.004). For the supplier
risk conditions, channel efficiency is 80.21%, 82.49% and 92.39% for Ult, Neg-W and Neg-WQ, respectively. Similar to retailer risk, a rank sum test cannot reject that Ult and Neg-W have the same efficiency \( p = 0.796 \), while the same test strongly rejects that Neg-W and Neg-WQ have the same efficiency \( p = 0.004 \). Finally, although the channel efficiency is over 90% in the Neg-WQ treatments, and achieves a larger relative efficiency gain over Neg-W than the normative theory predicts, a Wilcoxon signed-rank test rejects that this is equal to 100% \( p = 0.008 \).

Of course, the main driver of channel efficiency is the order quantity. As Figure 1(b) shows (\( p \)-values for tests are between the bars), we have the same comparative statics as efficiency. Specifically, for both retailer and supplier risk conditions \( Q_{\text{Ult}} = Q_{\text{Neg-W}} < Q_{\text{Neg-WQ}} \).

**Result (Pareto Improvement)** *In an unstructured bargaining setting, including the order quantity in the negotiation yields a Pareto improvement: the retailer and supplier earn higher expected profit.*

This result is evident in Figure 1(a), where the lower (and darker) bars show the average expected retailer profits and the upper (and lighter) bars show the average expected supplier profits. Comparing Neg-W to Neg-WQ, for both risk locations, one can see that both parties earn higher profit when the stocking quantity is included in the negotiation, leading to a win-win outcome.

**Result (Inventory Risk)** *In support of Hypothesis 2(a), we find that the risk holder always earns less than their counterpart. In support of Hypothesis 2(b), we find that both parties try to avoid inventory risk when its location is negotiable.*

Support for Hypothesis 2(a) can also be seen in Figure 1(a). For all six conditions, the party avoiding the inventory risk has higher expected profits than the party holding the inventory risk. Specifically, across all retailer risk conditions, suppliers earn an average of 68.63 points more than retailers (Wilcoxon signed-rank; \( p = 0.005 \)), while across all supplier risk conditions, retailers earn an average of 64.50 points more than suppliers (Wilcoxon signed-rank; \( p = 0.006 \)). Thus it is always better to be the party not exposed to inventory risk.

The main driver of the differences in expected profits is the agreed-upon wholesale prices, which can be seen in Figure 1(c). In all treatments, wholesale prices deviate from the normative theory in the direction of players not fully exploiting their bargaining power, which is indicative of anchoring. Thus in the retailer risk settings, the agreed wholesale price is generally less than 9, because a wholesale price of 9 would not compensate for the retailer’s risk exposure. Further, in the Neg-W and Neg-WQ treatments the retailer would like to push the wholesale price down to 6, but because a wholesale price of 9 is focal, the agreed wholesale price ends up above 6. A similar logic works
for the supplier risk treatment. In sum, in the Ult treatments, anchoring is not strong enough to overturn the normative prediction that the inventory risk holder earns less than the non-risk holder. Furthermore, when moving to the Neg-W and Neg-WQ treatments, because of anchoring, the inventory risk holders are unable to move the wholesale price sufficiently to compensate them for their risk exposure. Hence, it is always disadvantageous to hold the inventory risk.

To show support for Hypothesis 2(b), we need to look at our bargaining process data: specifically, whether players’ proposals seek to take the risk themselves or push the risk onto the other player. In Neg-W, 57.0% of opening offers tried to push the risk onto their opponent, and 83.6% of subjects tried to push risk onto their opponent at least once in the negotiation. In the Neg-WQ treatment, these numbers are 69.5% and 80.1%. Pooling the Neg-W and Neg-WQ treatments, we can reject that subjects are equally likely to propose to push the risk and to keep the risk, both from the start, and at least once during bargaining (Wilcoxon signed-rank; \( p_{\text{start}} = 0.046, p_{\text{once}} = 0.028 \)).

5.3. Endogenous Risk

In our analysis above, we pooled the data from the ER treatments into the relevant exogenous RR and SR conditions, depending on where the players agreed to locate the inventory risk. Table 4 illustrates the results from only the ER treatments, split between whether the retailer or supplier is determined to hold the risk. To show that our decision to pool was justified, we also include data from the relevant exogenous risk treatments.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Summary of Results in the ER Treatments (Conditional on an Agreement)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Neg-W</td>
</tr>
<tr>
<td></td>
<td>RR Risk</td>
</tr>
<tr>
<td></td>
<td>Channel Efficiency (%)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Expected Retailer Profit</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Expected Supplier Profit</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Order Quantity (( q ))</td>
</tr>
</tbody>
</table>

Note: Standard deviations across all observations in parentheses.

Result (Endogenous Risk) Allowing players to negotiate the inventory risk location does not influence the agreed-upon contract parameters, channel efficiency, or expected profits.
To account for this result, for each of the 10 (five performance metric × two risk location) pairs in Table 4, we estimated the following regression on session averages:

\[
\text{Performance Metric(Risk Location)} = \alpha + \beta(\text{Neg-W}) + \gamma(\text{Endogenous Risk}) + \epsilon,
\]

where Neg-W is an indicator for the Neg-W bargaining structure and Endogenous Risk is an indicator for the ER treatment. In all 10 cases, the estimated coefficient on Endogenous Risk is insignificant, having \( p \)-values ranging from a low of 0.299 to a high of 0.963. Thus we conclude that allowing subjects to bargain over the location of inventory risk does not affect the agreed-upon outcome. This is also evidence that the extra complexity of negotiating inventory risk location does not influence our results. We return to this in Section 7.

5.4. Risk Aversion and Outcomes

Thus far our results have shown that outcomes deviate from the normative theory, which may be due to an anchoring bias. However, another alternative explanation for outcomes is risk aversion. Although our theoretical treatment of risk aversion is found in Appendix A.4, we briefly recall the main predictions here: (i) the order quantity is decreasing in the risk aversion of the inventory risk holder and largely independent of the risk aversion of the other party; (ii) under both retailer and supplier risk, the wholesale price is decreasing in the risk aversion of the supplier; under retailer risk, the wholesale price is non-linear (first decreasing, then increasing) in the risk aversion of the retailer, and is increasing in the risk aversion of the retailer under supplier risk; and (iii) risk preferences can affect which party prefers to hold (or avoid) the inventory risk. The next two results summarize what can and cannot be supported by risk aversion.

**Result (Support for Risk Aversion)** (a) For Neg-W and Neg-WQ, the wholesale price and order quantity vary in a manner consistent with risk aversion. (b) In the ER conditions, there is partial sorting with respect to risk preferences. (c) There is a small positive association between risk aversion and the frequency of agreements.

Support for part (a) comes from Table 5(b). As can be seen, the order quantity is significantly decreasing in the risk aversion of the inventory risk holder and is unaffected by the risk aversion of the non-risk holder. With regard to the wholesale price, for retailer risk, it is largely invariant to the risk aversion of the retailer but is decreasing in the risk aversion of the supplier. For supplier risk, we also see that the wholesale price is decreasing in the supplier’s risk aversion but is not significantly affected by the retailer’s risk aversion (but is positive). All of these comparative statics are generally consistent with the predictions of risk aversion.
Turning to part (b), we estimated a random-effects regression (not depicted) where the dependent variable equals 1 if the supplier agrees to take the inventory risk and the explanatory variables are the risk aversion of each party. The results showed that the more risk averse the retailer, the more likely the supplier agrees to hold the inventory risk, whereas the risk aversion of the supplier does not affect the likelihood that the supplier agrees to hold the inventory risk. As shown in Table A.3(c) in the Appendix, this is partially consistent with the predictions of risk aversion.

