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# The Effect of Communication Media on Information Sharing in Supply Chains

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Using laboratory experiments, we study how communication media affect cooperation in a supply chain when the buyer has private information about the end-customer demand. We show that coordinating contracts (quantity discount) combined with efficient means to electronically share private information (one-way, pre-defined text message) result in almost efficient outcomes, but only if verbal communication takes place before the actual contracting stage. Content analysis shows that verbal communication is especially effective in establishing trust and trustworthiness when players talk about reciprocal strategies and it is more so when the buyer clearly expresses guilt from lying. Furthermore, the clarification of the mutual benefits of information sharing moves the buyer to truthfulness. Finally, we show that our results are not due to a reputation building mechanism of repeated interaction.

*Key words:* asymmetric information; cheap talk; trust; trustworthiness; behavioral operations management

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## 1. Introduction

The flow of Information is one of the most important challenges for supply chain management. To share information, many firms have recently experimented with advanced planning systems (APS), or collaborative planning, forecasting and replenishment (CPFR) initiatives. For example, Walmart and Sara Lee Branded Apparel successfully implemented a CPFR pilot. The parties involved reported an increase in sales of 32% after 24 weeks of implementation (Kurtuluş 2017). Nevertheless, while there is no doubt about the potential benefits of information sharing, many firms are reluctant to share demand information with their suppliers (Gümüüş 2017). Stein (1998) reports that managers often fear that information sharing may turn into a competitive disadvantage, given the strategic supply chain environment. Similarly, Verity (1996) notes managers' concerns with

regard to increases in prices when forecast information is shared. Fraser (2003) surveys 120 firms and finds that 42% of the respondents perceive a lack of trust as one of the largest obstacles hindering firms' adoption of information sharing systems.

In this study, we analyze how pre-game communication affects the impact of simple and efficient means of sharing private information (i.e., simple one-way text messages) on an operative basis (e.g., weekly or monthly) in a supply chain contracting context. Previous research shows that such simple messages are somewhat effective since truthful messages meet trusting recipients, and yet efficient outcomes are generally not achieved (Hyndman et al. 2013, Özer et al. 2011, 2014, Spiliotopoulou et al. 2016). We show that the efficiency enhancing effects of information sharing can be boosted by any form of verbal communication taking place prior to actually sharing the private demand information via simple one-way messages. To this end, this study guides managers as to which communication media to use (textual vs. verbal, anonymous vs. identification) and which topics to address at the very beginning of an information sharing initiative that may be plagued by strategic incentives to misrepresent demand information. For the sake of clarity, we use the term "information sharing"

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for the simple one-way text message that shares the private demand information and the term “communication” for any other information that is shared prior to the actual contracting stage.

We compare different means to communicate in a dyadic distribution channel with a single supplier and a single buyer where the buyer has private demand information. The typical, yet stylized, supply chain bargaining situation is characterized by (a) sequential moves, that is, a contract offer by the supplier and an order quantity or a rejection by the buyer, (b) non-linear quantity discount schemes that reduce informational rents and efficiency losses from double marginalization (Kolay et al. 2004), and (c) efficiency losses when information is used strategically.

In line with previous research on communication media in social dilemmas (see literature review), we rely on controlled laboratory experiments with a student subject pool. This method makes it possible to establish the root-cause effects of different communication media in the pre-phase of an information sharing initiative while ensuring internal validity. Although we believe that research on communication media can benefit from other empirical approaches (e.g., interview studies), we see one key advantage in using experiments: the critical aspects of underlying economic incentives and information availability can be tightly controlled. At the same time, it seems difficult to discern whether analytical forecasts (e.g., from an ERP system) are misrepresented by practitioners due to good will (e.g., factoring in expert knowledge) or strategic considerations.

We first replicate the finding of prior research that information sharing via simple one-way messages improves supply chain efficiency by comparing a baseline treatment without information sharing to a reference treatment with information sharing (i.e., subjects are allowed to share private demand information, that is, “low demand” or “high demand”). We then move forward by comparing different forms of pre-phase communication, that is, chats, verbal but anonymous, and videoconferences, to this reference treatment. In the pre-phase, the supply chain members may, for example, discuss how they are planning to share and process information and/or how to divide the bargaining pie.

We find that any form of verbal communication supports cooperative play in the supply chain. Content analysis reveals that this form and timing of communication is especially effective in establishing trust and trustworthiness when players talk about reciprocal strategies and this is more so when the buyer clearly expresses guilt from lying. The clarification of the mutual benefits of information sharing moves the buyer to truthfulness. The positive performance effect of verbal pre-phase communication can be further

strengthened by training that thoroughly explains the strategic issues and coordination potential when sharing information. Our main experiments consider a finite, repeated interaction (partner design). Assuming sequential rationality, the standard game-theoretic benchmarks collapse to the one-shot game. Yet, in order to be closer to the one-shot benchmark from a behavioral perspective, we replicate our main results in a one-shot interaction with a round-robin matching procedure (stranger design).

This study is organized as follows. Section 2 reviews the related literature, while Section 3 outlines the results from the game-theoretic model. Section 4 introduces our experimental design and hypotheses. Section 5 summarizes the experimental protocol, with the results being presented in Section 6. Section 7 describes the design and results from our communication content analysis. Section 8 presents the design and the results from the experiments with the one-shot round-robin matching procedure. Finally, we provide a summary of the results and conclude the study in Section 10.

## 2. Literature Review

We consider a situation in which the supplier negotiates the contract terms with a buyer who holds private information about price-sensitive and deterministic end-customer demand. There is a large body of literature that considers problems that are similar in the underlying incentive conflict but either vary in the operational setup, e.g., stochastic demand, or in the specific form of the private information, e.g., marginal production cost or holding cost (see, e.g., Corbett and Groote 2000, Corbett et al. 2004, Kolay et al. 2004).

The analytical supply chain (or channel) coordination literature shows that quantity discounts can fully coordinate the supply chain if private information is shared truthfully by the buyer and trusted by the supplier (leading to a full information scenario), see, for example, Corbett et al. (2004). Yet, the rational and profit-maximizing buyer has an incentive to misrepresent private information in order to obtain profits that are above her minimum acceptable level (i.e. outside option). In this case, it is in the supplier’s best interest to offer a menu of contracts (e.g. quantity discount) that trades off the informational rents paid to the buyer and the inefficiencies resulting from suboptimally low (inefficient) order sizes. A quite general result across this literature is that the inefficient type (in our case: low demand, in other cases: high marginal cost or high holding cost) chooses an inefficiently low order size (i.e., an order size that is lower than in a full information scenario) while the efficient type chooses an efficient order size (“no distortion at the top”). (Laffont and Martimort 2009).

Several recent laboratory studies test the effectiveness of nonlinear contracts, such as quantity discounts, to coordinate the supply chain under both full information (Ho and Zhang 2008, Kong et al. 2018, Lim and Ho 2007) and asymmetric information (Inderfurth et al. 2013, Johnsen et al. 2019, Kalkanci et al. 2011, 2014, Sadrieh and Voigt 2017). A general pattern in all of these experiments is that non-linear contracts reduce efficiency losses, but not to the extent theoretically expected. A substantial amount of performance loss is due to the buyer's contract rejections (Pavlov and Katok 2011). Behavioral biases such as bounded rationality (Kalkanci et al. 2011, Wu and Chen 2014) and social preferences (Johnsen et al. 2019, Katok and Pavlov 2013, Loch and Wu 2008) have been identified as two decisive factors.

Another stream of behavioral research investigates the information sharing process in supply chains under asymmetric information. One stream tested whether information sharing is, despite the game-theoretic benchmark, effective in supply chains operating under (exogenous) wholesale price contracts (Hyndman et al. 2013, Özer et al. 2011, 2014, 2018, Spiliotopoulou et al. 2016) and nonlinear contracting schemes (Inderfurth et al. 2013, Sadrieh and Voigt 2017, Scheele et al. 2017). All of these studies show that the cheap-talk benchmark (shared information is uninformative and therefore ignored) is too pessimistic, but not obsolete. On average, allowing supply chain parties to share private information enhances performance. Yet, efficiency losses prevail since there is a significant amount of deception and mistrust.

All of these laboratory studies on information sharing use relatively simple forms of information sharing devices, that is, one-way or two-way restricted textual signals such as a demand forecast (high/low) or a cost position (high/low). We extend this line of research by still sticking to restricted textual signals in the actual information sharing process while investigating whether, how, and which forms of, pre-game communication (face-to-face/telephone/e-mail) affects trust and trustworthiness in a supply chain bargaining environment that relies on simple information sharing devices (i.e., one-way restricted text messages).

While the communication media effects of pre-game communication have not been investigated in supply chain contexts, it has received some attention in the economic literature on social dilemmas.

Some experimental papers show the positive effects of pre-game face-to-face communication on subjects' propensity to cooperate in a social dilemma games (see the seminal papers of Dawes et al. 1977, Isaac and Walker 1988, Isaac et al. 1985, and, for a review, Bordia 1997). Other studies investigate the role of textual pre-game communication (Duffy and Feltovich 2002). Few authors compare the effects of different communication forms.

Brosig et al. (2003) decompose the cooperation-enhancing effect of communication. They observe that face-to-face communication significantly increases subjects' cooperative play compared to a no-communication baseline treatment. By contrast, they observe only slightly more cooperation in the audio-conference, while visual identification showed no systematic effect. Furthermore, they investigate the effect of a video-lecture that explained the standard public good game, characterizing both the subgame-perfect equilibrium (zero investment in the public good) and the outcome that maximizes group payments. They do not find any significant effect of the lecture. In line with our findings, Bos et al. (2002) and Bochet et al. (2006) observe that text-based communication induces less cooperative play than an audio- or video-conference or a face-to-face meeting.

The main difference between the economic literature and our supply chain setting is that our model comprises information sharing of private information, a bargaining stage, and efficiency gains arising from cooperation.

