The Impact of Decision Rights and Long Term Relationships on Innovation Sharing

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While sharing the innovation between a buyer and a supplier can increase the efficiency and total profit of the supply chain, many suppliers are reluctant to do so. Sharing innovations leaves the supplier in a vulnerable position if the buyer exploits the information (e.g. by re-sharing the supplier’s innovation with competing suppliers). In this paper, we examine conditions under which a collaborative relationship can arise in this situation, with a supplier voluntarily sharing an innovation and a buyer repays that trust by sharing the surplus increase rather than seeking competing bids from suppliers. First we show, both theoretically and experimentally, that decisions to collaborate are affected by the length of the relationship between the firms – longer relationships lead to higher collaboration and higher total profits. We additionally show that the collaborative relationship depends not just on the firm-level relationship length, but also on the long- or short-run focus of the employees within the firm that make decisions. We model the buyer as a dual decision maker, with long-run and/or short-run focused employees (“engineers” and “procurement managers”) determining the buyer’s actions. We characterize the equilibrium of this model and show that collaborative outcomes depend on the level of control the long-run employee has within the buyer. Our experimental results verify this intuition. Collaborative relationships occur more often when the engineer has more control. However, the supplier’s decision to share innovation depends primarily on the firm-level relationship length, while the buyer’s decision to seek competition depends more on the relationship focus of the controlling employees. Consequently, buyer’s profits increase with long-run firm relationships (for any decision maker), while the supplier profits only significantly increase with a long-run decision maker. Finally, while theoretically suppliers and engineers should ignore the actions of the previous procurement managers, we find that both suppliers’ and engineers’ actions are correlated with the previous procurement managers’ decision.

1. Introduction
Manufacturers often benefit from innovations and process improvements discovered by their suppliers. This happens particularly in industries where suppliers are involved in research and develop-
ment (R&D) and product design. In the automotive industry a substantial share of cost reductions come from parts and components suppliers. For example, General Motors’ suppliers developed hinges that did not need welding, resulting in significant cost savings for GM (Klier 2006). Similarly, Chrysler had major cost savings when a supplier, Becker Manufacturing eliminated excess fasteners by developing molded hooks in their interior trim panels so that door panels could be directly fastened to the frame.

The most valuable innovations often involve process improvements and benefits for both the supplier and the manufacturer. For example, the automotive industry has been transitioning from solvent based paint to waterborne paint, which is less toxic and easier to dispose and clean up. Implementing this technology requires significant changes to the manufacturing process - for example, painters have to be retrained to paint more evenly, new taping techniques are needed to prevent bleeding, new equipment needs to be installed to blow large volumes of clear air for drying, etc. Both the manufacturer and its suppliers transformed their paint booths during the transition, and sharing painting processes improvements could benefit both parties: increasing cost reductions or allowing better paint matching between parts.

However, since these discoveries usually happen spontaneously, the supplier has no contractual obligation to share them with the manufacturer. For small innovations or process improvements (which are usually not subject to patents) suppliers are often concerned that the buyer may pass the innovation on to other suppliers to increase competition and lower future prices. Sharing the innovation will then make the supplier vulnerable and, ultimately, take away the supplier’s competitive advantage. Therefore, an important question for manufacturers is how to incentivize suppliers to share these innovations with them. Historically, these acts of untrustworthiness have been quite frequent among U.S. car manufacturers (McMillan 1990). U.S. automakers have commonly used procurement strategies primarily focused on cost reduction even at the expense of destroying supplier’s trust (Burt 1989, Liker and Choi 2004). This focus on pushing for cost reductions is often associated with short-term supplier relationships and seeking competitive bids frequently

1 Neil De Koker, president of the Original Equipment Supplier Association reported in 2006 that in the automotive industry, suppliers are taking a bigger role in R&D, providing up to two thirds of the value added in the production of the car (Klier 2006).


3 In some cases, car manufacturers explicitly express their expectations that suppliers will innovate on their behalf. Burt (1989) reports that Ford and other automakers explicitly sent their suppliers lists of technologies they would have liked to have developed. TRW’s air bag and Bosch’s antilock brakes (ABS) are examples of technologies that resulted from these sort of initiatives.

(e.g. switching suppliers after each sale period). Recent initiatives, such as Ford’s “Aligned Business Framework” and GM’s “Strategic Supplier Engagement” program, have focused on building longer-run strategic partnerships with suppliers and encouraging innovation sharing. While this has led to recent improvements in measures of the quality of the working relationship between American automakers and their suppliers, however their ratings are still quite poor.

