Procurement in the Presence of Supply Disruptions

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We study the effect of bargaining, long-term relationships, and renegotiations on the performance of incomplete contracts in a supply chain setting with the possibility of supply disruption. Disruptions are a real threat to supply chains, especially as they become longer and more complex. Because disruptions are unpredictable, complete contracts that specify each contingency often cannot be written. We use a controlled laboratory experiments with human subjects incentivized based on performance. Our design manipulates the bargaining protocol, the relationship length, and the ability to renegotiate the contract after the disruption, as well as the ability to communicate through on-line chatting. Inefficiency, in our environment, comes from two sources: failing to reach an initial agreement (purchase inefficiency) and supplier's failure to mitigate the disruption (disruption inefficiency). We find that long term relationships and the ability to communicate decrease both inefficiencies and the option to renegotiate decreases disruption inefficiency only, while allowing free bargaining actually increases both inefficiencies. Our findings can help managers in the process of designing and negotiating incomplete contracts in environments with supply disruptions.

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1. Introduction

Supply disruptions are costly and unpredictable. The British Standards Institute (BSI) reported that in 2015 global supply chains incurred a total of $55.6 billion in disruption-related costs due to cargo theft and natural disasters. The empirical studies in operation management show that supply chain disruptions have a large effect on the operations of firms, for example due to earthquakes

(Papadakis and Ziemba 2001) that cause shipping delays and other interruptions (Hendricks and Singhal 2003, 2005a). This detrimental effect can be long lasting when firms cannot quickly recover from the damage to their logistical infrastructure (Hendricks and Singhal 2005b).

Disruptions are, by their very nature, unpredictable, and therefore it may not be feasible to write a complete contract that would specify how each disruption will be mitigated. In many cases, suppliers' efforts are crucial to mitigate disruptions. In many cases, suppliers, due to their proximity to the cause of disruptions, may be able to mitigate them more effectively and efficiently than buyers can. For example, in 2011, the earthquake and tsunami hitting Japan caused a worldwide shortage of auto parts provided by Japanese suppliers. Affected auto manufactures had to reduce, or even suspend, their production until their suppliers restarted deliveries. Most of these manufactures lost market share in that year. But there was an exception: Dongfeng-Nissan, joint-venture between Dongfeng Motor Group, a Chinese company, and Nissan Motors, quickly resumed of production following the disaster, because its Japanese supplier, Nissan, made all-out efforts to restart the delivery of auto parts such as the V6 piston engines and transmissions. As a result, Dongfeng-Nissan performance well that year, selling 808 thousand cars, and growing 22.3% between 2010 and 2011.

Firms involved in a long-term relationship can mitigate the inefficiency due to disruptions[1] through the promise of profitable future interactions. However, in many cases, a long-term relationship can be absent. For example, manufacturing products with shorter life cycles and updating the features of new products all demand a flexible supply chain. In this scenario, allowing renegotiation in the event of a disruption can be an effective tool to help deal with unanticipated disruptions. A potential problem, however, is that one party may demand an excessive payment when the other party does not have an attractive alternative.

In this paper, we use a behavioral experiment to investigate how long-term relationships, and the ability to renegotiation contracts affect supply chain performance when disruptions are possible but contingent contracts cannot be written. We construct a simple game that captures a

[1] Additionally, a long-term relationship with suppliers can help reduce costs (Spekman et al. 1998), provide strategic advantages (Stuart 1993), enhancing information sharing (Paulraj et al. 2008), and improve overall firm performance (Vickery et al. 2003, Prajogo and Olhager 2012).

procurement setting in the presence of supply disruptions. The game involves a *Buyer* and a *Supplier* who first negotiate the purchase price for a contract, knowing that a disruption can occurs with some probability. It is more efficient, in our scenario, for the Supplier to mitigate the disruption than for the buyer, but in the base model, the supplier does not have any economic incentive to do so.

Our *research question is to understand how different mechanisms perform in a setting in which a complete contingent contract cannot be written*. The *structural* factors we consider are (1) long-term relationships and (2) the ability to renegotiate. We also consider two *behavioral* factors: (3) the effect of informal communication, and (4) the implementation of the bargaining protocol in the laboratory. With informal communication, positive effects such as trust (Brinkhoff et al. 2015), signaling intentions (Crawford 1998) and persuasion (Chakraborty and Harbaugh 2010) can be produced to mitigate inefficiency caused by disruption. In terms of the bargaining protocol, we consider free form bargaining (players make offers and counter-offers for a specific amount of time) and ultimatum bargaining (the buyer makes a price offer and the supplier can accept or reject it; if renegotiation is allowed and the disruption occurs, the supplier makes a price offer to the buyer to mitigate the disruption, which the buyer can either accept, or reject).

We begin by analyzing a simple model of the game and use it to derive theoretical benchmarks based on the standard economic assumption of self-interested, expected-profit maximizing players. We then test this model in a series of controlled laboratory experiments with human participants and performance-based incentives. We report three main results from the laboratory study:

1. Consistent with the standard economic model, long-term relationships improve performance by increasing the likelihood of a successful transaction, and the efficient mitigation of the disruption. The ability to renegotiate improves performance by increasing the likelihood of the efficient disruption mitigation, but does not affect the likelihood of a successful transaction.
2. Contrary to the standard economic model, suppliers often correct disruptions without either long-term relationships or renegotiations. They are more likely to do this for buyers who pay higher initial purchase prices.
3. The ability to communicate has a major positive effect on performance. It increases purchase prices, as well as the likelihood of a successful transaction. It also increases the likelihood that the supplier corrects the disruption. We use content analysis to learn that players use

communication to make informal commitments to correct the disruption either for free (when no renegotiation is allowed) or at a low price.

In the absence of renegotiation, our setting resembles a *trust game* or a gift exchange game. In this game, the first mover makes an investment, or offers a wage to the second mover, and the second mover has an opportunity to exert costly effort, or to return part of the investment back to the first mover. Sub-game perfect equilibrium predicts that the second mover will not do any of those things, and therefore, the first mover will not invest, or offer the minimum possible wage. However, numerous experimental laboratory studies report that the first movers do trust the second movers, and the second movers are often trustworthy. Berg et al. (1995) was the original paper that tested the trust game in the laboratory, and they found reciprocity in a fully anonymous setting. Fehr et al. (1997) reported similar results in a gift exchange experiment: workers' efforts increased with wage. Bolton and Ockenfels (2000) inequality aversion model could organize these results. Furthermore, intentional reciprocity, distributive concerns, and altruism could all contribute to explaining these results (Charness and Haruvy 2002). Numerous other studies investigated the differences in cultures (Willinger et al. 2003), genders (Buchan et al. 2008), ages (Sutter and Kocher 2007), outside options (McCabe et al. 2003), and reputations (Anderhub et al. 2002, Charness et al. 2011) and found that some of these factors affected the observed amount of trust and trustworthiness. Our own experiments echo some of these results.