Although neither the normative model nor the risk aversion model predicts disagreement, risk aversion weakens a player’s bargaining position because they fear disagreement (which is often the worst possible outcome). Thus, part (c) of the above result should not come as a surprise. Indeed, support for it comes from a random-effects logistic regression in the first column of Table 5(c). Specifically, we regress an indicator for agreement on the retailers’ and suppliers’ risk aversion, as well as bargaining structure and risk location indicator variables. The estimated coefficients on both retailers’ and suppliers’ risk aversion are positive, and in the case of suppliers, significant, but the marginal effect (not shown) is very small. Specifically, a 1-unit increase in risk aversion increases the likelihood of agreement by 1.1 percentage points.

Although risk aversion has some explanatory power, there are key differences that it cannot explain. We highlight these in the following:

**Result (Discrepancies with Risk Aversion)** (d) For the Ult treatments, contrary to the predictions of risk aversion, we observe no relationship between risk aversion and wholesale prices, and a non-linear relationship between risk aversion and quantities. (e) In all treatments, there is a level effect in both wholesale prices and expected profits that risk aversion cannot explain.

For part (d) of this result, we refer to Table 5(a), which suggests that risk aversion provides almost no explanatory power in the Ult treatments. Specifically, for wholesale prices, there is no relationship with the risk aversion of the proposer. Moreover, there is a non-linear relationship between the risk aversion of the inventory risk holder and the order quantity. Both of these results contradict the theoretical predictions under risk aversion.

Support for part (e) comes from two sources. First, regarding wholesale prices, risk aversion predicts a tight range depending on the risk parameters of the players. For example, for supplier risk for Neg-WQ, the predicted range of wholesale prices is at most 9.65 to 10.40. However, recalling Figure 1(c), the average agreed-upon wholesale price is 9.21. Similarly for retailer risk the range in wholesale prices is at most 5.76 to 6.00, while the average agreed wholesale price is 7.44. Similar comparisons can be made for the Ult and Neg-W treatments. Hence, risk aversion cannot explain
Table 5  The Role of Risk Preferences on Outcomes

(a) Ultimatum Treatments

<table>
<thead>
<tr>
<th></th>
<th>Order Quantity</th>
<th>Wholesale Price (RR)</th>
<th>Wholesale Price (SR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own Risk Aversion</td>
<td>−10.784***</td>
<td>0.036</td>
<td>−0.175</td>
</tr>
<tr>
<td>(Own Risk Aversion)²</td>
<td>0.862***</td>
<td>(0.204)</td>
<td></td>
</tr>
<tr>
<td>RR × Oth. Risk Aversion</td>
<td>0.308</td>
<td>(0.573)</td>
<td></td>
</tr>
<tr>
<td>SR × Oth. Risk Aversion</td>
<td>−0.602</td>
<td>(1.823)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>70.399***</td>
<td>(13.585)</td>
<td>8.364***</td>
</tr>
</tbody>
</table>

(b) Neg-W and Neg-WQ

<table>
<thead>
<tr>
<th></th>
<th>Order Quantity</th>
<th>Wholesale Price (RR)</th>
<th>Wholesale Price (SR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own Risk Aversion</td>
<td>−2.230***</td>
<td>−0.005</td>
<td>−0.076***</td>
</tr>
<tr>
<td>(Own Risk Aversion)²</td>
<td>0.004</td>
<td>(0.025)</td>
<td></td>
</tr>
<tr>
<td>RR × Oth. Risk Aversion</td>
<td>0.179</td>
<td>(0.333)</td>
<td></td>
</tr>
<tr>
<td>SR × Oth. Risk Aversion</td>
<td>−0.336</td>
<td>(0.383)</td>
<td></td>
</tr>
<tr>
<td>Oth. Risk Aversion</td>
<td>−0.083**</td>
<td>(0.040)</td>
<td>0.082</td>
</tr>
<tr>
<td>Constant</td>
<td>68.503***</td>
<td>(3.551)</td>
<td>7.759***</td>
</tr>
</tbody>
</table>

(c) Agreement & Expected Payoffs

<table>
<thead>
<tr>
<th></th>
<th>Logit Agreement</th>
<th>Supplier EP</th>
<th>Retailer EP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ret. Risk Aversion</td>
<td>0.086</td>
<td>(0.058)</td>
<td>−2.196</td>
</tr>
<tr>
<td>Sup. Risk Aversion</td>
<td>0.097**</td>
<td>(0.049)</td>
<td>−3.779**</td>
</tr>
<tr>
<td>Neg-W</td>
<td>0.051</td>
<td>(0.209)</td>
<td>−41.595***</td>
</tr>
<tr>
<td>Ult</td>
<td>−0.069</td>
<td>(0.228)</td>
<td>−57.636***</td>
</tr>
<tr>
<td>Ret. Risk</td>
<td>0.151</td>
<td>(0.250)</td>
<td></td>
</tr>
<tr>
<td>Sup. Risk</td>
<td>−0.131</td>
<td>(0.224)</td>
<td></td>
</tr>
<tr>
<td>End. Risk</td>
<td>−1.468</td>
<td>(10.974)</td>
<td>6.685</td>
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<tr>
<td>Sup. Holds Risk</td>
<td>−51.507***</td>
<td>(11.366)</td>
<td>63.896***</td>
</tr>
<tr>
<td>Constant</td>
<td>0.910**</td>
<td>(0.447)</td>
<td>289.513***</td>
</tr>
</tbody>
</table>

Note 1: For Order Quantity we include only the inventory risk holders; for Wholesale Price we include only proposers (i.e., non-risk holders); for Supplier EP (resp. Retailer EP) we included only suppliers (resp. Retailers).

Note 2: Control variable for risk location included in the regressions in (a) and (b) but omitted from the table.

Note 3: *, ** and *** denote significance at the 10, 5 and 1% levels, respectively. Except “Logit Agreement” in (c), the tables report linear random effects models with standard errors in parentheses which have been corrected for clustering at the session level.

the level of wholesale prices. Second, regarding expected profits, consider the last two columns of Table 5(c), which regress supplier and retailer expected payoffs on the experimental parameters and the degree of risk aversion by the players. As can be seen, controlling for risk aversion and treatment parameters, when the supplier holds the inventory risk (Sup. Holds Risk), suppliers earn significantly lower expected profits, and retailers earn significantly higher expected profits.

6. Bargaining Process Results

Our results so far have focused largely on aggregate outcomes, and we have shown that neither the normative theory nor risk aversion can adequately explain our results. Instead we have argued that anchoring and insufficient adjustment offers a better explanation for our data. In this section,
we dig deeper into the bargaining process for our Neg-W and Neg-WQ treatments to present more evidence on the role of anchoring in negotiations (we provide further bargaining results, on the role of feedback and duration, in Appendix B).

Consider Figure 2, which shows histograms of agreed wholesale prices for the Neg-W and Neg-WQ treatments. The dashed vertical lines appear at 6 and 10, which are the normative theoretical predictions for retailer and supplier risk. As one can see, there is a great deal of heterogeneity, but most agreed-upon prices lie within these bounds. Moreover, there is a strong attraction to a price of 9. In the supplier risk conditions, over 44% of final agreements lie between 8.5 and 9.5, while only about 34% of agreements lie between 9.5 and 10.5, which encompasses the normative theoretical prediction of 10. Similarly, in the retailer risk conditions, despite the necessity of a large adjustment in the wholesale price to compensate for risk, between 15 and 28% of agreements are between 8.5 and 9.5. In contrast, only between 11 and 22.6% of agreements are in the range 5.5 to 6.5, which encompasses the normative theoretical prediction of 6. Thus it appears that wholesale prices around 9 – with some adjustment due to risk location – are generally acceptable. How the players reach this outcome is through a process of offers and concessions. This creates further opportunities for anchoring to influence the outcome.