The prospect of a long term relationship can make both suppliers and manufacturers more likely to collaborate. Relational contracts - defined by Gibbons and Henderson (2012) as “informal agreements enforced by the shadow of the future” - can provide enough incentives for collaboration, as poor behavior sacrifices future gains. In our setting, the manufacturer has an incentive to keep the supplier’s trust as long as his benefit from future innovation sharing exceeds the short-run gain from betraying the supplier’s trust by bringing in a competing supplier. In turn, the supplier is incentivized to maintain the collaborative relationships by sharing innovations. However, even when the firms have sufficient incentives to collaborate, the individuals making decisions for the firms may not. Conversations conducted with GM’s suppliers suggest that, the nature of a buyer-supplier relationship heavily depends on which employees within the firm manages the relationship. For some divisions within GM this responsibility is primarily with the procurement managers, while in others engineers have extensive control over supplier relations. Procurement managers are often evaluated by performance metrics that focus on short-run (immediate) cost savings. Thus, their incentives are driven by these KPIs. This is further exacerbated by the fact that, in many organizations, procurement managers are rotated through an organization to source different parts or negotiate with different companies. On the other hand, engineers care about quality and design, both of which are intrinsically long-term oriented objectives. In addition, since they have specific technical expertise, they are less likely to be rotated and commonly specialize in a certain auto part.

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5 McMillan (1990) reports that contracts of three to five years are generally considered long-term in the automotive industry. At times U.S. manufacturers have tried to forge longer supplier relationships, preserving a supplier of a part for the entire length of a car model (typically, five to seven years), and even beyond the life-cycle of a model. Dyer (1996) reports on Chrysler’s efforts in the 1990s to increase their commitments to their suppliers, which increased the average contract length of the contracts from 2.1 years to 4.4 years.

6 Planning Perspectives, Inc. develops one of the most reputable indexes in the industry, the Working Relations Index (WRI). The WRI is based on interviews with American automotive suppliers, and measures aspects such as trust and overall working relationship, communication, supplier profit opportunities, help company gives to suppliers, etc. The 2015 report can be found online at http://www.ppi1.com/wp-content/uploads/2015/05/2015-WRI-Press-Release-May-19.pdf


8 Conversations within GM and with three of GM’s top tier-one suppliers in the automotive industry were conducted by students of University of Michigan during the Spring-Summer semester of 2011. In other industries, such as electronics, there is also anecdotal evidence of engineers being involved in the development of a supplier base, particularly for new products (Monczka 2000).
The supplier’s trust in the buying firm depends, then, on which employee manages the relationship. This indicates that, if the buyer wants to build a long-term and collaborative relationship with the supplier, the buyer needs to be careful in assigning the roles and responsibility for managing the relationship.

In order to study this situation, we analyze a theoretical model and identify conditions supporting a collaborative equilibrium. We then develop hypotheses and conduct a laboratory experiment to examine how the allocation of decision rights within the buying firm affects firms’ actions. We answer the following research questions: (1) Does the length of the relationship between firms affect the likelihood of collaborative outcomes? (2) Within a long-run firm-level relationship, does giving control of the relationship to a short-run or long-run focused employee affect the buyer’s and supplier’s strategies and the likelihood of a collaborative relationship?

We find that focus on the long-run relationship matters, both at the firm and individual level. When buyers are represented by a single decision maker, suppliers are more likely to share innovations and buyers are more likely to be trustworthy when they have a long-run relationship than a one-shot interaction. When buyers are represented by a team an engineer and a procurement manager, the allocation of control over the relationship further affects firm strategies and relationship outcomes. The supplier’s decision is primarily driven by the firm-level relationship characteristics - suppliers share innovations more often when the procurement manager is in charge, compared to the pure one-shot interaction. Shifting control from the procurement manager to the engineer does not significantly change the supplier’s decision. Buying firms, however, are significantly more likely to be trustworthy and not seek a competing supplier when the engineer is in charge (compared to procurement manager control and to the one-shot interaction). As a result, while buyers earn higher profits from a long-run firm-level relationship (with any form of decision control) compared to the one-shot interaction, suppliers only receive significantly higher profits when a long-run decision maker is in control. Finally, we observe that employees may be influenced by their peers’ recommendations beyond their own monetary incentives.

2. Literature Review
There is a broad literature in operations management studying collaboration in buyer-supplier relations. Empirical papers show that cooperation between firms in a supply chain can lead to improved performance and higher profits. For example, an empirical study of U.S. automotive suppliers by Dyer and Hatch (2006) found that greater knowledge sharing by automakers resulted in faster learning and fewer defects by suppliers. Stallkamp (2005) analyzes several forms of collaboration: strategy, communication, information, and responsibility sharing. They find that strategic collaboration yields substantial cost and quality improvements. Buyer-supplier collaboration can
be implemented in practice in a variety of ways. For example, Aviv (2001), Aviv (2007) study collaborative forecasting, and Zhu et al. (2007) study quality-improvement efforts. Our paper focuses on collaboration via innovation sharing, with the final goal of reducing costs.