### 3. Outline of the Model

#### 3.1. Assumptions

Using the setting of all-units discounts extensively studied by Kolay et al. (2004), we consider a supply chain that consists of a supplier (male pronouns,  $s$ ) and a buyer (female pronouns,  $b$ ). The supplier produces a product at marginal cost  $c$  and distributes the product through the buyer, who then sells the product to the end-customers. For simplicity, the only cost the buyer incurs is the payment to the supplier. At the time of contracting, the supplier does not know the demand, whereas the buyer does. It is assumed that the price-sensitive end-customer demand follows a linear function. The buyer faces inverse demand  $p_i(q) = a_i - q$  with  $i \in \{l, h\}$  and  $a_l < a_h$ . For a higher choke-off price, e.g.,  $a_h$ , the buyer can charge the end-customer a higher price for a given quantity  $q$ , and vice versa. The supplier only knows the likelihood  $\theta_i = \text{prob}(a = a_i)$  that the buyer has choke-off price  $a_i$  at the moment of contracting. We assume  $\theta_l + \theta_h = 1$ . The order quantity decision  $q$  is tantamount to making the end-customer price decision. We use a principal-agent framework, in which the supplier is a Stackelberg leader and offers an all-unit quantity discount contract on a take-it-or-leave-it basis to the buyer. If a buyer rejects the offer, both parties earn zero profits.

#### 3.2. Full Information

We will compare our experimental results to the first-best benchmark that assumes that all information is common knowledge. In this benchmark, the optimal end-customer price is  $p_i^* = (a_i + c)/2$ , the optimal

sales quantity is  $q_i^* = (a_i - c)/2$ , and the resulting supply chain performance is  $\pi_i^{sc*} = (a_i - c)^2/4$  (Ho and Zhang 2008). We define the average expected performance under full information as  $E[\pi^{sc*}] = \theta_l \times \pi_l^{sc*} + \theta_h \times \pi_h^{sc*}$ .

### 3.3. Asymmetric Information

The supplier's quantity discount contract is a menu of contracts consisting of pairs of per unit prices  $w_j$ ,  $j \in \{0, l, h\}$ , and threshold quantities  $\bar{q}_j$ ,  $j \in \{0, l, h\}$ , to which the per unit price applies. The total payment from the buyer to the supplier,  $T(q)$ , is defined by

$$T(q) = \begin{cases} w_0 \times q & \text{for } \bar{q}_0 = 0 \leq q < \bar{q}_l \\ w_l \times q & \text{for } \bar{q}_l \leq q < \bar{q}_h \\ w_h \times q & \text{for } \bar{q}_h \leq q \end{cases} \quad (1)$$

We define  $q_{ij}^*$  as the  $a_i$ -type buyer's optimal order choice for the price  $w_j$  in the contract  $T(q)$ , that is  $q_{ij}^* = \arg \max_{q \geq \bar{q}_j} p_i(q) \times q - w_j \times q$ .

Kolay et al. (2004) show that the supplier can induce the low-demand type buyer to order  $\bar{q}_l$  by choosing  $w_0$  sufficiently high and he can induce the high-demand type buyer to order  $\bar{q}_h$  by choosing  $w_h$  such that the buyer is indifferent between ordering  $\bar{q}_h$  and  $q_{hl}^*$ . Thus, under the optimal menu of contracts, each  $a_i$ -type buyer will buy at the threshold quantity  $\bar{q}_{j=i}$ . Therefore, the supplier needs to determine the optimal threshold quantities  $\bar{q}_j$  and the corresponding per unit prices  $w_j$ . The supplier solves

$$\max_{\bar{q}_l, \bar{q}_h, w_l, w_h} E[\pi^s] = \theta_l \times (T(\bar{q}_l) - c \times \bar{q}_l) + \theta_h \times (T(\bar{q}_h) - c \times \bar{q}_h) \quad (2)$$

subject to

$$p_i(\bar{q}_i) \times \bar{q}_i - T(\bar{q}_i) \geq p_i(q_{ij}^*) \times q_{ij}^* - T(q_{ij}^*) \quad \forall i, j \in \{l, h\} \quad (3)$$

$$p_i(\bar{q}_i) \times \bar{q}_i - T(\bar{q}_i) \geq 0 \quad \forall i \in \{l, h\} \quad (4)$$

The participation constraints (4) ensure that both buyer types accept the contract. The incentive constraints (3) guarantee that buyer type  $a_i$  chooses the order quantity  $\bar{q}_i$ . This mechanism is commonly termed *self-selection* because the buyer reveals her private information with her contract choice. Thus, the supplier maximizes expected profits in (2) by anticipating that the order size  $\bar{q}_i$  and the resulting per unit price  $w_i$  will be chosen with a probability of  $\theta_i$ .

It is conventional wisdom that under the optimal menu of contracts: (i) the low-demand type buyer earns zero surplus; (ii) the high-demand type buyer earns an informational rent; (iii) the threshold

quantity  $\bar{q}_l$  is downward distorted ( $\bar{q}_l \leq q_l^*$ ); (iv) the threshold quantity  $\bar{q}_h$  is efficient; (v) communication and information sharing are cheap-talk (Laffont and Martimort 2009). In the following, we elaborate further on the contract design trade-offs (i.e., efficiency vs. informational rents) in order to show that the high-demand type buyer has an incentive to signal that she is a low-demand type.

In the optimal menu of contract, the participation constraint binds for the low-demand type buyer. It follows that for any  $\bar{q}_l$  the supplier sets  $w_l = a_l - \bar{q}_l$  to reap all supply chain profits from the low-demand type buyer.

Informational rents are a result of an incentive compatible contract requiring that the high-demand type earns at least as much when ordering at the per unit price  $w_h$  as when ordering at the per unit price  $w_l$ . Note that the high-demand type buyer earns more for any given order size than the low-demand type. Intuitively, the high-demand type buyer can charge higher end-customer prices to clear the market for any given order size  $q$ . In other words, a contract that leaves zero profits to the low-demand type will leave profits larger than zero to the high-demand type (= informational rent).

Formally, the trade-off between efficiency and informational rent can be depicted by expressing the high-demand type buyer's informational rent as a function of  $\bar{q}_l$ . Consider the high-demand type buyer's profit when ordering under  $w_l$ , that is,  $\pi_h^b(q_{hl}^*) = (p(q_{hl}^*) - w_l) \times q_{hl}^*$ . Inserting  $w_l = a_l - \bar{q}_l$  gives  $\pi_h^b(q_{hl}^*) = (a_h - q_{hl}^* - a_l + \bar{q}_l) \times q_{hl}^*$ .

There are two scenarios. First, the high-demand type buyer orders at the threshold when selecting  $w_l$ , that is,  $q_{hl}^* = \bar{q}_l$ . It follows that  $\pi_h^b(\bar{q}_l) = (a_h - a_l) \times \bar{q}_l$ . Second, the high-demand type buyer orders above the threshold, that is,  $q_{hl}^* > \bar{q}_l$ . In this case, the buyer optimally orders  $(a_h - w_l)/2$  (see Ho and Zhang 2008) and it follows  $\pi_h^b(\bar{q}_l) = (a_h - a_l + \bar{q}_l)^2/4$ . In both cases, the high-demand type buyer's profit is strictly increasing in the quantity  $\bar{q}_l$ . As argued below,  $\bar{q}_l$  is increasing in  $\theta_l$  and the high-demand type buyer has an incentive to make her supplier believe that she is a low-demand type.

The supplier faces an efficiency-informational rent trade-off. If the likelihood of trading with a low-demand type is high, that is,  $\theta_l$  is high, the supplier trades lower profits from trading with the high-demand type (higher informational rents due to higher  $\bar{q}_l$ ) against higher profits (tantamount to higher efficiency due to higher  $\bar{q}_l$ ) when trading with the low-type. In turn, when  $\theta_l$  is low, the informational rent paid to the high-demand type carries a higher weight and the threshold  $\bar{q}_l$  is set relatively low. In the extreme case of  $\theta_l = 0$ , the supplier sets  $\bar{q}_l = 0$  and thus, sets the information rent of the high-demand

type to zero. This scenario resembles the full information scenario.

Analytical results are provided in the Online Appendix EC.4.

The buyer’s expected profit is

$$E[\pi^b] = \theta_l \times (p_l(\bar{q}_l) \times \bar{q}_l - T(\bar{q}_l)) + \theta_h \times (p_h(\bar{q}_h) \times \bar{q}_h - T(\bar{q}_h)), \quad (5)$$

the expected supply chain profits are

$$E[\pi^{sc}] = E[\pi^s] + E[\pi^b], \quad (6)$$

and the channel efficiency is defined as follows:

$$\frac{E[\pi^{sc}]}{E[\pi^{sc*}]} \quad (7)$$

For  $\theta_l < 1$  it follows that  $\bar{q}_l < q_l^*$  and  $\frac{E[\pi^{sc}]}{E[\pi^{sc*}]} < 1$ , that is, inefficiencies arise.

### 3.4. Example

Table 1 presents the theoretical optimal all-unit quantity discount contract based on our parameter choices in the experiments, that is,  $a_l = 15$ ,  $a_h = 25$ ,  $c = 7$ , and  $\theta_l = \theta_h = 0.5$ . It follows from solving model (2)–(4) while ensuring that profits are strictly larger by at least the amount of 0.1 compared to any alternative in order to avoid ties. As an example: A high-demand type buyer orders under the contract with  $\bar{q}_l = 1.3$  and  $w_l = 13.6$  a quantity of  $q_{hl}^* = 5.7$  and earns an informational rent of  $(p(q_{hl}^*) - w_l) \times q_{hl}^* = (25 - 5.7) \times 5.7 - 13.6 \times 5.7 = 32.5$ , while her supplier earns  $(w_l - c) \times q_{hl}^* = (13.6 - 7) \times 5.7 = 37.6$ . In our experiments, the supplier inputs a subjective probability distribution into a decision support tool, which then calculates contract terms and profits. A table with possible contracts for  $\theta_i \in [0\%, 100\%]$  and  $\delta \in [0\%, 50\%]$  both in steps of 10% is provided in the Online Appendix, EC.5.

