

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

Andrew M. Davis

Johnson School of Management, Cornell University, [adavis@cornell.edu](mailto:adavis@cornell.edu), <https://courses.cit.cornell.edu/amd365/>

Kyle Hyndman

Jindal School of Management, University of Texas at Dallas, [KyleB.Hyndman@utdallas.edu](mailto:KyleB.Hyndman@utdallas.edu),  
[http://www.hyndman-honhon.com/Main/Kyle\\_Hyndman.html](http://www.hyndman-honhon.com/Main/Kyle_Hyndman.html)

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 interact either 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, 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 theory, this leads to a Pareto improvement whereby both the supplier and retailer earn higher profits. A second important result, which is also counter to 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 and unilaterally sets an order quantity. In such a setting, it is well known that wholesale price contracts lead to an efficiency loss from a supply chain perspective. Yet, previous work suggests that this purported 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”). Indeed, existing research indicates that this last term, the inventory risk location, may be the difference between success and failure of a firm (Randall et al. 2002). In this work, we investigate alternative bargaining environments and inventory risk locations, and study their resulting impact on supply chain performance, from both a theoretical and experimental perspective.

In terms of bargaining in supply chains, 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 onto 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, such as Campbell's Soup, Proctor & Gamble, and Frito-Lay, 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 is going to purchase inventory themselves for resale, or, alternatively, the supplier will be responsible for the inventory risk, and satisfy retailer demand through drop-shipping. Randall et al. (2006) find that 23% to 33% of e-retailers use drop-shipping, and the U.S. Census estimates that sales by e-commerce retailers totaled \$298.6 billion in 2014 (U.S. Census Bureau 2016). Given this flexibility, a number of theoretical studies have shown that it is actually 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 on bargaining and inventory risk necessitates a study in which both issues are evaluated in conjunction, and brings us to our main research questions: (1) How does a more natural, unstructured, bargaining process compare to 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., the 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 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 begin by theoretically deriving several predictions under the assumption of risk-neutral expected-profit maximizing decision makers. More specifically, our results provide equilibrium predictions for contract terms, such as wholesale prices and quantities, for the different bargaining settings that we consider (e.g., structured ultimatum versus unstructured bargaining), and various inventory risk locations (e.g., retailer, supplier or endogenously determined). 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. As mentioned, given that many supply chain contracts involve human decision makers, we then consider how certain behavioral biases may affect these normative predictions. We then use these behavioral predictions to develop a set of experimental hypotheses.

After developing our hypotheses, we conduct a controlled human-subjects experiment. One dimension of the experiment varies the bargaining environment, and the other manipulates the inventory risk location. For the bargaining dimension, we consider three levels. The first considers structured ultimatum offers, coinciding with that of Davis et al. (2014), of which we then extend through the remaining two levels. Specifically, these two levels consider unstructured bargaining by permitting the parties to dynamically negotiate either the wholesale price, or to simultaneously negotiate both the wholesale price and order quantity. For the second dimension, inventory risk location, we also consider three variants: the inventory risk is exogenously imposed on the retailer, exogenously imposed on the supplier, or endogenously determined in the bargaining process itself.

Our experiment yields a number of interesting insights, many of which run counter to the normative theory. In response to our main research questions we find: (1) Moving from a structured ultimatum setting to one where the wholesale price is negotiated, supply chain efficiency does not increase, contrary to theory. (2) Comparing a bargaining environment where only the wholesale price is negotiated to one where both the wholesale price and order quantity are negotiated simultaneously, supply chain efficiency increases significantly, and considerably more than the standard theory predicts. Furthermore, this improvement in efficiency comes with an added benefit that both the retailer and supplier earn higher expected profits, and thus represents a Pareto improvement. Yet we also find that this bargaining environment, where both the wholesale price and quantity

are negotiated simultaneously, fails to achieve its 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 standard theory in the unstructured bargaining environments. In addition to these main results, we also find that: (4) Allowing the inventory risk location to be negotiated does not affect agreed upon terms and outcomes, despite increasing complexity; (5) the number of terms included in the negotiation does not impact agreement rates; (6) risk aversion can explain some comparative statics but fails to capture a *level effect* on wholesale prices; and (7) in the unstructured bargaining environments, nearly every supply chain metric of interest (e.g., wholesale prices, quantities, retailer and supplier expected profits, efficiency) deviates significantly from the normative point predictions.

While our experimental data contradict many of the standard theoretical predictions, we observe that many of the outcomes are consistent with our main behavioral hypothesis, which posits 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, which affects the negotiated outcomes. 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 retailer's selling price, then inventory risk holders will not receive enough compensation for incurring the inventory risk, and will then be at a disadvantage in terms of expected profits, which is also consistent with our data. To further support our anchoring hypothesis, we conduct an additional experimental 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 prediction and that it is no longer disadvantageous to hold the inventory risk, thus coinciding with the standard theory. Lastly, 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 results, 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. There have been a number of papers that 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, in a setting where one party makes an ultimatum wholesale price offer to the other party, who then responds by setting a order quantity. 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 wide range of topics within supply chain contracting, including risk allocations under wholesale price, buyback, revenue-sharing, quantity flexible, and rebate contracts.

From a behavioral standpoint, 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 that consider such a bargaining structure. One example is Davis et al. (2014), who test the inventory risk allocation predictions from the model in Cachon (2004), which assumes ultimatum offers. 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 and Xia 2015).

Recently, some papers in behavioral operations have begun to allow for more natural bargaining processes in supply chain settings.<sup>1</sup> Leider and Lovejoy (2016) test the balanced-principal bargaining model proposed in Lovejoy (2010), where all roles are played by human participants that can communicate with each other through 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 (2016) 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

<sup>1</sup>There is also an extensive literature on bargaining in experimental economics, although many consider ultimatum settings with abstract contexts. Furthermore, fewer of these studies consider multidimensional bargaining with potential feedback to be sent. For a review, please see Kagel and Roth (1995) and Camerer (2003).

bargaining setting with back-and-forth offers and the ability to send limited feedback. Furthermore, per the discussion in the Introduction, it is important to consider the inventory risk location along with different bargaining environments. Therefore, we also vary where the inventory risk is located in the supply chain, and allow for it to be endogenously determined in certain treatments.

### 3. Theoretical Benchmarks

In this section we provide normative theoretical benchmarks for our study. In Section 3.1, we review a setting which considers structured bargaining through ultimatum offers. In Section 3.2, we evaluate an environment which considers unstructured bargaining by relaxing the ultimatum offer assumption, and allowing retailers and suppliers to make multiple back-and-forth offers. Specifically, in this unstructured setting, we derive theoretical benchmarks when only the wholesale price is included in the negotiation, and also when both the wholesale price and order quantity are included. After this, in Section 3.3, we comment on how the normative theory predicts the distribution of profits when the inventory risk location is endogenous (i.e. included in the negotiation). Lastly, in Section 3.4, we provide a short discussion as to how these normative predictions may change when behavioral factors such as anchoring and risk aversion are present, and use them to develop behavioral hypotheses and predictions.

For all settings, assume that demand is  $D$ , which is drawn uniformly from  $[a, b]$  where  $0 \leq a < b < \infty$ .<sup>2</sup> Assume also that the supplier's cost of production is  $c > 0$ , the retailer's selling price is  $p > c$ , 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  $i \in \{r(etailer), s(upplier)\}$  and inventory risk location  $RL \in \{r(etailer), s(upplier)\}$ . 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

Consider a traditional bargaining framework used in many supply chain contracting studies that involves one player making an ultimatum wholesale price offer  $w_{Ult}^{RL}$ , to the other player. If the offer is accepted, then the responding player unilaterally chooses an order quantity  $q_{Ult}^{RL}$  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:

$$\begin{array}{cc} \underline{\text{Retailer Risk}} & \underline{\text{Supplier Risk}} \end{array}$$

<sup>2</sup> In our experiment, we assume that demand is drawn from the discrete uniform distribution on the set  $\{0, 1, \dots, 100\}$ . There are no qualitative differences between our discrete implementation and the continuous case. The uniform distribution allows us to generate clear predictions that are amenable to experimental testing.

$$\begin{aligned} \pi_r^r &= \frac{p}{b-a} \int_a^b \min\{q, x\} dx - wq \quad , \quad \pi_r^s = \frac{p-w}{b-a} \int_a^b \min\{q, x\} dx \\ \pi_s^r &= (w-c)q \quad , \quad \pi_s^s = \frac{w}{b-a} \int_a^b \min\{q, x\} dx - cq. \end{aligned} \quad (1)$$