In the next section, we develop and analyze a simple model of the supply disruption game. In section 3 we describe the design of our experiment and state research hypotheses. We report experimental results in Section 4 and conclude with a summary and discussion in Section 5.

2. The Model

Consider a buyer (B) and a supplier (S) who negotiate a contract. The buyer's value from the contract is v and the supplier's cost of fulfilling the contract is c. If the buyer and the supplier are successful in negotiating the contract, there is a probability δ of a disruption[2]. Either the buyer or

[2] To formulate the uncertainty of disruptions, we induce a probability δ instead of an ambiguity without introducing a complexity to expected payoff functions.

the supplier can correct the disruption; the buyer at a cost of f_B and the supplier at a cost of f_S. We assume that all parameters in our model are public information and make a stylized assumption the parties cannot negotiate a contract contingent on whether or not the disruption occurs. This may be the case in reality because the nature of the disruption is unpredictable, although this is not the case in the laboratory.

We display the sequence of events graphically in Figure 1. Initially, the buyer and the supplier negotiate the price for the contract. We call this negotiated price w. If the transaction fails at this point, both parties walk away with their outside options, which without loss of generality we normalize to zero. If the transaction succeeds, and there is no disruption, which happens with probability $1-\delta$, then the buyer earns $\pi_B = v - w$ and the supplier earns $\pi_S = w - c$. If the disruption does occur, profits depend on who fixes the disruption. For simplicity we assume that there is no option to leave the disruption uncorrected, so if the buyer fixes the disruption, then the buyer earns $\pi_B = v - w - f_B$ and the supplier earns $\pi_S = w - c$. If the supplier fixes the disruption, then the buyer earns $\pi_B = v - w$ and the supplier earns $\pi_S = w - c - f_S$. Let us assume that fixing the disruption is costlier for the buyer than for the supplier, $f_B > f_S$, so the efficient outcome is for the supplier to fix the disruption. Therefore, there are two potential causes of inefficiency in this game (1) the initial negotiation fails, and (2) the wrong firm corrects the disruption.

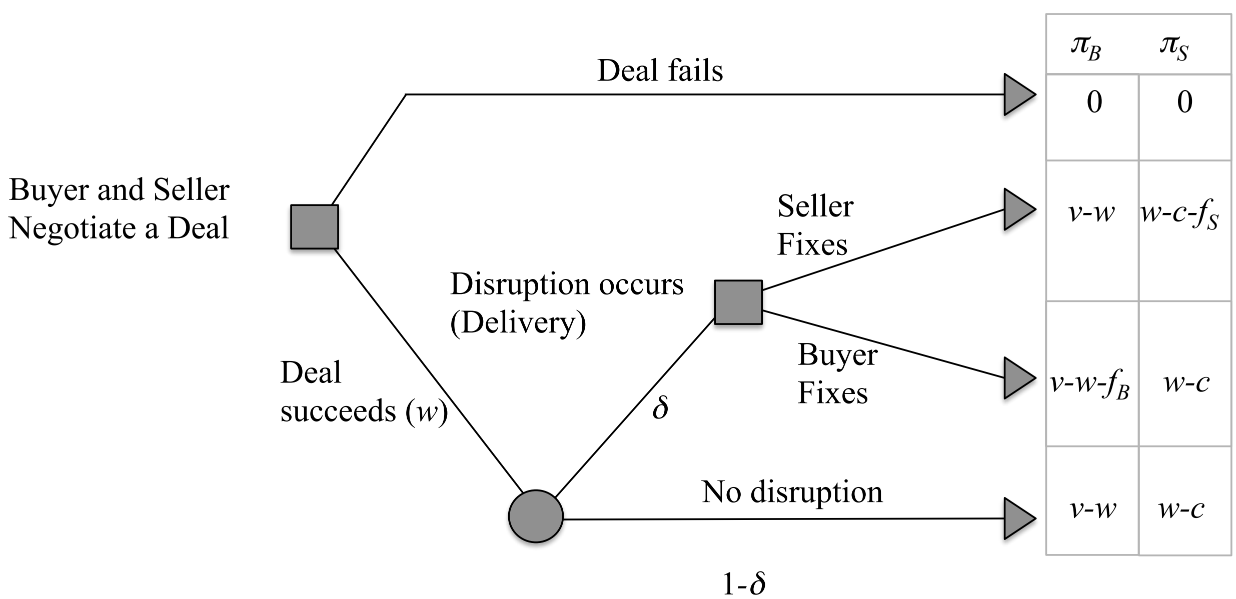


Figure 1. The Sequence of Events

We are interested in deriving analytical predictions for the initial transfer payment w, and for which of the two firms fixes the disruption. These predictions will also imply the expected profits for the two firms, as well as the channel efficiency. Of course, the transfer payment w depends on the relative bargaining power of the two firms and on the structure of the bargaining process.

In our experiments, we investigate two bargaining processes that are in a sense two extremes. The first one is *ultimatum bargaining*, in which, in the first stage, the buyer offer w to the supplier who can accept or reject, and in the treatments with the renegotiation stage the supplier proposes p to the buyer, which the buyer can accept or reject. So, in the first stage, the buyer is more powerful, and in the renegotiation stage, the supplier is more powerful. The sub-game perfect Nash equilibrium prediction is that the first mover in a given negotiation should be able to extract nearly the entire surplus. A great deal of experimental literature in behavioral economics demonstrated that the second movers (the recipients) reject profitable but extremely unequal offer and proposers make nontrivial offers (Güth et al. 1982, Kahneman et al. 1986, Roth et al. 1991, Bolton 1991, Forsythe et al. 1994, Hoffman et al. 1994, Camerer and Thaler 1995, Roth 1995). In behavioral operation management studies, ultimatum bargaining style is used to in laboratory experiments that test contracting models (Lim and Ho 2007, Loch and Wu 2008, Ho and Zhang 2008). Haruvy et al. (2018) find that a more flexible bargaining protocol improves channel efficiency in the laboratory.

The second bargaining process we consider is free bargaining (Gächter and Riedl 2005, Leider and Lovejoy 2016). Here both firms can exchange offers and counteroffers, and therefore in the first stage, the players are ex-ante symmetric. In the treatments with re-negotiation, the players still exchange offers and counteroffers, but the supplier is more powerful because if the negotiation fails, the buyer must fix the disruption at the cost of f_B. These two bargaining processes imply different negotiation outcomes. The ultimatum bargaining process outcome implies that the buyer should be able to extract more of the gains from trade in the initial stage, while the free bargaining process implies that the players will split the gains from trade more equally. In the remainder of this section we derive theoretical benchmarks to guide the rest of our study.