6.1. Initial Offers Anchor Negotiations and Influence Outcomes
Previous research has suggested that opening offers have an effect on the bargaining outcome, because they serve to anchor the negotiation (Galinsky and Mussweiler 2001). We now demonstrate
similar behavior in our data:

**Result (Initial Offers)** *In support of Hypothesis 3, final outcomes are positively correlated with initial offers. The final agreement is approximately midway between the opening offers of the retailer and supplier. More extreme opening offers increase the chance of disagreement.*

Support for this result is found in Table 6, Table 7 and Figure 3. Table 6 shows the average opening offer for each player in the Neg-W and Neg-WQ exogenous risk treatments, as well as the final negotiated agreement. As can be seen, the agreed-upon wholesale prices lie approximately midway between the retailer and supplier opening offers. It is also interesting that the average opening wholesale price offers are shifted down (between SR and RR) by approximately 1 in Neg-W and by about 1.5 in Neg-WQ for both player types. Given that the difference in the wholesale prices is around 4 between RR and SR for the normative theory (6 vs. roughly 10), it suggests that players do not adequately account for the shift in risk exposure between the two treatments (we return to this below). Panel (b) in Table 6 shows a similar pattern for the opening order quantities in the Neg-WQ treatments. The party holding the risk initially proposes a lower order quantity than her counterpart, which is not surprising because the players have different anchor points. Further, the agreed order quantity is higher than the risk holder’s initial proposal.

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Opening Offers by Role in Neg-W and Neg-WQ</th>
<th>(a) Wholesale Prices</th>
<th>(b) Order Quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
<td>SR</td>
<td>RR</td>
</tr>
<tr>
<td><strong>Neg-W</strong></td>
<td></td>
<td></td>
<td><strong>Neg-WQ</strong></td>
</tr>
<tr>
<td>Retailer’s First Offer</td>
<td>5.62</td>
<td>6.55</td>
<td>N/A</td>
</tr>
<tr>
<td>Supplier’s First Offer</td>
<td>10.45</td>
<td>11.46</td>
<td></td>
</tr>
<tr>
<td>Agreed Wholesale Price</td>
<td>7.89</td>
<td>9.10</td>
<td></td>
</tr>
<tr>
<td><strong>Neg-WQ</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retailer’s First Offer</td>
<td>6.48</td>
<td>7.82</td>
<td>Retailer’s First Offer</td>
</tr>
<tr>
<td>Supplier’s First Offer</td>
<td>9.01</td>
<td>10.74</td>
<td>Supplier’s First Offer</td>
</tr>
<tr>
<td>Agreed Wholesale Price</td>
<td>7.59</td>
<td>9.31</td>
<td>Agreed Order Quantity</td>
</tr>
</tbody>
</table>

To provide further evidence for the initial offers result, Table 7 takes a regression approach to learn more about the anchoring effects of opening proposals on outcomes. Table 7(a) shows that both the wholesale price and order quantity are strongly positively associated with the initial offer. For example, increasing the opening wholesale price offer by 1 point leads to a final wholesale price that is approximately 0.329 points higher (Figure 3(a) also illustrates this). Table 7(b) shows that

\footnote{Both in the interest of space and because the analysis is clouded by a proposed inventory risk location, for this analysis, except for how inventory risk location is determined, we omit a discussion of the ER treatments.}
the anchoring effect of initial offers also holds for inventory risk location in the ER treatments. If a player’s opening offer is for the supplier to take the inventory risk, then the supplier ends up taking the risk 43.7 percentage points more often in Neg-WQ and 15.2 percentage points more often in Neg-W, and both of these results are significant at the 1% level.

Table 7 Regression Analysis of Anchoring on Opening Offers in Neg-W and Neg-WQ

(a) Anchoring on Wholesale Price & Order Quantity

<table>
<thead>
<tr>
<th></th>
<th>Neg-W Wholesale Price</th>
<th>Neg-WQ Wholesale Price</th>
<th>Order Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w_{prop.}$</td>
<td>0.341*** (0.032)</td>
<td>0.329*** (0.082)</td>
<td></td>
</tr>
<tr>
<td>$q_{prop.}$</td>
<td></td>
<td></td>
<td>0.448*** (0.062)</td>
</tr>
<tr>
<td>Constant</td>
<td>4.435*** (0.321)</td>
<td>4.644*** (0.731)</td>
<td>31.034*** (3.982)</td>
</tr>
</tbody>
</table>

(b) Anchoring on Inventory Risk Location (Dep. Var.: Supplier Takes Risk)

<table>
<thead>
<tr>
<th></th>
<th>Neg-W</th>
<th>Neg-WQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propose Supplier Risk</td>
<td>0.152*** (0.049)</td>
<td>0.437*** (0.095)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.499*** (0.019)</td>
<td>0.399*** (0.044)</td>
</tr>
</tbody>
</table>

Note 1: $w_{prop.}$ and $q_{prop.}$ represent a player’s opening wholesale price and order quantity proposal.

Note 2: *, ** and *** denote significance at the 10, 5 and 1% levels, respectively. The table reports linear random-effects models with standard errors in parentheses which have been corrected for clustering at the session level.

Note 3: We omit additional control variables for the type of subject and risk condition, which are not central to this analysis.

Finally, in Figure 3(b), we provide a plot which shows the likelihood of reaching an agreement, based on proposed wholesale prices, in Neg-W (similar results exist for Neg-WQ), with a linear fit. As one can see, more extreme offers may lead to conflict and a lower chance of reaching an agreement (regression results, which we omit in the interest of space, confirm this pattern).

This analysis helps explain the result that it is always disadvantageous to hold inventory risk. That is, Table 6 showed that the average opening wholesale price offer is only 1 to 1.5 lower when the retailer has the risk than when the supplier has the risk. Indeed, in the retailer risk condition of Neg-WQ, the average opening offer by retailers is actually higher than the equilibrium prediction, 6.48 (vs. 6). Given that the final agreement lies midway between the opening offers, it is no longer surprising that it is disadvantageous to hold the risk.

Result (Inventory Risk Holders & Initial Offers) Inventory risk holders make relatively weak opening offers.

We saw initial support for this result in Table 6. We can observe further support by focusing on the Neg-WQ treatments, since one can directly compute the expected payoffs implicit in each
Figure 3  The Effect of Opening Offers on Agreements by Role for Neg-W

(a) Neg-W, Wholesale Price

(b) Neg-W, Wholesale Price & Agreements

Figure 4  Supplier’s Share of Supply Chain Surplus By Offer Number (Five or More Offers) for Neg-WQ

(a) Retailer Risk

(b) Supplier Risk

offer. In Figure 4, we show the average split of the expected supply chain surplus that the supplier receives by offer number when there were at least five offers (the observed pattern is robust to the number of offers). As one can see, there is a concession process, but the starting points are vastly different. For the party avoiding inventory risk, their first offer demands 80 to 90% of the surplus for themselves (90.6% RR, 79.5% SR), while the first offer of the party holding the inventory risk asks for only 63% of the surplus, in both risk scenarios. As a consequence, by the fifth offer, in the retailer risk condition, retailers are conceding more than half the surplus to the supplier (52.9%), and in the supplier risk condition, suppliers are requesting less than half (49.7%).

6.2. A Remedy for Anchor Points

To formally test our conjecture that anchoring on a wholesale price of 9, and insufficiently adjusting to account for risk, is a key driver of results, we ran an additional treatment that sought to remedy
said anchor bias. Specifically, we conducted two additional sessions of the Neg-WQ treatment under retailer risk where, in the instructions and on the screen during bargaining, subjects were told:

* A wholesale price of 9 equally splits the revenue from sales, but does not adjust for the fact that the retailer is responsible for any unsold inventory. Past research has shown that the negotiated agreement (i.e., wholesale price and order quantity) does not adequately take this into account.