Consider the case of retailer risk. The retailer's optimal quantity is  $q_{Ult}^R(w) = a + (b-a)((p-w)/p)$ . The supplier anticipates this quantity and chooses  $w$  to maximize its expected profits. With some work, one can obtain  $w_{Ult}^R = (p+c)/2 + ap/2(b-a)$ . As is well known in the literature, this generates inefficiency because  $w_{Ult}^R > c$ , which leads to an insufficient order quantity, relative to first best. Finally, because (i)  $w_{Ult}^R \geq (p+c)/2$  and (ii) the 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 the familiar solution  $q_{Ult}^S(w) = a + (b-a)((w-c)/w)$ . As before, the retailer will anticipate this order quantity and choose the wholesale price to maximize its expected profits. In this case, an analytical solution is not feasible because the retailer's first-order condition leads to a third degree polynomial in  $w$ . However, two things can be said. First, since the first-order condition is monotone in  $w$ , there is a unique real root. Second, one can show that  $w_{Ult}^S < (p+c)/2$ .<sup>3</sup> Just as in the retailer risk case, the outcome is inefficient because  $w_{Ult}^S < p$ , leading the supplier to produce too little relative to first best. Moreover, because  $w_{Ult}^S < (p+c)/2$ , 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,  $w_{Ult}^R = (p+c)/2 + ap/2(b-a) \geq (p+c)/2 > c$  and the supply chain is not coordinated.*
2. *Under supplier risk,  $w_{Ult}^S < (p+c)/2 < p$  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.<sup>4</sup> Therefore, we adopt the Nash bargaining

<sup>3</sup> In fact, holding  $b-a$  constant, for  $a$  large enough, it will be optimal for the retailer to set  $w=c$ . Changing  $w$  to  $c+\Delta$  will lead to a marginal increase in  $q$  to  $a+\Delta'$  and so higher revenues. However, the retailer must increase the wholesale price on all units produced. Hence, if  $a$  is large, this will be too costly for the retailer.

<sup>4</sup> It is well-known that there is a strong connection between the Nash bargaining solution and the equilibrium of an infinite horizon alternating offers model. In an earlier version of this paper we show that the limit of an alternating offers model as players become infinitely patient is equal to the Nash bargaining solution. Details are available upon request.

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  $[a, b]$ . We discuss the endogenous inventory risk location setting in Section 3.3.

**3.2.1. Wholesale Price is Negotiated.** Assume now 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  $q_{Neg-w}^R(w) = a + (b - a)((p-w)/p)$ , while under supplier risk, the supplier will choose  $q_{Neg-w}^S(w) = a + (b - a)((w-c)/w)$ . 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:

$$\begin{aligned} \max_w \quad & \pi_r^{RL}(w, q^{RL}(w)) \cdot \pi_s^{RL}(w, q^{RL}(w)) \\ \text{s.t.} \quad & c \leq w \leq p, \end{aligned}$$

where  $\pi_i^{RL}(w, q)$  are given in (1) and  $q^{RL}(w)$  is as above.

In Appendix A we formally prove the following proposition:<sup>5</sup>

**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. The supply chain is not coordinated.*

Compared to the structured ultimatum bargaining setting, 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 underlying intuition behind this is that the party proposing the wholesale price, in a structured ultimatum setting, 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

<sup>5</sup> In addition to the proof, we also provide details of a numerical study showing that the results hold for  $a > 0$  as well.



are on a more equal footing in terms of bargaining over 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).<sup>6</sup>

**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:

$$\begin{aligned} \max_{w,q} \quad & \pi_r^{RL}(w, q) \cdot \pi_s^{RL}(w, q) \\ \text{s.t.} \quad & c \leq w \leq p \text{ and } a \leq q \leq b, \end{aligned}$$

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

In this setting, one can solve for the Nash bargaining solution under both retailer and supplier risk. We summarize the solution as:

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

1. *Regardless of risk location,  $q_{Neg-wq}^{RL} = a + (b - a)^{(p-c)/p}$ , the supply chain is coordinated and expected payoffs for the retailer and supplier are equalized.*
2. *Under retailer risk,  $w_{Neg-wq}^R = \frac{3ac^2 + ap^2 - 3bc^2 + 2bcp + bp^2}{4(ac - bc + bp)} < \frac{p+c}{2}$ , while under supplier risk,  $w_{Neg-wq}^S = \frac{p(3ac^2 + ap^2 - 3bc^2 + 2bcp + bp^2)}{2(ac^2 + ap^2 - bc^2 + bp^2)} > \frac{p+c}{2}$ .*

The proof of this proposition is in Appendix A, however, some intuition for specific values can be provided. Note that  $(p+c)/2 - w_{Neg-wq}^R > w_{Neg-wq}^S - (p+c)/2 > 0$ . 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 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 actually risk free. Therefore, to equalize expected payoffs, the wholesale price must move significantly to make up for this asymmetry in risk exposure. In contrast, 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.

<sup>6</sup> 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.

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  $w_{Neg-w}^R = w_{Neg-wq}^R$ , while  $w_{Neg-w}^S > w_{Neg-wq}^S$ . 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 regardless of whether  $w$  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, behavioral work suggests that 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 formal 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 a subsequent discussion section (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 Karagözoğlu (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, it is possible that there may be focal points with respect to the wholesale price and quantity, when included in the negotiation. Regarding the wholesale price,  $(p+c)/2$  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,  $(p+c)/2$  would equalize payoffs. When the order quantity is included in the negotiation, there are two natural focal points: the mean demand,  $(a+b)/2$ , and the quantity which maximizes channel efficiency,  $a + (b - a)((p-c)/p)$ .<sup>7</sup> The former is likely to be more salient for the inventory risk holder, while the latter is likely to be more 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 outcomes may differ from the normative benchmarks, if an anchoring bias is present. Specifically, hypotheses focusing on supply chain efficiency and the effect of inventory risk on distribution of profits. For simplicity, let ‘Ult’ represent the structured bargaining environment with ultimatum offers, ‘Neg-W’ represent the unstructured 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

<sup>7</sup> When the quantity is not negotiated and 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).

quantity, which should have the effect of increasing the negotiated order quantity and, hence, increasing efficiency. This brings us to the following behavioral hypothesis:

**HYPOTHESIS 1 (EFFICIENCY).** *For both retailer and supplier risk, channel efficiency satisfies  $Ult = Neg-W < Neg-WQ < 100\%$ .*

Turning to inventory risk (which is tied to the distribution of profits), recall that the normative theory predicts: (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,<sup>8</sup> if players are anchored on a wholesale price of  $(p+c)/2$ , 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.*

Lastly, 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. Thus if inventory risk holders do not make a strong initial offer (e.g., because of anchoring and insufficient adjustment on  $(p+c)/2$ ), while the non-risk holders make an aggressive opening offer, it will further support the possibility that holding inventory risk is detrimental, and that the predicted 100% efficiencies in Neg-WQ will not be fully achieved.

**HYPOTHESIS 3 (INITIAL OFFERS).** *Agreed outcomes are anchored on initial offers, which can reduce efficiency and make it disadvantageous to hold inventory risk.*

<sup>8</sup> For the Ult setting, wholesale prices would have to be set in a way that is inconsistent with anchoring in order 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 in order for this to occur, whereas anchoring would predict it to be between 6 (the normative prediction) and 9 (the midpoint between  $c$  and  $p$ ).

**3.4.2. Risk Aversion.** Several studies have also noted roles for risk aversion in explaining deviations from normative theoretical predictions, such as Leider and Lovejoy (2016), who conduct a related bargaining study. In Appendix A.4 we generate detailed predictions under risk aversion, and provide a summary here 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 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. In an effort to determine whether risk aversion drives our experimental results, we will directly compare our data to these predictions (Section 5.4).

## 4. Experimental Design

In all treatments, subjects were assigned to the role of a supplier or a retailer and the roles were fixed for the duration of the experiment. In each period a retailer and a supplier were randomly paired together 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  $\{1, 2, \dots, 100\}$ , 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 experimental design). The first dimension manipulated the bargaining environment, while 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). We now highlight the three bargaining scenarios.

*Structured Bargaining: Ultimatum Offers (Ult).* In this setting, which only considered either retailer or supplier risk, 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

**Table 1** Experimental Design and Number of Subjects

				Location of Inventory Risk		
				Exogenous Risk	SR	Endogenous Risk
			RR		ER	
Bargaining Process	Structured	Ult	34	36		N/A
	Unstructured	Neg-W	44	42		42
		Neg-WQ		48	46	

receive a payoff of zero. If the offer was accepted, the responder – who bears inventory risk – would determine the quantity,  $q$ . At this point, random demand would be realized and players would receive feedback that included the outcome of the contract and realized profits.