Cost reduction is one of the main drivers of outsourcing decisions (Gray et al. 2009) and is an important part of supply chain relations (Rudzki 2004). A number of operations papers analyze the problem of providing incentives to invest in cost reduction in a supply chain. Kim and Netessine (2013) study collaborative effort by the manufacturer and supplier to lower expected cost in the development phase of an innovative product. Iyer et al. (2005) focus on how buyers can allocate their resources to help suppliers transform specifications into finished components and reduce total costs. Bernstein and Kök (2009) study suppliers’ incentives to invest in cost reduction over the life cycle of the product under different procurement approaches, and consider gradual investment in process improvement (e.g. Lean Production, Six Sigma Programs). Our paper aims to address this topic from an experimental perspective, in order to understand how behavioral factors affect supply chain collaboration. Firms’ organizational-level decisions may play a role in supply chain collaboration, as shown in Brinkhoff et al. (2015). They provide empirical evidence that trust is important for supply chain projects to be successful. However, the effect of trust is mediated by project-level factors such as between-firm communication and within-firm commitment. Our experimental results show that in an innovation sharing setting, the allocation of decision rights to employees with different incentives is important in determining the level of trust between the firms, and both firms’ willingness to collaborate.

During the late eighties and early nineties arguments in favor of procuring from a reduced number of suppliers and preserving long-term supplier relations became popular. Several studies reported a trend of shifting towards single sourcing (Han et al. 1993, Newman 1988), and assessed the benefits of this trend in terms of reducing costs and improving quality (Kalwani and Narayandas 1995, Treleven 1987). More recent papers in the OM literature have identified settings where longer relationships are beneficial for buyers. Swinney and Netessine (2009) model a non-cooperative supplier-buyer relationship in which the buyer is concerned with the failure of a supplier since switching suppliers in case of supplier default is costly. They find that, when they consider the possibility of default by the suppliers, buyers prefer long-term contracts and in particular, dynamic long-term contracts allow the buyer to coordinate the supply chain. Taylor and Plambeck (2007) analyze a setting where a firm is developing an innovative product and requires a supplier to invest in capacity for the product without being able to contract on it. They show that with long-term supplier relations, relational contracts provide enough incentive for the supplier to invest. Similarly, Li and Debo (2009) also find that committing to a longer relationship with a supplier can be more beneficial than running an auction in every period to select a supplier, since longer
relationships incentivize suppliers to bid more aggressively. We provide further evidence in this direction: our experimental results show that longer relationships are also beneficial (for both, buyers and suppliers) in a setting with supplier innovation sharing.

In order to study experimentally firms’ actions in long-term supplier relations (which we model as infinitely repeated games), we implement an experimental design where subjects play an indefinitely repeated game. This method of representing an infinitely repeated game has been used extensively in experimental economics. Roth and Murnighan (1978) and Murnighan and Roth (1983) were the firsts to induce infinitely repeated games using randomly terminated games, where the continuation probability is equated to the discount factor. Since then, indefinitely repeated games have been used to understand the evolution of cooperation in a prisoners dilemma game (Camera and Casari 2009, Aoyagi and Fréchette 2009, Bó 2005, Bó and Fréchette 2011, Fréchette and Yuksel 2013, Dal Bó and Fréchette 2013, Honhon and Hyndman 2015), in a two-period Bertrand game (Cooper and Kuhn 2009), in a veto game (Cabral et al. 2014), and in a trust game (Engle-Warnick and Slonim 2004, Engle-Warnick and Slonim 2006a, Engle-Warnick and Slonim 2006b), among others (Engle-Warnick 2007). For the most part, the focus of these papers has been on inferring subjects’ strategies from their actions in the game. This is not a trivial task since: (1) the set of possible strategies is infinite, and (2) strategy choices are not directly observable – the experimenter only observes the player’s choice for the history that actually happened and not what the player would have done for any possible history (Dal Bó and Fréchette 2013). Fortunately, there is evidence that relatively few basic strategies seem to explain players’ actions quite well, and furthermore, these strategies are best responses to the opponent strategies. Dal Bó and Fréchette (2013) find that the most popular strategies in indefinitely repeated prisoners dilemma, are Always Defect, Tit-For-Tat, and Grim Trigger. Similarly, Engle-Warnick and Slonim (2006a) find that in the indefinitely repeated trust game, relatively few strategies explain vast majority of behavior. For the trustor both Grim Trigger and Tit-For-Tat are relevant strategies, while the trustee conditions behavior on round number rather than on the history of play with the opponent. Rather than directly recovering players’ strategies, our focus is on the comparison of players’ actions across treatments with different allocations of decision rights to the employees of the buying firm.