All other aspects of the experiment and instructions were identical. Our hypothesis was that this would make salient the need (at least from the retailers’ perspective) for a lower wholesale price than we observed in our main treatments, and would diminish the focus on a price of 9. Indeed, we have

**Result (Remediaying Anchor Points)** When the potential anchor point is made salient, along with its implications for distribution of revenues and inventory risk, the agreed wholesale price shifts in favor of the inventory risk holder.

<table>
<thead>
<tr>
<th>Table 8</th>
<th>Bargaining Results With Anchor Point Remedy (Last 3 Periods)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Outcomes</td>
<td>Remedy</td>
</tr>
<tr>
<td>Wholesale Price ((w))</td>
<td>6.34</td>
</tr>
<tr>
<td>Order Quantity ((q))</td>
<td>60.26</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>89.8</td>
</tr>
<tr>
<td>Exp. Retailer Profit</td>
<td>224.1</td>
</tr>
<tr>
<td>Exp. Supplier Profit</td>
<td>206.9</td>
</tr>
<tr>
<td>(b) Opening Offers</td>
<td>Remedy</td>
</tr>
<tr>
<td>Retailer Wholesale Price ((w))</td>
<td>4.71</td>
</tr>
<tr>
<td>Order Quantity ((q))</td>
<td>53.57</td>
</tr>
<tr>
<td>Supplier Wholesale Price ((w))</td>
<td>9.19</td>
</tr>
<tr>
<td>Order Quantity ((q))</td>
<td>76.28</td>
</tr>
</tbody>
</table>

Note: ‘Original’ represents results from Neg-WQ exogenous retailer risk.

Support for this result is in Table 8. Unlike in the original experiments where we saw very little in terms of dynamics, in this treatment there were trends over time. This may suggest that the anchor point was effectively removed and that it took subjects time to identify a replacement. Given this, we focus on the last three periods. As can be seen, the wholesale price is more than a full point lower than in the original treatment (6.34 versus 7.59) and is close to the normative theoretical prediction of 6. Also, while this treatment attempted to communicate the implications of the anchor point for the wholesale price, it did not do so for the quantity, and we observe that neither the order quantity nor efficiency changes. The result is that once we nudge subjects away from the anchor for wholesale price, retailers earned slightly more than suppliers, in line with the normative benchmark. Also, interestingly, it is only retailers who adjust their opening wholesale price offer, while the average wholesale price offer by suppliers is virtually identical. This leads to more frequent disagreements compared with the original treatment. Overall, this treatment suggests
that a rather subtle manipulation, which attempts to communicate the hypothesized wholesale price anchor point, appears to shift the outcomes toward the normative theory.

7. Discussion of Alternative Explanations

Thus far we have observed that the normative theory fails to explain our data in terms of both point predictions and comparative statics. While risk aversion can explain some comparative statics, it misses a “level effect” on wholesale prices, which makes holding inventory risk universally disadvantageous. We argue that this level effect is better explained by subjects’ anchoring on focal points. However, given the richness of the setting, other factors may influence behavior.

In addition to risk aversion, several studies have noted roles for loss aversion and ex post inventory regret in supply chain experiments (e.g., Donohue et al. (2016), Schweitzer and Cachon (2000)). However, in much the same way that risk aversion cannot explain key aspects of our data, both of these behavioral alternatives are similarly inadequate (details available upon request).

Another alternative explanation relates to bounded rationality. Studies have shown that human decision makers often fail to make decisions that coincide with normative predictions in more complex settings (e.g., Katok and Wu (2009), Kalkanci et al. (2011)). A duration analysis of our data, detailed in Appendix B, suggests that bargaining takes longer when more terms are negotiable, which may be due to complexity. However, it is unlikely that complexity is a main driver of our results. For instance, we showed that the agreement rate was the same across all treatments, despite differences in complexity due to the number of contract terms that were negotiable (from one to three). Additionally, supply chain efficiency was higher in Neg-WQ than Neg-W, despite the former case having more parameters to negotiate simultaneously. Finally, in the endogenous risk treatments where the inventory risk is negotiated, the other contract terms are indistinguishable from the same exogenous risk treatments, conditional on how risk is allocated in an agreement.

Last, given that our experiment entailed two players interacting with each other, one may suspect fairness to influence results. Yet, fairness also neglects to fully capture our data. For example, in the Neg-WQ treatment, the normative theory predicts perfectly equitable payoffs, whereas we see significant differences in payoffs in these treatments. Therefore, to summarize, while there may be many dynamics at play in our experiment, we feel that anchoring offers the most compelling explanation of our data whereas risk aversion explains some comparative statics.

8. Conclusion

In this study we evaluated the effect of multidimensional bargaining and the location of inventory risk on supply chain performance. We considered a setting in which bargaining was highly structured, such as the canonical model with ultimatum offers, or unstructured, where both parties
could make multiple back-and-forth offers while sending and receiving feedback. Given that the location of inventory risk may affect outcomes in each bargaining setting, we also varied how the inventory risk is allocated: either exogenously given to the retailer or supplier, or endogenously determined through a negotiation. Our theoretical analysis generated predictions for each setting under the assumption of risk-neutral expected-profit maximization. Because managers, who may deviate from risk-neutral expected-profit maximization, are instrumental in negotiating supply chain contracts, we also generated a series of behavioral hypotheses centered around anchoring on salient focal points.

To understand the role of both normative theory and behavioral factors, we conducted a controlled laboratory experiment where human subjects act as decision makers in a two-stage supply chain. We find that many supply chain outcomes such as channel efficiency, distribution of profits, wholesale prices, and order quantities, deviate significantly from the normative theory, particularly in the unstructured bargaining contexts. Of particular interest to managers, we show, in contrast to normative theory, that channel efficiency does not improve when moving from an ultimatum setting to one where the wholesale price is negotiated. Instead, to improve channel efficiency, both the wholesale price and order quantity must be negotiated simultaneously. In this case, efficiency increases and the effect is far larger than the normative theory predicts (21% vs. 6.7% in retailer risk, and 12% vs. 1.5% in supplier risk). Furthermore, allowing the quantity to be included in the negotiation leads to a Pareto improvement in profits, generating a win-win outcome for the supply chain. Another interesting insight, which is contrary to normative theory but consistent with what managers told us, is that the party that incurs the inventory risk earns significantly lower profits than the party avoiding the risk, regardless of the bargaining environment. We also observe that a majority of these results persist even when the inventory risk location is endogenously determined through the bargaining process.

Although risk aversion can explain some comparative statics, we argue that the primary explanation for our results is that players have an anchoring bias. That is, wholesale prices are anchored between the standard theoretical prediction and another salient focal point: the midpoint between the supplier’s production cost and the retailer’s selling price. This bias can explain the comparative statics across treatments for supply chain metrics like efficiency, and also predicts that the inventory risk holder will earn less than their counterpart, regardless of the bargaining environment. Both of these predictions are validated in our data.

To further substantiate the validity of our anchoring hypothesis, we ran an additional experimental treatment where we attempted to communicate the salience of the midpoint wholesale price as
an anchor. In this treatment, wholesale prices shifted considerably toward the normative prediction and it was no longer disadvantageous to be the risk holder, as predicted. While beyond the scope of this study, we believe a thorough investigation of potential interventions aimed at mitigating behavioral biases, to try to improve outcomes in unstructured bargaining settings, would be an exciting opportunity for future research.