*Unstructured Bargaining: Wholesale Price is Negotiated (Neg-W).* In these 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 who bears the inventory risk would unilaterally choose an order quantity,  $q$ . Following this, demand would then be realized and players would receive feedback that included the outcome of the negotiation and realized profits.

*Unstructured Bargaining: Wholesale Price and Order Quantity is Negotiated (Neg-WQ).* As with Neg-W, each retailer/supplier pair was given five minutes to negotiate, but in these treatments they had to negotiate 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 with 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 various components of 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 (e.g., in Neg-WQ ER, they could reject any of the negotiated terms: the wholesale price, quantity, and/or risk location at any time, for the most recent offer). This feedback would be displayed on the proposer’s screen. Note that “rejections” of contract terms could not be rescinded but they did not preclude subsequent agreement on identical terms. That is, 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 also maintaining control of the setting (e.g., if we allowed face-to-face negotiations, we may miss facial cues) and enabling us to objectively track the feedback (e.g., chat box communication would require some subjectivity in coding). 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.<sup>9</sup>

In total, subjects participated in 7 bargaining 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).<sup>10</sup> 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, and relatively safe, from question-to-question, while the other lottery was more risky, and the payoff if the ‘good’ state occurred was increasing from question-to-question. Subjects were paid for one randomly selected lottery question. After completing the incentivized risk elicitation task, subjects were also asked a question about their general willingness to take risks. Specifically, they were asked: “How do you see yourself: are you generally a person who is fully prepared to take risks

<sup>9</sup> To be sure, there are other variants that one could consider for treatments. For example, letting dyads negotiate the quantity and/or inventory risk, given a fixed wholesale price. Indeed, while our aim is to consider unstructured settings where the wholesale price is always included, we hope that future work considers such extensions.

<sup>10</sup> 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).

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. We asked this question because Dohmen et al. (2011) shows that this question often has greater explanatory power in explaining risky behaviors such as holding stocks, occupational choice and other behaviors.

**Table 2** Normative Predictions Given our Experimental Parameters

	Retailer Risk (RR)			Supplier Risk (SR)		
	Ult	Neg-W	Neg-WQ	Ult	Neg-W	Neg-WQ
Channel Efficiency (%)	75	93.75	100	85.94	98.50	100
Retailer Expected Profit	120	270	240	337.5	224.58	240
Supplier Expected Profit	240	180	240	75	248.24	240
Wholesale Price ( $w$ )	9	6	6	6	10.07	10
Order Quantity ( $q$ )	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. Therefore, in Table 2, we report the predictions for our experimental parameters, based on our theoretical analysis of risk-neutral expected-profit maximizers outlined in Section 3. The predictions for the endogenous risk treatments are equivalent to either the supplier or retailer risk treatments (Neg-W and Neg-WQ), depending on how risk is allocated in the agreement, and are therefore omitted.

The experimental software was programmed in z-Tree (Fischbacher 2007), and the experiment took place in the laboratory of a private university in the Northeastern United States. Sessions took 80 minutes on average to complete, including the risk elicitation task, and average earnings were \$31, where subjects were compensated for all rounds of decisions.

## 5. Outcome Results

We present our experimental results in two sections. In this section we focus on outcomes, which includes details pertaining to efficiency, expected profits, and contract terms. In Section 6 we discuss bargaining process details.

For outcomes, we first provide a broad overview of our results. To begin, in all of our treatments, roughly 85% of negotiations successfully reached an agreement, or were accepted in the Ult treatments (no statistical differences between treatments). Given that agreement rates are not significantly different across treatments, we will present the average outcomes conditional on an agreement, and will explore the determinants of agreements later. Second, we find broad support for our behavioral hypotheses. Specifically, the agreed wholesale prices and order quantities differ



from the normative theoretical benchmarks in a manner which is consistent with our anchoring hypothesis: Players do not fully exploit the bargaining power that they have, which leads to small and insignificant differences between Ult and Neg-W, while 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 theoretical point predictions for a number of metrics of interest, 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 will discuss the ER treatments in detail in a later subsection.

**Table 3**  $p$ -values of Tests of Normative Theoretical Point Predictions (Conditional on an Agreement)

	Retailer Risk (RR)			Supplier Risk (SR)		
	Ult	Neg-W	Neg-WQ	Ult	Neg-W	Neg-WQ
Channel Efficiency (%)	1.000	0.028	0.028	0.109	0.028	0.028
Retailer Expected Profit	1.000	0.046	0.028	0.109	0.600	0.345
Supplier Expected Profit	0.593	0.345	0.028	0.109	0.028	0.028
Wholesale Price ( $w$ )	0.593	0.046	0.028	0.109	0.028	0.028
Order Quantity ( $q$ )	0.285	0.028	0.028	0.285	0.028	0.028

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.

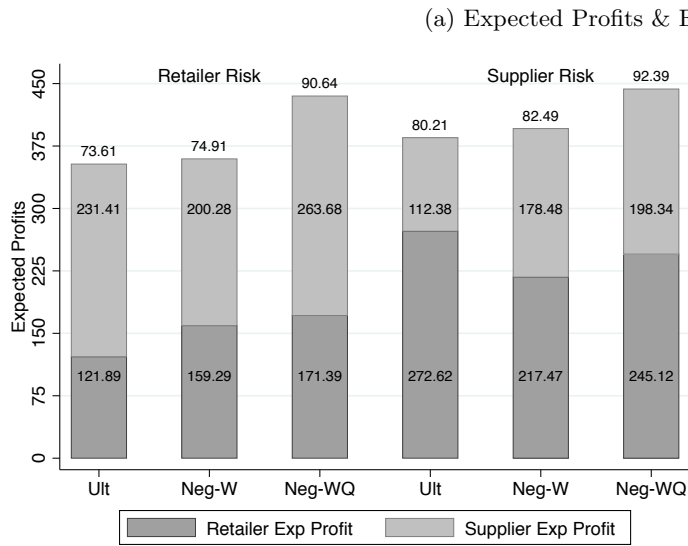
Note 2:  $p$ -values are generated from two-sided Wilcoxon signed-rank tests with the session average as the unit of independent observation.

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.

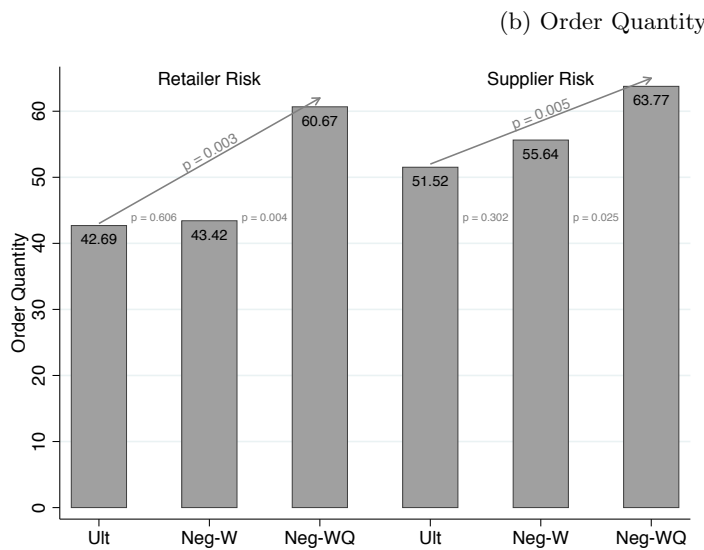
### 5.1. Comparisons to Point Predictions

Before discussing our hypotheses in detail, we briefly mention the results of tests of the normative theoretical point predictions, which are reported in Table 3. As can be seen, 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 point predictions for retailer/supplier expected profits. For the Ult RR treatment, we fail to reject point predictions for all five metrics (in all cases,  $p > 0.285$ ). For the Ult SR treatment, for 4 of 5 metrics we reject at

Figure 1 Summary of Results (Conditional on an Agreement)

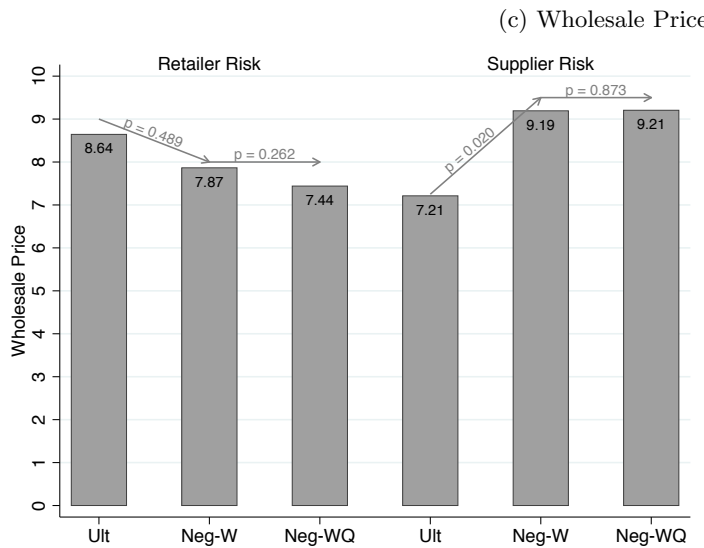


Note: The numbers inside each bar are the average expected profits by role. The numbers on top of each bar are the average supply chain efficiency for each treatment.



