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Communication in Vertical Markets: Experimental Evidence

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Abstract: When an upstream monopolist supplies several competing downstream firms, it may fail to monopolize the market because it is unable to commit not to behave opportunistically. We build on previous experimental studies of this well-known commitment problem by introducing communication. Allowing the upstream firm to chat privately with each downstream firm reduces total offered quantity from near the Cournot level (observed in the absence of communication) halfway toward the monopoly level. Allowing all three firms to chat together openly results in complete monopolization. Downstream firms obtain such a bargaining advantage from open communication that all of the gains from monopolizing the market accrue to them. A simple structural model of Nash-in-Nash bargaining fits the pattern of shifting surpluses well. Using third-party coders, unsupervised text mining, among other approaches, we uncover features of the rich chat data that are correlated with market outcomes. We conclude with a discussion of the antitrust implications of open communication in vertical markets.

JEL classification: L42, K21, C90, C70

Keywords: commitment, communication, experiments, vertical restraints

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1. Introduction

Whether vertical mergers can have anticompetitive effects remains a central question in the largest antitrust cases. For example, in January 2011, the U.S. Department of Justice applied the "most intense scrutiny ever for a planned media merger" before approving the takeover of NBC Universal (an upstream content provider) by Comcast (a downstream cable distributor) subject to a list of conditions (Arango and Stelter 2011). In April 2015, the European Competition Commission charged Google with the violation of favoring its affiliates over competitors in search displays (Kanter and Scott 2015).

An influential strand of the theoretical literature (summarized in Rey and Tirole 2007) connects the anticompetitive effects of vertical restraints to their ability to solve a commitment problem. An upstream monopolist serving downstream competitors might wish to offer contracts restricting output to the joint-profit maximum. It may fail to do so, however, because it has an incentive to behave opportunistically, offering one of the downstream firms a contract increasing their bilateral profits at the expense of all other downstream firms (the same logic extending to the bilateral contract with each downstream firm). In Hart and Tirole (1990), a vertical merger helps to solve this commitment problem by removing its incentive to behave opportunistically in a way that would harm the downstream unit with which it shares profits. While the upstream firm benefits from solving the commitment problem, overall the vertical merger has an anticompetitive effect on the market because prices rise and output falls. Similar anticompetitive effects can arise with vertical restraints aside from mergers including resale price maintenance (O'Brien and Shaffer 1992, Rey and Vergé 2004) and non-discrimination clauses (McAfee and Schwartz 1994).

The commitment problem is a somewhat delicate theoretical proposition. Depending on downstream firms' beliefs after receiving a deviating secret contract offer—not pinned down in a perfect Bayesian equilibrium—there can be multiple equilibria, with the commitment effect arising in some and not in others (McAfee and Schwartz 1994, and Rey and Vergé 2004). With *symmetric beliefs*, downstream firms reject deviating contracts generating negative profits for rivals because they infer that rivals received the same deviating contract. In this way, symmetric beliefs afford the upstream firm the ability to commit to monopolizing the market. With *passive beliefs*, on the other hand, deviation does not change downstream firms beliefs, increasing their willingness to accept deviating contracts, impairing the upstream firm's commitment power.

In the absence of a widely accepted refinement of perfect Bayesian equilibrium providing a firm theoretical foundation for selecting one or another equilibrium in this context, Martin, Normann, and Snyder (2001) turned to experiments to gauge the significance of the commitment problem. In their baseline treatment in which an upstream monopolist makes secret offers of nonlinear tariffs to two downstream firms, labeled *SECRAN*, they found that markets were rarely monopolized; industry profits averaged only two thirds of the joint maximum. By contrast, markets were regularly monopolized when either the upstream monopoly was vertically integrated with a downstream firm or when contracts were public. The experiments thus support the view that the commitment problem is genuine.

In this paper, we return to an experimental study of vertical markets with a new focus—on whether allowing firms to communicate can help them solve the commitment problem without resorting to vertical restraints. For the sake of comparison, we start with the same *SECRAN* treatment as Martin, Normann, and Snyder (2001). In addition to this baseline treatment without communication, we run a series of three treatments in which players can communicate whatever messages they want via a messenger-like tool. The communication treatments involve different levels of openness. One allows the upstream firm to engage in private two-way chat with each downstream firm. Another allows all three firms to engage in completely open (three-way) chat. A third is a hybrid of the other two, allowing players the option of using either or both of two- or three-way communication.

Communication is cheap talk in our experiments, so standard results (Crawford and Sobel 1982) leave open the possibility that adding this form of communication may have no effect on equilibrium. Yet we have a number of good reasons to believe communication might have real effects in our experiments. First, the vertical contracting game involves considerable strategic uncertainty. A downstream firm has to form an out-of-equilibrium belief and other firms have to conjecture what this belief is (or what the distribution of beliefs are in the case of heterogeneous beliefs). Communication could resolve some of this strategic uncertainty. Second, communication could help solve the commitment problem by allowing the upstream firm to make promises. Promises about rival contracts are not legally enforceable in our experiments but could still afford some commitment power if making a bald-faced lie involves a substantial psychological cost. Third, communication has been shown in previous experiments to reduce bargaining frictions (Roth 1995). On the other hand, communication could conceivably work in the opposite direction, impairing commitment. A conspiracy between the upstream and a downstream firm to deviate to a contract increasing their bilateral profits at the expense of the downstream rival would be easier to hatch if they could communicate privately. Of course, open communication precludes conspiracy, so open communication should either aid commitment or at worst have no effect. When firms are given the option of using either private or open communication, whether or not they are tempted to conspire, undermining commitment, is an interesting empirical question, which can be addressed by the hybrid treatment.

Along with the theoretical motives we just described for studying the effects of communication, we also have practical policy motives. Communication between vertically related firms is presumably the rule rather than the exception in the field,[1] the lab adds an important practical element to existing experiments. While a conversation between an upstream and a downstream firm would not violate antitrust law, communication in an open forum involving horizontally along with vertically related firms might raise antitrust concerns. Whether such communication has the potential to restrain competition has so far not been studied.

Our experimental results reveal a remarkably consistent pattern: increasing the openness of communication has a monotonic effect across virtually every market outcome and treatment we study. In the treatment without communication, the same severe commitment problem observed in Martin, Normann, and Snyder (2001) occurs: aggregate offered quantity is again much closer to the Cournot than the monopoly level. Two-way communication mitigates but does not solve the commitment problem, cutting the distance between aggregate offered quantity and the monopoly quantity about in half. Three-way communication cuts the remaining distance again in half, resulting in nearly complete monopolization of the market, particularly in the late rounds of play. Results for the hybrid treatment are between the other two, somewhat closer to the treatment with open communication. Further, we find that more open communication leads to more fluid bargaining, captured by an increasing rate of contract acceptance. The increase in acceptance rate, due in part to increasing confidence in the upstream firm's commitment to monopolize the market, is also due in part to a reduction in the upstream firm's tariff demands. Overall, the increase in acceptance rates leaves upstream profits essentially unchanged; the increase in industry profit accrues almost entirely to downstream firms.

That different communication treatments led to dramatically different divisions of surplus between upstream and downstream firms initially surprised us as we had not designed the treatments to look for such effects. In Section 5, we propose a simple bargaining model providing a straightforward explanation. In the absence of communication, the upstream firm makes take-it-or-leave-it offers; opening a communication channel affords participating subjects an opportunity to bargain. We assume bargaining outcomes are given by the widely used "Nash-in-Nash" solution concept proposed by Horn and Wolinksy (1988), recently given non-cooperative foundations by Collard-Wexler, Gowrisankaran, and Lee (2014). According to this solution concept, each bargain

[1] Lee and Whang's (2000) seminal article categorizes the kinds of information shared across vertical levels (inventories, sales, sales forecasts, order tracking, production plans, quality metrics), providing anecdotes for each involving well-known firms. Moving from anecdotal to survey evidence, 62% of the sample in Vanpoucke, Boyer, and Vereecke (2009) reported communicating with firms along the supply chain.

maximizes the Nash product assuming that other bargains occurring simultaneously are efficiently consummated. Our bargaining model delivers the same pattern of surplus division observed in the experiments: opening a two-way communication channel in the model causes the upstream firm to lose bargaining power and moving to three-way communication reduces upstream surplus yet further.

Section 6 delves into the content of communication to uncover correlations between content features and market outcomes. To deal with the difficulty in quantifying the rich content data, we take several analytical approaches: counting messages, employing third-party coders, and using text-mining methods to extract keywords. The communication stage appears to function like a bargaining process, with discussions successfully converging to a contract that is the one that ends up being offered. When the upstream firm is successful at committing to the monopoly outcome, his or her messages tend to mention deals given to all both downstream firms and market prices. Commitment sometimes breaks down when a subject tries to strike an exclusive deal to sell the entire industry quantity, inevitably leading to oversupply as exclusion proves unenforceable.

From a policy perspective, our results imply that some forms of communication can effectively function as an anticompetitive vertical restraint. In particular, allowing an upstream firm to discuss contracts with several downstream firms in a "smoke-filled room" (or simply to exchange public pronouncements) has the potential to substantially restrict output. On the other hand, if firms already have such forums for open communication, vertical mergers and restraints themselves may not raise further antitrust concerns.

Regarding its relationship to the literature, our paper is the first experimental study of communication in a vertically related market. Our paper is closest to the one on which we build, Martin, Normann, and Snyder (2001), which provides an experimental test of the theories of anticompetitive vertical restraints (vertical mergers, public contracts) put forth by the papers mentioned earlier (Hart and Tirole 1990, O'Brien and Shaffer 1992, McAfee and Schwartz 1994, Rey and Vergé 2004, Rey and Tirole 2007; see Avenel 2012 and Rey and Caprice 2015 for more recent developments). Other experiments in vertically related markets include Mason and Phillips' (2000) study of equilibrium when the upstream input is demanded by a Cournot duopoly in one market and perfectly competitive firms in another. Durham (2000) and Badasyan et al. (2009) analyze whether vertical merger mitigates the double-marginalization problem. Normann (2011) investigates whether vertical merger has an anticompetitive "raising rivals' cost" effect in a bilateral duopoly. None of these papers studies communication, the focus of the present paper.

Also related is the experimental literature on exclusive dealing (Landeo and Spier 2009, Smith 2011, Boone, Müller, and Suetens 2014). As in our setting, the vertical contract exerts an externality on other downstream firms. The nature of the externality is different: rather than secretly oversupplying a rival, an initial exclusive contract diverts demand that would otherwise prompt a more efficient upstream firm to enter, which then would supply other downstream firms at lower prices. Landeo and Spier (2009) and Smith (2011) show that communication between downstream firms reduces entry-deterring exclusion.

Our paper contributes to a large literature on cheap talk in experimental games. Theory suggests that potential gains from cheap talk are greatest in games of common rather than conflicting interests (Farrell and Rabin 1996). Consistent with theory, experiments find large gains from cheap talk in coordination games (see Crawford 1998 for a survey).[2] However, cheap talk also increases the rate of cooperation in dilemma games (Dawes, McTavish and Shaklee 1977, Isaac, Ramey and Williams 1984, Balliet 2010) in which neoclassical theory would suggest agreements to cooperate should be worthless. Our result that communication aids monopolization has a similar flavor, although decision making is more complex in our setting: final output is the result of a negotiation between upstream and downstream firms rather than being one firm's unilateral choice.[3,4]

Within the literature on cheap talk in experimental games, ours is closest to studies of the effect of cheap talk on bargaining. Adding a round of face-to-face communication before offers are made results in near perfect rates of agreement (Roth 1995). Typed messages—the sort of communication also used in our experiments—does not improve efficiency as much but still improves upon no communication (Brosig, Ockenfels and Weimann 2003, Andersson et al. 2010, Zultan 2012). Ours is the first to study how cheap talk between vertically related players affects bargaining with externalities. In this setting, the openness of communication becomes an important treatment variable. We find that private communication improves efficiency somewhat and open communication

[2]The closest in this literature is contemporaneous research by Grandjean et al. (2014). They report on three-player experiments involving a different base game from ours but similar communication treatments. Their base game is a coordination game with multiple Pareto-ranked equilibria, in which the Pareto-optimal one susceptible to coalitional deviations. They find that play of the Pareto-optimal equilibrium is promoted by open communication similar to our *Three Chat*.

[3]Several experimental industrial organization papers have the flavor of communication in a dilemma game. Anderson and Wengström (2007) analyze costly communication in Bertrand duopoly, finding that prices are higher and collusion more stable when communication is costly. Hinloopen and Soetevent (2008) and Bigoni et al. (2012) evaluate lenience programs in laboratory experiments with communication. Fonseca and Normann (2012) investigate Bertrand oligopolies with and without communication. Specifically, they analyze how the gain from communication is affected by the number of firms (ranging from two to eight). Cooper and Kühn (2013) study conditional cooperation: a simple cooperation game is followed by a coordination game, so the threat of coordinating on a payoff-inferior equilibrium in stage two is credible. They analyze what type of communication is most effective in achieving cooperation in this setup.

[4]Cheap talk has been found to achieve superior outcomes in trust games (Charness and Dufwenberg 2006). Although our vertically related markets are different from the standard trust game, they also have an element of trust: accepting a contract offer may only be profitable if the downstream firm trusts the upstream firm's promise (implicit or explicit) to restrict output traded to the rival firm.

still more, reaching 92% agreement rates.

2. Theoretical Framework

2.1. Market Model

Consider a simplified version of the model due to Rey and Tirole (2007).[5] The market has a vertical structure shown in Figure 1, with a monopoly upstream firm, U, and two downstream firms, D_i, $i = 1,2$. The upstream firm produces an intermediate product at zero cost. The downstream firms transform this product on a one-for-one basis, also at zero cost, into a final good sold to consumers. Consumers have inverse demand $P(Q)$ for this homogeneous final good.[6]

The timing is as follows. First, U offers contracts (x_i, T_i) to each D_i specifying a quantity x_i and fixed tariff T_i. Second, the D_i simultaneously decide whether to accept $(a_i = 1)$ or reject $(a_i = 0)$ their contract offers. The rest of the game proceeds deterministically from those decisions. Each D_i produces $q_i = a_i x_i$ resulting in total output $Q = q_1 + q_2$. Profits are $a_1 T_1 + a_2 T_2$ for U and $P(Q)q_i - a_i T_i$ for D_i.

To set some benchmarks, let $Q^m = \text{argmax}_Q P(Q)Q$ be the monopoly quantity for this market and $\Pi^m = P(Q^m)Q^m$ be monopoly profit. Let q^c be a firm's equilibrium quantity from Cournot competition between two firms in a market in which the vertical structure from Figure 1 were compressed into a single level. That is, defining the best-response function

$$BR(q) = \underset{\tilde{q}}{\text{argmax}}\, P(\tilde{q} + q)\tilde{q},$$

q^c is the fixed point $q^c = BR(q^c)$. Let $\pi^c = P(2q^c)q^c$ be a firm's Cournot profit.

2.2. Commitment Problem with Secret Contracts

To understand the nature of the commitment problem with secret contacts, suppose first that contracts are public, meaning that each D_i can see the contract offered to its rival. If so, U can extract

[5] Rey and Tirole (2007) is itself a simplified version of a number of earlier papers including Hart and Tirole (1990) and McAfee and Schwartz (1994). We modify Rey and Tirole (2007) in three ways. First, contracts here specify a single bundle at a fixed tariff rather than a tariff function. Second, downstream firms make a simple accept/reject decision rather than choosing some continuous quantity. Third, upstream marginal cost is set to $c = 0$ to simplify the analysis and reflect experimental conditions to follow.