2.1 Single Shot Game with No Renegotiation

Let us begin the analysis with a basic setting in which the parties do not renegotiate the contract in the event of disruption. In a single shot game, regardless of the bargaining process, the supplier will not fix the disruption, and therefore the buyer will be required to do so. Therefore, the total expected gains from trade are

$$G_N = v - \delta f_B - c.$$

The buyer, anticipating having to pay to fix the disruption with probability of δ, will demand a lower *w* from the initial negotiation so that if we let λ be the proportion of the total expected surplus the buyer earns, then the purchase price should be set at

$$w = v - \delta f_B - \lambda G_N.$$

The proportion λ is related to the bargaining power of the buyer, which can depend on bargaining protocols. Players have equal power in a free bargaining (see, e.g., Nydegger and Owen 1974), and the proposer has more power in an ultimatum bargaining (see, e.g., Güth et al. 1982, Bolton 1991, Hoffman et al. 1994, Bolton and Zwick 1995). The above outcomes are inefficient because $f_B > f_S$, and we consider two ways to improve efficiency: (1) allow renegotiations, and (2) long term relationships.

2.2 Game with Renegotiation

If firms are able to achieve the efficient outcome (in other words, the supplier fixes the disruption), then the expected gains from trade are

$$G_E = v - \delta f_S - c.$$

Suppose that the buyer pays p to the supplier to fix the disruption. The purchase price *w* at which the buyer earns λ of the surplus is

$$w = v - \delta p - \lambda G_E.$$

In equilibrium, the players anticipate p, and agree on the *w* accordingly, so a specific split λ can be achieved by many different (*w, p*) combinations.

2.3 Long Term Relationships

If the buyer and the supplier operate under a long-term relationship (ignoring the end-game effects), we would expect the efficient outcome regardless of whether there is re-negotiation or not, with gains from trade of G_E. In terms of splitting these gains, there are multiple equilibria, so the outcome with renegotiation may the same as we described in the previous sub-section.

In the absence of renegotiation, the supplier should agree to fix the disruption, and in return the buyer might agree to pay a higher wholesale price than he would with renegotiation. The contract price splits expected gains from trade and the buyer earns λ of the surplus:

$$w = v - \lambda G_E.$$

We summarize the theoretical predictions in Table 1.

Table 1. Summary of Theoretical Predictions

	Single Shot		Long-Term Relationship	
	No Renegotiation	Renegotiation	No Renegotiation	Renegotiation
Gains From Trade (G)	$v - c - \delta f_B$	$v - c - \delta f_S$	$v - c - \delta f_S$	$v - c - \delta f_S$
Renegotiation price (p)	-	p	-	p
Contract price (w) given buyer share is λ	$v - \delta f_B - \lambda G_N$	$v - \delta p - \lambda G_E$	$v - \lambda G_E$	$v - \delta p - \lambda G_E$
Inefficiency	$\delta(f_B - f_S)$	0	0	0

3. Experimental Design and Research Hypotheses

In all our sessions, we set $v = 50$, $c = 10$, f_B=20, $f_S = 5$, and average $\delta = 0.5$. We designed our study to examine the effect of four factors on negotiation outcomes. The four factors we manipulate are:

1. Ability to renegotiate (Yes = RN or No = N)
2. The presence of a long-term relationship (Partner = P or Random = R)
3. The negotiation format (Free bargaining or Ultimatum bargaining = U)
4. The ability to communicate informally (Chat or No Chat = NC)

We partition our analysis in three sub-studies, each looking at the ability to renegotiate jointly with one of the other three factors. We summarize our design in Figure 2. The small boxes correspond to the eight treatments in our study. The label in each box is the treatment label that we will use in the analysis. The grey boxes indicate the sets of 4 treatments in each of the three sub-studies.

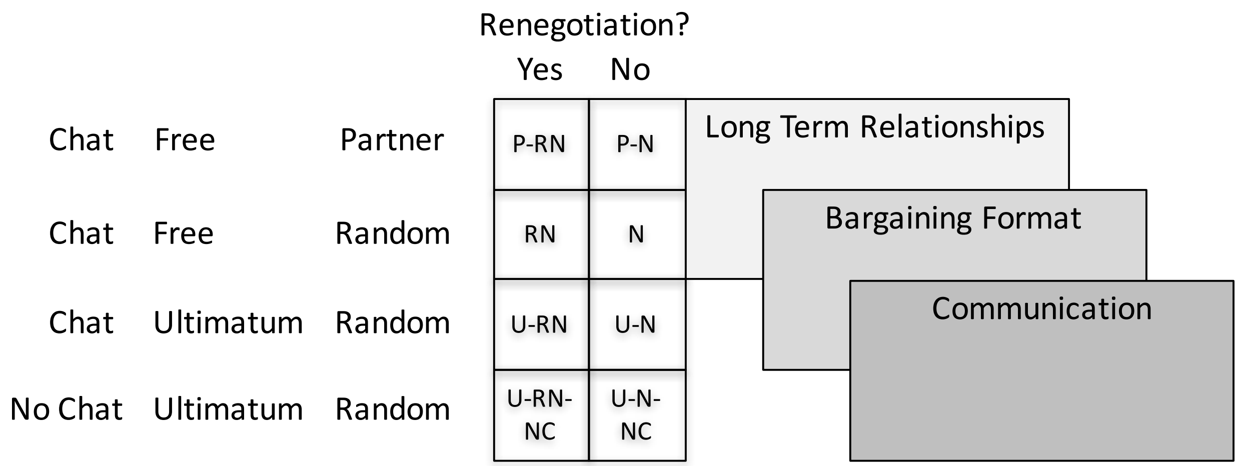


Figure 2. Experimental Design.

We measure the outcomes of negotiation based on the following four metrics:

1. Buyer profit (π_B)
2. Supplier profit (π_S)
3. Inefficiency due to purchase negotiation failure (purchase inefficiency)
4. Inefficiency due to the wrong party fixing the delivery problem (fixing inefficiency).

Each random matching treatment included four independent sessions, with four buyers and four suppliers who interacted for 20 periods[3], while the two partner treatments included 13 pairs. In total 2×13×2+8×4×6=244 participants were included in our study. In the Random condition, buyers and suppliers were randomly re-matched each period, and in the Partner condition buyers and suppliers were repeatedly matched every period. Participants were informed about the matching protocol.

We randomly assigned participants to treatments. Each human subject participated in one treatment only. We conducted all sessions at a public university in the United States, in a computer laboratory dedicated to research. Our participants were students, mostly master level, primarily business and engineering majors. We recruited them through SONA Systems (https://www.sona-systems.com), which is on-line subject recruitment system, offering earning cash as the only