The behavioral operations management literature has studied the effects of social preferences and decision biases on supply chain contracting (Bolton and Katok 2008, Katok and Wu 2009, Ho and Zhang 2008, Becker-Peth et al. 2013). Social preferences, such as trust, trustworthiness, and concern for fairness play an important role in supply chain performance (Cui et al. 2007, Loch and Wu 2008, Özer et al. 2011, Özer et al. 2014, Katok and Pavlov 2013). A few experimental papers in operations management study how buyer-supplier relationships are affected by relationship length. Loch and Wu (2008) find that inducing a positive relationship before the game leads to more
collaborative actions by suppliers and buyers, which persist over many rounds of the game. Özer et al. (2011) find that repeated interactions enhance trust and trustworthiness in forecast information sharing, resulting in lower forecast inflations, higher capacity investment, and higher supply chain efficiency. Beer et al. (2014) show that when suppliers can signal trustworthiness by making an upfront buyer-specific investment, more collaborative relationships arise. Repeated interactions strengthen the impact of signaling investments, leading to higher profits and efficiency. We are aware of only one experimental paper that directly compares short run and long run incentives in a related supply chain setting. Hyndman et al. (2014) study a setup where two firms simultaneously invest in capacity, and sales are the minimum of the two chosen capacities and realized demand. In their setting firms have private information about demand, and need to coordinate on the optimal investment level. Their experiment compares behavior when subjects are in fixed pairs and when they are randomly re-matched after every round. They find that while fixed pairs have higher alignment on average they do not achieve higher efficiency. With fixed matching, the alignment reached in the initial rounds of play has a strong impact on the overall profits throughout the relationship. Therefore, pairs with higher alignment in the initial rounds ended up with higher profits than those who started misaligned. On the other hand, with random rematching the initial rounds do not have much impact on overall average profits. Hyndman and Honhon (2014) find in a similar setting that when players are free to dissolve the relationship after every round, they earn higher average profits than when they are matched indefinitely. Our paper is different in both setting and research focus. First, our stage game more closely resembles a trust game (innovation sharing) than a coordination game (capacity alignment). Second, we introduce joint decision making within the buyer. Thirdly, our focus is on the firms’ allocation of decision rights, and therefore our treatments with procurement managers and engineers is in some ways a hybrid of those in Hyndman et al. (2014). Procurement managers have random rematching after every round, while engineers have fixed matching as long as the relationship between the firms lasts. With this setup, we capture the different incentives the employees in the buyer firm face, beyond the firm-level relationship length.

3. Model
We examine a supply chain consisting of a buyer and a supplier that are engaged in a multi-period relationship. In each period, the supplier may have discovered a new innovative idea and, if so, she needs to decide whether to share this with a buyer or not. The buyer needs to decide to collaborate with the supplier (offer a generous price) or to make the supplier compete against another supplier (to lower the price). We consider several scenarios varying in (i) duration of a relationship, and (ii) who makes a decision for the buyer and how the decision is made. We first consider a benchmark
case where the manufacturer and the supplier have a short-term relationship and model it as a single-period game. We then consider the case where the firms engage in a long-term relationship and model it as an infinitely repeated game with discounting, where the stage game is the single-period benchmark case. Finally, we analyze a case where the firms have a long-term relationship but the decision makers within the manufacturer are two employees, one short-run and one long-run focused.

### 3.1. Single period game

The single period game consists of a one-time transaction between a manufacturer and a supplier. The supplier produces a component that the manufacturer uses to produce a good. Let $C_i \geq 0$ be firm $i$’s variable cost, $i \in \{m = \text{manufacturer}, s = \text{supplier}, a = \text{alternative supplier}\}$ \(^9\). The supplier has a per unit production cost of $C_{s1}$ and sells each unit of component to the manufacturer at a wholesale price $w$. The manufacturer has a per unit manufacturing cost of $C_{m1}$ and a total per unit production cost of $C_{m1} + w$ and sells the product to the end customer at a retail price $p$. For simplicity, we model demand as a linear function of $p$, $Q(p) = a - bp$, where $a, b \geq 0$ and $a - bp > 0$ and assume the manufacturer can always meet demand. The manufacturer’s profit from a transaction is $\Pi_m(p, w) = Q(p - w - C_m)$ and the supplier’s profit is $\Pi_s(p, w) = Q(w - C_s)$.

At the beginning of a single-stage game, the supplier may have a new innovation which can lower the supplier’s cost from $C_{s1}$ to $C_{s2}$. We assume that this innovation occurs with probability $\pi$, which is exogenously determined. For instance, in the waterborne paint example discussed in Introduction, the supplier’s innovation was a change to the blower set up that led to faster paint drying and lower unit costs. The supplier can share the innovation with the manufacturer (and voluntarily reduce the unit cost). If the supplier shares this innovation, the manufacturer can also implement the same technology in his own painting booths which reduces the manufacturer’s production cost to $C_{m2}$, $C_{m2} \leq C_{m1}$. Alternatively, the supplier can decide to not to share the information and just increase the unit-product margin.

After the supplier decides whether to share the innovation with the manufacturer, the manufacturer can choose to solicit bids from a new supplier (we call this decision “to compete”) or to single source (“not to compete”). We assume that the alternative supplier has the initial production cost, $C_{a1}$, $C_{a1} > C_{s1}$. If the original supplier shared the cost reduction with the manufacturer and the manufacturer chooses to compete and bring the alternative supplier, then the production cost is reduced from $C_{a1}$ to $C_{a2}$, with $C_{a2} < C_{a1}$ and $C_{a2} = C_{s2}$, essentially taking away the competitive advantage of the supplier who had the innovation.