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 indicate the comparative static according to the normative benchmark.



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 indicate the comparative static according to the normative benchmark.

$p = 0.109$  the theoretical point predictions. While this is not significant at the 10% level, with only three independent sessions, this is the strongest possible rejection of theory. Thus, it is plausible that behavior is significantly different from the normative benchmark in this treatment as well.

It is also worth mentioning the direction of the differences from 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 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 of the deviations from theory are consistent with anchoring. For example, in Ult SR, the wholesale price of 7.21 is greater than the theoretical 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 theoretical 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 particular 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, we find that 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 can be seen visually 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 theory predicts, a Wilcoxon signed-rank test rejects that this is equal to 100% ( $p = 0.008$ ).

Of course, the main driver for 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 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 not exposed to inventory risk has higher expected profits than the party that holds 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 for 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 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 provide any compensation 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 sufficiently strong to overturn the 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, we look at 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, while 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, as they are to keep the risk, both from the start, and at least once during bargaining (Wilcoxon signed-rank;  $p_{start} = 0.046$ ,  $p_{once} = 0.028$ ).

### 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 4** Summary of Results in the ER Treatments (Conditional on an Agreement)

	Neg-W				Neg-WQ			
	Retailer Risk		Supplier Risk		Retailer Risk		Supplier Risk	
	RR	ER	ER	SR	RR	ER	ER	SR
Channel Efficiency (%)	73.8 (20.20)	77.8 (15.96)	81.0 (18.16)	83.4 (19.43)	90.7 (7.48)	90.4 (10.39)	94.2 (5.36)	91.5 (7.93)
Expected Retailer Profit	156.5 (75.88)	166.5 (65.96)	203.3 (67.55)	225.7 (84.41)	165.8 (64.73)	183.0 (104.98)	259.6 (53.27)	237.7 (65.56)
Expected Supplier Profit	197.7 (85.93)	206.8 (67.51)	185.4 (55.45)	174.4 (69.69)	269.8 (73.87)	251.0 (109.40)	192.4 (49.68)	201.4 (60.63)
Wholesale Price ( $w$ )	7.89 (1.48)	7.79 (1.26)	9.36 (1.14)	9.10 (1.34)	7.59 (1.13)	7.13 (1.82)	8.99 (1.16)	9.31 (1.42)
Order Quantity ( $q$ )	42.79 (17.15)	45.04 (14.23)	51.73 (20.51)	57.91 (24.06)	59.71 (13.47)	62.67 (17.74)	65.74 (13.12)	62.76 (15.77)

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  $\times$  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 will return to this in Section 7.

#### 5.4. Risk Aversion and Outcomes

Thus far our results have shown that outcomes deviate from the standard theory, which may be attributed to anchoring on salient focal points. However, another alternative explanation for outcomes is risk aversion. While 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 incorporating risk aversion into the baseline model.

**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 regards 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 takes value 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 is the retailer, the more likely it is that the supplier agrees to hold the inventory risk. On the other hand, 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 predict disagreement, risk aversion weakens a player's bargaining position because they fear disagreement (which is often the

**Table 5** The Role of Risk Preferences on Outcomes

(a) Ultimatum Treatments						
	Order Quantity		Wholesale Price (RR)		Wholesale Price (SR)	
Own Risk Aversion	-10.784***	(2.757)	0.036	(0.116)	-0.175	(0.229)
(Own Risk Aversion) <sup>2</sup>	0.862***	(0.204)				
RR $\times$ Oth. Risk Aversion	0.308	(0.573)				
SR $\times$ Oth. Risk Aversion	-0.602	(1.823)				
Constant	70.399***	(13.585)	8.364***	(0.951)	8.191***	(1.172)

(b) Neg-W and Neg-WQ						
	Order Quantity		Wholesale Price (RR)		Wholesale Price (SR)	
Own Risk Aversion	-2.230***	(0.562)	-0.005	(0.243)	-0.076**	(0.032)
(Own Risk Aversion) <sup>2</sup>			0.004	(0.025)		
RR $\times$ Oth. Risk Aversion	0.179	(0.333)				
SR $\times$ Oth. Risk Aversion	-0.336	(0.383)				
Oth. Risk Aversion			-0.083**	(0.040)	0.082	(0.067)
Constant	68.503***	(3.551)	7.759***	(0.531)	9.268***	(0.280)

(c) Agreement & Expected Payoffs						
	Logit Agreement		Supplier EP		Retailer EP	
Ret. Risk Aversion	0.086	(0.058)	-2.196	(2.313)	-1.146	(2.663)
Sup. Risk Aversion	0.097**	(0.049)	-3.779**	(1.718)	-1.067	(1.909)
Neg-W	0.051	(0.209)	-41.595***	(10.567)	-21.274*	(12.329)
Ult	-0.069	(0.228)	-57.636***	(20.654)	-6.676	(25.668)
Ret. Risk	0.151	(0.250)				
Sup. Risk	-0.131	(0.224)				
End. Risk			-1.468	(10.974)	6.685	(14.915)
Sup. Holds Risk			-51.507***	(11.366)	63.896***	(12.991)
Constant	0.910**	(0.447)	289.513***	(19.488)	188.018***	(20.519)

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.

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, it is significant, but the marginal effect (not shown in the table) 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 actually a non-linear relationship between the risk aversion of the inventory risk holder and the order quantity. Both of these results are contrary to the theoretical predictions under risk aversion.

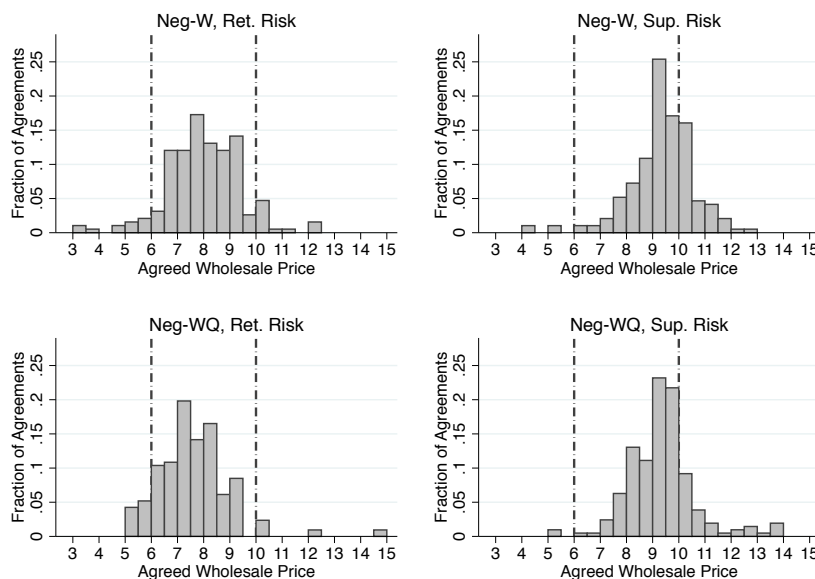
Support for part (e) comes from two sources. First, regarding wholesale prices, risk aversion predicts a relatively tight range depending on the exact risk parameters of the players. For example, in the case of supplier risk for Neg-WQ, the predicted range of wholesale prices is at most 9.65 to 10.40. 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, which is again well outside of the predicted range. Similar comparisons can be made for the Ult and Neg-W treatments. Hence, we conclude that risk aversion cannot explain 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 main experimental parameters and the degree of risk aversion by the supplier and retailer. 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, while 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 of 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 wholesale prices of 6 and 10, which are the theoretical predictions for retailer and supplier risk. As can be seen, there is a great deal of heterogeneity, but the vast majority of agreed prices lie within these bounds. Moreover, one can see



**Figure 2** Heterogeneity in Agreed Wholesale Prices in Neg-W and Neg-WQ

the 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 equilibrium 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 equilibrium prediction. Thus it appears that wholesale prices around 9 – with some adjustment based on 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. We investigate this now.