## 4. Experimental Design and Hypotheses

### 4.1. Decision Support

The design of menus of contracts with quantity price breaks has been reported to be very challenging for subjects (Kalkanci et al. 2011, 2014). Subjects have

difficulties in setting the price breaks effectively to separate different buyer types. This hampers them from reaping the benefits of non-linear contracts. Kalkanci et al. (2011) suggest: “a decision support tool that would help suppliers set their discount schemes effectively would be especially beneficial” (Kalkanci et al. 2011, p. 698). We take account of this complexity issue and adopt the decision support tool introduced by Inderfurth et al. (2013). The tool asks the supplier for the likelihood that the buyer is of type  $a_i$  (e.g.,  $\theta_l$  and  $\theta_h$ ) and then calculates the optimal contract parameters (e.g.,  $\bar{q}_l, \bar{q}_h, w_l, w_h$ ) for a rational and profit maximizing agent by solving model (2)–(4) while ensuring that profits are strictly larger by at least the amount of 0.1 compared to any alternative in order to avoid ties. The tool has two advantageous. First, it solves the complexity issue by providing the optimal price breaks, and, second, it provides a measure (entered probabilities) for the subject’s trust in the buyer’s signal.

To provide the supplier with more leeway to allocate profits, we give the supplier the option to lower the per unit prices  $w_l$  and  $w_h$ . Our price adjustment mechanism,  $\delta$ , applies to both prices in order to ensure that the buyer’s incentive compatibility and participation constraints are never violated while ensuring that the difference between contract alternatives is increasing. Formally, the slack in the otherwise binding incentive constraint (3) for the high-demand type and the participation constraint (4) for the low-demand type is increasing with increasing  $\delta$ . This price adjustment,  $\delta$ , allows the supplier to allocate the profits almost arbitrarily between the parties. The buyer’s and the supplier’s profits for a given  $\delta$  are calculated by

$$\pi_i^b = p_i(q) \times q - (1 - \delta) \times T(q) \quad (8)$$

$$\pi^s = (1 - \delta) \times T(q) - c \times q. \quad (9)$$

### 4.2. Sequence of Events

Figure 1 summarizes the sequence of events. In the first stage, the buyer obtains her private information  $a_i$  and can send one of the following computerized messages: “demand is low” (in the following formalized as  $S_l$ ), “demand is high” ( $S_h$ ) or “no message” ( $S_{no}$ ). The buyer is provided with a decision support tool that is identical to the tool of the supplier in the second stage. This provides the opportunity to simulate the consequences of the supplier’s reaction to her message.

In the second stage, the supplier designs his menu of contracts by (a) stating the subjective probability (i.e., the a posteriori belief after receiving signal  $S_k$ ) that the buyer has a choke-off price  $a_i$ , that is,  $\theta_i(S_k) \forall i \in \{l, h\}$  and  $k \in \{l, h, no\}$  with  $\theta_i(S_k) \in \{0\%, 10\%, \dots, 90\%, 100\%\}$  and by (b) stating an additional price adjustment ranging from  $\delta \in$

**Table 1** Supplier’s and Buyer’s Profits under the Menu of Contracts

Discount scheme	Profit supplier				Profit buyer	
	$\bar{q}_j$	$w_j$	$a_l$	$a_h$	$a_l$	$a_h$
0	0	15.0	0	10.5	0	11.4
l	1.3	13.6	8.7	37.6	0.1	32.5
h	9.0	12.4	48.5	48.5	−57.5	32.6

$\{0\%, 1\%, \dots, 49\%, 50\%\}$ . We enforced that  $\theta_l(S_k) + \theta_h(S_k) = 100\%$ . This information is then passed on to the decision support tool, which solves the optimization problem (2)–(4) with  $\theta_i = \theta_i(S_k)$  while ensuring that profits are strictly larger by at least the amount of 0.1 compared to any alternative in order to avoid ties. The decision support tool shows, for the given input of  $\theta_i$  and  $\delta$ , the profits of the supplier and the buyer for each possible realization of  $a_i$  and for each per unit price  $w_j$  offered in the menu of contracts (see Table 1 for an example). The supplier is allowed to check as many contracts as desired before submitting the final offer.

In the third stage, the buyer only chooses the per unit price  $w_j$  for which she wants to order, whereas the optimal order size  $q_{ij}^*$  is determined by the experimental software. As a decision support tool, the buyer sees her profit as well as her supplier's profit resulting from her per unit price choice  $w_j$  on the computer screen.

In the last stage, the following results are summarized: the contract offer from the supplier, the buyer's contract choice with the resulting per unit price  $w_j$ , and the respective profit from the current game round.

### 4.3. Information Sharing

We consider both a one-shot game and a finitely repeated game in our experiments. In both scenarios, the equilibrium strategy for (sequentially) rational and profit-maximizing supply chain parties provides our first hypothesis (Fudenberg and Tirole 1991). We consider the finitely repeated game in our main experiments and run another set of experiments with round-robin matching procedure to establish the robustness of our results in a set-up that is one-shot. Note that we hold the interaction mode constant across treatments, so it cannot explain treatment differences.

#### HYPOTHESIS 1. Standard game-theoretic expectations

- a) *No Trustworthiness*: The high-demand type buyer's profit is strictly increasing in the probability  $\theta_l(S_k)$  and vice versa (see Appendix EC.4). Thus, a high-demand buyer has a strict incentive

to send a message that increases the supplier's belief  $\theta_l(S_k)$ . Since the buyer can lie arbitrarily without any direct cost (e.g., no penalties if misreporting is detected ex post), shared information is cheap talk in the sense of Kartik (2009). Shared information is expected to be untrustworthy.

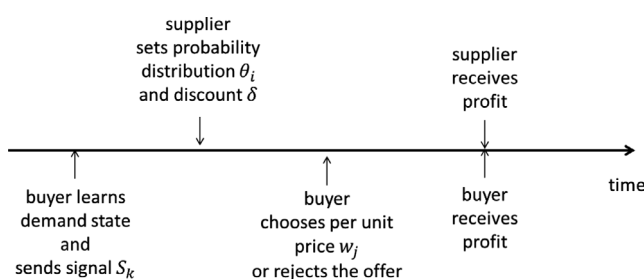
- b) *No Trust*: Since the buyer's signals are uninformative, the supplier will ignore any shared information and offer the quantity contract based on the most precise information he has about the buyer's type, that is, the a priori probability  $\theta_i = \theta_i(S_k)$ . The supplier mistrusts shared information.
- c) *No further profit allocation*: The model (2)–(4) already accounts for the buyer's compatibility and participation. Any price adjustment reduces the supplier's profits and it follows that  $\delta = 0$ .
- d) *Full self-selection*: The buyer maximizes profits by *self-selection*, that is, each buyer of type  $a_i$  chooses the block with price break and price  $w_i$ , respectively.
- e) *Performance*: Channel efficiency equals the second-best benchmark, that is,  $E[\pi^{sc}]$ .

In order to isolate the behavioral effect of information sharing from other behavioral factors, such as bounded rationality or fairness preferences, we compare a *baseline treatment* without information sharing (and without communication) to a *reference treatment* with information sharing. A treatment overview is provided in Table 2.

One source of inefficiency results if a low-demand type buyer chooses the downward distorted order size,  $\bar{q}_l < q_l^*$ . In line with previous research, we expect that inefficiencies from this source are reduced by information sharing, trust, and trustworthiness (Hypotheses 2a and 2b). If the low-demand type buyer truthfully shares her private information by sending the message  $S_l$  and the supplier trusts it, then the supplier will adjust the a posteriori belief to  $\theta_l(S_l) = 1$ . This results in efficient outcomes when solving (2)–(4), that is,  $\bar{q}_l = q_l^*$  and  $\frac{E[\pi^{sc}]}{E[\pi^{sc*}]} = 1$ . Note, though, that the high-demand type buyer has an incentive to signal low demand in order to increase informational rents (see Appendix EC.4). The supplier is expected to compensate the loss of informational rent of an apparently trustworthy buyer with a price adjustments  $\delta > 0$ .

Another source of inefficiency results if the buyer does not choose the profit-maximizing contract (i.e., she does not self-select into the contract that was designed for her). Reasons for this contract choice behavior are reported to be bounded rationality and fairness preferences (see Johnsen et al. 2019). These

Figure 1 Sequence of Events in the Game



**Table 2** Treatment Overview

Treatment	Information sharing	Pre-game communication	Visual identification	Tutorial
Baseline ( $n = 26$ )	No	No	No	No
Reference ( $n = 29$ )	Yes	No	No	No
Identification ( $n = 27$ )	Yes	No	Yes	No
Chat ( $n = 29$ )	Yes	Text	No	No
Audio ( $n = 27$ )	Yes	Verbal	No	No
Video ( $n = 28$ )	Yes	Verbal	Yes	No
Consulting ( $n = 30$ )	Yes	Verbal	Yes	Yes

*Notes.* In the first column, the numbers in parentheses indicate the number of independent observations. The second column indicates whether information exchange through a restricted message is allowed between supplier and buyer. The third column indicates the medium of the pre-game communication. The fourth column indicates whether the interaction is anonymous. The fifth column shows whether additional training was given to the subjects.

behavioral factors may also be present in our baseline treatment. Johnsen et al. (2019) show that the adverse effects of this contract choice behavior can be effectively mitigated by increasing the profit differences between the contract alternatives. As highlighted above, this can easily be done in our experiments by increasing  $\delta$ . We therefore postulate an increase in the price adjustment  $\delta$  under information sharing in Hypothesis 2c, because reciprocating behavior under information sharing should outweigh this effect. This, in turn, is expected to further increase self-selection behavior (Hypothesis 2d).

#### HYPOTHESIS 2. *Information sharing*

- Trustworthiness:* The buyer's signal  $S_k$  is informative about her private information  $a_i$ , that is,  $S_k$  and  $a_i$  are positively correlated.
- Trust:* The supplier relies on the buyer's signal  $S_k$  to set the a posteriori probabilities  $\theta_i(S_k)$  in the decision support tool.
- Profit allocation:* The supplier's price adjustment is stronger in the reference treatment than in the baseline treatment.
- Self-selection:* The buyer self-selects more in the reference treatment than in the baseline treatment, that is, each buyer of type  $a_i$  chooses the block with price break  $\bar{q}_i$  and price  $w_i$ .
- Performance:* The supply chain performance is higher in the reference treatment than in the baseline treatment.

#### 4.4. Face-to-Face Communication

We expect that the potency of this information sharing system can be substantially enhanced when subjects are allowed to communicate face-to-face before offering a contract. Face-to-face communication possesses several features that may be essential to foster cooperation (i.e., information is shared truthfully and trusted, the buyer self-selects into her contract, and the resulting efficiency gains are allocated between the parties).