A limitation of our work is that we do not allow participants to freely communicate with one another. Although we imposed this restriction to allow us to analyze the bargaining dynamics in our unstructured contexts, we recognize that contracts may be negotiated face-to-face, with no restrictions on communication. The only operations paper that we are aware of which incorporates such features is Leider and Lovejoy (2016), who allow chat boxes but not face-to-face bargaining. Additionally, our study considers a supply chain consisting of a single retailer and supplier. In reality, both parties may be able to contract with multiple retailers and suppliers. Moving to richer supply chain environments is an interesting avenue for future research.

A key managerial implication of our work is that retailers and suppliers should engage in an unstructured bargaining process where the stocking quantity is included in the negotiation, as it leads to higher supply chain efficiency and higher profits for both parties. From an implementation standpoint, given that a quantity may affect the wholesale price, and vice versa, it is not unreasonable to have both terms set jointly. In addition, having both parties negotiate the terms together may lead to more integrative outcomes. A second implication is that, regardless of the inventory location, the party facing the inventory risk is at a disadvantage. One potential way to address this issue is to try make salient the need for sufficiently large movement in the wholesale price away from \((\frac{p+c}{2})\) to provide adequate compensation for risk exposure. Indeed, this may be the role that communication can play in a negotiation – to defuse the salience of an inappropriate anchor. In summary, our results suggest that managers should take care when determining how to negotiate supply chain contracts and how to allocate the inventory risk, as both have a significant impact on profits.

References


Ramachandran, Karthik, Necati Tereyagoglu, Yusen Xia. 2016. Multi-dimensional decision making in operations: An experimental investigation of joint pricing and quantity decisions.


Appendix

A. Details of Theoretical Analysis

At the risk of some repetition, we provide a complete analysis in order that the appendix be self-contained. Unless otherwise stated, we assume that demand is drawn uniformly from $[a, b]$ ($0 < a < b < \infty$), the supplier’s cost of production is $c > 0$ and the retailer’s selling price is $p > c$.

A.1. Ultimatum Bargaining

In this case, the party who does not hold the inventory makes an ultimatum wholesale price offer $w_{RL}^{Ult}$ to the other player. If the offer is accepted, then the responding player, who is exposed to inventory risk, unilaterally chooses an order quantity $q_{RL}^{Ult}$. Depending on the inventory risk location, we can write each firm’s expected profit function as

\[
\pi^r = \frac{p}{b-a} \int_a^b \min\{q, x\} dx - wq, \quad \pi^s = \frac{p-w}{b-a} \int_a^b \min\{q, x\} dx
\]

\[
\pi^r_s = (w-c)q, \quad \pi^s_s = \frac{w}{b-a} \int_a^b \min\{q, x\} dx - cq
\]

We now state and prove the following proposition from the main text:

**Proposition 1.** In the subgame perfect equilibrium of the structured bargaining game,

1. Under retailer risk, $w_{RL}^{Ult} = \frac{(p+c)}{2} + \frac{ap}{2(b-a)} \geq \frac{(p+c)}{2} > c$ and the supply chain is not coordinated.

2. Under supplier risk, $w_{RL}^{Ult} < \frac{(p+c)}{2} < p$ and the supply chain is not coordinated.

3. In both cases, the party holding the inventory risk earns a lower expected payoff than the party not holding the inventory risk.

**Proof.** Consider the case of retailer risk. Given $w$, the retailer’s first order condition is

\[
\frac{2pq}{2a-2b} + \frac{-2aw - 2bp + 2bw}{2a-2b} = 0,
\]

which, upon solving for $q$, yields $q_{RL}^{Ult} = a + (b-a)(\frac{(p-w)}{p})$, which will be less than the coordinated supply chain quantity whenever $w > c$. We can then substitute this expression into the supplier’s profit function and compute the first-order condition as

\[
\frac{(a-b)(w-c)}{p} + \frac{aw + b(p-w)}{p} = 0.
\]

Solving for the optimal wholesale price yields $w_{RL}^{Ult} = \frac{(p+c)}{2} + \frac{ap}{2(b-a)} > \frac{(p+c)}{2}$, as required.

Consider next the case of supplier risk. Given $w$, the supplier’s first-order condition is

\[
\frac{2ac + 2b(w-c) + 2qw}{2(b-a)} = 0.
\]

Upon solving for $q$ we have $q_{RL}^{Ult} = a + (b-a)(\frac{(w-c)}{w})$, which will be less than the coordinated supply chain quantity whenever $w < p$. We can then substitute this into the retailer’s profit function and take the first-order condition to obtain

\[
-\frac{(p-w)(a(c^2 + w^2) + b(w^2 - c^2))}{w^4} - \frac{a(c^2 + w^2) + b(w^2 - c^2)}{2w^2} + \frac{(p-w)(2aw + 2bw)}{2w^2} = 0.
\]
After some simplification, this can be rewritten as
\[-(a + b)w^3 - c^2(b - a)w + 2pc^2(b - a) = 0.\]

Observe that this is a third degree polynomial, the left-hand side of which is monotone decreasing in $w$. Therefore, it will have exactly one real root. Notice also that if we evaluate the left-hand side at $w = (p+c)/2$, then we obtain
\[-25(7c^3 + 9c^2p + 15cp^2 + 5p^3) < 0.\]

Therefore, it must be that $w_{Ult}^S < (p+c)/2$, as required. Indeed, holding $b - a$ fixed, for $a$ large enough, the retailer’s optimal wholesale price will be $w_{Ult}^S = c$.

The last thing we need to show is that the party holding the inventory risk earns a lower expected profit than the party not holding the risk. This follows because the party holding the inventory risk gets a less favorable wholesale price (e.g., in supplier risk, $w < (p+c)/2$). Q.E.D.

A.2. Unstructured Bargaining: Wholesale Price is Negotiated

Assume now that the supplier and the retailer first negotiate over $w$ in an unstructured manner. Then, given the agreed-upon wholesale price, the party that is exposed to risk chooses the order quantity to maximize its expected profits. Just as in the case of the structured bargaining setting, under retailer risk, the retailer will choose
\[q^R(w) = a + (b - a)(p - w)/p,\]
whereas under supplier risk, the supplier will choose
\[q^S(w) = a + (b - a)(w - c)/w.\]
Since we assume that the disagreement outcome is 0 for both player, the Nash bargaining solution is the wholesale price, $w$, which maximizes the product of the retailer’s and supplier’s expected profits. In particular,
\[\max_w \pi_{RL}^R(w, q^R(w)) \cdot \pi_{RL}^S(w, q^R(w))\]
\[s.t. \ c \leq w \leq p,\]
where $\pi_{RL}^i(w, q)$ are given in (2) and $q^R(w)$ is as above.

The formal proposition considers the case $a = 0$, while we allow $b$ to be general. Below, we provide a short numerical analysis to show robustness against $a > 0$.

**Proposition 2.** If $a = 0$, then when only the wholesale price is negotiated in an unstructured setting,

1. **Under retailer risk,** $c < w_{Neg-w}^R = (p+3c)/4 < (p+c)/2 = w_{Ult}^R$, $q_{Neg-w}^R > q_{Ult}^R$ and the outcome is more efficient than the ultimatum setting. Since $w_{Neg-w}^R > c$, the supply chain is not coordinated.