### 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 associated with (i.e. anchored on) 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.<sup>11</sup> As can be seen, the agreed wholesale prices lie approximately midway between the retailer and supplier opening offers. It is also interesting to note 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 equilibrium wholesale prices is around 4 between RR and SR (6 versus roughly 10), it suggests players do not adequately account for the shift in risk exposure between the two treatments (we will 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 6 Opening Offers by Role in Neg-W and Neg-WQ**

		(a) Wholesale Prices		(b) Order Quantities			
		RR	SR		RR	SR	
Neg-W	Retailer's First Offer	5.62	6.55	Neg-W			
	Supplier's First Offer	10.45	11.46			N/A	
	Agreed Wholesale Price	7.89	9.10				
Neg-WQ	Retailer's First Offer	6.48	7.82	Neg-WQ	Retailer's First Offer	55.79	70.12
	Supplier's First Offer	9.01	10.74		Supplier's First Offer	62.96	57.60
	Agreed Wholesale Price	7.59	9.31		Agreed Order Quantity	59.71	62.76

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 shows this graphically). Table 7(b) shows that 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.

Finally, in Figure 3(b), we provide a plot which shows the likelihood of coming to 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 coming to an agreement (regression results, which we omit in the interest of space, confirm this pattern).

<sup>11</sup> 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.

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

(a) Anchoring on Wholesale Price & Order Quantity				
	Neg-W		Neg-WQ	
	Wholesale Price		Wholesale Price	Order Quantity
$w_{prop.}$	0.341*** (0.032)		0.329*** (0.082)	
$q_{prop.}$			0.448*** (0.062)	
Constant	4.435*** (0.321)		4.644*** (0.731) 31.034*** (3.982)	

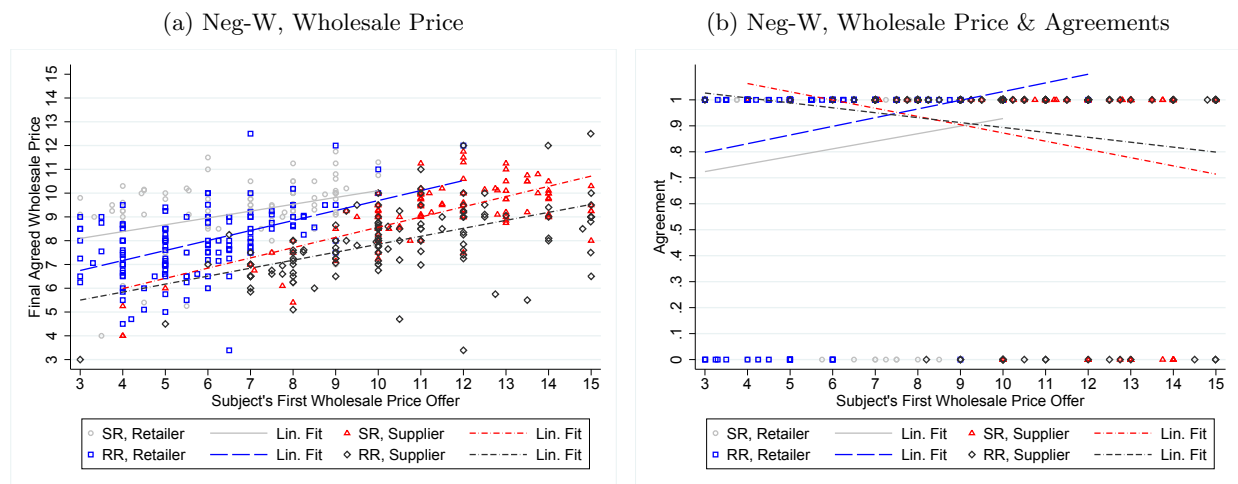
(b) Anchoring on Inventory Risk Location (Dep. Var.: Supplier Takes Risk)		
	Neg-W	Neg-WQ
Propose Supplier Risk	0.152*** (0.049)	0.437*** (0.095)
Constant	0.499*** (0.019)	0.399*** (0.044)

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.

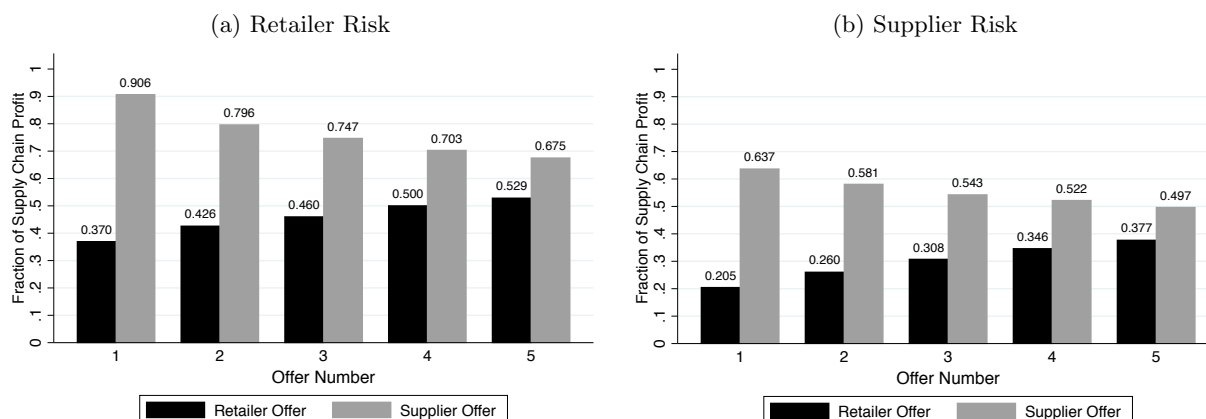
Note 3: We omit additional control variables for the type of subject and risk condition which are not central to this analysis.

**Figure 3 The Effect of Opening Offers on Agreements by Role for Neg-W**



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 RR condition of Neg-WQ, the average opening offer by retailers is actually *higher* than the equilibrium prediction, 6.48 (versus 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.*

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

We have already seen initial support for this result in Table 6. We can see further support by focusing on the Neg-WQ treatments where it is possible to directly compute the expected payoffs implicit in each offer. In Figure 4, we show the average expected split of the supply chain surplus that goes to the supplier for each offer number, in Neg-WQ, when there were at least five offers (the observed pattern is robust to the number of offers). As can be seen, there is a gradual concession process. However, the starting points are vastly different. For the party not holding inventory risk, their first offer demands 80-90% of the surplus for themselves (90.6% in RR, 79.5% in SR), while for the party holding the inventory risk, their first offer only demands about 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 of 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

In order to formally test our conjecture that anchoring on a wholesale price of 9, and insufficiently adjusting to account for risk, is an important driver of our 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. However, 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 diminish the focus on a price of 9. Indeed, we have:

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

**Table 8 Bargaining Results With Anchor Point Remedy (Last 3 Periods)**

(a) Outcomes			(b) Opening Offers			
	Remedy	Original		Remedy	Original	
Wholesale Price ( $w$ )	6.34	7.59	Retailer	Wholesale Price ( $w$ )	4.71	6.48
Order Quantity ( $q$ )	60.26	59.71		Order Quantity ( $q$ )	53.57	55.79
Efficiency (%)	89.8	90.7	Supplier	Wholesale Price ( $w$ )	9.19	9.01
Exp. Retailer Profit	224.1	165.8		Order Quantity ( $q$ )	76.28	62.96
Exp. Supplier Profit	206.9	269.8				

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 clear trends over time. This may suggest that the anchor point was effectively removed, and it took subjects time to try and identify a replacement. Given this, we focus on the last three periods. As can be seen, the agreed wholesale price is more than a full point lower than in the original treatment (6.34 versus 7.59), and is relatively close to the normative prediction of 6. It is also interesting to note that, while this treatment attempted to communicate the implications of the potential anchor point for the wholesale price, it did not do so for the quantity, and we observe that neither the order quantity nor efficiency change. The net result is that once we nudge subjects away from the traditional anchor for the wholesale price, retailers earned slightly *more* than suppliers, rather than substantially less, which is qualitatively 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 additional difference in offers leads to more frequent disagreements compared to 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 in a direction towards the normative theory.