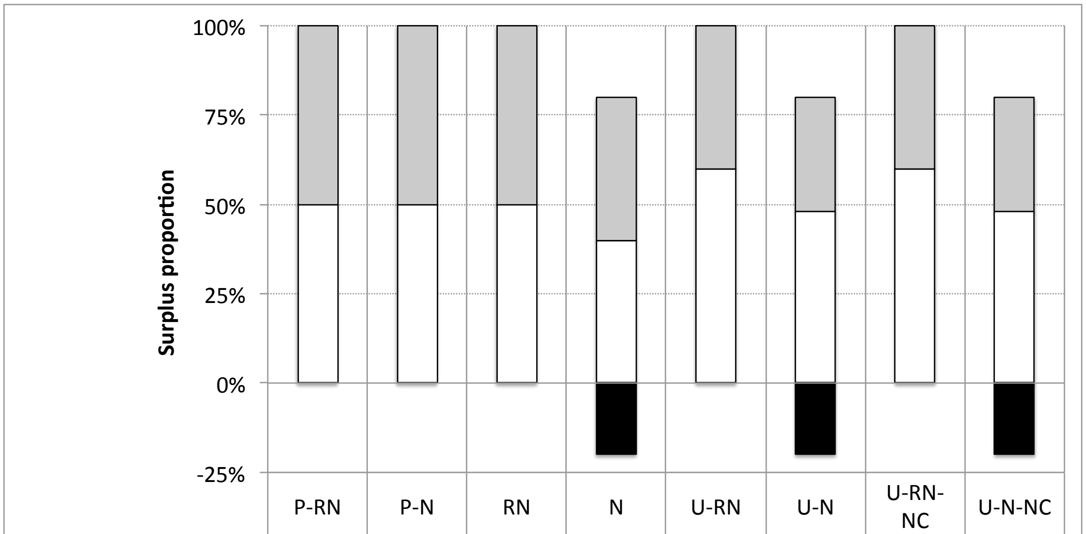
[3] To mitigate the end-game effect, we informed participants that the number of periods was at least 18 but not more than 24 instead of telling them the exact number of periods.

incentive to participate.

Upon arrival at the laboratory the subjects were seated at computer terminals in isolated cubicles. We handed out written instructions (see the Appendix for samples) to participants. After they read the instructions, to ensure common knowledge about the game's rules we then played for them a pre-recorded PowerPoint presentation that included the reading of the instructions that went along with the slides that displayed instructions text.

We programmed the experimental interface using the zTree system (Fischbacher 2007). At the end of each session we computed cash earnings for each participant by multiplying the total earnings from all rounds by a pre-determined exchange rate and adding it to a $5 participation fee. Participants were paid their earnings in private and in cash, at the end of the session. Average earnings, including the show-up fee, were approximately $30, and each session lasted approximately 90 minutes.

We conclude this section with a summary of quantitative predictions given our experimental parameters that we display in Figure 3. For free bargaining treatments (P-RN, P-N, RN, and N) we use $\lambda = 0.5$ in the absence of any better alternative prediction. Players in free bargaining treatments have equal power, so the assumption that they will split the surplus equally is reasonable. For ultimatum bargaining treatments (U-RN, U-N, U-RN-NC, and U-N-NC) the fully rational expected-profit-maximizing prediction would use $\lambda = 1$. A more realistic prediction, and one we use is $\lambda = 0.6$, which is consistent with typical average splits observed in ultimatum game experiments.



	P-RN	P-N	RN	N	U-RN	U-N	U-RN-NC	U-N-NC
■ Fixing Inefficiency	0.00	0.00	0.00	-7.50	0.00	-7.50	0.00	-7.50
■ Purchase Inefficiency	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
□ Seller Profit	18.75	18.75	18.75	15.00	15.00	12.00	15.00	12.00
□ Buyer Profit	18.75	18.75	18.75	15.00	22.50	18.00	22.50	18.00

Figure 3. Summary of Theoretical Benchmarks

Theoretical predictions in Figure 3 allow us to formulate the following structural hypotheses about the effect of the ability to renegotiate, long-term relationships, the communication, and the bargaining format, on profit distribution and the causes of inefficiency.

- *Hypothesis 1: The ability to renegotiate decreases fixing inefficiency in Short-Term Relationship condition and has no effect in the Long-Term Relationship condition.*
- *Hypothesis 2: Without renegotiation, Long-term relationships decrease fixing inefficiency.*
- *Hypothesis 3 (a): Purchase inefficiency will not be observed in any of the treatments.*

As stated, H3(a) is strong, and given existing work on bargaining is sure to be rejected, because inequitable offers are rejected in Ultimatum Games (Roth 1995), and because people make random errors. With free bargaining, rejections tend to be low when players are symmetric and the amount to be divided is known and fixed, but in other settings, rejections are prevalent (Ochs and Roth 1989). So we formulate a weaker version of the hypothesis:

- *Hypothesis 3 (b): Purchase inefficiency will be positive in all treatments and will be higher in treatments with Ultimatum bargaining.*
- *Hypothesis 4: In treatments without renegotiation, ultimatum bargaining format (a) benefits the buyer (the first mover) by increasing buyer's profit and decreasing supplier's profit*

(shifting λ from 0.5 to 0.6), which should be evident by lower purchase prices. It has (b) no effect on fixing inefficiency.

- *HYPOTHESIS 5 (a): Communication will have no effect on negotiation outcomes.*

Cheap-talk communication (costless, nonbinding and non-verifiable) in bargaining does not affect players' payoffs directly and should not be believed. Players who only maximize their own expected monetary payoff have incentives to lie. But there is an alternative point of view: if people happen to believe cheap talk, then it can be informative in bargaining and even can solve coordination problem efficiently (Farrell and Rabin 1996, Ellingsen and Johannesson 2004). Communication can also decrease the frequency of disagreements in the ultimatum game (Roth 1995). Therefore, we formulate an alternative hypothesis about the effect of communication.

- *HYPOTHESIS 5 (b): Communication will improve efficiency under the ultimatum bargaining protocol.*

4. Results

4.1 Descriptive Statistics

We present the summary of aggregate results and theoretical predictions [in square brackets] in Table 2. We measure inefficiency in terms of cost, as follows:

- *Purchase Inefficiency* = 0 is purchase transaction succeeded and $v - c - f_S\hat{\delta}$ if purchase transaction failed, where $\hat{\delta} = 1$ if disruption occurred and 0 otherwise.
- *Fixing Inefficiency* = 0 if disruption did not occur or if the supplier fixed the disruption, and $f_B - f_S$ if the buyer fixed the disruption.

All p-values we report are two sided and are from t-tests that use session average as the unit of analysis, which is also the unit of analysis for computing standard errors (in parenthesis). Theoretical predictions are based on $\lambda = 0.5$ for the free bargaining treatments, and $\lambda = 0.6$ for the ultimatum bargaining treatments. Because in RN treatments a continuum of (w, p) pairs result in the same expected profits, in the w column of Table 2 for RN treatments, we compute, and report in square brackets, the predicted w conditional on observed average p. We organize our results to correspond to the three sub-studies in Figure 2. In Figure 4 we plot the observed surplus distribution in all treatments.