\(^9\) As in Bernstein and Kök (2009), we assume complete information about cost structures: suppliers know the manufacturer’s complementary assembly costs and the manufacturer knows the suppliers’ production costs. This is a common assumption in the automotive industry, where suppliers share technical information with the manufacturer in the design phase.
After the manufacturer chooses whether to compete or not, the supplier and the manufacturer negotiate the terms of trade. As a result of this negotiation, the wholesale price, \( w^* \), and retail price, \( p^* \), are set to maximize the surplus of the supply chain. We assume the surplus is split between the supplier and the manufacturer according to Nash bargaining (Nash 1950): the manufacturer earns a fraction \( \alpha \), \( \alpha \in [0, 1] \) of the surplus and the supplier earns a fraction \( (1 - \alpha) \) of the surplus\(^{10}\).

In the case where the manufacturer chooses not to compete (case of bilateral bargaining), the Nash bargaining solution predicts equal splits of the surplus \( (\alpha^* = \frac{1}{2}) \) and the manufacturer’s and supplier’s profits are given by \(^{11}\):

\[
\Pi_m = \Pi_s = \frac{(a - b(C_s + C_m))^2}{8b}.
\]

In the case where the manufacturer chooses to compete, the Nash bargaining solution predicts \( \alpha^* = \frac{1}{2} + \frac{(p-C_a-C_m)}{2(p-C_a-C_m)} \). This instance is referred to in the literature as bargaining with supplier competition. In this case, the original supplier is still selected but now the manufacturer’s profit is:

\[
\Pi_m = \frac{[a - b(C_m + C_s)][a - b(C_m + C_a)]}{4b},
\]

and the supplier’s profit is:

\[
\Pi_s = \frac{[C_a - C_s][a - b(C_s + C_m)]}{4}.
\]

Note first that this requires \( p > C_a + C_m \) and \( p > C_s + C_m \). Second, if the innovation does not happen, or if it happens and the supplier does not share, \( C_a > C_s \) and therefore the manufacturer’s share of surplus, \( \alpha^* \), is greater than \( \frac{1}{2} \). In the case where the supplier shares and the manufacturer competes, we have \( C_s = C_a \) and the manufacturer takes all the surplus \( (\alpha^* = 1) \).

The detailed calculations are presented in the Appendix.

### 3.2. Numerical Example

As Figure 1 shows, the game has six possible outcomes: If the innovations occurs, the possible outcomes are Share-Compete (ISC), Share-Do not Compete (ISN), Not Share-Compete (INC) and Not Share- Do not Compete (INN). If the innovation does not occur, the possible outcomes are Compete (NC) and Do not Compete (NN). We analyze the equilibrium and draw hypotheses from a canonical example whose parameter values and payoffs are carefully chosen to facilitate our resulting lab experiments. The parameters used are presented in the Table 8 in the Appendix and the firms’ payoffs resulting from these parameters are presented in Figure 1.

\(^{10}\)While there are several models of supply chain bargaining, we choose this approach for simplicity. For a more detailed study of bargaining in supply chains we refer the reader to Lovejoy (2010).

\(^{11}\)We assume that the parameters are such that transacting is efficient, that is, \( p - C_m \geq C_s \) and at \( w^* = (1 - \alpha)(p - C_m) + \alpha C_s \), both firms choose to transact.
With these payoffs, if the innovation occurs, the total surplus increases relative to the case where the innovation does not occur. In addition, if the supplier shares the innovation with the manufacturer, the total surplus (the size of a pie that can be shared between the two parties) is the largest. However, sharing the innovation makes the supplier more vulnerable to competition. Specifically, the minimum possible payoff from not sharing is 7 and from sharing is zero. The manufacturer’s decision does not affect the total surplus but affects the allocation of this surplus between the two firms. Thus, we consider the supplier choosing to share and the manufacturer choosing not to compete as “collaborative” actions since both firms benefit from their counterpart’s action. Since the innovation occurs in each period with probability \( \pi \), when choosing his action the manufacturer cannot distinguish between the case where the innovation has occurred but the supplier has decided to not share and the case where the innovation has not occurred in the first place. This is captured in the information set of a manufacturer. When the outcomes are realized the manufacturer can learn whether an innovation had occurred, and therefore whether the supplier had shared. This exact same information structure is reproduced in the laboratory experiment.

The game in Figure 1 resembles the widely studied trust game (Kreps 1996) with two differences. First, in our setup, the supplier’s decision to trust the manufacturer is preceded by a random
innovation. Second, the manufacturer makes his decision even if he was not trusted. In the original
trust game, if the first decision was not to trust, the game ends and the second player is not called
upon to play. These two differences are important to characterize our setting, and may affect our
experimental results making them not directly comparable to those of the trust game. However,
the main dynamics captured in our game are those of a trust game.

We first analyze the most simple case where the supplier and the manufacturer have a short
term relationship and model it as a single-shot game. Since firms interact only once, there are no
incentives to play collaborative actions based on strategic concerns about future play. Thus, this
case serves as a benchmark for the lowest theoretical level of collaboration. We then analyze the
case where the firms have a long term relationship and model it as an indefinitely repeated game
with discounting.