## 7. Discussion of Alternative Explanations

Thus far we have observed that the normative theory fails to explain our data both in terms of point predictions and comparative statics. While risk aversion can explain some comparative statics, it misses a “level effect” on negotiated 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, there may be other factors which 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 complexity and bounded rationality. Indeed, several studies have shown that human decision makers often fail to make decisions that coincide with theoretical predictions in relatively more complex settings (e.g., Katok and Wu (2009), Kalkanci et al. (2011)). A duration analysis, the details of which can be found 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.

Lastly, 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, while risk aversion explains some comparative statics.

## 8. Conclusion

In this study we evaluate the effect of multidimensional bargaining and the location of inventory risk on supply chain performance. We consider a setting in which the bargaining interaction between a retailer and supplier is highly structured, such as the canonical model with ultimatum offers, or unstructured, where both parties can make multiple back-and-forth offers while sending and receiving feedback dynamically. 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, which we contrasted with a series of behavioral hypotheses centered around anchoring on salient focal points. Because managers, who may deviate from risk-neutral expected-profit maximization, are instrumental in negotiating supply chain contracts, it is important to understand those areas where theory works and those which may be influenced by behavioral factors.

To this end, we conducted a controlled laboratory experiment where human-subjects act as decision makers in a two-stage supply chain. We find a number of results that run counter to the normative theory, both with respect to the standard theoretical point predictions, as well as the predicted differences across treatments. With regards to the former, 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 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 predicted (21% versus 6.7% in retailer risk, and 12% versus 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 is consistent with what managers told us, is that the party which 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 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. Our analysis of the bargaining process showed further support for our anchoring hypothesis.

In an effort to determine whether anchoring is in fact a cause of our results, 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 shift considerably towards the normative prediction. Additionally, we no longer observe that it is disadvantageous to be the risk holder, which also coincides with the standard theoretical prediction. 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.

One of the limitations of our work is that we do not allow participants to freely communicate with one another. While this was done intentionally 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 have the ability to contract with multiple retailers and suppliers. Moving to richer supply chain environments is an interesting avenue for future research.

One 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, and whether it is negotiated or not, 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  $(p+c)/2$  in order to provide adequate compensation for risk exposure. Indeed, this may be the role that communication can play in a negotiation – to diffuse 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.

### **Acknowledgments**

We would like to thank seminar participants at the University of Michigan, Boston College and Purdue University for helpful comments, as well as conference participants at the 2015 INFORMS Annual Meeting and the 2015 POMS Annual Meeting. We also thank Elizabeth Mannix for helpful discussions on the paper. The financial support of Cornell University and the University of Texas at Dallas is gratefully acknowledged.



---

## References

- Becker-Peth, Michael, Elena Katok, Ulrich W. Thonemann. 2013. Designing buyback contracts for irrational but predictable newsvendors. *Management Science* **59**(8) 1800–1816.
- Bolton, Gary E., Emin Karagözoğlu. 2016. On the interaction of hard and soft bargaining leverage: A test of schelling's hypothesis and a modified zeuthen-harsanyi model. *Games and Economic Behavior* **99** 164–179.
- Cachon, Gerard P. 2003. Supply chain coordination with contracts. Steven Graves, Ton de Kok, eds., *Handbooks in Operations Research and Management Science: Supply Chain Management*. North-Holland, Amsterdam, 227–339.
- Cachon, Gerard P. 2004. The allocation of inventory risk in a supply chain: Push, pull and advance-purchase discount contracts. *Management Science* **50**(2) 222–238.
- Cachon, Gerard P., M. Fisher. 1997. Campbell's soup's continuous replenishment program: Evaluation and enhanced inventory decision rules. *Production and Operations Management* **6**(3) 266–276.
- Cachon, Gerard P., M. Fisher. 2000. Supply chain inventory management and the value of shared information. *Management Science* **46**(8) 1032–1048.
- Camerer, Colin F. 2003. *Behavioral Game Theory: Experiments in Strategic Interaction*. Princeton University Press.
- Davis, Andrew, Elena Katok, Natalia Santamaría. 2014. Push, pull, or both? a behavioral study of how the allocation of inventory risk affects channel efficiency. *Management Science* **60**(11) 2666–2683.
- Davis, Andrew M., Stephen G. Leider. 2016. Capacity investment in supply chains: Contracts and the hold-up problem. *Working Paper, Cornell University* .
- Devlin, Anna, Wedad Elmaghraby, Rebecca W. Hamilton. 2014. The effect of contract type on retailer's willingness to accept product risk. *Working Paper, University of Maryland* .
- Dohmen, Thomas, Armin Falk, David Huffman, Uwe Sunde, Jürgen Schupp, Gert G. Wagner. 2011. Individual risk attitudes: Measurement, determinants and behavioral consequences. *Journal of the European Economic Association* **9**(3) 522–550.
- Donohue, Karen, Yinghao Zhang, Tony Cui. 2016. Contract preferences and performance for the loss averse supplier: Buyback versus revenue sharing. *Management Science* **62**(6) 1734–1754.
- Fischbacher, Urs. 2007. z-tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics* **10**(2) 171–178.
- Gächter, Simon, Arno Riedl. 2005. Moral property rights in bargaining with infeasible claims. *Management Science* **51**(2) 249–264.
- Galinsky, Adam D., Thomas Mussweiler. 2001. First offers as anchors: The role of perspective-taking and negotiator focus. *Journal of Personality and Social Psychology* **81**(4) 657–669.

- Haruvy, Ernan, Elena Katok, Valery Pavlov. 2016. Bargaining process and channel efficiency. *Working Paper, University of Texas at Dallas*.
- Kagel, John H., Alvin E. Roth. 1995. *The Handbook of Experimental Economics*. Princeton University Press.
- Kalkanci, Basak, Kay-Yut Chen, Feryal Erhun. 2011. Contract complexity and performance under asymmetric demand information: An experimental evaluation. *Management Science* **57**(4) 689–704.
- Katok, Elena, Diana Wu. 2009. Contracting in supply chains: A laboratory investigation. *Management Science* **55**(12) 1953–1968.
- Kaya, Murat, Özalp Özer. 2012. Pricing in business-to-business contracts: Sharing risk, profit and information. Özalp Özer, Robert Phillips, eds., *The Oxford Handbook of Pricing Management*. Oxford University Press, USA, 738–783.
- Lee, Yun Shin, Enno Siemsen. 2016. Task decomposition and newsvendor decision making. *Management Science* Forthcoming.
- Leider, Stephen, William S. Lovejoy. 2016. Bargaining in supply chains. *Management Science* **62**(10) 3039–3058.
- Lovejoy, William S. 2010. Bargaining chains. *Management Science* **56**(12) 2282–2301.
- Netessine, Serguei, Nils Rudi. 2006. Supply chain choice on the internet. *Management Science* **52**(6) 844–864.
- Özer, Ozalp, Wei Wei. 2006. Strategic commitment for optimal capacity decision under asymmetric forecast information. *Management Science* **52**(8) 1238–1257.
- Ramachandran, Karthik, Yusen Xia. 2015. Multi-dimensional decision making in operations: An experimental investigation of joint pricing and quantity decisions. Working Paper, Georgia Institute of Technology and George State University.
- Randall, Taylor, Serguei Netessine, Nils Rudi. 2002. Should you take the virtual fulfillment path? *Supply Chain Management Review* November/December Issue.
- Randall, Taylor, Serguei Netessine, Nils Rudi. 2006. An empirical examination of the decision to invest in fulfillment capabilities: A study of internet retailers. *Management Science* **52**(4) 567–580.
- Roth, Alvin E., Michael W. K. Malouf. 1979. Game-theoretic models and the role of information in bargaining. *Psychological Review* **86** 574–579.
- Roth, Alvin E., Uriel Rothblum. 1982. Risk aversion and nash’s solution for bargaining games with risky outcomes. *Econometrica* **50**(3) 639–647.
- Schweitzer, Maurice E., Gerard P. Cachon. 2000. Decision bias in the newsvendor problem with a known demand distribution: Experimental evidence. *Management Science* **46**(3) 404–420.
- U.S. Census Bureau. 2016. *U.S. Census Bureau E-Stats*. URL <http://www.census.gov/content/dam/Census/library/publications/2016/econ/e14-estats.pdf>.