Table 2. Results Summary

	Treatment	Selling Price (w)	Fixing Price (p)	Buyer Profit (π_B)	Supplier Profit (π_S)	Purchase Inefficiency[a]	Fixing Inefficiency
1	P-RN	27.10	6.94	16.49	16.61	3.92**	0.69**
		(0.47)	(0.45)	(0.38)	(0.68)	(0.94)	(0.272)
		[27.78]		[18.75]	[18.75]	[0.00]	[0.00]
2	P-N	30.58		16.96	17.42	2.21**	1.05**
		(0.33)		(0.45)	(0.38)	(0.72)	(0.32)
		[31.25]		[18.75]	[18.75]	[0.00]	[0.00]
3	RN	24.61	7.68	18.35†	15.15	3.13***	1.08***
		(1.38)	(1.11)	(0.86)	(0.92)	(0.24)	(0.21)
		[27.41]		[18.75]	[18.75]	[0.00]	[0.00]
4	N	31.08**		11.83	16.69†††	6.38***	3.00***
		(0.95)		(0.63)	(1.12)	(1.20)	(0.45)
		[25.00]		[15.00]	[15.00]	[0.00]	[7.50]
5	U-RN	25.63	7.21	18.53†	16.53	1.50*	1.08***
		(1.08)	(1.56)	(0.65)	(0.59)	(0.84)	(0.12)
		[23.90]		[22.50]	[15.00]	[0.00]	[0.00]
6	U-N	29.53***		16.50	16.63	2.50**	1.97***
		(0.99)		(0.41)	(1.23)	(0.91)	(0.36)
		[22.00]		[18.00]	[12.00]	[0.00]	[7.50]
7	U-RN-NC	18.11***	12.08	18.35†††	9.50	8.33***	1.50***
		(0.57)	(0.54)	(0.26)	(0.35)	(0.44)	(0.19)
		[21.46]		[22.50]	[15.00]	[0.00]	[0.00]
8	U-N-NC	20.79**		16.14†††	9.08	6.38***	6.28***
		(0.33)		(0.61)	(0.49)	(1.25)	(0.32)
		[22.00]		[18.00]	[12.00]	[0.00]	[7.50]

Notes: standard errors (using session as the unit of analysis) are in parenthesis. And theoretical predictions are in square brackets. For ultimatum bargaining conditions we use $\lambda = 0.6$ for predictions.

[a], Purchase Inefficiency $\in [0, 37.5]$.

[b], Fixing Inefficiency $\in [0, 7.5]$

H_o: Observed = Predicted; $^{*}p< 0.1$, $^{**}p< 0.05$, $^{***}p<0.01$.

H_o: $\pi = \pi_j$ and H_a: $\pi > \pi_j$ where π_j is the profit of the player in the other role; $^{\dagger}p<0.1$, $^{\dagger\dagger}p<0.05$, $^{\dagger\dagger\dagger}p<0.01$.

4.1.1 The Effect of Renegotiation

A visual comparison of Figure 3 and Figure 4 reveals that the data is directionally consistent with H1. Recall that H1 states that the ability to renegotiate decreases fixing inefficiency in Short-Term

Relationship treatments, which is what we observe (p-value < 0.01 for N vs. RN, p-value = 0.06 for U-N vs. U-RN, and p-value < 0.01 for U-N-NC vs. U-RN-NC); and has no effect in the Long-Term Relationship treatments (p-value = 0.42 for P-RN vs P-N). The data is consistent with H1, in spite of several systematic deviations from other predictions.

4.1.2 The Effect of Long-Term Relationships

H2 states that without renegotiation, long-term relationships decrease fixing inefficiency, and the data is consistent with this hypothesis as well (the fixing inefficiency is higher in N than in PN treatments, where p-value = 0.01). Long-term relationship has the largest effect in the absence of renegotiation. While the other three treatments in the sub-study (P-RN, P-N and RN) look quite similar to one another and in terms of their comparison to the theoretical prediction, the N treatment has two important deviations from theoretical predictions: high purchase inefficiency (nearly twice that of the other three treatments), and buyer profits that are significantly lower than supplier profits (which may be what is causing the higher level of negotiation break-downs). Fixing inefficiency is also about three times higher than the other treatments in the sub-study, which contributes to lower buyer profits. We will see later (Section 4.2) that this is also a treatment with the most discussion of the lack of trust. So, the ability to renegotiate is most effective when relationships are short term.

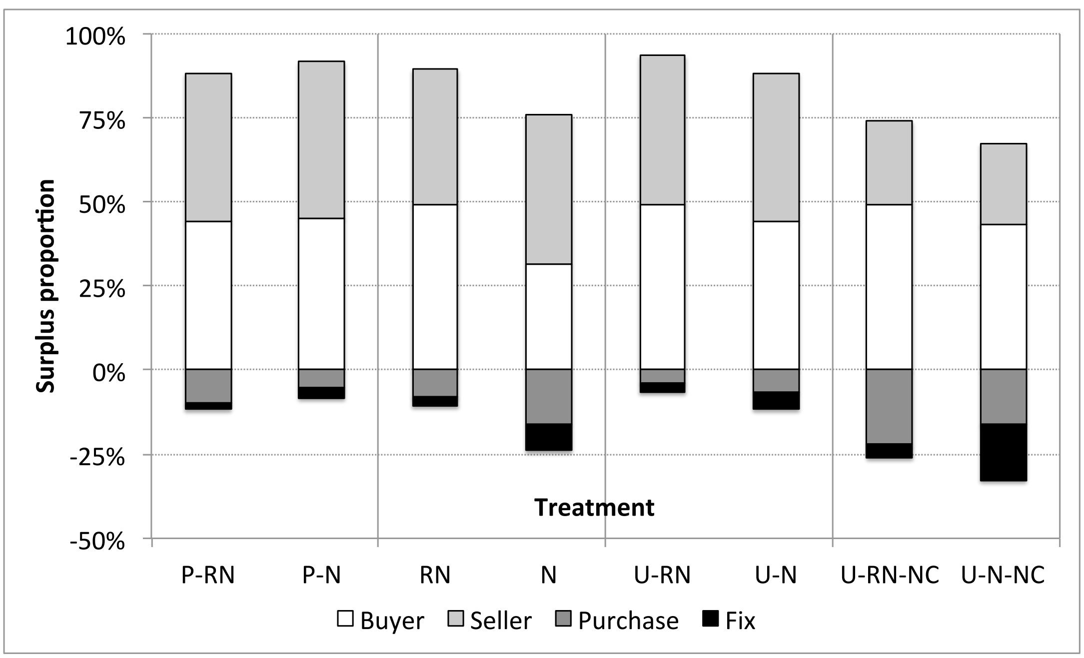


Figure 4. Surplus Proportion Across Treatments

4.1.3 Purchase Inefficiency

In contrast to the first two hypotheses, the data rejects many of the predictions of hypotheses 3-5 quite definitively. H3(a) states that purchase inefficiency should not be observed in any treatments and is rejected (see the Purchase Inefficiency column of Table 2). Purchase inefficiency is also significantly higher in N than in U-N, and is not significantly lower in N than in U-N-NC. The story in treatments with renegotiation is similar in that ultimatum bargaining does not increase purchase inefficiency there either (p-value = 0.11 for RN vs. U-RN). So, in our setting, free bargaining does not reduce purchase inefficiency at all. This may be due to the presence of communication.