Under face-to-face communication, players communicate through verbal and visual channels and can, therefore, *exchange unrestricted* messages, *respond* to each other, and *visually identify* each other (Brosig et al. 2003). For example, the exchange of unrestricted messages provides the opportunity to clarify how the players intend to use the information sharing system and how to allocate profits. Furthermore, the visual channel allows them to identify each other, which decreases the social distance and, in turn, increases the relevance of reputational effects (Bohnet and Frey 1999a, Hoffman et al. 1996).

In order to establish the effects of face-to-face communication, we compare a *video treatment* to the *reference treatment*. In the former, subjects engaged in a video conference that allowed for both visual identification and auditory communication via the headset before entering into a game identical to that in the reference treatment. We did not limit the content of communication, neither in this nor in any of the following treatments with communication. The pre-game communication phase in this treatment as well as in all of the following treatments lasted for up to 10 minutes.<sup>1</sup>

#### HYPOTHESIS 3. *Face-to-face communication*

- Trustworthiness:* The buyer's signals correlate more strongly with the private information,
- Trust:* The supplier relies more on the buyer's signals by adjusting the a posteriori probabilities  $\theta_i(S_k)$ ,
- Profit-allocation:* The supplier's price adjustments are stronger,
- Self-selection:* The buyer self-selects more,
- Performance:* The supply chain performance is higher, with face-to-face communication (video treatment) than without (reference treatment).

A series of experiments have shown that face-to-face communication on the relevant dimensions of the



dilemma is much more likely to arouse cooperation than a discussion on dilemma irrelevant issues (Bouas and Komorita 1996, Dawes et al. 1977). Since our supply chain model comprises bargaining and information sharing aspects, it is relatively complex, making it likely that participants do not address all relevant aspects of the dilemma. We therefore hypothesize that the effect of face-to-face communication on cooperation rates can be enhanced when subjects get an additional training on the relevant game dynamics.

In order to investigate the effects of training, we compare the *consulting treatment* to the *video treatment*. In the former, a tutorial showed how trustworthiness (i.e., honest messages) and trust (in the message) interact. We highlighted the potential gains from adjusting the beliefs  $\theta_i(S_k)$  as well as the risk of deception on individual profits. In the tutorial, we also discussed how the additional price adjustment,  $\delta$ , needed to be set in order to ensure that truthful messages result in a win–win outcome. A transcript of the tutorial is provided in the Online Appendix, EC.7.

**HYPOTHESIS 4.** *Training (analogue to Hypothesis 3 while replacing “face-to-face communication” by “training”).*

#### 4.5. Root-Cause Effects

In order to disentangle the reasons why face-to-face communication fosters cooperation, we systematically decompose the elements of face-to-face communication. We omit to provide hypotheses for this explorative part of the study.

In the *identification treatment*, we eliminated anonymity by showing the matching partner on the computer screen for 10 seconds. Any kind of visual signaling was not permitted.

In the *chat treatment*, subjects had the opportunity to communicate with their matching partner via a text-chat program. To prevent visual identification, there was no video transmission in this treatment.

In the *audio treatment*, subjects were given the opportunity to communicate with their matching partner via the audio headset. To prevent visual identification, there was no video transmission in this treatment.

## 5. Experimental Protocol

The experimental software was implemented with the toolbox *z-Tree* (Fischbacher 2007). Participants were recruited using the software *hroot* (Bock et al. 2014). 390 Subjects participated in our experiments. The subjects were randomly drawn from a pool of about 2300 graduate and undergraduate students of a mid-size university in Germany. Each subject participated only once

(between-subjects design). The number of independent observations are summarized in Table 2. We ran 26 experimental sessions. For each of the baseline, reference, and chat treatments, we ran two experimental sessions each with 24–30 subjects. For each of the audio, video and consulting treatments, we ran 6 sessions each with 8–10 subjects. In the audio, video, and consulting treatments, the number of participants was restricted by the limited number of sound-proof cubicles in the laboratory. The sound-proof cubicles were equipped with video conferencing technology (headset, video camera, video monitor). The instructions (see Online Appendix EC.6) were handed out to the subjects upon arrival and were read aloud. Then, after a short individual rereading time, the subjects had the opportunity to ask questions and these were answered privately. All the subjects had to pass a comprehension quiz before the experiment started. The computer randomly assigned the subjects the role of either the supplier or the buyer and then randomly matched pairs of supply chains. Neither the roles nor the matching was changed in the course of the experiment.

All subjects played 20 payoff-relevant rounds of the game explained in section 4.2. Before entering the payoff-relevant rounds, the subjects played six non-incentivized rounds of the game. In this training phase, each subject played with a computerized counterpart. The subjects knew that the decisions of the computer followed a preprogrammed and randomly determined algorithm. In particular, the messages sent by the computerized buyer, the contract offers from the computerized supplier, and the contract choices from the computerized buyer were randomly determined beforehand.

#### 5.1. Parameters

We set the choke-off prices at  $a_l = 15$  and  $a_h = 25$ , the marginal costs of the supplier at  $c = 7$ , and the a priori distribution of types  $\theta_l = \theta_h = 0.5$ . The game-theoretical expectation of the supplier's optimal all-unit quantity discount, that is, with the a priori distribution and zero price adjustment is displayed in Table 1. This information has been obtained by the subjects when entering the respective values in the decision support tool. We randomly determined a set of forecast states according to the a priori probabilities  $\theta_l$  and  $\theta_h$  in order to compare the performance over all rounds between the supply chains. To rule out order effects, the sequence in which the forecast states occurred varied between subjects but not between treatments.

#### 5.2. Incentives

In addition to a 3.00 euro show-up fee, subjects were paid proportionally to the sum of their profits in their experiments (measured in “thalers”) in all rounds in cash immediately after the experiment. The exchange

rate was set at 0.025 euro/thaler, that is, subjects received 2.50 euros for 100 thalers. In our experiments, participants earned 14.87 euros on average (suppliers: 15.35 euros, buyers: 14.40 euros). Each experimental session lasted approximately 70 minutes.

## 6. Results

We test the differences between all the treatment combinations in all further analyses with two-sided Mann–Whitney U (MWU) tests if not indicated otherwise. We account for the problem of multiple testing by using Bonferroni-corrected  $p$ -values<sup>2</sup> when we compare the effects between different communication media. If not stated otherwise, we use  $p < 0.005$  and  $p < 0.01$  for ten tests and an alpha group level of 0.1 and 0.05, respectively. The unit of analysis is the average decision of each supplier-buyer pair over the 20 payoff-relevant rounds. The numbers of independent observations are summarized in Table 2.

We perform the analysis on the buyer’s decisions with pooled data of both buyer types and the analysis on the supplier’s decision on pooled data of all signal types. We note that we do not find any qualitative differences if we disaggregate the analysis by buyer type or signal.

Table 3 presents the summary statistics for the buyer’s truthfulness and self-selection rate, the supplier’s trust and price adjustments across treatments. The supplier’s and the buyer’s profits, and the supply chain efficiency are summarized in Table 4. We present the results according to the sequence of events in the game. In section 6.1, we discuss the buyer’s trustworthiness, in section 6.2, the supplier’s trust, in section 6.3 the supplier’s price adjustments, in section 6.4 the buyer’s contract choices; in section 6.5 the implication for the supply chain performance, in section 6.6 the supplier’s and the buyer’s profits, in section 6.7 time trends, and in section 6.8, we summarize the main results.

### 6.1. Buyer’s Trustworthiness

We measure the buyer’s trustworthiness by her willingness to share her private information truthfully, that is, the percentage of cases in which the buyer sends a truthful signal to the supplier. The second column in Table 3 summarizes the results for all treatments, e.g., in the reference treatment, the signals of the high-demand type buyers were truthful in 61% of all cases, while in the remaining 39% of all cases a deceptive signal or no signal were sent.

We first test for a positive correlation between the buyer’s signal and her demand realization in the

**Table 3 Summary Statistics**

Treatment	Buyer				Supplier		
	Truthful signals [%]		Self-selection [%]	Rejection [%]	Trust [%]		Price adjustment [%]
	$a_l$ -type	$a_h$ -type			$\theta_l(S)$	$\theta_h(S_h)$	
Game-theor. expectation	100	0	100.0	0	50	100	0
Cooperative with equal profits	100	100	100.0	0	100.0	100	14.0
Baseline		–	62.11 (28.89)	21.54 (17.42)	–	–	4.86 (3.12)
Reference	71.03 (28.58)	61.03 (33.84)	71.90 (27.85)	17.41 (19.58)	64.05 (18.98)	78.01 (17.50)	7.04 (4.46)
Identification	77.31 (23.08)	69.23 (29.79)	78.46 (20.48)	11.73 (12.64)	70.28 (19.31)	80.39 (18.08)	7.24 (4.40)
Chat	84.83 (24.56)	73.10 (33.61)	85.87 (18.23)	5.34* (9.25)	69.42 (24.22)	80.48 (22.18)	9.40 (6.11)
Audio	87.41 (23.30)	85.93** (26.06)	90.74** (19.04)	5.62** (12.85)	89.77** (16.87)	89.82** (20.72)	9.82 (5.42)
Video	93.57** (11.62)	87.14** (25.22)	92.68** (12.21)	2.32** (5.52)	88.78** (16.70)	92.03** (14.56)	11.81** (5.24)
Consulting	96.67 (9.59)	96.00* (13.29)	94.00 (17.10)	0.07 (2.86)	96.38* (10.53)	97.60** (9.77)	13.24 (3.44)

*Notes.* “Truthful signals” describes the percentage of all cases in which the buyer types send a truthful signal. We set the game-theoretic expectations such that a low-demand type is always truthful while the high-demand type always lies while noting that any other randomization strategy is conceivable in the babbling-equilibrium. “Self-selection” describes the percentage of all cases in which the buyer chooses the self-selection contract. “Trust” describes the supplier’s average adjustment of the posteriori probability to the buyer’s signal. We set this to zero if the buyer sent no signal. The numbers in parentheses are the standard errors. The stars indicate significant differences from the reference treatment based on Bonferroni corrected  $p$ -values of \*\* $p < 0.005$  and \* $p < 0.01$  for ten tests. The stars at the consulting treatment indicate significant differences from the video treatment at conventional  $p$ -values of \*\* $p < 0.01$  and \* $p < 0.05$ .