[6] Assume $P(Q)$ has properties ensuring that the Cournot game formed by compressing the vertical structure in Figure 1 into a single level is well behaved. In particular, the resulting profit functions are strictly quasiconcave and actions are strategic substitutes. A sufficient condition is $P'(Q) + P''(Q)Q < 0$ for all Q.

the monopoly profit in equilibrium. For example, by offering the contract $(Q^m/2, \Pi^m/2)$ to each D_i. The D_i earn zero profit whether or not they accept so they accept in equilibrium.

Secret contracts transform the model into a dynamic game of imperfect information. The relevant solution concept is perfect Bayesian equilibrium, requiring strategies to be best responses given posterior beliefs and requiring posterior beliefs to be formed using Bayes' rule along the equilibrium path. Bayes rule does not pin down beliefs off the equilibrium path, and different assumptions about out-of-equilibrium beliefs give rise to different perfect Bayesian equilibria.

One assumption, called *symmetric beliefs*, is that D_i believes its rival receives the same deviating contract. Under such beliefs, U can obtain the same monopoly outcome as it did with public contracts, that is, having both D_i accept contract offers $(Q^m/2, \Pi^m/2)$. To see that this is an equilibrium, note that if U deviates to some quantity x^d in its contract offer, D_i would be unwilling to pay a fixed tariff greater than $P(2x^d)x^d$, which is obviously no greater than the fixed fee $\Pi^m/2$ that U charged in the equilibrium contract.[7]

Another assumption, called *passive beliefs*, is that after receiving a deviating offer, D_i continues to believe its rival receives the equilibrium contract. These beliefs make deviation particularly attractive, rendering the monopoly outcome unstable. Formally, there will always exist a strictly profitable deviation unless equilibrium firm quantity q^* is best response to itself, that is, $q^* = BR(q^*)$. But as we saw above, the Cournot output q^c is the unique quantity satisfying this equation. Hence the equilibrium contract offer is (q^c, π^c), which both D_i accept. Here we see the commitment problem: if the D_i have passive beliefs, U cannot restrict output to the monopoly level despite being an upstream monopolist.[8]

Because neither the monopoly outcome—predicted when all downstream firms have symmetric beliefs—nor the Cournot outcome—predicted when they all have passive beliefs—fit their experimental results well, Martin, Normann, and Snyder (2001) proposed a model of heterogeneous beliefs. Each D_i holds symmetric beliefs with probability $s \in [0,1]$ and passive beliefs with $1-s$. The authors show that there exists a threshold $\hat{s}$, the value of which depends on the experimental parameters, such that for $s \in (0, \hat{s})$ the extremal perfect Bayesian equilibrium involves U offering

[7] D_i would reject a tariff greater than $P(2x^d)x^d$ if it believes D_i its rival accepts the deviating contract. If one or both downstream firms rejects the deviating contract, deviation would be certainly less profitable than the equilibrium $(Q^m/2, \Pi^m/2)$ contracts to each.

[8] While symmetric and passive beliefs are the main cases typically studied, other beliefs are possible. McAfee and Schwartz (1994) proposed *wary beliefs*, that after receiving a deviating offer D_i believes its rival receives and accepts a contract that is the best response to this deviation. In the present context in which downstream firms essentially engage in Cournot competition, wary beliefs turn out to select the same perfect Bayesian equilibrium as passive beliefs. In most of the rest of the paper, for brevity, statements that apply equally to wary and passive beliefs will just mention passive beliefs. Rey and Vergé (2004) show that wary and passive beliefs lead to different equilibrium outcomes if downstream firms engage in Bertrand competition.

the Cournot duopoly output, q^c, as with passive beliefs. However, the fixed tariff is higher, $T_i > \pi^c$, inducing D_i to respond with an acceptance probability strictly less than one. The heterogeneous-beliefs model could rationalize the modal contract offers observed in the experiment, of the form (q^c, T_i) with $T_i > \pi^c$, as well as the observed acceptance rates.

2.3. Communication and the Commitment Problem

We modify the benchmark model by adding a communication stage prior to contract offers. Since this is just cheap talk, it is always possible that communication—whether between two or among all three parties—changes nothing. The outcome of the communication stage can always be a babbling equilibrium with completely uninformative communication.

On the other hand, it is conceivable that communication could enhance U's commitment power. In two-way communication, D_i could extract a promise from U not to oversupply its rival. While this would be an empty promise coming from a neoclassical agent, a behavioral agent may face psychic costs from reneging on an explicit promise.[9] Simply discussing beliefs may resolve a lot of strategic uncertainty and perhaps persuade D_i to hold favorable (symmetric) beliefs.

It is also conceivable that two-way communication could exacerbate the commitment problem. A deviating contract specifying a higher output and tariff than expected may be unappealing. U might be able to increase the appeal by adding an explanation that the deviation is the best response to the equilibrium offer, a special deal just for D_i. Two-way communication may destabilize the monopoly outcome.

While the effect of two-way communication on U's commitment power is ambiguous, open communication among all three market participants seems likely to only enhance U's commitment power. U can describe exactly the symmetric offers it will make and can urge the D_i to reject any other offers. The downstream firms observe everything U says, so they can verify that U has no opportunity to cut side deals with rivals or convince rivals to accept deviating offers.

3. Experimental Design

We build on the experimental design of Martin, Normann, and Snyder (2001). We will maintain their baseline treatment—which they called *SECRAN* because it involves secret contracts with randomly re-matched players—as our baseline treatment with no communication here. We will then introduce treatments allowing for different forms of communication.

[9] See Gneezy, Rockenbach and Serra-Garcia (2013), Serra-Garcia, van Damme and Potters (2013) and the references cited therein for recent studies on lying aversion.

The market, shown in Figure 1, involves three subjects, one playing the role of the upstream firm (called a producer in the experiment) and two playing the role of downstream firms (called retailers in the experiment). The upstream player moves first, making a take-it-or-leave-it offer (x_i, T_i) to each D_i, where x_i had to be an integer in $[0, 10]$ and T_i had to be an integer in $[0, 120]$. After observing its own contract only, D_i chooses whether to accept ($a_i = 1$) or reject it ($a_i = 0$). These decisions result in each D_i supplying $q_i = a_i x_i$ to the final-good market, for a total supply of $Q = q_1 + q_2$. Market price $P(Q)$ is calculated from the discrete demand function in Figure 2A. All firms produce at zero cost. Thus profits are $\pi_U = a_1 T_1 + a_2 T_2$ for U and $\pi_{Di} = P(Q)q_i - a_i T_i$ for D_i. Let $\pi_D = \pi_{D1} + \pi_{D2}$ denote total downstream profit and $\Pi = \pi_U + \pi_D$ denote market profit. Figure 2B graphs the profit function in the experiment; it is concave, achieving a maximum of $\Pi^m = 100$ at an output of $Q^m = 2$. The Cournot outcome involves market output $Q^c = 4$, firm output $q^c = 2$, and industry profit $\Pi^c = 72$.

Participants were randomly assigned to their roles (U or D_i), which they played each round for the entire course of the session. We recruited 15–21 subjects for each session, allowing us to form 5–7 markets. Each session consisted of 15 rounds of game play. The three subjects constituting a market were randomly re-matched before every round to minimize effects of repeated interaction. (Experimenter effects aside, observations may be dependent within sessions but should be independent across sessions because new subjects were recruited for each session.) After each round, each D_i learned his profit; U was told his own and each of the two downstream firm's profits that round. All these design features were explained to subjects in the instructions.

We conducted four different treatments. Our baseline treatment replicates the *SECRAN* treatment from Martin, Normann, and Snyder (2001). To compare the communication element with other treatments, in particular that there is no communication involved, we relabel this treatment *No Chat*. The remaining treatments introduced the possibility of communication using an instant-messaging technology via a chat window. In *Two Chat*, U could engage in private, two-way communication with each D_i. D_1 and D_2 could not communicate with each other, and D_i could not observe U's communications with his competitor. U had separate chat windows for each D_i on its screen; each D_i had only one chat window on its screen through which it communicated to U. In *Three Chat*, U, D_1, and D_2 could freely communicate with each other. Whatever a player typed in his chat window was displayed to all three players in the market. It was not possible to exclude one of the players and engage in two-way chat. *Choose Chat* allowed each player to send each message via whichever communication channel—private communication between vertical levels as in *Two Chat* or the open communication as in *Three Chat*—he wanted. All channels were open in separate windows allowing receivers to know whether the message was sent privately or publicly.

Every round of *Two Chat*, *Three Chat*, and *Choose Chat* began with a chat stage prior to U's making contract offers. Except for threats to be carried out outside the lab or information that could be used identify subjects, the content of the chat was unrestricted. The duration of the chat stage turned out to be a delicate experimental-design choice. We wanted to allow subjects enough time for full communication yet not so much that they became bored, possibly leading to distorted behavior. Equalizing chat time across treatments leads to different chat time per channel in treatments with different channels; we specified chat times balancing these considerations. In *Two Chat*, subjects had 90 seconds to chat during the first five rounds, reduced to 60 seconds for the last ten rounds. The communication stage lasted 60 seconds in all 15 rounds in *Three Chat* and 90 seconds in all 15 rounds in *Choose Chat*.[10] Subjects could not leave the chat stage before the time expired. Apart from the added chat stage, the design of the communication treatments was otherwise identical to *No Chat*.

Subjects were invited using the ORSEE system (Greiner 2015). Upon arrival in the lab, each was assigned to a cubicle and provided with instructions, reproduced in Appendix C, available online. The instructions were the same in all treatments except for a short section about the chat stage added in the communication treatments. After reading the instructions, subjects were allowed to ask questions privately in their cubicles. Subjects were then informed about their role in the experiment (U or D) and the experiment proceeded. The experiments were programmed in Z-tree (Fischbacher 2007).

It is possible for downstream firms to earn negative payoffs. To offset this possibility as well as to provide a payment for showing up, subjects playing the D role received an initial endowment of 200 ECU (experimental currency units). Subjects playing the U role received an initial endowment of 60 ECU. At the end of the experiment, participants were paid in euros, exchanged at a rate of one euro for each 40 ECU. Including the show-up fee, participants earned about 14 euros on average (19 euros on average for subjects playing the role of U, 12 for subjects playing the role of D).

We conducted a total of 16 sessions, four sessions for each of the four treatments. All sessions were run at DICElab of the University of Duesseldorf from November 2013 to February 2015. Each session lasted for about one hour. In total, 285 subjects participated.

[10]The shorter chat time in certain rounds appears not to have unduly constrained subjects. For example, in rounds 6–15 of *Two Chat* having the shorter chat stage, a subject were typing at the last second in only 15% of the cases, similar to the 12% in rounds 1–5 with the longer chat stage. A majority of these last-second messages involved a confirmation or pleasantry. That boredom is a possible concern is embodied in one subject's chat message, "Boooooooooooooooooooooooooooooooooooooooooooring."

4. Results

To streamline the discussion of our results, we will confine the initial discussion to the distinct treatments *No Chat*, *Two Chat*, and *Three Chat*. Once the relationship between *Two Chat* and *Three Chat* is understood, we can study which one the hybrid treatment *Choose Chat* is closer to.

The top part of Table 1 can be interpreted as summary statistics for the main experimental variables. It regresses these variables (X, T_i, a_i, ...) on an exhaustive set of treatment indicators, suppressing the constant. This specification allows us to recover the treatment means of the variables as the coefficients on the indicators. The advantage of the regressions is that the supplied standard errors allow statistical tests of the differences between the means, provided in the bottom part of the table. We compute White (1980) heteroskedasticity-robust standard errors clustered by session, allowing for dependence among observations arising from the same set of interacting subjects, throughout the analysis.

Comparing the results for the *No Chat* treatment to those for *SECRAN* from Martin, Normann, and Snyder (2001) provides a consistency check. Total offered quantity $X = x_1 + x_2$ averaged 3.64 in *SECRAN*,[11] nearly identical to the 3.68 in *No Chat* (see the first column of Table 1). The averages for total accepted quantity $Q = q_1 + q_2$ are also almost identical—2.41 in *SECRAN* versus 2.47 in *No Chat*—as are the averages for industry profit Π—68.2 in *SECRAN* versus 68.3 in *No Chat*. Upstream firms earned somewhat higher profit π_U in *SECRAN* (mean 51.2) compared to *No Chat* (mean 45.3). The remarkable consistency between *SECRAN* and *No Chat* suggests that *No Chat* is a good baseline for comparing treatments with communication.

4.1. Offered Quantity

We begin by analyzing total offered quantity, X. This single variable captures whether U is able to solve the commitment problem. Table 1 shows that the mean of X is highest in *No Chat*, 3.68, falling to 2.98 in *Two Chat*, falling further to 2.41 in *Three Chat*, close to the monopoly output of 2. These results are consistent with more open communication facilitating commitment and monopolization.

The bottom part of the table provides formal statistical tests of the differences between treatment means. It reports differences between all combinations of treatment-indicator pairs, providing

[11] The means for *SECRAN* reported here differ from those reported in Table 2 of Martin, Normann, and Snyder (2001). To reduce noise from inexperienced play, they dropped the first five rounds of each session. We are primarily interested in communication, which may have the largest effects in early rounds of play, so have chosen to focus on results for all rounds. Martin, Normann, and Snyder (2001) report results for all rounds, not in Table 2, but in Figures 3–6, in the form of histograms.

the appropriate standard errors for these differences. The fall in the mean of X from *No Chat* to *Two Chat* of 0.70, statistically significant at the 1% level, represents 40% of the gap between *No Chat* and the monopoly output. The fall from *Two Chat* to *Three Chat* of 0.57, statistically significant again at the 1% level, brings offered quantity close to the monopoly level of $X = 2$ (although a formal statistical test rejects equality at the 1% level).[12]

Figure 3 provides a histogram for X for the various treatments in Panel A. The white bars for *No Chat* show a mode at $X = 4$ and considerable additional mass on yet higher offers. Moving from the white to the light grey bars, representing *Two Chat* observations, shifts the mass of the distribution from these high levels to the lower levels $X = 2$ and $X = 3$, and $X = 2$ becomes the mode. Moving to the black bars for *Three Chat* piles almost all the mass in the monopoly ($X = 2$) bin.

Table 2 can be used to test for the statistical significance of these shifts in the histogram. The first column is a linear probability model regressing a 0–1 indicator for whether $X = 2$ on a set of treatment indicators, again suppressing the constant. This specification allows us to recover the relative frequency of the monopoly outcome (graphically, the height of the bars in Figure 3A in the $X = 2$ bin) directly from the coefficients on the treatment indicators. The reported standard errors allow statistical tests of the difference across treatments, which are reported in the lower part of the table. *Three Chat* is 32 percentage points more likely to generate monopoly offers than *Two Chat*, a difference significant at the 1% level. *Two Chat* is 18 percentage points more likely to generate monopoly offers than *No Chat*, although this difference does not achieve significance at the 10% level.[13] The next column regresses an indicator for the event $X \geq 4$, that is, that the offers total to at least the Cournot output. *Three Chat* is 17 percentage points less likely than *Two Chat* to have offers this high, and *Two Chat* is 23 percentage points less likely than *No Chat* to have offers this high, both differences significant at the 5% level. We conclude that increasing the openness of communication from *No Chat* to *Two Chat* to *Three Chat* results in a substantial and generally statistically significant shift in the mass from the Cournot to the monopoly bin.