4.1.4 The Effect of the Bargaining Format

Bargaining format has no effect on treatments with renegotiation—RN and U-RN treatments are qualitatively very similar in terms of prices, profit distributions, and levels of efficiency. However, ultimatum bargaining format improves performance in treatments without renegotiation—U-N prices continue to be significantly higher than predicted prices, but buyer and supplier profits are very close, and levels of inefficiency are back down to the levels of partner treatments. This finding is surprising at first glance. A potential explanation may be that free bargaining causes a disconnect between the buyer's and the supplier's beliefs about their relative power, while ultimatum bargaining restores the understanding that the buyer (being the first mover) is more powerful. An implication of this finding is that in a setting in which trust is important (no renegotiation and no long-term relationship to fall back on) it is important for power relationships to be clear.

Formally, H4(a) states that Ultimatum bargaining should increase buyer's profit and decreases supplier's profit in treatments without renegotiation. Consistent with the hypothesis, buyer's profits are significantly higher in the U-N than in the N treatment (p-value < 0.01) but contrary to the hypothesis, supplier's profits are not different in N treatments (p-value = 0.97 for N vs. U-N) So, we find that ultimatum bargaining helps the buyer (the first mover) without hurting the supplier (the second mover). The reason for this is that purchase inefficiency is higher in the U-N than in the N treatment, purchase prices are similar, and fixing inefficiency is lower in U-N than in N. In other words, the players are splitting a larger pie in U-N than in N, and the benefits from the added purchase efficiency go to the buyer without hurting the supplier H4(b) states that the Ultimatum bargaining format should have no effect on fixing inefficiency, which is supported by the data regardless of the ability to renegotiate (-value $p = 0.12$ for N vs. U-N) and RN (p-value > 0.99 for RN vs. U-RN) treatments.

4.1.5 The Effect of Communication

Non-binding communication, like we implemented, should not have an effect on performance, as we state in H5(a). Communication in our study does have an effect on most outcome metrics. It increases supplier's profit in both renegotiation conditions (p-value <0.01 for U-RN-NC vs. U-RN), without affecting buyer's profit. Communication also decreases purchase inefficiency in both renegotiation conditions and decreases fixing inefficiency without renegotiation (p-value <0.01 for U-N vs. U-N-NC). So, our data is not consistent with H5(a) and is instead, largely consistent with H5(b). Because communication has such a positive effect on contract outcomes, we conducted content analysis of the chat data, in order to better understand which aspects of communication that helpful. We report this analysis in section 4.2.

It is worth noting that in the U-RN-NC treatment, the average w is significantly lower than predicted ($p = 0.03$) and is significantly lower than in the U-RN treatment (p-value < 0.01), while the average p is significantly higher than in the U-RN treatment (p-value < 0.01), so on the face of it, it seems like the supplier should benefit from not communicating. However, the supplier does not, because its average profit is significantly lower than the buyer's and is significantly lower than supplier's profit in the U-RN treatment (p-value < 0.01). Essentially, the concessions in terms of the purchase and renegotiation prices that the supplier is able to obtain due to the absence of communication are wiped out by the purchase inefficiency that is more than 5 times higher in the U-RN-NC treatment than in the U-RN treatment. We can, therefore, conclude that non-binding communication yields additional benefits even in the setting with renegotiation, when in theory it should not matter (H5a).

What is the effect of communication in treatments without renegotiation? Here we see that the average w's are above predicted when communication is allowed (p-value < 0.01 U-N) and below predicted when communication is not allowed (p-value $= 0.03$ in U-N-NC). The reason for these differences is probably due to the fact that when communication is allowed (the U-N treatment), suppliers fix the disruption more than 50% of the time, while they almost never fix it when communication is not allowed (U-N-NC treatment). Anticipated suppliers' fixing behavior affects purchase prices buyers demand. Because communication has such a positive effect on contract outcomes, we conducted content analysis of the chat data, in order to better understand which aspects of communication that helpful. We report this analysis in section 4.2.

Table 3. Regression Estimates

	Model 1: OLS	Model 2: Logit	Model 3: Logit[a]
Independent Variables	Purchase Price (w)	Likelihood of Successful Purchase	Likelihood of Supplier Fixing the Disruption
Partner	2.24**	0.63**	1.58***
1 for P-N and P-RN treatment and 0 otherwise	(0.75)	(0.24)	(0.35)
Renegotiation	-3.59***	0.12	3.03***
1 when renegotiation is allowed and 0 otherwise	(0.52)	(0.16)	(0.27)
Communication	10.58***	1.66***	2.13***
1 when chat is available and 0 otherwise	(0.73)	(0.24)	(0.37)
Bargaining protocol	-1.83**	-1.07***	-0.92**
1 for free bargaining and 0 for ultimatum bargaining	(0.71)	(0.24)	(0.31)
Period (1-20)	0.05*	0.03***	0.04**
	(0.02)	(0.01)	(0.01)
Purchase Price (w)			0.16***
			(0.02)
Constant	16.83***	1.32***	-6.46***
	(0.62)	(0.18)	(0.53)
Observations (Individuals)	2440 (244)	2440 (244)	1081 (244)
Log Likelihood		-1555.9	-881.4
R^2	0.23		

Notes: Standard errors in parentheses; Random Effects for individuals.
[a] Only the observations with successful purchase and disruption occurred are counted in Model 3.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.1.6 Results Summary

To consolidate the analysis we presented thus far on the effect of long-term relationship, the bargaining protocol, and communication, we conducted a set of regressions that include indicator variables for the factors we manipulated: repeated interaction, ability to renegotiate, bargaining format, and communication (variables defined in the first column of Table 3) as independent variables. We also included the Period number to control for linear trend. The dependent variables (listed in the top row of Table 3) are the Purchase Price (w) (Model 1), whether the purchase was successful (Model 2) and whether the supplier fixed the disruption (Model 3) when it occurred. We estimated Model 1 using OLS with random effects for individuals and Models 2 and 3 using Logit with random effects for individuals.

Models 1 and 3 provide a systematic way for analyzing the relationship between purchase prices and successful resolution of the disruption. Recall that suppliers are more likely to fix disruptions either when there is a long-term relationship, or when there is the ability to renegotiate. We see this effect in Model 3. But while long-term relationships induce this behavior while keeping prices high, the ability to renegotiate achieves the same effect by sharing disruption risk between the buyer and the supplier (Renegotiation coefficient is negative and significant in Model 1 and positive and significant in Model 3). Free bargaining appears to slightly but significantly degrade performance relative to the analogous ultimatum bargaining treatments that include communication. Purchase prices are lower, and consequently the suppliers do not fix disruptions as often. Also, the likelihood of a successful purchase is lower.

We report two behavioral findings. The first one is that suppliers fix the disruptions even without long-term relationships or renegotiation. The positive and significant coefficient of Purchase Price in Model 3 provides an explanation: Suppliers reward buyers for generous purchase prices by fixing the disruption—the higher the purchase price, the more likely is the supplier to fix the disruption.[4]

The second behavioral finding is the effect of communication. The ability to communicate (in ultimatum bargaining treatments) causes an increase in purchase prices, the related increase in the likelihood that the supplier fixes the disruption, and an additional increase in the likelihood of successful transaction (Model 2). In the next section we use content analysis to gain better understanding into how participants use communication to improve performance.