## 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  $w_{Ult}^{RL}$ , to the other player. If the offer is accepted, then the responding player, who is exposed to inventory risk, unilaterally chooses an order quantity  $q_{Ult}^{RL}$ . Depending on the inventory risk location, we can write each firm's expected profit function as:

$$\begin{aligned} \pi_r^r &= \frac{p}{b-a} \int_a^b \min\{q, x\} dx - wq & \pi_r^s &= \frac{p-w}{b-a} \int_a^b \min\{q, x\} dx \\ \pi_s^r &= (w-c)q & \pi_s^s &= \frac{w}{b-a} \int_a^b \min\{q, x\} dx - cq \end{aligned} \quad (2)$$

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,  $w_{Ult}^R = (p+c)/2 + ap/2(b-a) \geq (p+c)/2 > c$  and the supply chain is not coordinated.*
2. *Under supplier risk,  $w_{Ult}^S < (p+c)/2 < p$  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:  $q_{Ult}^R = a + (b-a)((p-w)/p)$ , 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,  $w_{Ult}^R = (p+c)/2 + ap/2(b-a) > (p+c)/2$ , 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  $q_{Ult}^S = a + (b-a)((w-c)/w)$ , 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:

$$-\frac{(p-w)(a(c^2+w^2) + b(w^2-c^2))}{w^3} - \frac{a(c^2+w^2) + b(w^2-c^2)}{2w^2} + \frac{(p-w)(2aw + 2bw)}{2w^2} = 0.$$

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 that 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  $q^R(w) = a + (b-a)^{(p-w)/p}$ , while 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:

$$\begin{aligned} \max_w \quad & \pi_r^{RL}(w, q^{RL}(w)) \cdot \pi_s^{RL}(w, q^{RL}(w)) \\ \text{s.t.} \quad & c \leq w \leq p, \end{aligned}$$

where  $\pi_i^{RL}(w, q)$  are given in (2) and  $q^{RL}(w)$  is as above.

The formal proposition considers the case  $a = 0$ , while we allow  $b$  to be general. Below, we will 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  $w_{Neg-w}^R = \frac{p+3c}{4} < (p+c)/2$ , and the corresponding order quantity is given by:  $q_{Neg-w}^R = \frac{3b(p-c)}{4p} < \frac{b(p-c)}{p}$ . 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:

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

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 FOC 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  $p(c^2 - p^2) < 0$ , while evaluating at  $w = (p+c)/2$ , we obtain  $(c/4)(-7c^2 + 6cp + p^2) > 0$ . Hence  $w_{Neg-w}^S > (p+c)/2$ . 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, while for supplier risk, we summarize it in Table A.2. In both cases, we keep  $p = 15$  and  $c = 3$ , as in the experiment.

**Table A.1 Numerical Study: Retailer Risk**

(a) Wholesale Price						(b) Percent Difference in Profits ( $\pi^r > \pi^s$ )					
	$b$						$b$				
$a$	100	200	300	400	500	$a$	100	200	300	400	500
0	6.00	6.00	6.00	6.00	6.00	0	50.0%	50.0%	50.0%	50.0%	50.0%
100		7.76	7.21	6.92	6.74	100		27.3%	38.0%	42.7%	45.1%
200			8.25	7.76	7.44	200			16.7%	27.3%	33.8%
300				8.47	8.07	300				11.9%	20.8%
400					8.59	400					9.2%

There are three main points to make. First, under retailer risk, the retailer always earns strictly more than the supplier, while under supplier risk, the reverse is true. Second, under retailer risk  $w < (p+c)/2$ , while under supplier risk the reverse is true. Thus the main results from the Proposition 2 continue to hold for  $a > 0$ , over the range that we consider. Finally, holding  $b - a$  constant, the wholesale prices converge to  $(p+c)/2$  and the payoff differences between retailers and suppliers diminishes.

**Table A.2 Numerical Study: Supplier Risk**

(a) Wholesale Price						(b) Percent Difference in Profits ( $\pi^s > \pi^r$ )					
$b$						$b$					
$a$	100	200	300	400	500	$a$	100	200	300	400	500
0	10.07	10.07	10.07	10.07	10.07	0	10.5%	10.5%	10.5%	10.5%	10.5%
100		9.36	9.54	9.65	9.72	100		4.5%	6.3%	7.3%	8.0%
200			9.22	9.36	9.47	200			2.8%	4.5%	5.5%
300				9.16	9.27	300				2.0%	3.4%
400					9.12	400					1.6%

### 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,  $q_{Neg-wq}^{RL} = a + (b - a)^{(p-c)/p}$ , the supply chain is coordinated and expected payoffs for the retailer and supplier are equalized.*
2. *Under retailer risk,  $w_{Neg-wq}^R = \frac{3ac^2 + ap^2 - 3bc^2 + 2bcp + bp^2}{4(ac - bc + bp)} < \frac{p+c}{2}$ , while under supplier risk,  $w_{Neg-wq}^S = \frac{p(3ac^2 + ap^2 - 3bc^2 + 2bcp + bp^2)}{2(ac^2 + ap^2 - bc^2 + bp^2)} > \frac{p+c}{2}$ .*

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

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

and the first order conditions are given as:

$$q: \frac{q(p - w)(50c(3q - 400) + w(20000 - 300q + q^2))}{(q - 200)q^2(-200c + (q - 200)(p - 2w))} = 0$$

$$w: \frac{10000}{40000} = 0.$$

$$q: \frac{(w - c)(a^2p - 2aqw - 2bpq + 2bqw + pq^2)}{2a - 2b} + \frac{q(w - c)(-2aw - 2bp + 2bw + 2pq)}{2a - 2b} = 0$$

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

With some algebra, one obtains that  $w_{Neg-wq}^R = \frac{3ac^2 + ap^2 - 3bc^2 + 2bcp + bp^2}{4(ac - bc + bp)} < (p+c)/2$  and  $q_{Neg-wq}^R = a + (b - a)^{(p-c)/p}$ . Observe that  $q_{Neg-wq}^R$  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  $w_{Neg-wq}^R$  and  $q_{Neg-wq}^R$  into the expressions for expected profits. Upon doing so, we immediately see that:

$$\pi_s^s = \pi_r^s = \frac{(p - c)(a(c + p) + b(p - c))}{4p}.$$

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:

$$q: \frac{(p - w)(a^2 + q(q - 2b))(-2ac + 2b(c - w) + 2qw)}{4(a - b)^2} + \frac{(2q - 2b)(p - w)(a^2w - 2acq + q(2b(c - w) + qw))}{4(a - b)^2} = 0$$

$$w: \frac{(p - w)(a^2 + q(q - 2b))^2}{4(a - b)^2} - \frac{(a^2 + q(q - 2b))(a^2w - 2acq + q(2b(c - w) + qw))}{4(a - b)^2} = 0.$$

From this, one obtains that  $w_{Neg-wq}^S = \frac{p(3ac^2 + ap^2 - 3bc^2 + 2bcp + bp^2)}{2(ac^2 + ap^2 - bc^2 + bp^2)}$  and  $q_{w,q}^r = a + (b - a)^{(p-c/p)}$ . Observe that, as in the case of retailer risk,  $q_{Neg-wq}^S$  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,

$$\pi_s^r = \pi_r^r = \frac{(p - c)(a(c + p) + b(p - c))}{4p}.$$

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  $w^R = (3c+p)/4$ . 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  $w_{Neg-w}^S$ . 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  $w = w_{Neg-wq}^S$  yields negative and positive numbers, respectively. Therefore,  $w_{Neg-w}^S > w_{Neg-wq}^S$ . 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, implies that 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:

$$\begin{aligned}\mathbb{E}[u_r(w, q, \pi_0)] &= \frac{100 - q}{100(1 - \rho_r)} (\pi_0 + (p - w)q)^{1 - \rho_r} + \frac{1}{100(1 - \rho_r)} \int_0^q (\pi_0 + (p - w)x)^{1 - \rho_r} dx \\ \mathbb{E}[u_s(w, q, \pi_0)] &= \frac{100 - q}{100(1 - \rho_s)} (\pi_0 + (w - c)q)^{1 - \rho_s} + \frac{1}{100(1 - \rho_s)} \int_0^q (\pi_0 + wx - cq)^{1 - \rho_s} dx.\end{aligned}$$

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, while 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 must satisfy  $q \leq \pi_0/w$ .<sup>12</sup> Therefore, when  $(w, q)$  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 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

<sup>12</sup> Because of this, somewhat counterintuitively, the lower is  $\pi_0$ , the more likely the constraint is to bind, which strengthens the position of the inventory risk holder and makes him/her **more** willing to hold the inventory risk.