The fifth column of results in Table 2 measures symmetry implicit in offered quantities. It presents estimates from a linear model of the probability that the two contract offers involve symmetric quantities, $x_1 = x_2$. As noted in Section 2, theory predicts that the *No Chat* treatment should yield a symmetric equilibrium whether players hold symmetric or passive beliefs—the beliefs were shown to affect equilibrium quantities, not the symmetry between them. The estimate on the *No*

[12] As we will see, the mean of market quantity Q, 2.05 in *Three Chat*, is yet closer to the monopoly level of 2, the difference now only significant at the 6% level.

[13] As we will see in Table 3, the difference is significant at the 10% level after dropping the first five rounds, reflecting noisier play, from the sample.

Chat indicator implies that 68% of the offers in that treatment involve symmetric quantities. A large majority of observations thus comport with the symmetry prediction. Yet from a more pessimistic view, almost a third of the observations are asymmetric (perhaps not an overwhelming rejection of the theory given the noisy nature of experimental play).

That off-equilibrium-path outcomes are actually observed in the experiment provides an opportunity to learn about out-of-equilibrium beliefs. In Section 2, we hypothesized that, in an environment of heterogeneous and fluid beliefs, communication could serve to coordinate players on symmetric beliefs, which are beneficial for monopolization. The quantity offers observed by downstream firms in the *Two Chat* treatment would not justify their shifting toward more symmetric beliefs. The estimate on the *Two Chat* indicator in Table 2 shows that the percentage of symmetric offers did not increase but in fact slightly declined relative to *No Chat*. Evidently the private communication channel helps with monopolization but not by promoting symmetric beliefs, if anything impairing symmetry. By contrast, the open communication associated with *Three Chat* promotes symmetry: 88% of the offers involve symmetric quantities, over 20 percentage points more than *No Chat* or *Two Chat*, differences statistically significant at the 1% level. As the last column of results shows, the results for symmetry are similar if we take a stricter definition of symmetry, requiring all contractual terms (x_i and T_i) to be the same.

4.2. Tariffs

We next turn to the other variable in the contract, the fixed tariff T_i. Because it is a pure transfer between parties, this variable can help measure how communication affects the division of surplus in the experiment. The mean reported in Table 1 falls from 34.7 ECU in *No Chat* to 31.4 in *Two Chat* to 26.9 in *Three Chat*. The means in *No Chat* and *Two Chat* are not significantly different from each other, but the mean in *Three Chat* is significantly lower than the others at the 5% level.

Definitive inferences are difficult to draw from the raw means of T_i, however, because x_i varies systematically across treatments as well.[14] To purge these quantity effects, the third column of Table 1 restricts the sample to contracts with $x_i = 1$. Now we see a decrease in the mean of T_i of 6.4 from *No Chat* to *Two Chat*, significant at the 1% level, and a further decrease of 3.2 from *Two Chat* to *Three Chat*, significant at the 5% level. These results suggest that starting from a situation in which U makes contract offers to the D_i, layering increasingly open communication allows the

[14] To understand why this fact can pollute inferences, consider the contracts $(1,30)$ and $(2,30)$. While they specify the same fixed tariff of 30, if D_i has symmetric beliefs, the first contract is more generous, providing him with a profit of 20 compared to 6 for the second contract. With passive beliefs, the computation is less clear because the generosity of a contract depends on whether it is an equilibrium or out-of-equilibrium offer.

D_i to extract a greater share.

The fall in T_i from *No Chat* to *Three Chat* holding x_i constant is an intriguing result. The drop in tariff from *No Chat* to *Two Chat* is consistent with previous experimental work: introducing pre-play communication in the ultimatum game leads to more generous splits for the responder (Zultan 2012, using video chat). The further fall in T_i from *Two Chat* to *Three Chat* is to our knowledge a new experimental result. We will return to this result in Section 5, showing how it can be rationalized in a standard bargaining model.

4.3. Acceptance Behavior

Having analyzed upstream behavior, we next turn to downstream behavior, embodied in the acceptance decision a_i in Table 1. The acceptance rate rises from 70% in *No Chat* to 85% in *Two Chat* to 89% in *Three Chat*. Table 1 shows that the 15% increase from *No Chat* to *Two Chat* is significant at the 1% level but the further increase from *Two Chat* to *Three Chat* is insignificant.

The raw means of a_i provide a reduced-form measure of how acceptance rates vary with communication when the contract offers underlying the acceptance decision are also allowed to vary. The fifth column of Table 1 sheds light on how acceptance rates vary with communication holding contract offers constant. This column regresses a_i on the treatment indicators controlling for the contract's terms in a semi-parametric way by restricting the sample to observations with $x_i = 1$ and including a second-order polynomial in standardized values $\tilde{T}_i$ of the tariff (standardized by subtracting the sample mean and dividing by the variance). With this sample restrictions and added controls, the coefficients on the treatment indicators can be interpreted as the acceptance rates of a contract offering one unit at the sample mean tariff.

Controlling for contract offer reduces the gap between the *No Chat* and *Two Chat* acceptance rates as well as the *Two Chat* and *Three Chat* acceptance rates. We conclude, therefore, that the main reason acceptance rates rise from *No Chat* to *Two Chat* to *Three Chat* is not that open communication somehow makes the D_i more receptive to offers but because U offers more generous contracts, involving more profitable output levels and lower tariffs.

4.4. Market Output

The rest of the variables for which we provide summary statistics in Table 1 are deterministic functions of subjects' actions in the experiment. Still they deserve some study because these would be the observables in a non-experimental market.

The mean for market output Q in *No Chat*, 2.47, is about the same as in *Two Chat*, 2.49. The constancy of the mean between these treatments masks a significant change to the distribution of Q, shown in Figure 3B. Moving from *No Chat* to *Two Chat* concentrates the distribution from above and below on the mode at the monopoly outcome. The concentration from above is inherited from the effect that communication helps monopolize the market resulting in more offers of $X = 2$. The concentration from below is inherited from the increase in the raw acceptance rate with better communication, reducing the mass in the $Q = 0$ and $Q = 1$ bins, which, except for one case out of 720, never arise unless there has been a rejection. Looking at the coefficient differences in the sixth column of Table 2, the monopoly outcome ($Q = 2$) is 17 percentage points more likely in *Two Chat* than *No Chat*, significant at the 10% level.

It should be emphasized that firms and consumers are not indifferent between treatments with the same mean for Q. Due to the concavity of industry profit in Q, a treatment which averages together values of Q well above the monopoly level with zero values from contract rejections will be much less profitable than a treatment in which Q varies less around its mean of 2.49. The opposite is true for consumer surplus, which is convex in Q. These facts will come into play in the analyses of profits and consumer surplus in following subsections.

Moving from *Two Chat* to *Three Chat* reduces the mean of Q by 0.44 according to Table 1, significant at the 1% level. The mean of Q is 2.05 in *Three Chat*, very close to the monopoly output. Examining the full distribution of Q, it turns out the monopoly outcome ($Q = 2$) is 26 percentage points more likely in *Three Chat* than *Two Chat* according to Table 2, and Cournot or higher outputs ($Q \geq 4$) 14 percentage points less likely, both differences significant at the 5% level or better.

Thus, more communication leads to more monopolization. *Three Chat* is conducive to monopolization not just relatively to the other treatments but in an absolute sense, attaining the monopoly outcome in a remarkable 81% of the observations. Free communication facilitates nearly complete monopolization whether measured in terms of offered or actual quantity.

4.5. Profits

An analysis of profits will let us put a monetary value on the differences across treatments uncovered so far. First consider industry profit, Π. Table 1 shows that the mean rises from 68.3 to 82.5 to 89.5 ECU. The table shows that the 14.2 increase in the mean of Π from *No Chat* to *Two Chat* and 7.0 increase from *Two Chat* to *Three Chat* are statistically significant at the 5% level or better. These profit increases are the direct consequence of the concentration of the distribution of Q on the bin ($Q = 2$) that maximizes industry profits. Mean profit in *Three Chat*, 89.5, is close to the monopoly profit of 100 (although a formal statistical test rejects equality at the 1% level).

Moving to the allocation of profit across industry levels, U's profits change non-monotonically across the treatments, increasing from 45.3 in *No Chat* to 51.1 in *Two Chat* and then falling to 42.5 in *Three Chat*. The substantial increase in the acceptance rate offsets a small decrease in tariff to cause the 5.8 increase in π_U from *No Chat* to *Two Chat*, significant at the 5% level. The adverse bargaining effects for U in moving from *Two Chat* to *Three Chat* ends up reducing π_U by 8.6, significant at the 5% level. The first rise and then fall leads to a fairly similar value of π_U between *No Chat* and *Three Chat*.

Although U's profit level changes non-monotonically, its profit share, $s_U = \pi_U/\Pi$, shows a monotonic pattern in Table 1, falling from 0.63 in *No Chat* to 0.59 in *Two Chat* to 0.47 in *Three Chat*. More—and more open—communication leads U to obtain a smaller share of a growing pie. The biggest drop in s_U (and only significant one), however, occurs in the move from *Two Chat* to *Three Chat*. As discussed further in Section 5, the move from *Two Chat* to *Three Chat* could represent a change in the structure of bargaining, which, if bargaining is characterized by the Nash-in-Nash solution, ends up eroding U's bargaining surplus. This bargaining theory explains the fall in s_U in *Three Chat*.

So far we have examined how s_U changes across treatments. We have not remarked yet on the fact that the mean of s_U in *No Chat* is 63%, considerably less than the 100% theory would predict for that treatment in which U makes take-it-or-leave-it offers. It is standard in ultimatum games to find a more equitable split of surplus than the subgame-perfect equilibrium predicts (see Roth's 1995 review). Martin, Normann, and Snyder (2001) found similar results in their analogous *SECRAN* treatment, devoting all of Section 6 to evaluating alternative explanations.

Downstream firms gain both in absolute and relative terms from more and more open communication. Table 1 shows that the sum of downstream profits, π_D, rises from 23.0 ECU in *No Chat* to 31.4 in *Two Chat* to 47.1 in *Three Chat*, both increases significant at the 5% level or better, as shown in Table 1. Downstream profit is so high in *Three Chat* that they obtain a majority of the profit (53% compared to U's 47%).

4.6. Consumer Surplus

The last column of Table 1 presents results for consumer surplus, *CS*. The mean of *CS* falls from 39.7 ECU in *No Chat* to 34.1 in *Two Chat* to 17.1 in *Three Chat*. The 5.6 fall from *No Chat* to *Two Chat* is not statistically significant, but the 17.1 fall from *Two Chat* to *Three Chat* is, at the 1% level. This large decline in *CS* between these treatments is due in part to the large reduction in the mean of Q, from 2.49 to 2.05, as consumers prefer higher quantities. Another factor relates to the convexity of *CS* in Q, which implies that consumers prefer more rather than less variance in Q. The reduction in the spread of Q from *Two Chat* to *Three Chat* shown in Figure 3B leads to a further reduction in *CS* between those treatments. This factor leads to the fall in *CS* moving from *No Chat* to *Two Chat* despite the increase in mean Q between the treatments. Hence we see that more and more open communication can lead to substantial consumer harm.

The monotonic increase in profit and decrease in consumer surplus offset each other, leading to fairly small changes in mean welfare across treatments. While U's ability to monopolize the market is improved, reducing welfare, the decline in rejections (and decline in variance of Q, which is socially beneficial because, like profit, welfare is concave in Q) keeps welfare from falling very far in *Three Chat*. Whether these fairly benign welfare results carry over to markets outside the lab depends on how relatively important in real markets are the offsetting factors found in the lab. The possibility that enhanced monopolization may be the dominant factor in real markets, coupled with the unambiguous and large harm to consumers found in our experiments, leave ample cause for policy concern.

4.7. *Choose Chat* Treatment

We now pick up the analysis of the *Choose Chat* treatment. The results show a clear pattern. For every variable in Table 1, the *Choose Chat* mean is between the means of the treatments of which *Choose Chat* is a hybrid, that is, the *Two Chat* and *Three Chat* treatments. For example, the 2.55 mean of X in *Choose Chat* is between the 2.98 for *Two Chat* and 2.41 for *Three Chat*. Comparing the *Choose Chat* – *Two Chat* difference to the *Three Chat* – *Choose Chat* difference at the bottom of Table 1, in every column the magnitude of the *Choose Chat* – *Two Chat* difference is weakly larger, meaning that the results for *Choose Chat* are closer to *Three Chat* than *Two Chat*.

Evidently, allowing players the option to communicate both privately and openly affords almost as much commitment power as restricting them to communicate openly. The results suggest that open communication can lead to monopolization even if, as is realistic, the upstream and downstream firms are also free to communicate privately.

4.8. Trends Within Session

The analysis so far has considered average effects over all rounds of play. In this subsection we explore whether the results show convergence or divergence trends as players gain experience in the market from early to late rounds. To uncover these trends, Table 3 repeats the regressions from

Table 1 interacting the treatment indicators with indicators for the initial and end periods. For example, *No Chat*$_0$, is the interaction between the *No Chat* indicator and an indicator for rounds 1–5, and *No Chat*$_1$ is the interaction between *No Chat* and an indicator for rounds 6–15. The bottom of the table reports the change in the treatment indicator across the two periods along with the appropriate standard error, allowing an assessment of the significance of the change.

The results show a fairly consistent trend. *No Chat* shows few significant changes over time. By contrast, almost all the variables for the treatments with communication have significant changes, many at the 1% level. What this pattern reveals is that subjects played fairly consistently over the rounds in *No Chat* but took several rounds to settle down to how they eventually played in the communication treatments. Apparently subjects needed more time to understand the functionality of communication. As play progresses into the later rounds, the communication treatments diverge from *No Chat* and increasingly reveal the distinctive monopolization and bargaining effects we have been highlighting. This monopolization leads to a significant rise in industry profit Π, and a significant fall in *CS*. U is more generous with the D_i over time, leading to significant reductions in T_i, significant reductions in π_U, significant increases in π_D, and significant reductions in s_U.

The main change in *No Chat* is a 7 percentage point increase in the acceptance rate, leading to a 0.20 increase in Q, both trends statistically significant at the 1 % level. Thus, as players gain experience in *No Chat*, output diverges further from the monopoly output. The opposite happens in the communication treatments, as lower offered quantity translates into lower output. The mean of Q falls from early to late period across all of them, by as much as 0.35 units (in *Two Chat*, significant at the 1% level in that case). The combined effect of the increase in Q in *No Chat* and its decrease in the communication treatments results in the mean of Q being significantly higher in *No Chat* than in any of the communication treatments—even *Two Chat*—in the late period. This result leads us to conclude with even more confidence that communication leads to monopolization, whether measured by offered or realized quantity.

This analysis of within-session trends suggests that our main findings are representative of play by experienced agents and thus should not be expected to disappear over time. Play in the simple treatment without communication settles down almost immediately to long-run averages. Play in the treatments with communication takes time to settle down, perhaps because the environment is more complex, perhaps because subjects need time to develop trust in trading partners' cheap talk.