4.2 Content Analysis of Communication

There are six treatments in our study that allow communication. We analyzed the content of conversations by first identifying five substantive themes that we list in Table 4 along with an

[4] This is similar to the Gift Exchange Game result (Fehr et al. 1993).

explanation and an example. We then classified each communication as relating to one or more of the five themes.

Table 4. Substantive Themes in Communication

Theme	Explanation	Example
Fairness	References the equity norm	The price of 30 is fair because we both make 20.
Presence Trust	References being willing to trust the other player	Fine, I will trust you this round
Lack of Trust	References not trusting the other player.	I trusted many seller and then they cheated
Hard Bargaining	Mentions the highest or lowest acceptable price	I cannot go above 30.
Informal Commitment	Promises to fix the delivery problem.	I will fix the delivery problem if it happens

In addition to the five themes we listed above, some chats were purely social, including greetings and chatting about subjects not related to the experiment, and some negotiations did not include any chatting at all. The proportion of such communications did not vary by treatment, so we do not report them here. For each treatment, we calculated the proportion of chats that fall into each category and compared these proportions across treatments. Significant differences in treatments were in only two categories: Informal Commitment, and Lack of Trust. Therefore, we further calculated *Trustworthiness*, for each treatment, as the proportion of time that the supplier who made an informal commitment followed up and fixed the disruption in the second stage. In Table 5 we report the proportion of chats that include references to informal commitment and lack of trust, as well as Trustworthiness.

Table 5. Proportion of Chats

Treatment		Informal Commitment [a]	Lack of Trust [a]	Trustworthiness	
				Percentage	# of Obs. [b]
1	P-RN	5.83 (1.02)	0.31 (0.31)	88.89 (9.62)	8
2	P-N	4.69 (1.40)	0.00 (0.00)	100 .00 (0.00)	7
3	RN	14.06 (3.48)	0.31 (0.31)	76.15 (8.91)	23
4	N	54.69** (8.73)	8.75# (2.25)	66.99† (6.03)	81
5	U-RN	40.00* (6.81)	2.81 (1.29)	89.24 (3.2)	73
6	U-N	64.06** (5.24)	3.33 (1.30)	80.25 (7.29)	103

There are three findings related to the differences in chatting content:

1. Treatments N and U-N had significantly more "Informal Commitment" messages (marked with ** in Table 5) than the other four treatments and U-RN (marked with * in Table 5) had fewer than N and U-N but more than the other three treatments.
2. Treatment N (marked with # in Table 5) had significantly more "Lack of Trust" messages than any of the other treatments (8.75% in N and less then 3% across the other five treatments).
3. Treatment N marked with † in Table 5) had significantly lower trustworthiness than U-RN treatment and then the two P treatments. No other differences in trustworthiness are significant.

The N treatment has the lowest overall efficiency of all treatments with chat—the highest purchase and fixing inefficiency. High fixing inefficiency is consistent with higher informal commitment, lack of trust and lower trustworthiness in that treatment. Higher lack of trust, in turn may explain high purchase inefficiency.

In the U-N treatment, fixing inefficiency is significantly lower than in the N treatment, so while informal commitment is still prevalent, the suppliers follow through often enough to decrease fixing inefficiency and this higher trustworthiness decreases purchase inefficiency.

5. Conclusion

We study a supply chain setting in which an unanticipated supply disruption can cause losses for buyers and suppliers, and complete contracts that specify how these disruptions are to be handled cannot be written. We consider a situation in which a disruption can be corrected at a cost, and the disruption correction cost is lower for the supplier than for the buyer.

This setting causes two kinds of potential inefficiencies. The supplier, in general, has no incentive to fix the disruption in the absence of some mechanism that would compensate it for the additional cost. So, one type of inefficiency happens if the wrong party (the buyer instead of the supplier) ends up paying for the disruption. Another type of inefficiency may happen if renegotiation is possible, but the disruption correction cost cannot be specified until the disruption actually occurs (this may be the case if the nature of the disruption, and therefore the cost to correct it, is unknown). The supplier may be willing to correct the disruption but will try to extract the highest possible price from the buyer. When this price is not known in advance, or even the supplier's willingness to correct the disruption is unknown in advance, the initial purchase price may be difficult to negotiate. If the buyer anticipates having to pay an additional disruption cost, the buyer would try to incorporate this cost in the purchase price and insist on the lower purchase price. At the same time, the supplier may prefer a higher purchase price, and may be willing to fix the disruption at a reasonable price but may not have any way to make the buyer trust it. Consequently, the transaction may not take place to begin with.

There are two structural methods that have been suggested in the literature to deal with this problem, and these are two methods we investigate. If there is a long-term relationship between the buyer and the supplier, the supplier has an economic incentive to uphold its reputation in order to earn profitable future business. If the relationship is short-term and reputation does not enter into consideration, a possibility to renegotiate in the event of disruption may mitigate the problem.

We also consider two behavioral aspects of the negotiation. One is communication, and the second is the structure of the negotiation itself. In treatments with communication, this communication is non-binding. The two bargaining structures we consider are, the take-it-or-leave it structure (that we call ultimatum bargaining) in which the buyer makes a purchase price offer to the supplier, which supplier can only accept or reject. If the supplier accepts the purchase price, and the disruption occurs, then the supplier can either fix the disruption for free (when renegotiation is not allowed) or offer the buyer a price (in the renegotiation phase, when renegotiation is allowed), which the buyer can either accept or reject. The second bargaining structure is free form bargaining, in which the players can exchange offers and counter-offers for a pre-specified amount of time.

Our main findings are behavioral. First, the effect of long-term relationships and the ability to renegotiate is directionally consistent with benchmarks derived from an analytical model that assumes rational self-interested players. This is the case even though our data exhibits several systematic deviations from the analytical benchmarks, namely, that certain proportion of initial negotiations do break down, and the buyer extracts only about 60% of the channel expected surplus even in take-it-or-leave-it treatments.

Our second behavioral finding is that suppliers sometimes fix the disruptions even with no economic incentive to do so. In fact, in treatments with non-binding communication but without renegotiation, suppliers fix the disruption about 50% of the time.

Our third behavioral finding is that non-binding communication has a major positive effect - it decreases inefficiencies from transaction break-down, as well as from the wrong party fixing the disruption. Content analysis that we performed on the messages shows that a large proportion of conversations include informal commitment, from the supplier to the buyer, to correct the disruption in the event it happens. Supplier trustworthiness varies by treatments, and in treatments in which suppliers keep their words more often, transactions are completed successfully more often.

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Appendix: Instructions for RN treatment

Instructions

You are about to participate in an experiment in the economics of decision-making. If you follow these instructions carefully and make good decisions, you will earn money that will be paid to you in cash at the end of the session. If you have a question at any time, please raise your hand and the experimenter will come to your station and answer it. We ask that you not talk with one another for the duration of the experiment.