**Table A.3 Contract Parameters Given Risk Aversion for Neg-WQ**

		(a) Retailer Risk																		
		Risk Aversion of Supplier																		
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9									
0	6.00	80.0	5.98	80.0	5.95	80.0	5.93	80.0	5.91	80.0	5.88	80.0	5.86	80.0	5.84	80.0	5.82	80.0	5.79	80.0
0.1	5.98	78.7	5.96	78.8	5.94	78.8	5.91	78.8	5.89	78.8	5.87	78.8	5.85	78.8	5.83	78.8	5.80	78.8	5.78	78.8
0.2	5.97	77.4	5.94	77.4	5.92	77.4	5.90	77.5	5.88	77.5	5.86	77.5	5.84	77.5	5.82	77.5	5.79	77.5	5.77	77.5
0.3	5.95	76.1	5.93	76.1	5.91	76.1	5.89	76.1	5.87	76.1	5.85	76.1	5.83	76.1	5.81	76.1	5.79	76.1	5.77	76.1
0.4	5.94	74.6	5.92	74.6	5.90	74.7	5.88	74.7	5.86	74.7	5.84	74.7	5.82	74.7	5.80	74.7	5.78	74.7	5.76	74.8
0.5	5.93	73.2	5.91	73.2	5.89	73.2	5.87	73.2	5.85	73.2	5.83	73.2	5.81	73.3	5.80	73.3	5.78	73.3	5.76	73.3
0.6	5.93	71.7	5.91	71.7	5.89	71.7	5.87	71.7	5.85	71.7	5.83	71.8	5.81	71.8	5.79	71.8	5.77	71.8	5.76	71.8
0.7	5.92	70.1	5.91	70.2	5.89	70.2	5.87	70.2	5.85	70.2	5.83	70.2	5.81	70.3	5.79	70.3	5.78	70.3	5.76	70.3
0.8	5.92	68.6	5.91	68.6	5.89	68.6	5.87	68.7	5.85	68.7	5.83	68.7	5.81	68.7	5.80	68.8	5.78	68.8	5.76	68.8
0.9	5.93	67.1	5.91	67.1	5.89	67.1	5.87	67.1	5.85	67.2	5.84	67.2	5.82	67.2	5.80	67.2	5.78	67.3	5.77	67.3

		(b) Supplier Risk																		
		Risk Aversion of Supplier																		
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9									
0	10.00	80.0	9.96	79.4	9.92	78.7	9.88	78.0	9.84	77.3	9.80	76.6	9.77	75.9	9.73	75.2	9.69	74.5	9.65	73.7
0.1	10.05	79.9	10.01	79.3	9.96	78.6	9.92	78.0	9.89	77.3	9.85	76.6	9.81	75.8	9.77	75.1	9.73	74.4	9.70	73.6
0.2	10.09	79.9	10.05	79.2	10.01	78.6	9.97	77.9	9.93	77.2	9.89	76.5	9.85	75.7	9.81	75.0	9.78	74.3	9.74	73.5
0.3	10.14	79.8	10.09	79.2	10.05	78.5	10.01	77.8	9.97	77.1	9.93	76.4	9.90	75.7	9.86	74.9	9.82	74.2	9.78	73.4
0.4	10.18	79.7	10.14	79.1	10.10	78.4	10.06	77.7	10.02	77.0	9.98	76.3	9.94	75.6	9.90	74.8	9.86	74.1	9.82	73.3
0.5	10.22	79.7	10.18	79.0	10.14	78.4	10.10	77.7	10.06	76.9	10.02	76.2	9.98	75.5	9.94	74.7	9.90	74.0	9.87	73.2
0.6	10.27	79.6	10.23	79.0	10.18	78.3	10.14	77.6	10.10	76.9	10.06	76.1	10.02	75.4	9.98	74.7	9.94	73.9	9.91	73.1
0.7	10.31	79.6	10.27	78.9	10.23	78.2	10.19	77.5	10.14	76.8	10.10	76.1	10.06	75.3	10.02	74.6	9.99	73.8	9.95	73.0
0.8	10.35	79.5	10.31	78.8	10.27	78.2	10.23	77.5	10.19	76.7	10.15	76.0	10.11	75.2	10.07	74.5	10.03	73.7	9.99	72.9
0.9	10.40	79.5	10.35	78.8	10.31	78.1	10.27	77.4	10.23	76.7	10.19	75.9	10.15	75.2	10.11	74.4	10.07	73.6	10.03	72.8

		(c) Who Wants Risk																		
		Risk Aversion of Supplier																		
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9									
0	both	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret
0.1	sup	sup	none	sup	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret
0.2	sup	sup	sup	none	sup	none	none	none	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret	ret
0.3	sup	sup	sup	sup	sup	sup	sup	none	none	none	none	none	none	none	none	none	none	none	none	none
0.4	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup
0.5	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup
0.6	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup
0.7	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup
0.8	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup
0.9	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup	sup

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**.

prefer to hold the inventory risk. As can be seen, there is a relatively small region – when the supplier is more 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 yet still prefers to avoid being exposed to inventory risk. Finally, the lower region, which comprises the majority 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 give 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 with wholesale prices. (b) When proposed contract terms were “rejected” players respond by adjusting their next proposal in a concessionary manner and adjust more than when contract terms were not “rejected”.*

For bargaining duration, we remind the reader that in all of 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 impact bargaining duration.*

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

	Dep. Variable: $\Delta w_{prop}$				Dep. Variable: $\Delta$ Risk Location			
	Resp. to Feedback By				Resp. to Feedback By			
	Retailer		Supplier		Retailer		Supplier	
Offer Number	-0.015***	(0.005)	0.013***	(0.004)	0.003	(0.005)	-0.000	(0.000)
Period	-0.025***	(0.006)	0.015***	(0.006)	-0.002***	(0.001)	-0.021***	(0.003)
Risk Willing.	0.016	(0.018)	0.014	(0.013)	-0.014*	(0.008)	-0.007	(0.006)
Reject $w$	0.065**	(0.030)	-0.061*	(0.036)	0.036	(0.079)	-0.096***	(0.022)
Oth. Concession	0.026	(0.020)	-0.036	(0.033)	0.061	(0.046)	-0.110***	(0.035)
Reject Location					-0.131	(0.133)	0.268***	(0.060)
Constant	0.371***	(0.097)	-0.516***	(0.113)	0.042	(0.085)	0.226***	(0.030)

Note 1: \*, \*\* 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 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**

	Dep. Variable: $\Delta w_{prop}$				Dep. Variable: $\Delta q_{prop}$				Dep. Variable: $\Delta$ Risk Location			
	Resp. to Feedback By				Resp. to Feedback By				Resp. to Feedback By			
	Retailer		Supplier		Retailer		Supplier		Retailer		Supplier	
Offer Number	-0.041***	(0.008)	0.047***	(0.010)	-0.177**	(0.077)	-0.193**	(0.087)	-0.006***	(0.001)	-0.008	(0.015)
Period	-0.041***	(0.012)	0.021**	(0.008)	0.362***	(0.131)	-0.059	(0.045)	0.020***	(0.003)	-0.006	(0.011)
Risk Willing.	0.015	(0.016)	0.040***	(0.012)	-0.205	(0.176)	0.167	(0.297)	-0.016***	(0.005)	0.014	(0.017)
Reject $w$	0.314***	(0.071)	-0.408***	(0.059)	-0.107	(1.019)	-0.715	(1.853)	0.078**	(0.034)	-0.123***	(0.041)
Reject $q$	-0.160***	(0.047)	0.141***	(0.052)					-0.002	(0.028)	0.014	(0.033)
Don't Reject $q \times (q \leq 60)$					6.218***	(0.976)	6.126***	(1.074)				
Reject $q \times (q > 60)$					-2.645*	(1.390)	-3.899***	(1.030)				
Reject $q \times (q \leq 60)$					8.241***	(1.393)	7.736***	(1.707)				
Reject Location									-0.315**	(0.136)	0.433***	(0.039)
Oth. Concession	0.050	(0.042)	-0.066	(0.059)	-0.004	(0.607)	-0.203	(0.918)	-0.016	(0.035)	0.002	(0.014)
Constant	0.450***	(0.139)	-0.703***	(0.101)	-3.099***	(1.093)	-1.354	(1.775)	0.037*	(0.021)	0.009	(0.040)

Note 1: \*, \*\* 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 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 and order quantity.

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

	Neg-W		Neg-WQ	
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: \*, \*\* and \*\*\* denote significance at the 10, 5 and 1% levels, respectively. The table reports a 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).