5. Rationalizing Effects on Surplus Division

We designed our experiments to test the hypothesis that communication can help vertically related firms monopolize a market by solving a commitment problem. The results, as seen, bear this hypothesis out. We found another set of results for which we did not have *a priori* hypotheses—results related to the division of surplus between upstream and downstream firms varied across communication treatments—which were strong, systematic and beg explanation. It is worth recapitulating these results. They were clearest in the case of tariff levels (T_i) accompanying monopoly quantity offers ($x_i = 1$). Holding offered quantities constant fixes total surplus, so that changes in T_i represent a free transfer of surplus between upstream to downstream. We found that the move from *No Chat* to *Two Chat* reduced T_i by 6.4 and from *Two Chat* to *Three Chat* reduced T_i by a further 3.2. The results for the tariffs are mirrored in profit shares: moving from *No Chat* to *Two Chat* reduced s_U by 3 percentage points and from *Two Chat* to *Three Chat* by a further 11 percentage points. In sum, the move from *No Chat* to *Two Chat* to *Three Chat* shifted surplus from the upstream to downstream firms.

In this section we show that these experimental results can be rationalized as bargaining effects in a standard bargaining model. We assume that opening up a communication channel sets up a bargaining process among the subjects involved. We further assume that bargaining is characterized by the Nash-in-Nash solution proposed by Horn and Wolinksy (1988), now a widely used bargaining concept in applied industrial organization as evidenced by the scores of references in Collard-Wexler, Gowrisankaran, and Lee's (2014) review paper. The Nash-in-Nash solution (short for "Nash bargains nested within a Nash equilibrium") turns out to predict the precise pattern of the variation in the division of surplus across communication treatments we observe in the experiment.

5.1. Nash-in-Nash Bargaining

This subsection provides some theoretical background on Nash-in-Nash bargaining and its application to our experimental setting. To focus exclusively on implications for surplus division, we assume away the commitment problem for now by positing that contracts offer $x_i = Q^m/2 = 1$ unit to each D_i, so that firms end up monopolizing the market. The only issue is the tariff offered (T_i) and whether the contract ends up being accepted (a_i). We assume that opening a communication channel sets up a bargaining process among the subjects involved. Whatever contracts parties agree to in the communication stage are the contracts U then offers. This is a key assumption that requires some discussion. In theory, U could regard the chat as cheap talk, and instead make the take-it-or-leave-it offer it would have in the absence of communication. We can provide several explanations for why chat settles on the actual contract offer. The results from ultimatum games suggest that responders react negatively to offers violating their internal expectations of fairness; it is likely the D_i would react even more negatively to contracts violating their explicitly stated expectations. If U faces a sufficiently high cost of reneging on a promise (see the references to recent empirical work measuring lying aversion in footnote 9), he or she will be inclined to offer the agreed-to contract. Whatever the reason, chat did settle on the offered contract in a large majority of cases, as we will document in Section 6.2.

In the absence of communication in *No Chat*, there is no bargaining. In this case, U issues take-it-or-leave-it offers to the D_i, allowing it to extract all of the gross profit ($\Pi^m/2 = 50$) that D_i earns in the monopoly outcome with an equilibrium tariff of $T_i^* = 50$. Of course, this extreme theoretical predication may not materialize in practical markets or experiments because of fairness and other considerations. In practice, the familiar results from the ultimatum game may be observed with positive surplus afforded the responder (here represented by tariffs lower than 50) and contract rejections for less than equal divisions for the responder. In competitive settings such as ours, we may expect outcomes closer to the extreme theoretical prediction (Roth, Prasnikar, Okuno-Fujiwara, and Zamir 1991).

The bilateral communication channels in *Two Chat* set up two separate bargaining processes, one between U and each D_i. The Nash-in-Nash solution posits that U and D_1 reach an agreement maximizing their joint payoffs, arriving at a tariff maximizing their Nash product assuming that the other bargain between U and D_2, occurring simultaneously, also reaches an agreement maximizing those parties' joint payoffs. That U and D_1 split surplus between them according to the Nash product is the Nash bargaining alluded to by "Nash-in-Nash"; that U and D_1 assume the other bargain is consummated in the rational (jointly efficient) way is the Nash equilibrium alluded to by "Nash-in-Nash." In our setting, it can easily be seen that acceptance ($a_i = 1$) and trade of one unit ($q_i = 1$) is jointly efficient for U and each D_i because it is true regardless of what happens in the other bargain: if U and D_1 trade, their joint surplus equals 60 if U and D_2 happen not to come to an agreement and 50 if they do. Given that U and D_2 end up trading one unit, the joint payoff to be split between U and D_1 equals 50. Their Nash product is $T_i^{1/2}(50 - T_i)^{1/2}$ if they have equal bargaining power. The equilibrium tariff maximizing this Nash product is $T_1^* = 25$ (and $T_2^* = 25$ by symmetry). More generally, letting $\alpha \in [0,1]$ be U's bargaining power vis-á-vis D_i, the relevant Nash product is $T_i^{\alpha}(50 - T_i)^{1-\alpha}$, maximized by equilibrium tariff $T_i^* = 50\alpha$.

That the outcome of the bilateral bargains is characterized by the Nash-in-Nash solution is another key assumption behind our explanation of surplus division. This assumption is less strong than it may appear. Collard-Wexler, Gowrisankaran, and Lee (2014) provide sufficient conditions for the Nash-in-Nash solution to be the limit of the unique equilibrium of a generalized Rubinstein (1982) process in which upstream and downstream firms alternate offers.[15] In Appendix A1, we show that these sufficient conditions for uniqueness are satisfied in our setting.

Moving to *Three Chat*, the open communication channel in this treatment sets up a single three-way bargain. Since there is no other simultaneously occurring bargain in this case, the Nash-in-Nash solution concept reduces simply to Nash bargaining, maximizing the Nash product of three players' payoffs. If they have equal bargaining power, this Nash product simplifies to $(2T_i)^{1/3}(50-T_i)^{2/3}$, maximized by equilibrium tariff $T_i^* = 50/3 = 16.\overline{6}$. More generally, they may have asymmetric bargaining powers. There are several ways to generalize bargaining weights for Nash product involving more than two players. A natural generalization in our setting maintains a constant ratio between the bargaining weight for U and for an individual downstream firm for any number d of downstream firms, leading to the following Nash product:[16]

$$(dT_i)^{\frac{\alpha}{\alpha+d(1-\alpha)}} \prod_{i=1}^{d} \left(\frac{\Pi^m}{d} - T_i\right)^{\frac{1-\alpha}{\alpha+d(1-\alpha)}} = \left[(dT_i)^{\alpha} \left(\frac{\Pi^m}{d} - T_i\right)^{d(1-\alpha)}\right]^{\frac{1}{\alpha+d(1-\alpha)}}. \tag{1}$$

Maximizing this expression and substituting the experimental parameters $\Pi^m = 100$ and $d = 2$ yields equilibrium tariff $T_i^* = 50\alpha/(2-\alpha)$ in the *Three Chat* treatment.

Comparing equilibrium tariffs across treatments, the model predicts T_i^* falls from 50 in *No Chat* to 25 in *Two Chat* to $16.\overline{6}$ in *Three Chat* if subjects have equal bargaining power. In the general case of asymmetric bargaining weights, T_i falls from 50 in *No Chat* to 50α in *Two Chat* to $50\alpha/(2-\alpha)$ in *Three Chat*. As long as $\alpha < 1$ so that U does not have all the bargaining power, the tariff is predicted to strictly fall from *No Chat* to *Two Chat* to *Three Chat* in the general case. It is clear in theory why moving from *No Chat* to *Two Chat* should reduce the tariff: moving from U's making take-it-or-leave-it offers to affording some bargaining power to D_i should be expected to

[15]The limit is the usual one in analyzing Rubinstein (1982) processes, taking the time between offers to zero. The authors restrict attention to perfect Bayesian equilibria with an additional refinement.

[16]Laurelle and Valenciano (2008) provide a noncooperative foundation for the generalized Nash bargaining formulae in (1). In the limit as the probability of bargaining breakdown vanishes, the payoffs in a stationary subgame perfect equilibrium converge to those emerging from maximization of the Nash product, where the weights are given by the probability that the party is selected to be the proposer in a round. Translated into their terms, our specification would be equivalent to assuming that the ratio between the probability of selecting U for the proposer and of selecting a given D_i does not vary with d.

Perhaps the most natural alternative to our specification of bargaining weights maintains a constant ratio between U's bargaining weight and the sum of all downstream firms' bargaining weights rather than an individual downstream firm's. One can show that the model would predict equal tariffs in the *Two Chat* and *Three Chat* treatments under this variant, which is rejected by the experimental results, whereas our specification rationalizes them. Indeed any nontrivial linear combination of our and the alternative bargaining weights would generate the comparative statics for tariffs observed across experimental treatments.

reduce upstream and increase downstream surplus generally, regardless of the assumed bargaining concept, whether Nash-in-Nash or some other. The tariff reduction moving from *Two Chat* to *Three Chat* rests more heavily on the Nash-in-Nash assumption; as we will see, other solution concepts need not deliver this prediction. Behind the Nash-in-Nash solution is the intuition that including more downstream firms in the more comprehensive bargains just means that U has to split the surplus among more parties.

The intuition can be different with a different solution concept. Consider an alternative we propose here, which we will label Shapley-in-Nash bargaining. As Nash-in-Nash, Shapley-in-Nash posits that individual bargains are consummated efficiently assuming others are as well; the only difference is that the incremental surplus generated by each bargain is divided using the Shapley value rather than Nash product. In our setting, the two concepts turn out to yield identical outcomes in *Two Chat*. They diverge with *Three Chat*. With Nash-in-Nash, U is harmed by combining the separate bilateral bargains in one grand bargain because the surplus is fairly divided among whichever players happen to be "in the room." With Shapley-in-Nash, U benefits from combining bargains. The formula builds in the idea that if one of the downstream firm rejects its contract, the others observe this in real time and move from bargaining over the division of a surplus of 60 rather than 50. While Nash-in-Nash and Shapley-in-Nash both have reasonable economic intuition behind them, in the end it is an empirical question which fits the data better.

5.2. Structural Estimates

Table 4 provides structural evidence on how well these bargaining models fit the data on tariffs. For comparison, the last row shows the mean tariffs in the actual data in the *Two Chat* and *Three Chat* treatments, restricting the sample to offers with $x_i = 1$. The first row shows predicted tariff values, $\hat{T}_i$, from Nash-in-Nash bargaining positing a bargaining-power term for U of $\alpha = 0.5$, consistent with equal surplus division. Predicted tariffs match the comparative-static property of actual tariffs, falling from *Two Chat* to *Three Chat*, although predicted tariffs considerably underestimate actual ones in the *Three Chat* treatment. The next row continues with Nash-in-Nash bargaining but now allows α to be a free parameter. We estimate α using non-linear least squares, in effect searching for the value providing the best fit between predicted and actual tariffs. The estimate is $\hat{\alpha} = 0.60$ with a standard error (clustered across sessions) of 0.02. Using the estimated $\hat{\alpha}$ in place of the posited $\alpha = 0.5$ results in a slightly worse fit between predicted and actual tariffs for *Two Chat* but a much improved fit for *Three Chat*.

To provide a counterpoint to Nash-in-Nash bargaining, the next two rows show fitted values for the Shapley-in-Nash alternative. The row with $\alpha = 0.5$ is the standard version of the Shapley value in which all permutations of players used to compute marginal contributions are equally likely. The model gets the wrong comparative-static result, predicting a rise in tariffs with more open communication. The next row analyzes a generalized version of Shapley value, introducing a bargaining-power-like parameter that can be estimated to give it a better chance to fit the tariff data. Appendix-A2 provides the details of this generalization, based on Kalai and Samet (1987). Non-linear least squares produces an estimate of $\hat{\alpha}$ of 0.39. In effect, the estimated version of Shapley-in-Nash bargaining tries to moderate the grossly overestimated tariffs in *Three Chat* by reducing U's bargaining power. While this helps the fit in *Three Chat*, predicted tariffs now substantially undershoot actual in *Two Chat*. Thus the incorrect comparative-static result that tariffs rise with more open communication persists.

Overall, Table 4 shows that the model of Nash-in-Nash bargaining with the estimated $\hat{\alpha}$, besides getting the qualitative result right that tariffs fall from *Two Chat* to *Three Chat*, provides a reasonably good quantitative fit for tariffs in each treatment. The Bayesian Information Criterion (BIC) in the last column provides one gauge of fit across these non-nested models. An increase in BIC of 10 is typically taken as "very strong" evidence against the model with the higher BIC (Kass and Raftery 1995). Here we see that any of the alternatives to Nash-in-Nash bargaining with the estimated $\hat{\alpha}$ involve hundreds or thousands of points higher values of BIC.

6. Analysis of Chat Content

In this section we draw further insights about the effect of communication by analyzing the content of the chat itself. The rich content data does not lend itself to easy quantification (Kimbrough et al. 2008), so in this section we take a series of approaches to do so: counting messages, employing third-party coders, and mining the text for keywords. Unlike the results reported to this point, the results in this section should be interpreted as associations, not causal relationships.

6.1. Message Counts

Table 5 provides descriptive statistics on aspects of the unstructured chat text that are amenable to simple counting. Apart from *Three Chat*, the other chat treatments involve multiple communication channels operating simultaneously. To provide a full picture of the nature of chat in these treatments, we provide analyses separating and combining the channels in a series of columns.

The first set of variables are indicators for a message being sent in a round of chat: $Any\ Mes_U$ is an indicator for a message being sent by U, $Any\ Mes_D$ by one or both D_i, and *Any Mes* by any player. Virtually all chat rounds (98% or higher) had at least some chat across all treatments. A conspicuous finding in *Choose Chat*, looking at the *Any Mes* variable, is that subjects relied on the open more often than the private channel.

The next set of variables, *Num Mes*, record the number of messages sent by one level or the other or in total. In *Two Chat*, U sent 2.5 messages and each D_i sent 3.0 messages on average each round. The averages are almost identical in *Three Chat* (the downstream firms together sent 6.0 messages, implying 3.0 per individual D_i). In *Choose Chat*, players sent about this same number of messages via the open channel, but because they could also use the private channel, players ended up sending more messages in this than the other communication treatments.

The *Init* variables indicate which level (U or D) initiated the chat, if any. In *Two Chat*, each bilateral chat was about equally likely to have been initiated by either side. In *Three Chat*, the probability of initiating chat, 29% for the upstream and 71% for the downstream firms, is close to what one would expect if each of the three players had an equal chance of being the first mover. The same is true for *Choose Chat* regarding the open channel, although the private channel was more likely to be initiated by a downstream firm.

Finally, the last set of rows presents correlations between the existence or extent of chat from the two sides. A positive correlation would be consistent with more chat from one side stimulating chat from the other, a negative correlation with chat from one side crowding out the other. Across all treatments the correlation is positive, suggesting that messages typically induce replies.

Table 6 regresses various experimental outcomes on variables characterizing the chat from Table 5 among others. The regressors are endogenous so their coefficients will not have causal interpretations, but will still reveal interesting correlations and provide some measure of the strength of these correlations.