The unit of exchange in all the transactions is called experimental currency unit (ECU). At the end of the session, your earnings in ECUs will be converted to US dollars at a pre-specified rate of 20 ECU for 1 USD. These earnings will be added to your $5 show-up fee, displayed on your screen, and paid to you in cash at the end of the session.

In this experiment, you will be randomly assigned a role of either **Buyer** or **Seller**.
Your role will remain the same for the duration of the experiment.

The session consists of a pre-determined number of rounds that is at least 18 but not more than 24. In each round, you will be randomly matched with one other person in the room who has a different role than you. Note you will be matched with a **different person** every round.

How you earn money

In this experiment the Buyer and the Seller negotiate over the **Sales Price** and **Delivery Price** of some product. Each round there will be either a 30% or a 70% chance of a delivery problem that will result in additional cost. At the beginning of each round you will know the probability of a delivery problem this round.

The value of this product to the Buyer is 50 ECU. The production cost of this product to the Seller is 10 ECU. In the **first stage** the Buyer and Seller negotiate over the Sales Price. The first stage will last 4 minutes (this time will change to 2 minutes after the first two rounds). During this time the Buyer and the Seller can make offers and counteroffers, as well as use the chat window to communicate.

If first stage time runs out before you agree on a Sales Price, the round ends with both participants earning zero from the round.

Buyer Profit = 0
Seller Profit = 0

If the Buyer and Seller agree on a Sales Price during the first stage, the experiment will progress to the **delivery stage**. During the Delivery Stage, a delivery problem will occur with given probability (either 30% or 70%). If the delivery problem does not occur, the round ends and both players earn:

Buyer Profit = 50 – Sales Price
Seller Profit = Sales Price – 10

If the delivery problem occurs, the seller's cost is 5 ECU if he fixes the delivery problem. The buyer's cost is 20 ECU if he fixes the delivery problem. The Buyer and the Seller will negotiate again about the **Delivery Price** that the Buyer will pay to the Seller to fix the delivery problem. If the Buyer and Seller do not agree on the Delivery price, the Buyer will fix the delivery problem (at a cost of 20 ECU). The delivery stage will last 4 minutes (2 minutes after the first two rounds).

If the Buyer and the Seller agree on a Delivery Price then they earn:

Buyer Profit = 50 – Sales Price – Delivery Price
Seller Profit = Sales Price – 10 + Delivery Price - 5

If delivery stage time runs out before the Buyer and the Seller agree on a Delivery Price, the Buyer will have to fix the delivery problem and players earn:

Buyer Profit = 50 – Sales Price - 20
Seller Profit = Sales Price – 10

At the end of each round you will see negotiation outcome for this round, including the prices (if any) and resulting profits for both players. You will also see these results for all past rounds.

The Negotiation Interface

Figure1 shows Buyer's screen in the first stage negotiation.

On the left side of the screen you will see your role (Buyer or Seller), the Buyer value and Seller cost (50 and 10), the probability of a delivery problem this round (30% or 70%) and the cost of fixing the delivery problem if it happens (20 for the Buyer or 5 for the Seller).

On the right side, there are 4 windows:

- **Timer:** shows how many seconds remaining in this stage
  Result 1.
- **Accept offer window:** when the other player makes an offer, it will show in this window. If you want to accept this offer, **you should highlight the offer** which you intend to accept and click "Accept Offer" button. **Note**: clicking "Accept Offer" without highlighting an offer will not transmit your acceptance.

- **Make offer window:** you can send an offer to the other player by typing it into the text box and clicking "Make Offer" button. The other player will see your offer and can accept it.

- **Chat window:** you can communicate with the other player by typing your message into the chat window and pressing the "enter" key to send it.
  The agreement will be reached when one of the players accepts the other player's offer.

Figure 1 Buyer's negotiation screen (Seller's is similar)

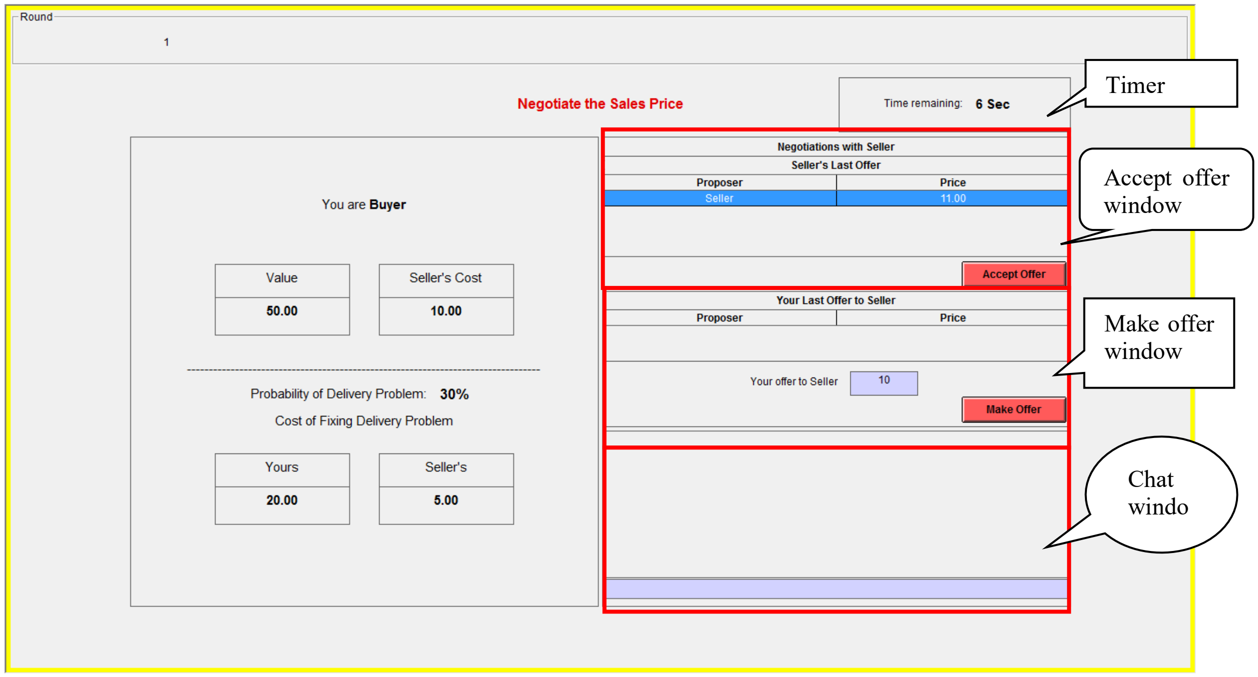

Figure 2 shows Buyer's screen in the delivery stage negotiation (It only happens when the delivery problem occurs).

You can chat, make offers and accept offers the same as in the first stage negotiation, but note that communication windows now appear on the left side of the screen.

Figure 2 Buyer's negotiation screen in the delivery stage (Seller's is similar)