**Table 4** Summary Statistics of Profits

Treatment	Supplier [m.u.]	Buyer [m. u.]	Efficiency [%]
Game-theor. expectation	28.58	16.32	92.58%
Cooperative with equal profits	24.25	24.25	100.0
Baseline	21.75 (3.14)	19.16 (2.31)	84.35 (6.64)
Reference	22.42 (3.89)	20.61 (2.94)	88.72 (8.95)
Identification	22.78 (2.65)	20.72 (2.43)	89.68 (7.36)
Chat	23.34 (1.90)	21.94 (3.42)	93.37 (6.85)
Audio	24.81 (3.55)	21.88 (3.59)	96.27** (6.35)
Video	24.44 (1.92)	22.65** (2.36)	97.09** (3.93)
Consulting	24.33 (1.55)	23.38 (1.81)	98.38** (4.76)

Notes. “Supplier” and “buyer” describe the average monetary profits of the supplier and the buyer over all rounds. “Efficiency” describes the ratio of the average channel profits to the first-best profits. [m.u.] stands for monetary units. The numbers in parentheses are the standard errors. The stars indicate significant differences from the reference treatment based on Bonferroni corrected  $p$ -values of  $**p < 0.005$  and  $*p < 0.01$  for ten tests. The stars at the consulting treatment indicate significant differences from the video treatment at conventional  $p$ -values of  $**p < 0.01$  and  $*p < 0.05$ .

reference treatment, and observe a significant correlation coefficient of 0.38 ( $p < 0.01$ ). We find that the buyer’s average rates of truthful signals are significantly higher than the theoretical 50% benchmark<sup>3</sup> ( $p \leq 0.01$ , sign test). Thus, we reject the standard game theory Hypothesis 1a stating that the buyer’s signals are uninformative about her private information and accept Hypothesis 2a. This supports the view that the buyer is more trustworthy than standard theory suggests. However, we note that the buyer makes decisions that go in the direction predicted by standard game theory as we observe that the high-demand type buyer lies significantly more often than the low-demand type buyer ( $p = 0.02$ ).

The results show that face-to-face communication has a strong impact on the buyer’s trustworthiness as we find that the rates of truthful signals are significantly higher in the video treatment compared to the reference treatment ( $p < 0.001$ ), which supports Hypothesis 3a.

We test the differences between all the pre-game treatment combinations and summarize the results in the Online Appendix (see Table 1 in EC.1). The results show that verbal communication has a significant and certainly the largest impact on the buyer’s trustworthiness as we find that the rates of truthful signals are significantly higher in the audio, video, and consulting treatment compared to the reference

treatment,  $p = 0.003$ ,  $p \leq 0.001$ ,  $p \leq 0.001$ , respectively. Irrespective of whether communication takes place with or without video transfer, it has—if at all—a minor impact on trustworthiness since we do not find a significant difference between the video and audio treatments,  $p = 0.614$ . Lifting anonymity in the identification treatment has no significant effect in comparison to the reference treatment ( $p = 0.328$ ). When communication takes place via text-chat, we observe a positive but not significant effect on the buyer’s trustworthiness compared to the reference treatment ( $p = 0.087$ ). We find no significant effects between the chat treatment and the audio and video treatments ( $p = 0.446$  and  $0.204$ ). Furthermore, comparing the video and the consulting treatments, we find that the tutorial additionally shown just before the videoconference has a positive effect on the buyer’s trustworthiness, thus supporting Hypothesis 4a ( $p = 0.033$ ).

## 6.2. Supplier’s Trust

We measure the supplier’s trust by his willingness to adjust the subjective probability towards the signal from the buyer. For each supplier in each period, we calculate the supplier’s adjustment using  $\theta = \frac{\theta_h(S_h) - 50}{50} \times 100$  if the supplier receives the signal  $S_h$  (demand is high) and  $\theta = \frac{\theta_l(S_l) - 50}{50} \times 100$  if the supplier receives the signal  $S_l$  (demand is low). If the supplier receives no signal, we set  $\theta = 0$ . Thus,  $\theta$  ranges between  $-100$  and  $+100$ , with  $\theta = -100$  indicating full distrust (entire adjustment in the opposite direction),  $\theta = +100$  indicating full trust (entire adjustment in the direction of the buyer’s signal), and  $\theta = 0$  describing the game-theoretic expectation, that is, the supplier ignores the signals from the buyer. The sixth and seventh column in Table 3 compare the supplier’s probability adjustments  $\theta_l(S_l)$  and  $\theta_h(S_h)$  between treatments.

The supplier’s probability adjustments  $\theta$  in the reference treatment are found to be significantly higher than the game-theoretic benchmark ( $= 0$ ) ( $p < 0.001$ , sign test). In line with previous research, we therefore reject the standard game-theoretic Hypothesis 1b, which claims that the supplier ignores the buyer’s signal, and accept Hypothesis 2b. Furthermore, the supplier’s trust is significantly higher in the video treatment than in the reference treatment, providing support for Hypothesis 3b. Face-to-face communication increases the supplier’s trust ( $p < 0.001$ ).

In a comparison of the pre-game communication media, the MWU tests (see Table 2 in EC.1 in the Online Appendix) show that it is verbal communication that has the strongest effect on the supplier’s trust, since we observe that the effect of verbal communication (audio treatment) is similar ( $p < 0.001$ ) to that of face-to-face communication (video treatment).

These treatments combine higher levels of trust with high levels of trustworthiness. Lifting anonymity has no significant effect on trust ( $p = 0.189$ ), and no effect on the buyer's trustworthiness. This is consistent with a non-significant effect between the audio treatment and the video treatment ( $p = 0.944$ ). Interestingly, the supplier seems reluctant to trust text-form communication as we do not find a significant difference in the adjustment of the subjective probabilities between the chat and the reference treatments ( $p = 0.256$ ). While, in section 6.1, we did not find a significant difference in the buyer's trustworthiness between the chat and the audio/video treatments, we now observe that the supplier's trust is significantly stronger in the audio and video treatments compared to the chat treatment ( $p = 0.002/p = 0.001$ ). In sum, we find that verbal communication increases the supplier's willingness to trust, with the strongest difference occurring between the verbal and text communication formats. The training tutorial has a positive effect on the supplier's trust ( $p = 0.012$ ), which is in line with Hypothesis 4b.

We finally note that we do not find any systematic differences if we consider the probabilities  $\theta_i(S_i)$  or  $\theta_i(S)$  separately and refer the reader to the Online Appendix for these results (see Tables 3 and 4 in EC.1).

### 6.3. Supplier's Price Adjustment

The sixth column in Table 3 summarizes the supplier's price adjustments  $\delta$  per treatment. We find that the average price adjustments in the baseline treatment are well above the theoretical benchmark ( $p < 0.001$  sign test). Furthermore, the supplier provides higher price adjustments in the reference treatment than in the baseline treatment ( $p = 0.035$ ). We thus reject the standard game-theoretic Hypothesis 1c and accept Hypothesis 2c, concluding that the supplier's price adjustments are higher with information sharing than without.

The MWU tests (see Table 5 in EC.1 in the Online Appendix) show that the supplier's price adjustments are significantly higher in the video treatment than in the reference treatment ( $p < 0.001$ ), thus supporting Hypothesis 3c. Face-to-face communication facilitates benefit sharing of cooperative behavior. The other communication forms (chat and audio) show a positive but not significant effect ( $p = 0.085/p = 0.061$ ). Identification has no significant effect, neither between the reference and the identification treatments ( $p = 0.826$ ) nor between the audio and video treatments ( $p = 0.323$ ). While we observed in section 6.2 that the supplier's trust increases significantly in the audio treatment, we find that the supplier's willingness to give (by high price adjustment) does not increase in the audio treatment. It seems that only the combination of verbal communication with visual identification makes the

supplier constantly less demanding, which translates to higher price adjustment offers.

Furthermore, we do not find support for Hypothesis 4c as the training tutorial does not increase the price adjustments (consulting vs. video treatments,  $p = 0.612$ ). However, a closer look shows that one benefit of the training (consulting treatment) may be less variance in the supplier's price adjustment offers. The  $F$ -test confirms this observation ( $p < 0.01$ ).

### 6.4. Buyer's Contract Choice Behavior

The third column in Table 3 presents the buyer's average self-selection rate per treatment. To recap, self-selection describes that a buyer of type  $a_i$  orders at a wholesale price  $w_i$  in the appropriate order size range. The theoretical benchmark is that the buyer always chooses the self-selection contract, thereby maximizing her profits.

We observe a mean frequency of self-selection of 62% in the baseline treatment, which is significantly lower than the theoretical benchmark of a rate of 100% ( $p < 0.001$ , sign test). We therefore reject the standard game theory Hypothesis 1d. This observation resembles the observations by Inderfurth et al. (2013) and Johnsen et al. (2019) that the frequent assumption of the agents' profit maximizing contract choice (self-selection) is a fragile mechanism.

In our findings, we note that information sharing slightly increases the self-selection rates to 72%. This effect points in the predicted direction (Hypothesis 2d), but is not significant ( $p = 0.214$  reference vs. baseline treatments). Moreover, we find support for Hypothesis 3d as the buyer's self-selection rates are significantly higher in the video treatment than in the reference treatment ( $p < 0.001$ ).

Comparing the pre-game communication treatments to the reference treatment (see Table 6 in EC.1 in the Online Appendix for  $p$ -values of the MWU tests), we find that only under verbal communication (audio, video) is the self-selection mechanism significantly and effectively restored ( $p < 0.001$ ,  $p < 0.001$ ). If communication takes place via text chat, we observe an effect that is positive but not significant ( $p = 0.020$ ) given the Bonferroni corrected alpha level. Furthermore, allowing for visual identification leads to no significant differences in the results ( $p = 0.406$ ).