3.2.1. Single-Period Game For the single-period game we solve by backward induction,
starting with the manufacturer’s strategy. The manufacturer’s profit from the action “compete”
is given by Equation 1 and from “not compete” is given by Equation 2. Since \( p > C_a + C_m \),
\( a - b(C_m + 2C_n - C_s) > 0 \) which implies that the manufacturer’s profit is always higher when he
chooses to compete (than to not compete). Given that the manufacturer chooses “compete”, the
supplier’s profit is given by Equation 3. Rolling back to the supplier’s strategy, if he chooses to share
the innovation, then \( C_{a2} = C_{s2} \) and the supplier earns zero profit, if he does not share, \( C_{a1} > C_{s2} \)
and the supplier earns positive profits. As a result, the supplier does not share and the only Nash
equilibrium in a one-period play of the game in Figure 1 are INC if the innovation occurs and NC
if the innovation does not occur.

3.2.2. Repeated Interactions We now consider the infinitely repeated play of the stage
game depicted in Figure 1. We assume firms discount their payoffs across periods with a discount
factor \( \delta \) per period, \( \delta \in [0,1] \). That is, a dollar to be received next period is worth today \( \delta \) and a
dollar to be received \( n \) periods from today is worth today \( \delta^n \). This implies that the smaller \( \delta \) is, the
more impatient the player is. Another interpretation of the discount factor \( \delta \) is the continuation
probability of the indefinitely repeated game (game with random end). This interpretation is com-
monly used in the experimental economics literature, where it was first introduced by Murnighan
and Roth (1983) and Roth and Murnighan (1978)\textsuperscript{12}. We resort to this interpretation later on in
the Experimental Design section.

Consider the six different possible outcomes of the stage game presented in Figure 1 and let
\( ISC_i, ISN_i, INC_i, INN_i, NC_i, NN_i \) be player \( i \)'s payoffs, \( i \in \{m = \text{manufacturer}, s = \text{supplier}\} \),

\textsuperscript{12} Recent experimental work by Fréchette and Yuksel (2013) verify that games with random termination can be used
to induce infinitely repeated games in the laboratory, as they generate behavior that is consistent with the theoretical
predictions for these games.
from each possible outcome. Additionally, recall that at the end of the stage game, the manufacturer learns whether the innovation occurred and whether the supplier shared. Therefore, the manufacturer can condition his strategies on the past sharing decisions of the supplier. Similarly, the supplier can condition his strategies on the manufacturer’s past decisions to compete. The next proposition characterizes the conditions for the collaborative actions (the supplier shares and the manufacturer does not compete) to be part of a Nash Equilibrium of the infinitely repeated game. In preparation, we define a threshold \( \hat{\delta}_1 = \frac{ISC_m - ISN_m}{ISC_m - (\pi INC_m + (1-\pi)ISN_m)} \).

**Proposition 1.** If \( \delta \geq \hat{\delta}_1 \), there exists a subgame perfect Nash equilibrium where both parties adopt the following grim-trigger strategy. In the first period where there is an innovation, the supplier plays “share”. In all subsequent periods, the supplier shares the innovation if in all the previous periods where there was an innovation the actions were “share - do not compete”. Otherwise, the supplier plays “not share”. The manufacturer plays “do not compete” when the supplier shared an innovation if in all the previous periods where there was an innovation the actions were “share - do not compete”. Otherwise, the manufacturer plays “compete”. In every period where the innovation does not occur or it is not shared by the supplier, the manufacturer plays “compete”.

The proof follows the same logic as Gibbons (2001). Grim trigger strategies dictate that both players play collaborative actions until either of them deviates. Once a deviation occurs, neither of the two parties collaborates again. In order for the grim-trigger strategy to be a Nash equilibrium, the present value from collaboration needs to outweigh the gains from a one-time deviation from collaboration followed by a perpetual defection of both parties.

For the supplier the condition holds if her payoff from the outcome “share - not compete” is greater than her payoff from the outcome “not share - compete”, that is \( ISN_s \geq INC_s \). The expression for \( ISN_s \) is given by Equation 1 with \( C_s2 \) and \( C_m2 \), \( ISN_s = \frac{(a-b(C_s2+C_m2))^2}{86} \). The expression for \( INC_s \) is given by Equation 3 with \( C_s2 \), \( C_m1 \), and \( C_a1 \), \( INC_s = \left[\frac{C_a1-C_s2}{4}\right]^{4} - \left[\frac{a-b(C_s2+C_m1)}{4}\right]^{4} \). Thus, the condition always holds since \( p > C_a1 + C_m1 \) and \( C_m2 < C_m1 \). In particular, in the numerical example \( ISN_s = 56 \) and \( INC_s = 18 \). The manufacturer’s condition requires \( \delta \geq \hat{\delta}_1 \), which in our numerical example means \( \delta \geq \frac{112 - 56}{112 - 0.75(22) + (1-0.75)56} = 0.69 \). Detailed calculations are presented in the Appendix. Based on the two interpretations of \( \delta \), this means that the manufacturer needs to care enough about his future payoff (be patient enough) or that the relationship needs to be likely enough to continue after each round of play.