2. **Under supplier risk,** $w_{Neg-w}^S$ is the real root of a third degree polynomial. Furthermore, $p > w_{Neg-w}^S > (p+c)/2 > w_{Ult}^S$. Therefore, $q_{Neg-w}^S > q_{Ult}^S$ and the outcome is more efficient than the structured bargaining setting. Since $w_{Neg-w}^S < p$, the supply chain is not coordinated.
Proof. We first prove the result for the case of retailer risk. Suppose that the players have agreed upon a wholesale price, \( w \). The retailer chooses \( q \) to maximize its expected profits. Hence, \( q = b((p-w)/p) \). We now substitute this into the expected profit functions for the supplier and retailer and maximize the Nash product:

\[
\frac{b^2(w-c)(p-w)^3}{2p^2}.
\]

The first-order condition is (with some simplification) given by

\[
\frac{b^2(p-w)^2(3c + p - 4w)}{2p^2} = 0.
\]

In this case, the relevant root can be solved as \( w_{N \mid q}^R = \frac{p+3c}{4} < \frac{(p+c)}{2} \), and the corresponding order quantity is given by \( q_{N \mid q}^R = \frac{3b(p-w)}{4p} < \frac{b(p-w)}{p} \). Therefore, again, when \( q \) is not directly negotiated, we will have inefficiency.

Next consider the case of supplier risk and assume that the retailer and supplier have agreed upon a wholesale price, \( w \). Again, this is identical to the ultimatum case; hence, \( q = b((w-c)/w) \). We now substitute this into the expected profit functions for the supplier and retailer and maximize the Nash product:

\[
\frac{b^2(c-w)^3(c+w)(w-p)}{4w^3}.
\]

The first-order condition is:

\[
\frac{b^2(c-w)^2(3c^2 - 10c p - 2w^2) + 2cw(p-w) + w^2(p - 2w)}{4w^4} = 0.
\]

This has one root at \( w = c \), which we know cannot be optimal since then both the supplier and retailer earn 0 profits. Beyond this, we also see that the wholesale price at the optimal solution is actually independent of \( b \). Therefore, the relevant portion of the first-order condition can be stated as

\[
3c^2p + w(2cp - 2c^2) + w^2(p - 2c) - 2w^3 = 0.
\]

Finding an analytical solution to this is possible because we know that a third degree polynomial has at least one real-valued solution. However, the process of doing so is not informative, but we can bound the solution. In particular, evaluating the left-hand side of the above expression at \( w = p \), we obtain \( p(c^2 - p^2) < 0 \), whereas evaluating at \( w = \frac{(p+c)}{2} \), we obtain \( (c/4)(-7c^2 + 6cp + p^2) > 0 \). Hence \( w_{S \mid q}^N > \frac{(p+c)}{2} \). Q.E.D.

The above results are valid for \( a = 0 \). However, a numerical investigation confirms their validity for a wide range of \((a,b)\) pairs. For the case of retailer risk we summarize this in Table A.1, whereas for supplier risk, we summarize it in Table A.2. In both cases, we keep \( p = 15 \) and \( c = 3 \), as in the experiment.

There are three main points to make. First, under retailer risk, the retailer always earns strictly more than the supplier, whereas under supplier risk, the reverse is true. Second, under retailer risk \( w < \frac{(p+c)}{2} \), whereas under supplier risk the reverse is true. Thus the main results from Proposition 2 continue to hold for \( a > 0 \), over the range that we consider. Finally, holding \( b - a \) constant, the wholesale prices converge to \( \frac{(p+c)}{2} \) and the payoff differences between retailers and suppliers diminish.
Table A.1 Numerical Study: Retailer Risk

(a) Wholesale Price

<table>
<thead>
<tr>
<th>b</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>0</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
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<tr>
<td>100</td>
<td>7.76</td>
<td>7.21</td>
<td>6.92</td>
<td>6.74</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>8.25</td>
<td>7.76</td>
<td>7.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>8.47</td>
<td>8.07</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>400</td>
<td>8.59</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

(b) Percent Difference in Profits ($\pi^r > \pi^s$)

<table>
<thead>
<tr>
<th>b</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>0</td>
<td>50.0%</td>
<td>50.0%</td>
<td>50.0%</td>
<td>50.0%</td>
</tr>
<tr>
<td>100</td>
<td>27.3%</td>
<td>38.0%</td>
<td>42.7%</td>
<td>45.1%</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>16.7%</td>
<td>27.3%</td>
<td>33.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>11.9%</td>
<td>20.8%</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>400</td>
<td>9.2%</td>
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</tr>
</tbody>
</table>

Table A.2 Numerical Study: Supplier Risk

(a) Wholesale Price

<table>
<thead>
<tr>
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<th>300</th>
<th>400</th>
<th>500</th>
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<td>9.54</td>
<td>9.65</td>
<td>9.72</td>
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<td>9.27</td>
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<td>400</td>
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</table>

(b) Percent Difference in Profits ($\pi^s > \pi^r$)

<table>
<thead>
<tr>
<th>b</th>
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<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
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<tbody>
<tr>
<td>a</td>
<td>0</td>
<td>10.5%</td>
<td>10.5%</td>
<td>10.5%</td>
<td>10.5%</td>
</tr>
<tr>
<td>100</td>
<td>4.5%</td>
<td>6.3%</td>
<td>7.3%</td>
<td>8.0%</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>2.8%</td>
<td>4.5%</td>
<td>5.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>2.0%</td>
<td>3.4%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>1.6%</td>
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</tbody>
</table>

A.3. Unstructured Bargaining: Wholesale Price and Order Quantity are Negotiated

Finally, we come to the case in which the order quantity and wholesale price are simultaneously negotiated. We prove the following:

**Proposition 3.** When both the wholesale price and order quantity are negotiated in an unstructured setting,

1. Regardless of risk location, $q_{RL}^{Neg} - wq = a + (b - a)(p - c)/p$, the supply chain is coordinated and expected payoffs for the retailer and supplier are equalized.

2. Under retailer risk, $w_{RL}^{Neg} - wq = \frac{3ac^2 + ap^2 - 3bc^2 + 2bpq + bpq^2}{4(ac-bc+bp)} < \frac{p+c}{2}$, while under supplier risk, $w_{RL}^{Neg} - wq = \frac{p(3ac^2 + ap^2 - 3bc^2 + 2bpq + bpq^2)}{2(ac^2 + ap^2 - bc^2 + bpq)} > \frac{p+c}{2}$.

**Proof.** Under retailer risk, the Nash product is

$$(q(w - c)) \frac{(a^2p - 2aqw - 2bpq + 2bqw + pq^2)}{2a - 2b}$$

and the first-order conditions are given as

$$q: \frac{q(p-w)(50c(3q-400) + w(20000 - 300q + q^2))}{10000} = 0$$

$$w: \frac{(q - 200)q^2(-200c + (q - 200)(p - 2w))}{40000} = 0.$$
\[ w : \frac{q(a^2p - 2aqw - 2bpq + 2bqw + pq^2)}{2a - 2b} + \frac{q(w - c)(2bq - 2aq)}{2a - 2b} = 0. \]

With some algebra, one obtains that \[ w^R_{Neg-wq} = \frac{3arc + ap^2 - 3bc^2 + 2bcp + bp^2}{4(ac - bc + bp)^2} < \frac{(p+c)/2}{p-c} \] and \[ q^R_{Neg-wq} = a + (b - a) \frac{(p-c)/p}{p-c} \]. Observe that \( q^R_{Neg-wq} \) is given by the critical fractile of the integrated supply chain. That is, the outcome will achieve 100\% supply chain efficiency.