A comparison of the consulting treatment with the video treatment indicates that the training tutorial in the consulting treatment has a positive effect on the buyer's self-selection frequency ( $p = 0.012$ ), as predicted in Hypothesis 4d. We find that the buyer's self-selection decision correlates with the generosity of the supplier's price adjustments since we find that higher price adjustments increase the likelihood of self-selection on the part of the buyer (see Appendix EC.3 for details.)

### 6.5. Supply Chain Performance

Table 4 summarizes the supply chain efficiency per treatment. We calculate the supply chain efficiency using  $\frac{1}{T+I} \sum_{i=1}^I \sum_{t=1}^T \frac{\pi_{it}^{sc}}{E[\pi_{it}^{sc}]}$ , where  $\pi_{it}^{sc}$  denotes the supply chain profits of the supplier-buyer pair  $i$  in period  $t$ , while  $I$  is the number of supplier-buyer pairs in the respective treatment and the number of rounds is  $T = 20$ .

In comparison to the game-theoretical expectation, we observe that the efficiency of the supply chains without information sharing (baseline treatment) is far below the second-best benchmark ( $p < 0.001$ ). Introducing information sharing significantly increases the supply chain efficiency, with a significant difference between the reference and baseline treatments ( $p = 0.009$ ) being observed, as predicted by Hypothesis 2d. However, the supply chain efficiency in the reference treatment is not different from the second-best benchmark ( $p = 0.251$ ).

We find that face-to-face communication has a significant positive effect on the supply chain performance. The average supply chain efficiency in the video treatment reaches 97% and is significantly higher than that in the reference treatment ( $p < 0.001$ ). The supply chains in the video treatment significantly outperform the second-best benchmark ( $p < 0.001$ ). The results strongly support Hypothesis 3e.

No significant differences can be found between the second-best benchmark and the performances of the supply chains using text-chat communication ( $p = 0.251$ ) and visual identification ( $p = 0.315$ ). See Table 7 in EC.1 in the Online Appendix for all the  $p$ -values from pairwise comparisons. Comparing the pre-game communication treatments with the reference treatment, we observe that verbal communication (audio/video) has a strong and significant effect on the supply chain performance ( $p < 0.001$ / $p < 0.001$ ), while text-chat communication has no significant effect ( $p = 0.019$ ) given the Bonferroni corrected alpha level. Lifting anonymity without further communication has no significant effect on the supply chain performance ( $p = 0.783$ ). Overall, the results support the notion that richer forms of communication increase the supply chain performance. Lastly, the training tutorial in the consulting treatment has a significant positive effect on the supply chain performance ( $p = 0.002$ ), thus supporting Hypothesis 4e.

### 6.6. Supplier's and Buyer's Profits

Table 4 summarize the supplier's and the buyer's average profits, respectively (see Tables 8 and 9 in EC.1 in the Online Appendix for  $p$ -values).

The results show that in all treatments, the supplier's average profits are significantly below the

game-theoretic expectation ( $p < 0.001$ , sign-test), while the buyer's profits are all significantly above the game-theoretic solution ( $p < 0.001$ , sign-test). In comparison to the reference treatment, we observe that communication per se has a positive effect on both the supplier's and the buyer's profits. Thus, both parties benefit from communication. From the supplier's perspective, we find the largest effects arise from verbal communication (audio and video) ( $p = 0.018$  and  $0.011$ ),<sup>4</sup> while from the buyer's perspective, it seems relevant that verbal communication is combined with visual identification, since we find a significant effect in the video treatment ( $p = 0.002$ ) but not in the audio treatment ( $p = 0.100$ ). This observation may be a consequence of the supplier's price adjustments, since we observed larger price adjustments in the video treatment than in the audio treatment (see section 6.3).

Furthermore, the results show that the condition lifting the anonymity as such has no significant effect on both the supplier's and the buyer's profits ( $p = 0.466$  and  $0.670$ ). The training tutorial seems to have a slight benefit for the buyer ( $p = 0.096$ ), while it does not significantly pay off for the supplier ( $p = 0.819$ ).

### 6.7. Time Trends

In this section, we investigate whether the subjects' behavior changes over time. We run the following four random effects regressions with respect to the four dependent variables: buyer's truthfulness, buyer's self-selection, supplier's trust, and supplier's price adjustment:

$$\begin{aligned} true_{it} = & i.treatment + i.treatment \times period + a\_h_{it} \\ & + period + u_i + \epsilon_{it} \end{aligned}$$

$$\begin{aligned} self\_selection_{it} = & i.treatment + i.treatment \times period \\ & + a\_h_{it} + period + u_i + \epsilon_{it} \end{aligned}$$

$$\begin{aligned} \theta_{it} = & i.treatment + i.treatment \times period + a\_h_{it} + period \\ & + u_i + \epsilon_{it} \end{aligned}$$

$$\begin{aligned} \delta_{it} = & i.treatment + i.treatment \times period + a\_h_{it} + period \\ & + u_i + \epsilon_{it} \end{aligned}$$

The subscript  $i$  indicates the supplier-buyer pair and the subscript  $t$  is the index for the time. The dependent variable  $true_{it}$  is a binary variable, which is one if the signal from buyer  $i$  in period  $t$  is truthful, otherwise zero. The dependent variable  $self\_selection_{it}$  is a binary variable, which is one if buyer  $i$  in period  $t$  chooses the self-selection contract. The dependent variable  $\theta_{it}$  describes the probability

adjustment of supplier  $i$  in period  $t$ . The dependent variable  $\delta_{it}$  describes the price adjustment of supplier  $i$  in period  $t$ . The variable  $i.treatment$  is a factor variable that specifies indicators for each treatment level. We include a dummy variable  $a_{hit}$  for the buyer's demand information ( $1 = a_{hi}$ ;  $0 = a_i$ ) and the variable  $period$  to measure the impact of the time on subjects' decisions. We further include interaction effects between the treatment and the period. There are two error terms:  $u_i$  is pair specific controlling for heterogeneity and  $\epsilon_{it}$  is independent across all observations.

We use a general linear model to estimate  $\theta_{it}$  and  $\delta_{it}$  and a logit model for the estimation of  $true_{it}$  and  $self\_selection_{it}$  since the latter are binary variables.

The results are presented in Table 5. The coefficient of  $period$  is not significant in all four regression models, which indicates that the subjects' cooperation is low but relatively stable in the reference treatment. The interaction effects reveal that the stability of cooperation substantially varies with the communication form. For the chat medium, we find that the buyer's

trustworthiness, the supplier's trust and price adjustment significantly decline over time, indicating that cooperation is of little stability. For the audio and video communications, we find that the buyer's trustworthiness slightly decreases over time, but the supplier's trust and price adjustment are relatively stable over time. For audio communication, we even find a slight increase in the supplier's trust over time. With respect to the self-selection rates, we do not find a significant time trend for either the chat, audio or video treatments. In sum, the results indicate that trust cooperation is less stable under text-chat communication than under verbal communication forms (audio/video).

### 6.8. Overall Comparisons

In Table 6, we summarize the main effects of the four communication treatments in comparison to our reference treatment and the effect of consulting in comparison to the video treatment.

Our observation is that communication is very helpful for players when coordinating the supply

**Table 5 Regression Results**

Variable	$true_{it}$ Coefficient (standard error)	$self\_selection_{it}$ Coefficient (standard error)	$trust\ \theta_{it}$ Coefficient (standard error)	Price adjustment $\delta_{it}$ Coefficient (standard error)
<i>identification</i>	0.25 (0.69)	0.17 (0.69)	6.37 (4.8)	-0.35 (1.44)
<i>chat</i>	2.06*** (0.72)	1.74* (0.72)	11.99* (4.67)	3.63** (1.4)
<i>audio</i>	2.84*** (0.78)	1.85* (0.77)	18.41*** (4.75)	3.86** (1.43)
<i>video</i>	3.29*** (0.80)	1.76* (0.75)	21.74*** (4.71)	4.44** (1.41)
<i>consulting</i>	5.84*** (1.06)	2.57*** (0.85)	30.72*** (4.63)	6.64*** (1.39)
<i>period</i>	-0.01 (0.02)	-0.02 (0.02)	-0.15 (0.14)	0.07 (0.04)
$a_h$	-0.77*** (0.12)	0.80 (0.13)	2.82*** (0.66)	-4.24*** (0.18)
<i>period</i> × <i>identification</i>	0.01 (0.03)	0.03 (0.03)	0.03 (0.2)	0.05 (0.05)
<i>period</i> × <i>chat</i>	-0.06* (0.03)	-0.03 (0.03)	-0.52*** (0.19)	-0.12* (0.05)
<i>period</i> × <i>audio</i>	-0.07+ (0.04)	0.05 (0.04)	0.36+ (0.2)	-0.1+ (0.05)
<i>period</i> × <i>video</i>	-0.06+ (0.04)	0.04 (0.04)	0.09 (0.19)	0.03 (0.05)
<i>period</i> × <i>consulting</i>	-0.13* (0.05)	0.10* (0.05)	0.02 (0.19)	-0.04 (0.05)
<i>constant</i>	2.44*** (0.52)	0.62 (0.51)	13.56*** (3.47)	12.7*** (1.03)
$\sigma_u$	1.59	1.48	15.45	4.78
$\sigma_\epsilon$	2.21	2.10	18.89	5.07
$\rho$	0.60	0.57	0.4	0.47
<i>prob</i> > $\chi^2$	0.00	0.17	0	0.00

Notes. We use a logit random effect model for the regression of the binary dependent variables  $true_{it}$  and  $self\_selection_{it}$ . For the regression of the variables  $\delta_{it}$  and  $\theta_{it}$ , we use a general linear random effect model. The numbers in parentheses are the standard errors. \*\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$ , + $p < 0.1$ .

**Table 6** Summary of the Main Effects

	Identification	Chat	Audio	Video	Consulting
Trustworthiness	n.s.	n.s.	+	+	+
Trust	n.s.	n.s.	+	+	+
price adjustment	n.s.	n.s.	n.s.	+	n.s.
self-selection	n.s.	n.s.	+	+	+
sc performance	n.s.	n.s.	+	+	+
supplier performance	–	n.s.	n.s.	n.s.	n.s.
buyer performance	n.s.	n.s.	n.s.	+	n.s.