Note that the Folk theorem for infinitely repeated games implies that many strategies can support equilibria with collaborative outcomes \(^{13}\). We focus on trigger strategies since they provide the

\(^{13}\) See Fudenberg and Maskin (1986), Rubinstein (1979). For an application of the Folk Theorem to problems similar to ours, refer to Miller (2001); Miller and Smith (1993).
highest disincentive to deviate from collaboration. Thus, the conditions above provide the largest set of parameters under which collaboration can be sustained in equilibrium. In addition, trigger strategies are the less risky for suppliers when matched with manufacturers playing always compete, which is a very common strategy based on previous experimental evidence (Dal Bó and Fréchette 2013).

We focus now on the setting where the firms have a long term relationship and assume that the manufacturer’s decision is made by a procurement manager and an engineer. The procurement manager works for the firm for only one period (or equivalently is assigned to this supplier for one period, and rotates to another position in the firm in the next period). The engineer works for the firm (and is assigned to this supplier) throughout the infinite game. We further assume that both employees make recommendations for what the manufacturer should do and that their compensation is the manufacturer’s profit. The procurement manager, being a short-run player, only cares about profits this period. The engineer, however, is a long-run player that cares about total profits during the whole buyer-supplier relationship.

Consider first the procurement manager’s recommendation. Since the procurement manager works for the buyer for only one period, the game between the supplier and the procurement manager resembles that of two firms playing a single period game. Thus, in a setting where the procurement manager’s recommendation is always implemented, the procurement manager recommends to always compete and the supplier always chooses not to share. The only Nash equilibrium in this case are Not share-Compete (INC) when the innovation occurs, and Compete (NC) when the innovation does not occur.

Consider now the engineer’s recommendation. Since the engineer works for the buyer to infinity and the firms have a long term relationship, the game between the supplier and the engineer resembles an infinitely repeated game. Thus, when the engineer’s recommendation is always implemented, Proposition 1 applies: trigger strategies can sustain a repetition of the collaborative outcome Share-Do not Compete (ISN) in every period where there is an innovation. When the innovation does not occur, the engineer will choose compete (NC)\(^{14}\).

Finally, consider the case where if both employees’ recommendations agree, their recommendation is implemented and if they disagree, one of the two recommendations is implemented at random, both with equal probability. We will assume that the supplier can perfectly observe both

\(^{14}\)We focus only on pure strategies that lead to an equilibrium with high sharing rates. In mixed strategies, the engineer could induce the supplier to share by using, for example, a strategy where he does not compete only with some probability when the supplier shares. This would result in more sophisticated review strategies as the supplier needs to gather probabilistic evidence of the engineer’s actions across several periods.
employees’ recommendations\textsuperscript{15}. In this case, trigger strategies analogous to those in Proposition 1 can sustain the collaborative outcome, Share - Not compete. The result is presented in the next proposition, for which we define $\hat{\delta}_2 = \frac{ISC_m - ISN_m}{(1 + \frac{\pi}{2})ISC_m - \pi INC_m - (1 - \frac{\pi}{2})ISN_m}$.

**Proposition 2.** If $\delta \geq \hat{\delta}_2$, there exists a subgame perfect Nash equilibrium where the parties adopt the following strategies. The supplier shares the innovation in the first period where there is an innovation. In all subsequent periods, if in all the previous periods where there was an innovation the suppliers’ actions were “share” and the engineer’s recommendations were “do not compete”, the supplier plays “share”. Otherwise, the supplier plays “not share”. The engineer recommends “do not compete” when there is an innovation if in every previous period where there was an innovation the supplier’s actions were “share” and the engineer’s recommendation was “do not compete”. Otherwise, the engineer recommends “compete”. In all periods where there is no innovation, the engineer recommends “compete”. The procurement manager recommends “compete” in every period.

The proof is analogous to that of Proposition 1 and is relegated to the Appendix. The supplier’s incentive compatibility requires $\frac{ISN_s + ISC_s}{2} \geq INC_s$, and the engineer’s requires $\delta \geq \hat{\delta}_2$. Note that the supplier’s condition is tighter than in Proposition 1, where the incentive compatibility condition is $ISN_s \geq INC_s$. This is because Proposition 1 prescribes that if the supplier shares in every period, the buyer will chose “not compete” in every period. On the other hand, Proposition 2 prescribes that if the supplier shares in every period, in expectation half of the times the procurement manager’s recommendation will be implemented and the buyer will compete. Thus, the supplier’s expected profit from collaboration is lower under the set of actions described in Proposition 2 than under those in Proposition 1. Also, note that the engineer’s condition is less tight than in Proposition 1 (one can easily see that $\hat{\delta}_2 < \hat{\delta}_1$). This is because with the set of actions described in Proposition 2, the engineer enjoys the monetary benefits of the procurement manager’s recommendation to compete without facing the supplier’s punishment. As long as the engineer always chooses “not compete” when the innovation occurred, the supplier will always share the innovation. In the numerical example, the supplier’s incentive compatibility condition holds since $ISN_s = 56$, $ISC_s = 0$, $INC_s = 18$, and $\frac{56 + 0}{2} > 18$. The engineer’s incentive compatibility requires $\delta \geq 0.55$.