A conspicuous and statistically significant finding is that $\textit{Num Mes}_D$ is associated with lower offered quantities, X, in all treatments and also with lower x_i in *Two Chat*. Evidently, more downstream chat helps arrive at quantities closer to the monopoly or at least is correlated with those outcomes. Whether the upstream firm initiates chat and how many messages it sends are not measurably associated with offered quantities. Another significant association that is somewhat robust is that $\textit{Num Mes}_U$ is positively associated with s_U. More chat seems to help U extract a greater profit share.

Perhaps the most interesting findings are in the columns for *Choose Chat* including the *Any Private* variable, an indicator for whether any player used the private channel in the chat round. Resorting to the private channel is associated with a huge increase in X by 0.59 units, significant at the 1% level. Resorting to the private channel is also associated with a huge increase in s_U, by 16 percentage points, also significant at the 1% level. It appears that vertical pairs sometimes resort to the private channel to cut side deals that secretly expand traded output, thereby expropriating surplus from the other downstream firm. If so, the descriptive statistics from Table 5 tell us that the D_i initiate many more of these side deals than U. That the D_i initiate private communication that ends up reducing aggregate downstream surplus is reminiscent of the equilibrium outcome in the related Prisoners Dilemma, in which players destroy joint surplus in equilibrium by finking on each other. What may come as more of a surprise is how infrequent the side deals are: as Table 5 shows, the D_i resort to the open channel twice as often as the private channel, so the option to use the private channel in *Choose Chat* does not destroy commitment power completely.

6.2. Coder Exercises

To probe more deeply into the chat content, in this section we report on several exercises using input from external coders. Following Houser and Xiao (2011), we asked two coders to independently analyze the chat content of *Two Chat*, *Choose Chat* and *Three Chat*. Specifically, their task was to read the chat in a given round of play in a given market and guess the vector (x_1, x_2, T_1, T_2) that would most likely result from the chat. If they thought that no plausible guess could be made, they were asked to enter "n.a." instead of a number. They had read the instructions for the experiment up front and were aware of the communication structure in the treatments. At no point in time could the coders see the offers actually made. The coding was incentivized: five chats were randomly selected and the coders paid for the number of guesses that agreed with each other. For all treatments with communication, the same coders analyzed one complete session and five random rounds from the remaining three sessions. The sequence of markets and rounds were randomized such that the coders could not follow patterns involving certain subjects over time.

Our first use of the coder data is to determine whether chat content conveyed meaningful information about the terms of the contracts that would be offered that round. Figure 4 presents the results. Panels A and B show that communication was remarkably informative in *Two Chat*. Over 80% of the coders' guesses for x_i matched the actual offer; over 95% of these also agreed with the other coder's guess. Nearly two thirds of coder's guesses for T_i matched the actual offer, and nearly 95% of these again agreed with the other coder's guess. What makes the accuracy of T_i coding particularly noteworthy is that this variable could take on any of the large number of integers between 0 and 120. In the minority of the cases in which a coder's did not match actual, their guesses still agreed with each other more often than not, suggesting that the chat was informative but misleading. This sort of misleading chat was fairly rare, for example accounting for fewer than

12% of coder's guesses for x_i. Panels C–F show similar results for *Choose Chat* and *Three Chat*.

The accuracy of the chat coding leads us to strongly reject the null hypothesis that chat is meaningless babble in either the private or the open channel. More typically, it appears that subjects used the chat stage to come to an agreement about contractual terms that are then reflected in U's offers.

Table 7 compares downstream acceptance behavior depending on whether U's contract fulfilled downstream expectations from the chat stage. The table restricts attention to just those observations that the coders' provided an integer guess for x_i and T_i and the coders' guesses matched for both. Presumably the coders' guess provides a good proxy of what downstream expectations were for U's contract offer. The regression in each column implements a linear probability model in which a_i is the dependent variable, specified so that coefficients on the treatment indicators can be interpreted as average acceptance rates in each treatment. Column (1) shows that when downstream expectations are met, the contract is almost certain to be accepted across all treatments, more certain in more open communication treatments. In *Three Chat*, 100% of such contracts were accepted. Offers that do not fulfill expectations in columns (2) and (3) are accepted less often. We see that only 42% of offers that differ in both terms from expectations are accepted in *Three Chat*. As the the last column of the table shows, the reduction in acceptance rate from column (1) to column (3) is large and statistically significant for all three treatments. Following this last column down to the bottom part of the table, we see that this decline in acceptance is significantly greater for the most open form of communication (*Three Chat*) compared to the other two (*Two Chat* and *Choose Chat*). Downstream rejection seems to be a mechanism for enforcing agreements made in the chat stage, a mechanism that is strongest in the *Three Chat* treatment, suggestion why commitment is strongest in that treatment.

6.3. Mining Text for Keywords

Perhaps the deepest insight into the association between chat content and outcomes comes from the final analytical approach reported in this subsection. We are interested in determining whether there was something unique about the chat leading to monopoly offers ($X = 2$) compared to chat that did not. We proceed by using text-mining methods for extracting keywords from a body of text, referred to as a corpus.

To describe the methods, it is easiest to work through a concrete example. To make the comparisons as clean as possible, focus just the messages sent by U in the *Two Chat* treatment leading up to symmetric offers. This yields two corpora to compare, chat associated with low-quantity offers

$x_1 = x_2 = 1$ (label this corpus L) and chat associated with high-quantity offers $x_1 = x_2 = 2$ (label this corpus H). We measure the "keyness" of word w in corpus L relative to H using Huerta's (2008) relative rank difference, computed as follows. Generate ranks $r_L(w)$ for all words w in corpus h according to frequency, ranging from 1 for the most common to $\underline{r}_L$ for the least. Similarly, generate ranks $r_H(w)$ for all words w in corpus h. The difference in the rank of w in corpus L relative to corpus H is defined as

$$\frac{r_H(w) - r_L(w)}{r_L(w)}. \tag{2}$$

When w does not appear in H, $\underline{r}_H$ will substitute for $r_H(w)$. Huerta's (2008) measure captures two essential properties for word w to be key: first, that w appears more frequently in L than H (captured by the numerator of expression (2)); and, second, that w is commonly used in L (captured by the denominator of (2)).

The keywords extracted from corpus L relative to H using this method are provided in the first box in Table 9. The box shows keywords that are among the top 50 most common in L for which expression (2) exceeds 3.5, omitting conjunctions, prepositions, and articles. The first box should be compared to the third box in the first row, providing keywords from the same exercise swapping the corpora (i.e., keywords from H relative to L). As one would expect—but reassuring that the extraction method is giving sensible results—words related to the number of units in the offer ("unit," "one," and "1" in the first box; "2" in the third box) emerge as key. The rest of the words tell us something deeper about chat content. By far the most key word in the first box, with a relative rank difference of 43.0, is *ihr*, the plural form of you in German, translated in the table as "you both." Although U is privately communicating with a single retailer in this *Two Chat* treatment, this word apparently bolsters commitment by indicating that whatever is being written applies to the other retailer (and presumably vice versa). Keywords "also" and "both" might have this same effect. Use of verbs conjugated in the third person ("gets," "gives") presumably reference the other retailer. Together, these keywords suggest that commitment to the monopoly outcome may be bolstered by referring to the retailer left out of the private communication channel in *Two Chat*. Other words may contribute to commitment as well: "price" get retailers thinking about the high market price that can result from monopolization; "guaranteed" is a direct reference to commitment.

Quite a different picture emerges in the third box. These keywords suggest a conspiracy hatched in the private communication channel for them to trade "2" units at a tariff of "50," splitting the profits between them "50:50," leaving the other retailer with "nothing." The first-person pronoun "we" and verb form *haben*, translated "(we) have," seem to contribute to this conspiracy.

The loss of commitment in these cases (recall this is only a minority of observations) appears to due to an overreach, U's attempt to duplicate the monopoly industry outcome with each retailer.

The second and fourth boxes in the first row of Table 9 repeats the exercise for *Two Chat* messages sent by downstream firms. The keyword lists are shorter and the relative rank differences smaller than just seen for messages sent by U, suggesting that U was the driving force behind the direction chat took. The number of units in the offer shows up in the keyword lists but few other words besides.

The last row of the table looks at chat content in the *Three Chat* treatment. The keywords associated with low-output offers are similar to those in *Two Chat*. We see references to the single unit involved in the offer ("1," "unit," "one") and "you both" again shows up as key. Turning to the keywords associated with the high-output offers, besides the reference to the number of units ("units," '2"), there is less of a clear pattern. Gone are the conspiratorial keywords seen in *Two Chat*; of course the absence of a private communication channel in *Three Chat* would preclude such a conspiracy. Instead, we see words that could reflect a frustration at being unable to achieve a satisfactory outcome, such as "loss," "only," and "hampers," likely the effect rather than the cause of an inability to commit.

Table 10 turns from symmetric quantity offers to report keywords extracted from chat leading up to asymmetric quantity offers. Whereas before we treated all chat exchanged in a market in a round was treated together, here we separate the chat in the two private channels, putting the chat in the channel with the low offer ($x_i = 1$) in corpus L and the chat in the channel with the high offer in corpus H, so the interpretation of L and H is slightly different in this than the previous table. Because so few offers in *Three Chat* were asymmetric, we restrict attention to the *Two Chat* treatment. The length of the keyword list is the reverse of before, now much longer for messages sent by downstream firms than upstream, suggesting that what downstream firms write generates offer asymmetry. As expected, the number of units in the offer constitute some of the keywords. Chat leading to the low offer features references to the two retailers ("each," "us") as well as a consideration of counterfactuals ("otherwise," "would"). Chat leading to the high offer suggests selfish considerations, referring to "me" rather than "us," perhaps indicating that the other retailer receive "nothing."

Overall, the text-mining exercise shows that when U was able to successfully commit to the monopoly outcome, the messages it sent featured references to the other retailer, to market outcomes, and to guarantees. The trigger breaking down commitment in *Two Chat* in some instances appears to have been one of the bilateral pair suggesting an exclusive deal cutting out the other retailer. U sometimes tried to initiate purportedly exclusive deals with both retailers simultaneously, leading to $X = 4$ units. When a downstream firm was the initiator, it appears that U was sometimes happy to play along but then not follow through on the exclusion, leading to asymmetric offers and a total offer of $X = 3$ units. The finding that exclusive deals exacerbate the commitment problem is not anticipated by theory. In the model of Section 2, commitment is eroded not by active attempts to cut exclusive deals but by passive beliefs that the bilateral pair can do nothing to reduce the amount sold by the rival, so they may as well best respond. The chat in *Three Chat* conforms more closely with the theory. Cutting special deals is difficult in that treatment because all chat is public. The chat associated with unsuccessful attempts at monopolization in *Three Chat* appears to reflect frustration at an inability to escape equilibrium forces leading to a Pareto inferior outcome for the industry.

7. Conclusion

In this paper, we introduce communication to a strategically complex vertical market. One upstream and two downstream firms can jointly earn monopoly rents but they may well fail to do so due to a commitment problem (Hart and Tirole 1990, Rey and Tirole 2007). The relevance of this commitment problem in turn depends on technical modeling assumptions: the (possibly heterogeneous) beliefs players maintain may suggest different equilibria in which the market may or may not be monopolized. In addition to players holding different expectations, bargaining frictions may add to the intricacy of the setup. Communication has the potential to overcome these problems. Our experimental treatments vary the openness or transparency of communication among the three players. The first treatment allows the upstream firm to engage in private two-way chat with each downstream firm. A second one lets all three firms engage in completely open (three-way) chat. The third is a hybrid of the other two, allowing players the option of using either or both of two- or three-way communication.

Our first result is that increasing the openness of communication has a monotonic effect on market performance. Industry profits realize a minimum in the treatment without communication, increase for private two-way chat and the hybrid treatment, and attain a maximum for the open (three-way) chat. We thus find support for the hypothesis that communication can solve the commitment problem and results in higher profits. How firms communicate is important, though, and only when all three players can talk openly we observe full monopolization of the markets.

A second finding is a bargaining effect. More open communication leads to an increasing rate of contract acceptance. The increase in acceptance rate is partly due to a reduction in the upstream firm's tariff demands. Overall, increasing the openness of communication monotonically reduces the share of industry profits the upstream firm accrues. The additional profits from being able to better monopolize the market almost entirely go to downstream firms. A simple structural model of Nash bargaining fits the pattern of shifting surpluses well.

The last section delved into content analysis using a variety of analytical approaches. Our analysis of message counts found that more messages correlated with successful monopolization. There was also a positive correlation between messages sent by a subject and that individual's bargaining share. The exercise employing third-party coders confirmed that chat functioned like a bargaining process, with discussions successfully converging to a contract that is the one that ends up being offered. Departures from these expectations were significantly less likely to be accepted. The keyword-mining exercise found that when the upstream firm was successful at committing to the monopoly outcome, his or her messages tend to mention deals given to all both downstream firms and market prices. Commitment sometimes breaks down when a subject tries to strike an exclusive deal to sell the entire industry quantity, inevitably leading to oversupply as the exclusion proves to be unenforceable.

What are the positive and normative implications of our experimental results for real-world markets? It is reasonable to assume that open communication is not a practical option because firms cannot commit not to engage in private communication on the side. This leaves no communication, two-way chat and the hybrid form as practical communication structures. Both upstream and downstream profits are higher with two-way chat and the hybrid variant, thus firms prefer some form of communication to the treatment without, suggesting that some form of communication would endogenously emerge in the market. Given that upstream and downstream firms differ in their preferences over two-way chat versus the hybrid form of communication, it may be difficult to predict which would emerge without making additional assumptions. For instance, if private and public communication channels exist in the market, it may be difficult for parties to commit not to use them, in which case the hybrid variant would be a natural communication structure. Given that there are plausible conditions under which this form of communication may endogenously emerge, the monopolizing effects of communication and the steep decline in consumer surplus in this variant may be cause for antitrust concern.

Appendix A: Additional Bargaining Results

This appendix presents several theoretical results on bargaining referenced in the text.

A1. Verifying Uniqueness Conditions

Collard-Wexler, Gowrisankaran, and Lee (2014) provide two sets of sufficient conditions for the Nash-in-Nash solution to be the limit of the unique equilibrium of a generalized Rubinstein (1982) process in which upstream and downstream firms alternate offers (see their Theorem 4.6). In this section of the appendix, we verify that one of these sets, Condition Set #2, holds in our setting. As an aside, one can prove that the other, simpler set of sufficient conditions, Condition Set #1, does not hold in our setting.

Before proceeding, we need to introduce some of the authors' notation, adapted to our setting. Let j indicate the consummation of a successful bargain between U and D_j, $j \in \{1,2\}$, resulting in the trade of one unit. If all efficient trades are made, the outcome is denoted $\mathscr{G} = \{1,2\}$. An arbitrary outcome is denoted by the set $\mathscr{A} \subseteq \mathscr{G}$. U's gross surplus (payoff not include transfers T_j) in outcome $\mathscr{A}$ is denoted $\pi_U(\mathscr{A})$ and D_j's is $\pi_{D_j}(\mathscr{A})$. Let $\Delta\pi_U(\mathscr{A},\mathscr{B}) = \pi_U(\mathscr{A}) - \pi_U(\mathscr{A} \setminus \mathscr{B})$ denote U marginal contribution when agreements $\mathscr{B}$ are added to agreements $\mathscr{A}$, $\mathscr{B} \subseteq \mathscr{A} \subseteq \mathscr{G}$. Define $\Delta\pi_{D_j}(\mathscr{A},\mathscr{B})$ analogously.