To show that expected profits are equalized, we simply substitute the expressions for \( w^R_{Neg-wq} \) and \( q^R_{Neg-wq} \) into the expressions for expected profits. Upon doing so, we immediately see that
\[ \pi_s^r = \pi_r^s = \frac{(p-c)(a(c + p) + b(p - c))}{4p}. \]

Now consider the case of supplier risk. The Nash product is
\[ \left( \frac{(a^2 + q(-2b + q))(p - w))}{(2(a - b))} \right) \left( \frac{(-2acq + a^2w + q(2b(c - w) + qw))}{(2(a - b))} \right) \]
and the first-order conditions are given by
\[ q : \left( \frac{(p - w)(a^2 + q(q - 2b))}{(2(a - b)^2} \right) \left( \frac{2ac - 2acq + q(2b(c - w) + qw))}{(2(a - b)^2} \right) = 0 \]
\[ w : \left( \frac{(p - w)(a^2 + q(q - 2b))}{(2(a - b)^2} \right) \left( \frac{2ac - 2acq + q(2b(c - w) + qw))}{(2(a - b)^2} \right) = 0. \]
From this, one obtains that \( w^S_{Neg-wq} = \frac{p(3ar+c+3ar^2+3bc^2+2bcp+bp^2)}{2(ac - ap^2 - bc^2 + bp^2)} \) and \( q^S_{wq} = a + (b - a) \frac{(p-c)/p}{p-c} \). Observe that, as in the case of retailer risk, \( q^S_{Neg-wq} \) is given by the critical fractile of the integrated supply chain. That is, the outcome will be fully efficient. Finally, substituting the solution back into the expressions for expected profits yields
\[ \pi_s^r = \pi_r^s = \frac{(p-c)(a(c + p) + b(p - c))}{4p}. \]

Q.E.D.

Finally, we can prove, for the case of \( a = 0 \) and \( b > 0 \),

**Corollary 1.** If \( a = 0 \), then when only the wholesale price is negotiated, the inventory risk holder earns a higher expected payoff than the party not holding the inventory risk.

**Proof.** Under retailer risk, regardless of whether \( q \) is negotiated or not, the wholesale price is \( w^R = \frac{3ar+p}{4}. \) We know that when \( (w, q) \) is negotiated, the expected payoffs are equalized. Therefore, when only \( w \) is negotiated and the retailer can choose the order quantity, it must be that she earns a strictly higher payoff than the supplier.

Under supplier risk, we do not have a workable closed-form solution for \( w^S_{Neg-w} \). However, we can make use of the first-order condition:
\[ w \ (2cp - 2c^2) + 3c^2p + w^2(p - 2c) - 2w^3 = 0. \]
Evaluating at \( w = p \) and \( w = w^S_{Neg-wq} \) yields negative and positive numbers, respectively. Therefore, \( w^S_{Neg-w} > w^S_{Neg-wq} \). Since expected payoffs are equalized when \( (w, q) \) is negotiated, combined with the fact that the supplier gets to choose the order quantity when only \( w \) is negotiated, the supplier must earn strictly more than the retailer. Q.E.D.

Note that Tables A.1(b) and A.2(b) provide numerical evidence that the result can be expected to hold for \( a > 0 \) in both the retailer and supplier risk conditions.
A.4. Incorporating Risk Aversion Into Theoretical Analysis

When players are possibly risk averse, a full theoretical analysis becomes analytically challenging. We follow much of the literature and assume that players have constant relative risk aversion of the form $u(x) = (1/(1-\rho))(x + \pi_0)^{1-\rho}$, where $\rho$ captures risk preferences and $\pi_0$ represents initial wealth, which is necessary because it is possible for the inventory risk holder to incur a loss if the realized demand is sufficiently below the order quantity. The parameter will also play a role in the theoretical analysis because, depending on its size, it may limit the set of feasible agreements. We also specialize to the case of $a = 0$ and $b = 100$, as we implemented in the experiment and focus on the case in which both the order quantity and the wholesale price are negotiated.

Consider the case in which the supplier has the risk (the case of retailer risk is similar and, therefore, omitted). Then the expected utility is

$$
\mathbb{E}[u_s(w, q, \pi_0)] = \frac{100 - q}{100(1-\rho_s)} (\pi_0 + (w - c)q)^{1-\rho_s} + \frac{1}{100(1-\rho_s)} \int_{0}^{q} (\pi_0 + (p - w)x)^{1-\rho_s} dx
$$

Note that if $\rho_s \neq 0$, then for utility to be well defined we require $\pi_0 \geq cq$ so that final wealth is positive even if demand is realized to be 0. Hence, only agreements in which $q \leq \pi_0/c$ are feasible. Under the case of retailer risk, similar computations show that only agreements with $q \leq \pi_0/w$ are feasible. Therefore, unless $\pi_0$ is sufficiently large, the mere presence of risk aversion – regardless of how small – generates a potentially large inefficiency.

In Table A.3 we summarize the contract parameters for various levels of risk aversion of the retailer and supplier for Neg-WQ. The upper-left cell in each panel corresponds to the risk-neutral benchmark. Moving down across rows means the retailer is becoming increasingly risk averse; moving right across columns means the supplier is becoming increasingly risk averse. In panels (a) and (b), the first number in each cell is the agreed wholesale price and the second number is the agreed order quantity.

We can summarize the results as follows. First, the order quantity is decreasing as the inventory risk holder becomes more risk averse. This is intuitive because risk is increasing in order quantity. Second, the order quantity is decreasing (though much less) as the party not holding the inventory risk becomes more risk averse. Third, under supplier risk, the wholesale price is decreasing in the supplier’s risk aversion and increasing in the retailer’s risk aversion. This is consistent with the standard results in the bargaining literature that risk aversion is (usually) a disadvantage in bargaining (Roth and Rothblum 1982). Fourth, under retailer risk, we still obtain that the wholesale price is decreasing as the supplier becomes more risk averse (consistent with risk aversion being a proxy for bargaining strength) but there is actually a non-monotonic relationship between the wholesale price and the retailer’s risk aversion. Initially, when the retailer moves from being risk neutral to slightly risk averse, the wholesale price actually decreases, before eventually starting to increase for more extreme levels of risk aversion. Recall that under retailer risk, the order quantity
Because of this, somewhat counterintuitively, the lower is 12. Therefore, when (a) are as in the risk neutral case and the retailer becomes slightly risk averse, the retailer’s marginal utility is relatively high, which gives her a strong bargaining strengthens the position of the inventory risk holder and makes him/her more willing to hold the inventory risk.

### Table A.3

<table>
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<tr>
<th>Risk Aversion of Supplier</th>
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<th>0.1</th>
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<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
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</table>

Note 1: In panels (a)-(b), the first number is the wholesale price and the second number is the order quantity.

Note 2: A player with a risk aversion of 0 is actually risk neutral.
position and generates the reduction in the wholesale price.

Finally, consider panel (c), which shows which party – if any – prefers to hold the inventory risk. Except when both players are risk neutral (in which case they are indifferent), it is never the case that both players prefer to hold the inventory risk. As can be seen, there is a relatively small region – when the supplier is significantly more risk averse than the retailer where the retailer wants to hold the inventory risk and the supplier wants to avoid it. As the risk aversion of the retailer increases, we shift to another small region in which both parties actually prefer to avoid the inventory risk. Interestingly, in this area, the retailer is moderately less risk averse than the supplier but still prefers to avoid being exposed to inventory risk. Finally, the lower region, which includes most of the parameter space gives the area where the supplier prefers to hold the inventory risk and the retailer wants to avoid it. The reason for this is that there are two sources of risk – inventory risk and demand risk. Regardless of who holds inventory risk, the retailer always faces demand risk. Therefore, by having the supplier be exposed to inventory risk, the overall risk is shared in the supply chain. From the retailer’s perspective, unless she is substantially less risk averse than the supplier, the efficiency gain from the two parties sharing these risks outweighs the additional compensation that the supplier receives for accepting the inventory risk.

B. Supplemental Bargaining Analysis: Response to Feedback and Duration

The richness of our data gives rise to several other interesting results that we cannot discuss in detail. Here we briefly present two: offer feedback – subjects could “reject” proposed contract terms – and bargaining duration. We summarize these in the following results, which are supported in Tables B.1, B.2, and B.3.