*Note.* + significant positive effect, – significant negative effect, n.s. not significant.

chain. This contradicts the game-theoretic prediction. Communication is especially successful when a verbal communication channel is available. In contrast, text-based communication shows positive effects, but these effects are much weaker. Lifting the anonymity by using identification does not seem to have any relevant effects.

## 7. Communication Content Analysis

We observed that communication has a strong effect on supply chain coordination and more so when a verbal communication medium is used (audio/video conference). But what makes verbal communication more effective than text-based communication? And why do some groups of subjects cooperate while others do not? In this section, we first discuss a potential behavioral explanation for the impact of communication on trust and cooperation and afterwards we use content analysis to identify what promotes cooperation.

### 7.1. Theory and Rationale

We provide five explanations for why communication media affects trust and cooperation: comprehension of the game, reciprocity, the salience of the mutual benefits, the psychological cost of lying, and inequity aversion.

*Comprehension of the game:* One explanation is that communication increases the players' comprehension and understanding of the dilemma. A deep understanding of the game dimensions is a requirement for players to form expectations about the opponent's intentions and future actions. In addition, these expectations are likely influenced by their own assessment of the opponent's game comprehension, e.g., an opponent is likely judged as unreliable if his/her game comprehension is perceived to be poor.

*Reciprocity:* Another explanation is reciprocity. A reciprocal player rewards an action he perceives to be kind and punishes an action he perceives to be harmful (Falk and Fischbacher 2006). Reciprocal strategies, e.g. tit-for-tat, have become famous for promoting cooperation in social dilemma games (Axelrod and

Hamilton 1981, Parks and Rumble 2001, Sheldon 1999). Players who communicate are allowed to make promises on how to mirror kind actions and threats and how to retaliate against harmful, non-cooperative actions. Brosig et al. (2003) observe that players in their public good experiment effectively use reciprocal promises and threats in the pre-game communication phase to coordinate behavior.

*Salience of mutual benefits:* Another explanation involves mutual benefits. Weimann et al. (2019) show that a critical factor in establishing cooperative behavior is the salience of the mutual advantages among players. They demonstrate that the participants' willingness to cooperate in a social dilemma increases when each person's advantages from cooperation become more salient. Hence, only if all players share the view that cooperation is to everyone's advantage does the willingness to cooperate rise. Communication likely promotes the subject's confidence that cooperative behavior produces mutual benefits. We, therefore, hypothesize that communication work as a mechanism to convey the salience of the mutual benefits of cooperation.

*Psychological cost:* Following Kartik (2009), talk is cheap when it is not possible for players to verify the truth of the information they receive from other players and when it is possible to lie without incurring costs. However, there may be several reasons to bear costs from a lie. Recent experimental work shows that even in the absence of any direct monetary costs (e.g. a penalty for ex post verification of a misreport), people incur psychological cost (disutility) from lying, specifically from not being true to one's word, or from betraying someone's trust (Battigalli and Dufwenberg 2009, Charness and Dufwenberg 2006, Erat and Gneezy 2012, Gneezy 2005). Therefore, in situations in which talk seems to be cheap at first glance (no monetary cost for lying), talk can be strategically relevant because players incur latent psychological costs from lying. The communication medium may play a critical role because rich face-to-face communication offers more social context cues than leaner text communication. These cues make the interaction more personalized (Kiesler et al. 1984, 1985) and facilitates the building of a positive relationship (Burgoon et al. 2011), which in turn increases the psychological cost of lying (Van Zant and Kray 2014).

*Inequity aversion:* Another aspect is the role of social preferences in the bargaining stage (Bolton and Ockenfels 2000, Fehr and Schmidt 1999). In our experiments, the frequency of the buyer choosing the profit-maximizing contract increases and the rate of contract rejections decreases from leaner to richer communication forms. One potential explanation for contract rejections is that the buyer's preferences for fairness are private information (Pavlov and Katok

2011) and communication may resolve information asymmetries in this dimension as well. Another explanation is that, as outlined above, the interaction becomes more personalized, and by gaining more personal information about each other, subjects become more generous (Bohnet and Frey 1999a,b, Charness and Gneezy 2008).

## 7.2. Method

In light of the potential explanations discussed above, we will focus on the following content analysis variables: *comprehension of the game dimensions*, *reciprocity*, *mutual benefits*, *lying aversion*, and *inequity aversion*. We conceptually define the variables as follows. Comprehension of the game refers to the players' understanding of how their individual decisions affect the outcome. Psychological cost from lying pertains to the players' demonstrating guilt from lying. Mutual benefits concerns communicating about each other's advantages from cooperation. Reciprocity is the players' willingness to reward (punish) a favorable (negative) action. Inequality aversion focuses on the players' preferences for fairness in the profit allocation.

To measure the variables, two independent raters assessed the communication contents and answered a coding scheme with 21 questions referring to one of the variables introduced above (see Online Appendix EC.2) For each question, the raters filled out two scales: a 5-point Likert scale and a yes–no scale. On the yes–no scale (yes: 1, no: 0) the coders assessed whether the aspects are present in the communication phase. On the 5-point Likert scale, the coders provided their personal assessment to capture more subtle aspects in the message meaning. With this strategy, we attempted to measure both the manifested aspects as well as the latent aspects in the content. The Likert scale ranges from *strongly disagree* (–2), *disagree* (–1), *neutral* (0), *agree* (+1), *strongly agree* (+2).

For the sake of brevity, in the following, we will only present an analysis based on the data from the Likert scale. The same analysis on the yes–no scale is to be found in the Online Appendix EC.2. If not mentioned otherwise, the presented results remain qualitatively the same for the yes–no scale.

We assessed the inter-rater reliability for the 5-point Likert scale with an intraclass correlation (ICC) statistic based on the random-effect, consistency, average-measure variant (McGraw and Wong 1996). The resulting ICC was in a fair to excellent range for 14 questions, whereas seven questions gained a poor ICC of less than 0.4 (Cicchetti 1994). We therefore removed these seven questions from further analysis. Among them were also the two questions concerning inequity aversion. The coders' ratings on the yes–no scale revealed that these aspects were hardly

explicitly expressed in the communication phase, which presumably made the judgement less clear. It seems that aspects of inequity aversion were, if at all, only a minor topic in subjects' conversation. We show that our results are robust to the exclusion of these questionnaire items, see Online Appendix EC.2 for details. We form one scale for each variable by averaging the raters' scores over the related questions (e.g., the variable *mutual benefits* averages the answers from four questions, see Online Appendix EC.2). We calculate Cronbach's  $\alpha$  to measure the internal consistency of each variable (Cronbach 1951). The internal consistency is acceptable for all variables (*mutual benefits*  $\alpha = 0.92$ , *reciprocity*  $\alpha = 0.60$ , and *comprehension*  $\alpha = 0.77$ ).

## 7.3. Results

Table 7 compares the mean of the coders' ratings across treatments. The analysis shows that the raters attributed higher psychological cost of lying to the subjects in the videoconference treatment than in the chat treatment, since we find the coders' ratings to be significantly higher in the video treatment than in the chat treatment ( $p = 0.006$ ). Interestingly, we do not find this difference in the data from the yes–no scale. Therefore, it seems that the buyer hardly expresses guilt from lying explicitly but indicates this preference in a more latent manner. With respect to reciprocity, we do not find any significant differences in the coders' ratings between the chat treatment and the video treatment ( $p = 0.121$ ). The coders assessed the salience of mutual benefits to be slightly higher in the video treatment than in the chat treatment. However, this effect is not significant ( $p = 0.389$ ). The coders rated the overall game comprehension of the buyer and the supplier slightly higher in the video treatment than in the chat treatment, but the difference is not significant ( $p = 0.266$ ). However, the data from the yes–no scale indicate that the players in the video treatment had a better overall understanding of the game than the ones in the chat treatment.

**Table 7** Summary Statistics of Coder's Ratings

	Chat	Audio	Video	Consulting
<i>lying aversion</i>	–0.22 (0.66)	0.26* (0.86)	0.46** (1.10)	0.50** (0.96)
<i>reciprocity</i>	0.77 (0.49)	0.65 (0.50)	0.96 (0.51)	0.92 (0.38)
<i>mutual benefits</i>	1.23 (0.81)	1.17 (0.83)	1.34 (0.59)	1.60 (0.35)
<i>comprehension</i>	1.28 (0.59)	1.44 (0.49)	1.50 (0.34)	1.47 (0.26)

*Notes.* The numbers present the mean of the coders' ratings on the 5-point Likert scale (strongly disagree (–2), disagree (–1), neutral (0), agree (+1), strongly agree (+2)) over all questionnaire items referring to the same variable. The stars indicate significant differences from the ratings of the chat treatment with \*\* $p < 0.01$ , \* $p < 0.05$ .



To gain more insights, we next investigate the effects of the communication content on the subjects' individual decisions. We use four linear regressions regarding the dependent variables: the buyer's trustworthiness, the supplier's trust, the supplier's price adjustment, and the buyer's self-selection rate. We include the coders rating with respect to the four variables (lying aversion, reciprocity, mutual benefits, and comprehension) and treatment dummies in the models. We use the data from the communication treatments (chat, audio, video, and consulting) and treat each subject's average decision over the 20 playing rounds as one independent observation.

The results presented in Table 8 confirm a strong correlation between the raters' perception of the players' psychological cost from lying and both the buyer's trustworthiness and the supplier's trust. Furthermore, reciprocity has a significant positive effect on the buyer's trustworthiness, the supplier's trust and price adjustment, which indicates that players effectively used reciprocal strategies to establish cooperation. We find that the salience of mutual benefits has a significant effect on the buyer's truthfulness. The comprehension of the game has a slight positive effect on the supplier's trust and there is also a positive effect from the consulting treatment on supplier's trust. This implies that a deep understanding of the game dynamics fosters the building of trust. Furthermore, there is a strong negative effect from the chat treatment dummy on the supplier's trust. We conjecture that there are also non-content related factors attributed to the communication forms that affect the supplier's trust, e.g., the use of nonverbal communication such as tone of voice, body language or dress may also affect the building of trust (Kiesler et al.

1985). Lastly, we do not find any significant effects on the buyer's self-selection rates.<sup>5</sup>

In sum, the analysis reveals that communication is especially effective in establishing trust and trustworthiness when players use reciprocal strategies and is more so when the buyer clearly expresses guilt from lying. Furthermore, the clarification of the mutual benefits of information sharing moves the buyer to truthfulness.