Condition Set #2 involves three assumptions: Acceptance Strategies Refinement (A.ASR), Strong Conditional Decreasing Marginal Contribution (A.SCDMC), and Limited Negative Externalities (A.LNEXT). A.ASR states that players weakly willing to accept offers accept them in equilibrium. We will directly posit this innocuous assumption. That leaves two assumptions. Both of these are divided into two parts, one for upstream and one for downstream firms. In our setting, U's only source of surplus is T_i. It otherwise earns no gross surplus, and its production is costless. Thus, $\pi_U(\mathscr{A}) = \Delta\pi_U(\mathscr{A},\mathscr{B}) = 0$ for all $\mathscr{B} \subseteq \mathscr{A} \subseteq \mathscr{G}$, implying A.SCDMC and A.LNEXT are trivially satisfied for the upstream firm because they reduce to the inequality $0 \geq 0$. We need only verify A.SCDMC and A.LNEXT.

Translated into our setting, A.SCDMC holds for a representative downstream firm, say D_1, if

$$\pi_{D_1}(\mathscr{A} \cup \mathscr{B} \cup \{1\}) - \pi_{D_1}(\mathscr{A}' \cup \mathscr{B}) \geq \Delta\pi_{D_1}(\mathscr{G},\{1\}) \tag{A1}$$

for all $\mathscr{B} \subseteq \mathscr{G}_{-U}$ and $\mathscr{A},\mathscr{A}' \subseteq \mathscr{G}_U \setminus \{1\}$, where $\mathscr{G}_{-U}$ is the set of agreements that can be made with upstream firms besides U and $\mathscr{G}_U$ is the set of agreements that can be made with U. Considering the first term on the left-hand side of (A1), for all $\mathscr{B} \subseteq \mathscr{G}_{-U}$ and $\mathscr{A},\mathscr{A}' \subseteq \mathscr{G}_U \setminus \{1\}$, we have

$$\begin{aligned} \pi_{D_1}(\mathscr{A} \cup \mathscr{B} \cup \{1\}) &= \pi_{D_1}(\mathscr{A} \cup \{1\}) && \text{(A2)} \\ &\geq \pi_{D_1}(\{2\} \cup \{1\}) && \text{(A3)} \\ &= \pi_{D_1}(\mathscr{G}). && \text{(A4)} \end{aligned}$$

To see (A2), noting that U is the only upstream firm, we have $\mathscr{G}_{-U} = \varnothing$, implying that $\mathscr{B} = \varnothing$. To see (A3), noting again that U is the only upstream firm, $\mathscr{G}_U = \mathscr{G}$, implying $\mathscr{G}_U \setminus \{1\} = \{2\}$. Hence $\mathscr{A}$ must be either $\varnothing$ or $\{2\}$. D_1's lowest payoff is generated by $\mathscr{A} = \{2\}$. Considering the second term on the left-hand side of (A1), for all $\mathscr{B} \subseteq \mathscr{G}_{-U}$ and $\mathscr{A},\mathscr{A}' \subseteq \mathscr{G}_U \setminus \{1\}$, we have $\pi_{D_1}(\mathscr{A}' \cup \mathscr{B}) = \pi_{D_1}(\mathscr{A}')) = 0$, where the first equality follows from $\mathscr{B} = \varnothing$ and the second from the fact that $1 \notin \mathscr{A}' \in \mathscr{G}_U \setminus \{1\}$. Hence the left-hand side of (A1) is at least $\pi_{D_1}(\mathscr{G})$. The right-hand side is $\Delta\pi_{D_1}(\mathscr{G},\{1\}) = \pi_{D_1}(\mathscr{G}) - \pi_{D_1}(\mathscr{G} \setminus \{1\}) = \pi_{D_1}(\mathscr{G})$ because $\pi_{D_1}(\mathscr{G} \setminus \{1\}) = 0$. This completes the proof that A.SCDMC holds.

It remains to verify A.LNEXT. Translated into our setting, A.LNEXT holds if, for all nonempty $\mathscr{C} \subseteq \mathscr{G}$, there exists $j \in \mathscr{C}$ such that

$$\Delta\pi_{D_j}(\mathscr{G},\mathscr{C}) \geq \sum_{j \in \mathscr{C}_{D_j}} \Delta\pi_{D_j}(\mathscr{G},\{j\}), \tag{A5}$$

where $\mathscr{C}_{D_j} = \mathscr{C} \cap \{j\}$. Consider each of the three possibilities for $\mathscr{C}$ in turn, namely, $\{1\}$, $\{2\}$, and $\mathscr{G}$. First suppose $\mathscr{C} = \{1\}$. Taking $j = 1$, the left-hand side of (A5) becomes $\Delta\pi_{D_1}(\mathscr{G},\{1\}) = \pi_{D_1}(\mathscr{G}) - \pi_{D_1}(\mathscr{G} \setminus \{1\}) = \pi_{D_1}(\mathscr{G})$. The right-hand side of (A5) can be simplified by noting $\mathscr{C}_{D_1} = \mathscr{C} \cap \{1\} = \{1\} \cap \{1\} = \{1\}$. Hence the summation reduces to the single term $\Delta\pi_{D_1}(\mathscr{G},\{1\}) = \pi_{D_1}(\mathscr{G}) - \pi_{D_1}(\mathscr{G} \setminus \{1\}) = \pi_{D_1}(\mathscr{G})$. This proves that (A5) holds for $\mathscr{C} = \{1\}$. The proof that (A5) holds for $\mathscr{C} = \{2\}$ is identical. That leaves $\mathscr{C} = \mathscr{G}$. Taking $j = 1$, the left-hand side of (A5) then is $\Delta\pi_{D_1}(\mathscr{G},\mathscr{G}) = \pi_{D_1}(\mathscr{G})$. The right-hand side can again be shown to involve a single term in the summation because $\mathscr{C}_{D_1} = \mathscr{G} \cap \{1\} = \{1\}$. This sum can again be shown to reduce to $\pi_{D_1}(\mathscr{G})$, proving the left- and right-hand sides of (A5) are equal in this case. This completes the proof that A.LNEXT holds.

A2. Generalizing Shapley Value

In this section of the appendix, we present a generalization of Shapley value allowing for asymmetric weights. We follow Kalai and Samet's (1987) foundation of this version of the Shapley value in a model of asymmetric arrival times.

To this end, assume that coalitions are formed from permutations arising from players randomly arriving at a location. Let A_U be U's arrival time, exponentially distributed with rate parameter λ_U, and let A_i be the arrival time for a given D_i, exponentially distributed with rate parameter λ_D, symmetric across downstream firms. Assume arrival times are independent. Define $\alpha = \Pr(A_U > A_i)$. Using standard results for exponential distributions, one can show

$$\alpha = \frac{\lambda_D}{\lambda_D + \lambda_U}. \tag{A6}$$

U's marginal contribution to its coalition is 0 if it comes first in the permutation and Π^m otherwise. Thus U's generalized Shapley value from a bargain in which U and d downstream firms participate is

$$\begin{aligned}
\Pi^m \Pr\left(A_U > \min_{i \in \{1,\ldots,d\}} \{A_i\}\right) &= \Pi^m \left[1 - \Pr\left(A_U < \min_{i \in \{1,\ldots,d\}} \{A_i\}\right)\right] && \text{(A7)}\\
&= \Pi^m \left(\frac{d\lambda_D}{\lambda_U + d\lambda_D}\right) && \text{(A8)}\\
&= \Pi^m \left(\frac{\alpha d}{1 - \alpha + \alpha d}\right), && \text{(A9)}
\end{aligned}$$

where (A8) follows from standard results for exponential distributions and (A9) from (A6).

The tariff implementing the equilibrium surplus share in (A9) is

$$T_i^* = \frac{\Pi^m}{2}\left(\frac{\alpha d}{1-\alpha+\alpha d}\right). \tag{A10}$$

This equation provides the fitted tariff values for the rows in Table 4 for the Shapley value.

These formulas nest the standard Shapley value with symmetric weights, which can be recovered by substituting $\alpha = 1/2$. Take the case of $d = 1$, corresponding to the bilateral bargaining of *Two Chat*. U's share of the monopoly profit Π^m then is $1/2$ and the equilibrium tariff is $\Pi^m/4$. Take the case of $d = 2$, corresponding to the open communication of *Three Chat*. U's share of the monopoly profit rises to $2/3$ and the equilibrium tariff to $\Pi^m/3$.

The fact that U's share and tariffs rise with d generalizes beyond the symmetric case of $\alpha = 1/2$. For any $\alpha \in (0,1)$, one can show that equations (A9) and (A10) are increasing in d. This provides a contrasting comparative-static result to that derived in the text for the Nash-in-Nash solution with general asymmetric bargaining weights.

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Table 1: Regressions Examining Differences in Means

Dependent variable:	X	T_i		a_i		Q	Π	π_U	π_D	s_U	CS
Sample:	Full	Full	$x_i = 1$	Full	$x_i = 1$	Full	Full	Full	Full	$\Pi > 0$	Full
No Chat	3.68***	34.7***	33.3***	0.70***	0.77***	2.47***	68.3***	45.3***	23.0***	0.63***	39.7***
	(0.19)	(1.2)	(0.9)	(0.02)	(0.03)	(0.19)	(1.8)	(0.5)	(1.8)	(0.01)	(5.7)
Two Chat	2.98***	31.4***	26.9***	0.85***	0.85***	2.49***	82.5***	51.1***	31.4***	0.59***	34.1***
	(0.19)	(2.3)	(1.2)	(0.04)	(0.03)	(0.12)	(2.7)	(2.6)	(3.0)	(0.03)	(4.4)
Choose Chat	2.55***	26.9***	24.8***	0.89***	0.89***	2.20***	87.4***	46.2***	41.2***	0.52***	22.6***
	(0.15)	(1.2)	(1.1)	(0.01)	(0.02)	(0.07)	(2.3)	(2.4)	(3.1)	(0.03)	(3.2)
Three Chat	2.41***	25.0***	23.7***	0.89***	0.86***	2.05***	89.5***	42.5***	47.1***	0.47***	17.1***
	(0.06)	(1.0)	(0.9)	(0.01)	(0.02)	(0.03)	(1.0)	(1.5)	(2.1)	(0.02)	(0.6)
Other controls	None	None	None	None	$\tilde{T}_i, \tilde{T}_i^2$	None	None	None	None	None	None
Observations	1,425	2,850	1,797	2,850	1,797	1,425	1,425	1,425	1,425	1,324	1,425
R^2	0.12	0.09	0.14	0.05	0.17	0.02	0.09	0.02	0.11	0.09	0.06
Coefficient differences											
Two Chat – No Chat	−0.70***	−3.2	−6.4***	0.15***	0.09*	0.02	14.2***	5.8**	8.9**	−0.03	−5.6
	(0.27)	(2.6)	(1.5)	(0.04)	(0.05)	(0.23)	(3.2)	(3.2)	(3.5)	(0.03)	(7.2)
Choose Chat – No Chat	−1.13***	−7.7***	−8.5***	0.19***	0.12***	−0.27	19.1***	0.9	18.2***	−0.11***	−17.1**
	(0.25)	(1.7)	(1.4)	(0.02)	(0.04)	(0.20)	(2.9)	(2.5)	(3.6)	(0.03)	(6.5)
Three Chat – No Chat	−1.27***	−9.7***	−9.6***	0.20***	0.09***	−0.42*	21.2***	−2.9*	24.1***	−0.15***	−22.6***
	(0.20)	(1.5)	(1.2)	(0.02)	(0.04)	(0.19)	(2.0)	(1.6)	(2.7)	(0.02)	(5.7)
Choose Chat – Two Chat	−0.43*	−4.5*	−2.1	0.04	0.03	−0.29*	4.9	−4.9	9.7**	−0.07*	−11.5*
	(0.24)	(2.5)	(1.6)	(0.04)	(0.03)	(0.14)	(3.5)	(3.5)	(4.3)	(0.04)	(5.4)
Three Chat – Two Chat	−0.57**	−6.4**	−3.2**	0.04	0.00	−0.44***	7.0**	−8.6**	15.6***	−0.12***	−17.0***
	(0.20)	(2.5)	(1.5)	(0.04)	(0.03)	(0.13)	(2.9)	(3.0)	(3.6)	(0.03)	(4.4)
Three Chat – Choose Chat	−0.14	−1.9	−1.1	−0.00	0.03	−0.15*	2.1	−3.8	5.9	−0.05	−5.5
	(0.17)	(1.5)	(1.4)	(0.02)	(0.02)	(0.07)	(2.5)	(2.8)	(3.7)	(0.03)	(3.3)

Notes: Each column is an ordinary least squares regression. Specification includes an exhaustive set of treatment indicators (*No Chat*, *Two Chat*, *Choose Chat*, *Three Chat*) and omits the constant, allowing one to read coefficients as sample means. Sample includes all 15 rounds in each session. Sample for s_U column excludes observations with $\Pi = 0$ for which s_U undefined. A small subset (6%) of these involve $\pi_D < 0$; we set $s_U = 1$ for these. White (1980) heteroskedasticity-robust standard errors clustered at session level reported in parentheses. Regressions for T_i and a_i run for all contract offers and for with $x_i = 1$. The regression for a_i with other controls includes standardized tariff $\tilde{T}_i$ and its square, giving coefficients on the treatment indicators the interpretation of mean acceptance rates for contracts offering mean tariff. Significantly different from 0 in a two-tailed test at the *10% level, **5% level, ***1% level.

Table 2: Linear Probability Models of Outcome Variables

	Measuring monopolization				Measuring symmetry	
	Offered quantity, X		Market output, Q			
	$X = 2$	$X \geq 4$	$Q = 2$	$Q \geq 4$	$x_1 = x_2$	$x_1 = x_2$, $T_1 = T_2$
No Chat	0.30***	0.54***	0.30***	0.29***	0.68***	0.55***
	(0.06)	(0.06)	(0.04)	(0.07)	(0.01)	(0.01)
Two Chat	0.48***	0.30***	0.47***	0.21***	0.63***	0.39***
	(0.10)	(0.07)	(0.07)	(0.05)	(0.07)	(0.05)
Choose Chat	0.71***	0.17***	0.67***	0.10***	0.76***	0.65***
	(0.06)	(0.04)	(0.06)	(0.03)	(0.04)	(0.05)
Three Chat	0.79***	0.13***	0.73***	0.07**	0.88***	0.76***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.03)
Observations	1,425	1,425	1,425	1,425	1,425	1,425
R^2	0.16	0.13	0.12	0.06	0.05	0.08
Coefficient differences						
Two Chat – *No Chat*	0.18	−0.23**	0.17*	−0.08	−0.05	−0.16***
	(0.12)	(0.09)	(0.08)	(0.09)	(0.07)	(0.05)
Choose Chat – *No Chat*	0.41***	−0.37***	0.37***	−0.19**	0.08*	0.10*
	(0.09)	(0.08)	(0.07)	(0.07)	(0.04)	(0.05)
Three Chat – *No Chat*	0.50***	−0.41***	0.43**	−0.22***	0.21***	0.21***
	(0.07)	(0.06)	(0.05)	(0.04)	(0.02)	(0.03)
Choose Chat – *Two Chat*	0.23*	−0.14	0.21**	−0.11*	0.13	0.26***
	(0.12)	(0.08)	(0.09)	(0.06)	(0.08)	(0.07)
Three Chat – *Two Chat*	0.32***	−0.17**	0.26***	−0.14**	0.25***	0.37***
	(0.10)	(0.07)	(0.07)	(0.05)	(0.07)	(0.05)
Three Chat – *Choose Chat*	0.08	−0.03	0.05	−0.03	0.12**	0.11*
	(0.07)	(0.05)	(0.07)	(0.03)	(0.04)	(0.05)

Notes: Each column is an ordinary least squares regression in which the dependent variable is a 0–1 indicator for the event in the column heading. Regression thus interpreted as linear probability model. Specification includes an exhaustive set of treatment indicators (*No Chat*, *Two Chat*, *Choose Chat*, *Three Chat*) and omits the constant, allowing one to read coefficients as sample frequencies. Sample includes all 15 rounds in each session. White (1980) heteroskedasticity-robust standard errors clustered at session level reported in parentheses. Significantly different from 0 in a two-tailed test at the *10% level, **5% level, ***1% level.