**Result (Feedback)** (a) Feedback about contract terms was common overall but concerned mostly wholesale prices. (b) When proposed contract terms were “rejected” players responded by adjusting their next proposal in a concessionary manner and adjusted more than when contract terms were not “rejected”.

For bargaining duration, we remind the reader that in all the unstructured bargaining treatments subjects had the same, fixed amount of time to reach an agreement (five minutes). While the maximum time to negotiate an agreement could affect outcomes, we did not manipulate this. Instead, we look at factors which affect when, within the overall time constraint, subjects reached an agreement.

**Result (Bargaining Duration)** Key factors in determining bargaining duration are (a) in all treatments, the difference between proposed wholesale prices and (b) in Neg-WQ, the difference in proposed stocking quantities. In addition, neither risk aversion nor allowing inventory risk location to be negotiated significantly impacted bargaining duration.
Note 2: $L$ with standard errors in parentheses which have been corrected for clustering at the session level.

Note 1: $\ast$, $\ast\ast$, and $\ast\ast\ast$ denote significance at the 10, 5 and 1% levels, respectively. The table reports linear random-effects models with standard errors in parentheses which have been corrected for clustering at the session level.

Note 2: $L$ was coded as 1 (resp. 2) if the retailer (resp. supplier) was proposed to hold the inventory risk. Therefore, for example, a negative coefficient on $L$ for the retailer indicates that retailers are more likely to propose that they take the inventory risk following a rejection by the supplier.

Note 3: We omit additional control variables for risk location in the regressions for wholesale price.

### Table B.1 The Response of Offers to Feedback in Neg-W

<table>
<thead>
<tr>
<th>Offer Number</th>
<th>Retailer</th>
<th>Supplier</th>
<th>Retailer</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta w_{prop}$</td>
<td>$-0.015^{**}$ (0.005)</td>
<td>$0.013^{**}$ (0.004)</td>
<td>$0.003$ (0.005)</td>
<td>$-0.000$ (0.000)</td>
</tr>
<tr>
<td>Period</td>
<td>$-0.025^{**}$ (0.006)</td>
<td>$0.015^{**}$ (0.006)</td>
<td>$-0.002^{**}$ (0.001)</td>
<td>$-0.021^{**}$ (0.003)</td>
</tr>
<tr>
<td>Risk</td>
<td>$0.016$ (0.018)</td>
<td>$0.014$ (0.013)</td>
<td>$-0.014^{*}$ (0.008)</td>
<td>$-0.007$ (0.006)</td>
</tr>
<tr>
<td>Reject</td>
<td>$0.065^{**}$ (0.030)</td>
<td>$-0.061^{*}$ (0.036)</td>
<td>$0.036$ (0.079)</td>
<td>$-0.096^{**}$ (0.022)</td>
</tr>
<tr>
<td>Oth. Concession</td>
<td>$0.026$ (0.020)</td>
<td>$-0.036$ (0.033)</td>
<td>$0.061$ (0.046)</td>
<td>$-0.110^{**}$ (0.035)</td>
</tr>
<tr>
<td>Constant</td>
<td>$0.371^{**}$ (0.097)</td>
<td>$-0.516^{***}$ (0.113)</td>
<td>$0.042$ (0.085)</td>
<td>$0.226^{**}$ (0.030)</td>
</tr>
</tbody>
</table>

Note 2: $L$ was coded as 1 (resp. 2) if the retailer (resp. supplier) was proposed to hold the inventory risk. Therefore, for example, the negative coefficient on $L$ for the retailer indicates that retailers are more likely to propose that they take the inventory risk following a rejection by the supplier.

Note 3: We omit additional control variables for risk location in the regressions for wholesale price.

### Table B.2 The Response of Offers to Feedback in Neg-WQ

<table>
<thead>
<tr>
<th>Offer Number</th>
<th>Retailer</th>
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<th>Retailer</th>
<th>Supplier</th>
</tr>
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<tbody>
<tr>
<td>$\Delta w_{prop}$</td>
<td>$-0.041^{*}$ (0.008)</td>
<td>$0.047^{*}$ (0.010)</td>
<td>$-0.177^{*}$ (0.077)</td>
<td>$-0.193^{*}$ (0.087)</td>
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<tr>
<td>Period</td>
<td>$-0.041^{**}$ (0.012)</td>
<td>$0.021^{**}$ (0.006)</td>
<td>$0.363^{***}$ (0.131)</td>
<td>$-0.059$ (0.045)</td>
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<tr>
<td>Risk</td>
<td>$0.015$ (0.016)</td>
<td>$0.040^{**}$ (0.012)</td>
<td>$-0.205$ (0.176)</td>
<td>$0.167$ (0.297)</td>
</tr>
<tr>
<td>Reject</td>
<td>$0.314^{***}$ (0.071)</td>
<td>$-0.408^{***}$ (0.059)</td>
<td>$-0.107$ (0.109)</td>
<td>$-0.715$ (1.853)</td>
</tr>
<tr>
<td>Reject</td>
<td>$-0.160^{**}$ (0.047)</td>
<td>$0.141^{**}$ (0.052)</td>
<td>$-0.062$ (0.028)</td>
<td>$0.014$ (0.053)</td>
</tr>
<tr>
<td>Don’t Reject $q$</td>
<td>$6.218^{***}$ (0.976)</td>
<td>$6.126^{**}$ (1.074)</td>
<td>$-2.645^{*}$ (1.390)</td>
<td>$3.899^{**}$ (1.030)</td>
</tr>
<tr>
<td>Oth. Concession</td>
<td>$0.050$ (0.042)</td>
<td>$-0.066$ (0.059)</td>
<td>$-0.004$ (0.607)</td>
<td>$-0.203$ (0.918)</td>
</tr>
<tr>
<td>Constant</td>
<td>$0.450^{***}$ (0.139)</td>
<td>$-0.701^{***}$ (0.101)</td>
<td>$-1.009^{***}$ (0.193)</td>
<td>$-1.354$ (1.775)</td>
</tr>
</tbody>
</table>

Note 1: $\ast$, $\ast\ast$, and $\ast\ast\ast$ denote significance at the 10, 5 and 1% levels, respectively. The table reports linear random-effects models with standard errors in parentheses which have been corrected for clustering at the session level.

Note 3: We omit additional control variables for risk location in the regressions for wholesale price and order quantity.

### Table B.3 The Determinants of Bargaining Duration (Weibull Regression)

| Absolute Difference Between Wholesale Price Offers | $-0.808^{***}$ (0.118) | $-0.285^{***}$ (0.078) |
| Absolute Difference Between Order Quantity Offers | $-0.020^{***}$ (0.006) |
| Absolute Difference Between Risk Location Offers | $-0.157$ (0.118) | $-0.102$ (0.171) |
| Retailer Willingness to Take Risk | $-0.017$ (0.065) | $-0.020$ (0.029) |
| Supplier Willingness to Take Risk | $-0.027$ (0.033) | $0.024$ (0.031) |
| Absolution Difference Between Risk Loc. Fairness | $0.129$ (0.132) | $-0.170^{*}$ (0.089) |
| Endogenous Risk Treatment | $0.243^{*}$ (0.141) | $0.214^{**}$ (0.088) |
| Constant | $-7.838^{***}$ (1.237) | $-16.841^{***}$ (2.270) |

Note 1: $\ast$, $\ast\ast$, and $\ast\ast\ast$ denote significance at the 10, 5 and 1% levels, respectively. The table reports the results of a Weibull regression with random effects. Standard errors are in parentheses and have been corrected for clustering at the session level.

Note 2: To interpret the coefficients, observe that a negative coefficient implies increased duration (i.e., bargaining takes longer), while a positive coefficient implies reduced duration (i.e., bargaining is faster).