## 8. One-Shot Interactions

We used a partner matching design in all our experiments. Since the experiment had a finite end, sequential rationality predicts that outcomes are identical to the one-shot game. Furthermore, we held the interaction mode constant across treatments; as such the interaction mode cannot explain the treatment differences. We test if our results are robust in one-shot interactions, since behavioral research shows that partner matching likely increases cooperative play (Cooper et al. 1996, Croson et al. 2003, Kamecke 1997).

We replicated the experiments of our main study in a round-robin matching procedure, that is, subjects played only once with each other possible partner. We ran three experiments to replicate our main insights, with the only exception being the round-robin (rr\_) procedure: rr\_baseline, rr\_reference, and rr\_video treatment. We chose to use the videoconference communication medium in the pre-game communication phase, because this medium showed the strongest effect in fostering cooperation.<sup>6</sup>

Given the round-robin matching, we restricted the number of rounds to five due to limited availability of ten sound-proof cabins. We ran six sessions for the rr\_video and rr\_reference treatments each and five sessions for the rr\_baseline treatment each with 10 subjects. We used session averages as one independent observation for the statistical analysis and an exchange rate of 0.1 in all treatments. The subjects' average earnings were 14.50 euros and the experiments lasted for about 50 minutes. The rest of the protocol was identical to that in our main experiment.

### 8.1. Results

Tables 9 and 10 summarizes the statistics. We find no significant differences between the rr\_baseline and rr\_reference treatments for the overall performances, that is, the supplier's, the buyer's, and the supply chain profits.

We find that the buyer's trustworthiness, supplier's trust and buyer's self-selection frequency are significantly higher in the rr\_video treatment than in the rr\_reference treatment. Furthermore, the supply chain performance, the supplier's profits, and the buyer's is

**Table 8** Regression Results from the Content Analysis

	Truthful signals	Trust $\theta$	Price adjustment $\delta$	Self-selection rate
<i>lying aversion</i>	0.05** (0.02)	10.24*** (3.03)	0.56 (0.49)	0.01 (0.02)
<i>reciprocity</i>	0.15** (0.05)	22.34* (8.64)	3.01* (1.40)	0.06 (0.06)
<i>mutual benefits</i>	0.08* (0.03)	4.81 (5.54)	1.45 (0.90)	0.02 (0.04)
<i>comprehension</i>	0.07 (0.07)	15.80+ (8.42)	3.15* (1.36)	0.02 (0.05)
<i>consulting</i>	0.04 (0.04)	16.01* (6.94)	1.21 (1.12)	0.01 (0.05)
<i>audio</i>	0.03 (0.04)	8.29 (7.18)	-0.71 (1.16)	0.00 (0.05)
<i>chat</i>	-0.04 (0.04)	-18.07* (7.26)	-0.74 (1.18)	-0.05 (0.05)
<i>constant</i>	0.56*** (0.06)	26.75** (9.79)	2.73+ (1.59)	0.82*** (0.06)

Note. \*\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$ , + $p < 0.1$ .

**Table 9 Summary Statistics**

Treatment	Buyer				Supplier		
	Truthful signals [%]		Self-selection [%]	Rejection [%]	Trust [%]		Price adjustment $\delta$ [%]
	$a_r$ -type	$a_n$ -type			$\theta_r(S_i)$	$\theta_n(S_n)$	
rr_baseline	–	–	80.00 (9.38)	10.40 (7.79)	–	–	5.14 (2.68)
rr_reference	51.39 (12.27)	60.26 (30.92)	80.67 (11.43)	13.33 (11.22)	63.49 (12.79)	76.31 (13.35)	6.41 (2.13)
rr_video	91.67** (12.90)	89.74** (7.94)	91.33+ (6.41)	2.67+ (3.26)	89.25** (5.85)	87.61* (8.89)	9.87* (1.71)

Note. The stars indicate significant differences from the rr\_reference treatment with \*\* $p < 0.01$ , \* $p < 0.05$ , + $p < 0.1$ . Values in parentheses are the standard errors.

**Table 10 Summary Statistics of Profits**

Treatments	Supplier [m.u.]	Buyer [m.u.]	Supply chain [m.u.]
rr_baseline	23.92 (0.81)	20.74 (0.81)	44.66 (1.47)
rr_reference	24.29 (2.62)	20.44 (3.64)	44.74 (1.85)
rr_video	25.18 (0.75)	23.01+ (1.30)	48.18* (1.37)

Note. The stars indicate significant differences from the rr\_reference treatment with \*\* $p < 0.01$ , \* $p < 0.05$ , + $p < 0.1$ . Values in parentheses are the standard errors.

significantly higher in the rr\_video than in the rr\_reference treatment. Overall, the results of the one-shot interaction experiments replicate the insights of the main experiments. Thus, the strong effect of the video communication on the supply chain coordination remains significant under one-shot interactions.

## 9. Discussion

In laboratory experiments with a student subject pool, we find that (a) information sharing with simple one-way text messages improves supply chain performance and that (b) this is even more so if the supply chain parties communicate verbally before the demand data is exchanged.

Our stylized supply chain setup considers central aspects of bargaining in supply chains (sequential moves, quantity discounts, efficiency losses) while abstracting from others that set bounds on the generalizability, which we discuss below.

First, we used a student subject pool for our experiments. This is well in line with other studies that analyze information sharing in supply chains (Hyndman et al. 2013, Özer et al. 2011, 2014, Spiliotopoulou et al. 2016). Yet, a cautionary note that decision makers in practice might have a different set of skills, experience, and beliefs that render communication less effective is warranted. As an example, the study from

Özer et al. (2014) shows that the extent of trust and trustworthiness varies with the social distance of the supply chain members. We further note that all of the students were at least fluent in German. It is certainly an interesting avenue for future research to analyze how personal traits and social background interact with the effectiveness of communication media on a tactical level.

Second, we made the payoff consequences of contract design and contract choices via a decision support tool very transparent at all stages of the game. Carpenter (2002) shows in the best shot game, a version of a sequential move public good game, that this information provision has a strong effect on the fairness of the final profit allocation. In line with Carpenter (2002), we observed much fairer profit allocations than theoretically predicted, particularly in our verbal communication treatments. As such, the information provision of payoff consequences may be an important antecedent and therefore a limitation on verbal communication being effective. A rigorous assessment is left for future research.

Third, we restricted our setting to supply chains with deterministic supply and demand. In this situation, quantity discounts are among the most widely used contract forms in practice (Munson and Rosenblatt 1998) and are also theoretically effective in coordinating a supply chain with asymmetric information and stochastic demand (Burnetas et al. 2007). It is an interesting avenue for future research to analyze whether communication regarding contract terms on a tactical planning level can also boost supply chain performance when supply and demand are uncertain. While doing so, other contract formats that allow for risk sharing (buy-back or revenue sharing, see Katok and Wu 2009 for laboratory experiments or Arya and Mittendorf 2004 for asymmetric information and buy-back contracts) might also be considered.

Fourth, we assumed that there are two buyer types, that is, low-demand and high-demand. While there

are most likely more types prevalent in practice, one might certainly consider quantity discounts with more price breaks. However, Kalkanici et al. (2011) show in a laboratory supply chain experiment that, due to decision biases, an increase in contract complexity does not necessarily lead to an increase in the supplier's profit and simpler contracts can thus be sufficient for a supplier.

Fifth, we provided a decision support tool that eases many of the complexity issues when designing nonlinear contracts (how to set price breaks and corresponding prices). Our results may be sensitive to the availability of such a support tool, but at the same time strengthen the insight that training may help coordinate the supply chain.

## 10. Conclusion

We have revisited one of the fundamental topics in supply chains: information sharing. We have considered a typical supply chain environment in which strategic incentives for misrepresentation of private information are prevalent, the supply chain parties operate on a basis offering a take-it-or-leave-it contract, and efficiency gains from a win–win cooperation can be achieved.

We have replicated, in a different setting, the findings from previous laboratory experiments that the simplest form of information sharing, that is, one-way messages, enhances supply chain performance; however, efficiency losses prevail (Hyndman et al. 2013, Özer et al. 2011, 2014, Spiliotopoulou et al. 2016). We find that these efficiency losses can be significantly and almost fully reduced if the supply chain parties verbally communicate before the actual demand information is exchanged while simple one-way messages are still used on an operative basis (i.e., when contracts are negotiated and information is actually shared). Our results therefore indicate that management can use simple and efficient means to electronically share private information; however, the critical strategic issues should be discussed beforehand.

Communication content analysis reveals that communication is especially effective in establishing trust and trustworthiness when players use reciprocal strategies and more so when the buyer clearly expresses guilt from lying. The clarification of the mutual benefits of information sharing moves the buyer to truthfulness. We have shown that our results are robust against subjects interacting repeatedly or once.

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## Notes

<sup>1</sup>If subjects reached the 10-minute limit, they were asked to finish the communication phase by a blinking text message. The phase did not terminate automatically.

<sup>2</sup>The Bonferroni correction controls the familywise error rate, that is, the probability of making at least one Type I error. Note, this procedure is relatively conservative and increases the probability of Type II errors (Sheskin 2004).

<sup>3</sup>Note, the 50% benchmark results when the buyer always sends the signal "demand is low." Alternatively, the buyer may randomize between the signal alternatives (e.g., "demand is low," "demand is high" or "no signal") and a benchmark of 1/3 results. If the buyer always chooses the "no signal" option, a benchmark of zero results.

<sup>4</sup>Note that the pairwise comparison of the video and audio treatments with the reference treatment results in a *p*-value of 0.011 and 0.018, indicating that the Bonferroni-corrected alpha level might be too conservative to detect a significant effect.

<sup>5</sup>There are also no significant treatment effects for self-selection. Note, this is in line with the MWU test as we found strong treatment differences between the reference and the communication treatments but not between the communication treatments.

<sup>6</sup>Note, since subjects engage in videoconferences, social concerns about reputation (e.g., participants may not wish be identified as selfish) may not be ruled out. However, this design rules out any effects arising from the expectations about future interactions (e.g., participants may cooperate in the expectation of higher profits in future periods).

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### Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**Appendix S1.** Online Appendix.