Table 3: Trends in Treatment Effects

Dependent variable:	X	T_i		a_i		Q	Π	π_U	π_D	s_U	CS
Sample:	Full	Full	$x_i = 1$	Full	$x_i = 1$	Full	Full	Full	Full	$\Pi > 0$	Full
No Chat$_0$	3.80***	38.2***	35.0***	0.66***	0.75***	2.33***	64.4***	45.5***	19.0***	0.66***	36.5***
	(0.31)	(3.1)	(2.2)	(0.01)	(0.04)	(0.19)	(4.1)	(3.0)	(2.3)	(0.02)	(4.9)
No Chat$_1$	3.62***	32.9***	32.4***	0.72***	0.77***	2.54***	70.3***	45.3***	25.0***	0.61***	41.3***
	(0.15)	(0.4)	(1.2)	(0.02)	(0.04)	(0.19)	(1.3)	(1.7)	(2.7)	(0.03)	(6.4)
Two Chat$_0$	3.32***	33.5***	26.8***	0.84***	0.86***	2.72***	78.9***	53.5***	25.4***	0.61***	42.5***
	(0.25)	(2.2)	(1.0)	(0.04)	(0.03)	(0.16)	(3.4)	(2.6)	(2.9)	(0.03)	(5.4)
Two Chat$_1$	2.80***	30.4***	26.9***	0.85***	0.85***	2.37***	84.3***	49.9***	34.5***	0.59***	29.9***
	(0.17)	(2.3)	(1.3)	(0.04)	(0.04)	(0.12)	(2.4)	(2.7)	(2.1)	(0.03)	(4.2)
Choose Chat$_0$	2.90***	29.6***	27.7***	0.85***	0.90***	2.32***	82.1***	48.2***	33.9***	0.57***	28.9***
	(0.23)	(1.4)	(1.2)	(0.03)	(0.01)	(0.09)	(3.6)	(1.8)	(4.0)	(0.03)	(4.0)
Choose Chat$_1$	2.37***	25.6***	23.7***	0.92***	0.88***	2.14***	90.1***	45.2***	44.8***	0.50***	19.5***
	(0.13)	(1.3)	(1.2)	(0.01)	(0.02)	(0.11)	(1.9)	(2.9)	(3.3)	(0.03)	(3.9)
Three Chat$_0$	2.86***	30.0***	28.4***	0.83***	0.87***	2.20***	83.7***	45.7***	37.9***	0.54***	24.7***
	(0.25)	(1.5)	(1.7)	(0.02)	(0.03)	(0.10)	(2.2)	(3.0)	(3.5)	(0.03)	(3.2)
Three Chat$_1$	2.18***	22.5***	21.9***	0.92***	0.85***	1.98***	92.4***	40.8***	51.6***	0.44***	13.4***
	(0.03)	(0.7)	(0.4)	(0.00)	(0.02)	(0.03)	(0.5)	(1.0)	(1.4)	(0.01)	(1.0)
Other controls	None	None	None	None	$\tilde{T}_i, \tilde{T}_i^2$	None	None	None	None	None	None
Observations	1,425	2,850	1,797	2,850	1,797	1,425	1,425	1,425	1,425	1,324	1,425
R^2	0.15	0.12	0.20	0.05	0.17	0.03	0.10	0.03	0.14	0.12	0.08
Coefficient differences											
No Chat$_1$ − *No Chat*$_0$	−0.18	−5.3*	−2.6	0.07***	0.02	0.20***	5.8	−0.2	6.0	−0.05	4.8
	(0.19)	(2.9)	(2.9)	(0.02)	(0.06)	(0.05)	(4.0)	(4.6)	(3.8)	(0.05)	(3.4)
Two Chat$_1$ − *Two Chat*$_0$	−0.52***	−3.1***	0.2	0.01	−0.01	−0.35***	5.5***	−3.6**	9.1***	−0.03	−12.6***
	(0.13)	(0.4)	(0.3)	(0.01)	(0.01)	(0.11)	(1.4)	(1.6)	(0.4)	(0.02)	(3.3)
Choose Chat$_1$ − *Choose Chat*$_0$	−0.53***	−3.9**	−4.0***	0.07*	−0.03	−0.18	8.0***	−2.9	10.9***	−0.07***	−9.4*
	(0.15)	(1.5)	(1.1)	(0.03)	(0.02)	(0.15)	(2.6)	(1.9)	(3.6)	(0.02)	(4.9)
Three Chat$_1$ − *Three Chat*$_0$	−0.68***	−7.5***	−4.7**	0.09***	−0.01	−0.22*	8.8***	−4.9*	13.7***	−0.10***	−11.3**
	(0.27)	(0.9)	(2.1)	(0.02)	(0.02)	(0.12)	(1.8)	(2.6)	(2.4)	(0.02)	(4.1)

Notes: Each column is an ordinary least squares regression including interactions between a set of treatment indicators and a set of (initial, end) period indicators. Interactions denoted with subscripts: for example, *No Chat*$_0$ is the interaction between *No Chat* and the initial period consisting of rounds 1–5, and *No Chat*$_1$ is the interaction between *No Chat* and the end period consisting of rounds 6–15. Specification includes an exhaustive set of treatment indicators (*No Chat*, *Two Chat*, *Choose Chat*, *Three Chat*) and omits the constant, allowing one to read coefficients as sample means. Sample includes all 15 rounds. Sample for s_U column excludes observations with $\Pi = 0$ for which s_U undefined. A small subset (6%) of these involve $\pi_D < 0$; we set $s_U = 1$ for these. Two regressions run for T_i and a_i, one for all contract offers and one for contract offers with $x_i = 1$. The regression for a_i with other controls includes standardized tariff $\tilde{T}_i$ and its square, giving coefficients on the treatment indicators the interpretation of mean acceptance rates for contracts offering mean tariff. White (1980) heteroskedasticity-robust standard errors clustered at session level reported in parentheses. Significantly different from 0 in a two-tailed test at the *10% level, **5% level, ***1% level.

Table 4: Tariffs Predicted by Various Bargaining Models

Bargaining model	Mean $\hat{T}_i$ in subsample: *Two Chat*	*Three Chat*	BIC
Nash-in-Nash			
Posit $\alpha = 0.50$	25.0	16.7	70,351
NLLS estimate $\hat{\alpha} = 0.60$	30.2	21.6	6,998
Shapley-in-Nash			
Posit $\alpha = 0.50$	25.0	33.3	108,258
NLLS estimate $\hat{\alpha} = 0.39$	19.7	28.2	7,298
Actual data	26.9	23.7	

Notes: Sample restricted to offers involving $x_i = 1$ in *Two Chat* and *Three Chat* treatments only. Each row is a different model, for which we display fitted tariff values $\hat{T}_i$ for the two included treatments as well as the Bayesian Information Criterion (BIC) to compare model fits. For rows involving an estimate $\hat{\alpha}$, estimation performed using non-linear least squares, equivalent to maximum likelihood assuming $\varepsilon_i = T_i - \hat{T}_i$ has standard normal distribution.

Table 5: Descriptive Statistics on Message Counts

	Two Chat		*Choose Chat*				
	Channels separated	Channels combined	Private channels separated	Private channels combined	Open channel	All channels combined	*Three Chat*
Means of indicators for some message sent							
Any Mes_U	0.97	0.99	0.32	0.43	0.86	0.97	0.85
Any Mes_D	0.99	1.00	0.39	0.55	0.93	0.99	0.98
Any Mes	0.99	1.00	0.42	0.58	0.95	0.99	0.98
Means of number of messages sent							
Num Mes_U	2.5	5.0	0.8	1.5	3.0	4.6	2.4
Num Mes_D	3.0	6.0	1.0	2.0	6.6	8.6	6.0
Num Mes	5.5	11.0	1.8	3.5	9.6	13.1	8.3
Means of indicators for chat initiation							
$Init_U$	0.52	0.48	0.15	0.16	0.28	0.30	0.29
$Init_D$	0.50	0.57	0.27	0.42	0.70	0.72	0.71
Correlations across market levels							
Any Mes_U with *Any* Mes_D	0.29	*a*	0.72	0.66	0.46	0.47	0.36
Num Mes_U with *Num* Mes_D	0.43	0.43	0.72	0.76	0.61	0.38	0.50
Observations	690	345	690	345	345	345	360

Notes: Sum of $Init_U$ and $Init_D$ down column can exceed 1 because time was measured in discrete units (seconds), resulting in some ties for initiator. Sum of $Init_U$ and $Init_D$ down column can be less than 1 when that channel was not used, so there was no chat initiator, for some observations. [a]Correlation undefined because variance of *Any* Mes_D equals 0.

Table 6: Regressions on Message-Count Covariates

	Two Chat			*Choose Chat*				*Three Chat*	
	x_i	X	s_U	X	X	s_U	s_U	X	s_U
Constant	1.50***	3.04***	0.65***	2.81***	2.49***	0.50***	0.41***	2.92***	0.54***
	(0.09)	(0.23)	(0.10)	(0.20)	(0.18)	(0.04)	(0.03)	(0.18)	(0.04)
Num Mes$_U$	0.03	0.04	0.02*	0.04	0.02	0.02*	0.01	−0.08**	0.00
	(0.04)	(0.06)	(0.01)	(0.04)	(0.03)	(0.01)	(0.01)	(0.02)	(0.01)
Num Mes$_D$	−0.03***	−0.04**	−0.02	−0.05**	−0.04**	−0.00	−0.00	−0.06*	−0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.02)	(0.01)
Init$_U$	−0.00								
	(0.07)								
Any Private					0.59***		0.16***		
					(0.08)		(0.03)		
Observations	690	345	330	345	345	327	327	360	346
R^2	0.00	0.01	0.02	0.03	0.10	0.02	0.06	0.08	0.05

Notes: Each column is an ordinary least squares regression. Sample includes all 15 rounds in each session. White (1980) heteroskedasticity-robust standard errors clustered at session level reported in parentheses. Significantly different from 0 in a two-tailed test at the *10% level, **5% level, ***1% level.

Table 7: Variation of Acceptance Rate with Fulfillment of Chat Expectations

	Offer terms matching coders' guess			
	Both x_i, T_i	One of x_i, T_i	Neither x_i, T_i	Difference
	(1)	(2)	(3)	(1) − (3)
Two Chat	0.92***	0.73***	0.58***	0.34***
	(0.01)	(0.05)	(0.01)	(0.02)
Choose Chat	0.96***	0.85***	0.67***	0.30**
	(0.01)	(0.04)	(0.11)	(0.11)
Three Chat	1.00***	0.85***	0.42***	0.58***
	(0.00)	(0.05)	(0.09)	(0.09)
Observations	603	156	50	
R^2	0.02	0.02	0.03	
Coefficient differences				
Choose Chat − Two Chat	0.04***	0.12	0.09	−0.05
	(0.01)	(0.07)	(0.11)	(0.11)
Three Chat − Two Chat	0.08***	0.12	−0.16	0.24**
	(0.01)	(0.07)	(0.09)	(0.09)
Three Chat − Choose Chat	0.04***	0.00	−0.25	0.29*
	(0.01)	(0.07)	(0.14)	(0.14)

Notes: Each column is an ordinary least squares regression using acceptance a_i as the dependent variable. Regression thus interpreted as linear probability model. Sample begins with the subset of observations from communication treatments that were subjected to coding (one complete session and five randomly selected periods from the three other sessions) and drops all but ones in which coders' integer guesses match each other for both x_i and T_i. First three columns consider different subsamples of this restricted sample depending on how many of the coders' guesses for terms x_i and T_i match U's offers. Specification includes an exhaustive set of indicators for the communication treatments (*Two Chat*, *Choose Chat*, *Three Chat*) and omits the constant, allowing one to read coefficients as sample frequencies. White (1980) heteroskedasticity-robust standard errors clustered at session level reported in parentheses. Significantly different from 0 in a two-tailed test at the *10% level, **5% level, ***1% level.

Table 8: Variation of Acceptance Rate with Fulfillment of Chat Expectations

	Offer terms matching coders' guess			
	Both x_i, T_i	One of x_i, T_i	Neither x_i, T_i	Difference
	(1)	(2)	(3)	(1) − (3)
Two Chat	0.92***	0.73***	0.58***	0.34***
	(0.01)	(0.05)	(0.01)	(0.02)
Choose Chat	0.96***	0.85***	0.67***	0.30**
	(0.01)	(0.04)	(0.11)	(0.11)
Three Chat	1.00***	0.85***	0.42***	0.58***
	(0.00)	(0.05)	(0.09)	(0.09)
Observations	603	156	50	
R^2	0.02	0.02	0.03	
Coefficient differences				
Choose Chat − *Two Chat*	0.04***	0.12	0.09	−0.05
	(0.01)	(0.07)	(0.11)	(0.11)
Three Chat − *Two Chat*	0.08***	0.12	−0.16	0.24**
	(0.01)	(0.07)	(0.09)	(0.09)
Three Chat − *Choose Chat*	0.04***	0.00	−0.25	0.29*
	(0.01)	(0.07)	(0.14)	(0.14)

Notes: Each column is an ordinary least squares regression using acceptance a_i as the dependent variable. Regression thus interpreted as linear probability model. Sample begins with the subset of observations from communication treatments that were subjected to coding (one complete session and five randomly selected periods from the three other sessions) and drops all but ones in which coders' integer guesses match each other for both x_i and T_i. First three columns consider different subsamples of this restricted sample depending on how many of the coders' guesses for terms x_i and T_i match U's offers. Specification includes an exhaustive set of indicators for the communication treatments (*Two Chat*, *Choose Chat*, *Three Chat*) and omits the constant, allowing one to read coefficients as sample frequencies. White (1980) heteroskedasticity-robust standard errors clustered at session level reported in parentheses. Significantly different from 0 in a two-tailed test at the *10% level, **5% level, ***1% level.

Table 9: Keywords Mined from Chat Leading to Symmetric Offers

	Low-quantity offers with $x_1 = x_2 = 1$ (corpus L)				High-quantity offers with $x_1 = x_2 = 2$ (corpus H)			
	Messages sent by U		Messages sent by D_i		Messages sent by U		Messages sent by D_i	
Treatment	Word	Rank diff. relative to H	Word	Rank diff. relative to H	Word	Rank diff. relative to L	Word	Rank diff. relative to L
Two Chat	you both	43.0	times	7.1	50:50	19.4	risk	9.5
	unit	23.3	other	6.3	50	18.7	2	5.0
	one	7.9	unit	4.3	2	14.0		
	also	7.7			nothing	9.0		
	1	6.3			profit share	7.2		
	me	5.9			we	6.3		
	ever	4.9			(we) have	5.2		
	(you) have	4.5						
	gets	4.5						
	gives	4.1						
	price	3.7						
	guaranteed	3.7						
	both	3.7						
Three Chat	1	29.0	40	21.0	other	51.0	pay	9.9
	20	10.6	:)	5.8	units	31.4	2	4.9
	unit	8.3	each	5.4	total price	15.5	only	4.0
	you both	5.5	retailer	5.3	loss	15.5	hampers	3.6
	ever	3.8	one	3.9	2	15.5		
					amount	7.9		
					going	7.9		
					better	3.9		

Notes: Words ranked by frequency within chat corpus c. Lower numbers for rank r_c indicates a more common word. Displayed are words whose absolute rank satisfies $r_c \leq 50$ and whose rank differential relative to comparison corpus c' satisfies $(r_c - r_{c'})/r_c \geq 3.5$. Conjunctions, prepositions, and articles omitted. Comparisons hold constant treatment (*Two Chat* or *Three Chat*), source of message (upstream or downstream), and symmetry of offered quantities, only varying total quantity involved in offer ($X = 2$ versus $X = 4$). Words are translations from the original German.

Table 10: Keywords Mined from Chat Leading to Asymmetric Offers

	Low-quantity offer with $x_i = 1$ (corpus L)				High-quantity offer with $x_i = 2$ (corpus H)			
	Upstream messages (1)		Downstream messages (2)		Upstream messages (3)		Downstream messages (4)	
Treatment	Word	Rank diff. relative to H	Word	Rank diff. relative to H	Word	Rank diff. relative to L	Word	Rank diff. relative to L
Two Chat	how	48.0	how	15.8			45	9.7
			only	9.3			makes	9.7
			going	9.3			units	8.6
			are	7.1			nothing	5.8
			each	7.1			60	5.8
			us	7.1			2	5.5
			10	6.1			35	4.2
			1	5.3			me	4.2
			otherwise	5.0				
			would	5.0				

Notes: Words ranked by frequency within chat corpus c. Lower numbers for rank r_c indicates a more common word. Displayed are words whose absolute rank satisfies $r_c \leq 50$ and whose rank differential relative to comparison corpus c' satisfies $(r_c - r_{c'})/r_c \geq 3.5$. Conjunctions, prepositions, and articles omitted. Comparisons hold constant treatment (*Two Chat*), source of message (upstream or downstream), and asymmetry of offered quantities, only varying quantity involved in individual offer ($x_i = 1$ versus $x_i = 2$). Words are translations from the original German.

Figure 1: Vertical Structure

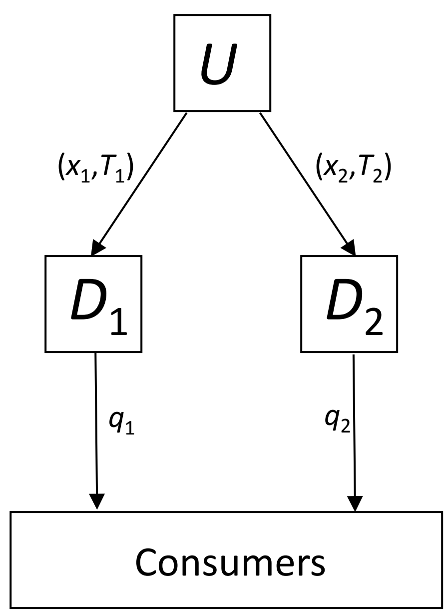


Figure 2: Experimental Market Demand and Profit

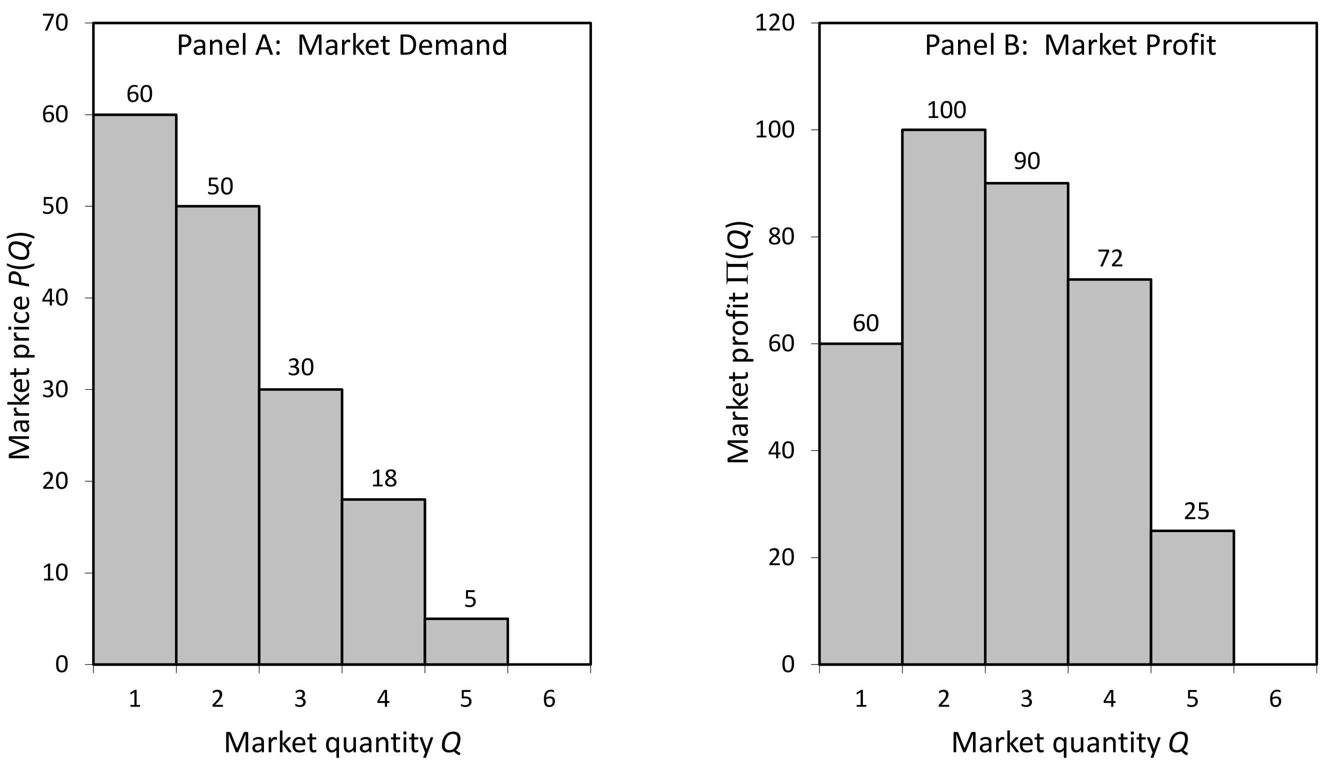
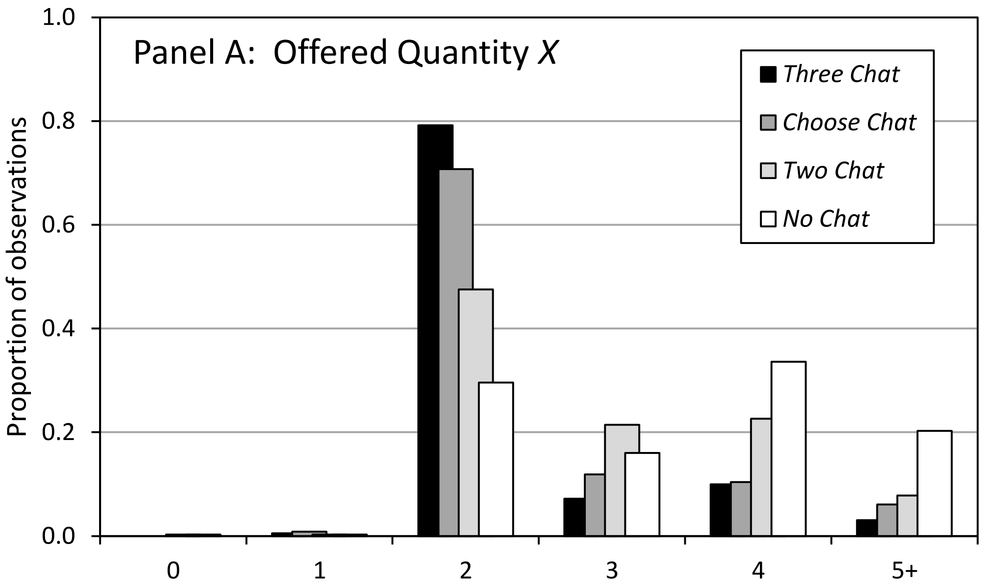


Figure 3: Quantity Histograms



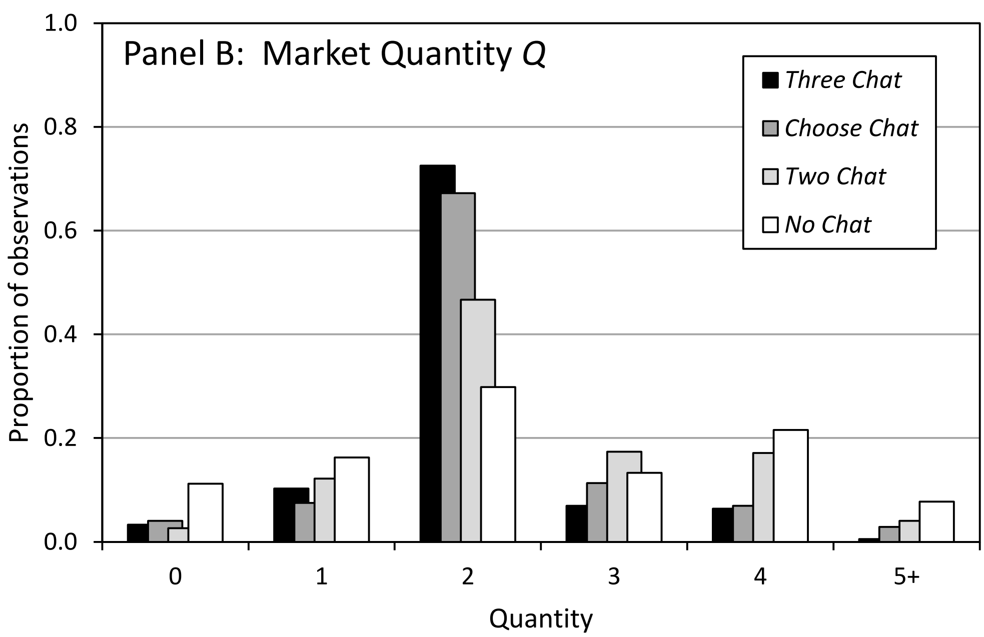
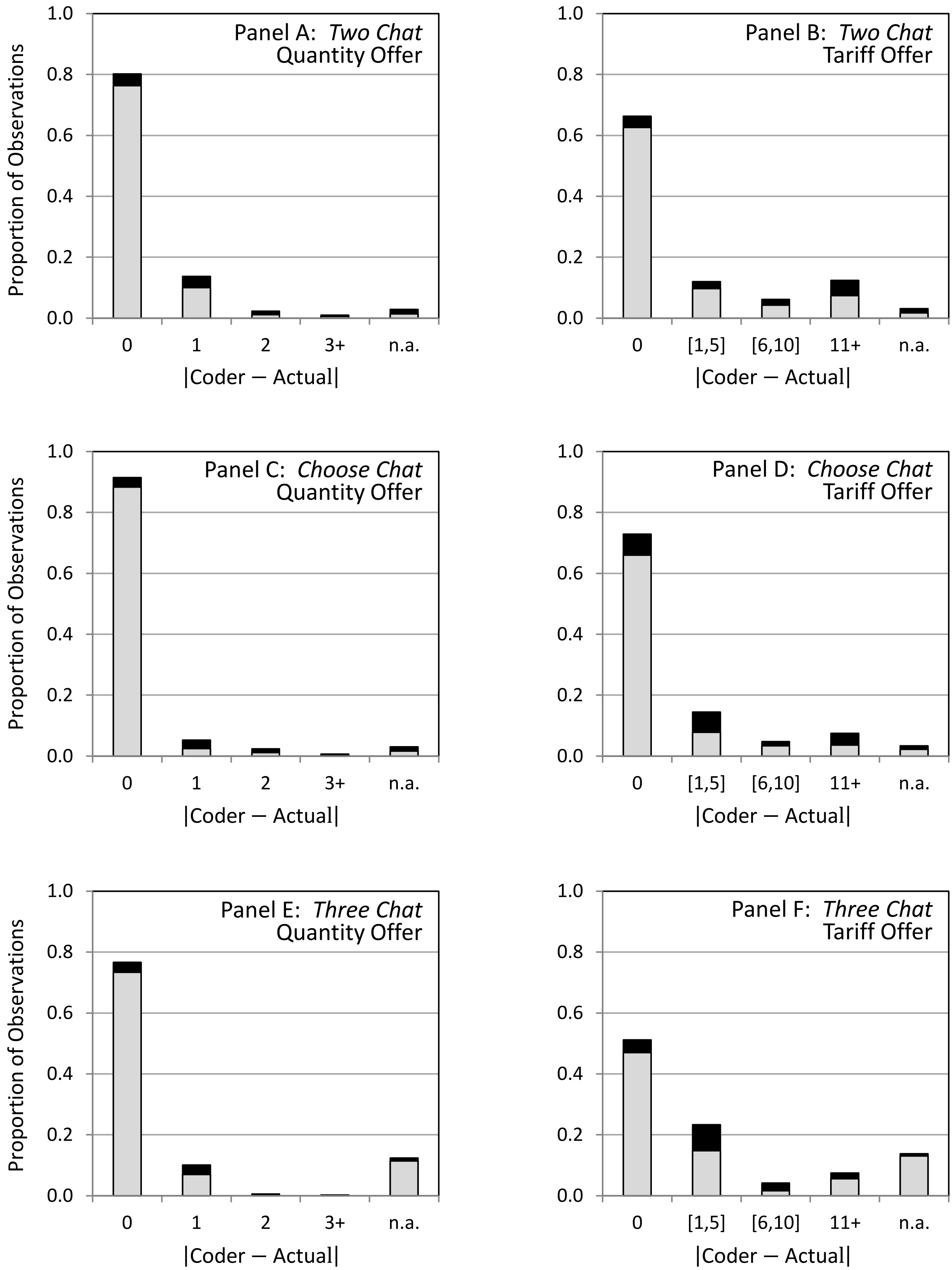


Figure 4: Accuracy and Mutual Agreement of Coded Chat



Notes: *Two Chat* sample consists of 350 contract offers, *Choose Chat* of 370, and *Three Chat* of 360, each of which is assessed by two coders. Grey bar is proportion of sample for which coder's guess of contractual variable agrees with other coder and black for which his guess disagrees with the other coder. N.a. indicates an affirmative statement that coder could not guess variable based on chat content.

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