\textsuperscript{15}We make the assumption that suppliers can observe both employees’ recommendations for simplicity. This could represent either the supplier directly observing the buyer’s decision-making, or the engineer being able to credibly verify his recommendation. If the supplier cannot observe both recommendations, a collaborative equilibrium can be reached if the supplier resorts to review strategies (Radner 1985) by which he can assess the engineer’s strategy probabilistically after observing several rounds of play.
4. Experimental Design

The sequence of events and payoffs in each round follow the stage game presented in Figure 1. In order to elicit complete strategies from the participants, we use the strategy method in which participants make conditional decisions for each possible scenario that may arise. First, suppliers are asked whether, if the innovation has occurred, they want to share it with the buyer. Second, buyers are asked whether they want to compete or not in case the supplier shared the innovation, and in case the innovation did not happen or the supplier did not share it. After suppliers and buyers have made their decisions, the computer randomly determines whether the innovation occurs (it occurs with probability $\pi$) and implements the chosen actions. At the end of the stage game all the subjects in the group are informed whether the innovation occurred, the supplier’s and buyer’s decision (as well as the individual recommendations of the procurement manager and engineer), and their payoffs.

We design two different experimental settings. The first set-up involves two subjects – one acting as a buyer and the other acting as a supplier. The second set-up is similar except that the buying firm consists of two subjects – the first subject acting as a procurement manager and the other subject acting as an engineer. In each set-up, we conduct experiments under several treatments.

In the first set-up, denoted Buyer-as-Single-Employee, subjects are assigned to a role (either a supplier or a buyer), which they keep throughout the experiment. In the first treatment, “Short Run” (SR), the buyer-supplier relationship lasts only one round (a single transaction). We induce this by randomly re-matching buyers and suppliers after each round. In the second treatment, the buyer-supplier relationship is long term (LR). To capture this, the buyer and the supplier will play a repeated game with a random stopping time. Previous experiments (Fréchette and Yuksel 2013) have verified that this is an effective implementation of infinite games, as random termination yields equivalent behavior to payoff discounting. After each round, with probability $\delta$, the relationship continues to the next round and the buyer and the supplier engage in another stage game. On the other hand, with probability $1 - \delta$, the relationship terminates. We use a random number generator to simulate the random stopping time. Once the relationships end, buyers and suppliers will be randomly re-matched again to begin a new relationship. The length of a relationship is equal to the number of rounds where the same buyer and supplier engage in stage games. To analyze how the behavior of a subject changes during a session, we use the term period, to represent the total number of rounds that a subject has played until now. Thus, period $= 10$ means that a subject has played a stage game 10 times. In both treatments, the subjects know the continuation and re-matching rules.

In the second set-up, denoted Buyer-as-Two-Employees, there are two subjects working for the buyer – one procurement manager and one engineer. As before, one subject will be assigned to play
a role of a supplier. At the firm level the “supplier” and “buyer” have a long term relationship. Subjects in the supplier and engineer role play together as long as the relationship between the two firms last. However, subjects in the procurement manager role are rotated between buyer-supplier pairings each round (representing the procurement manager rotating across departments). We implement this as follows: After each round, a random number is drawn to determine if the relationship between the firms continues. If the relationship continues, suppliers and engineers remain matched for the following round and procurement managers are randomly and anonymously re-matched with a new supplier-engineer pair. If the relationship between the firms ends, all players are re-matched into new groups. Suppliers keep their role throughout the experiment, while procurement managers and engineers are randomly re-assigned a role at the beginning of each new relationship. The stage game in the Buyer-as-Two-Employees set-up is as in the Buyer-as-Single-Employee set-up, except for the second stage (buyer’s decision). In the second stage, both the engineer and the procurement manager make recommendations for what the buyer should do. Engineers and procurement managers answer whether the buyer should compete if the supplier shared the innovation, and if the innovation did not happen or the supplier did not share it. Since the engineer has been matched with the same supplier starting from the first round of the relationship between the firms, he knows all the previous history of play within the relationship. The procurement manager on the other hand, joins a new relationship in every round and does not know the history of play in the relationship he is joining in. To allow for strategies that are contingent on previous play, procurement managers are informed of the last round history in the relationship they have joined before they make their recommendations. All subjects know that this information is provided to procurement managers.

We conduct three different treatments in the Buyer-as-Two-Employees set-up to examine different allocations of decision rights between the engineer and procurement manager: In the procurement manager treatment (denoted PM treatment), the procurement manager’s recommendation is always implemented. The opposite happens in the engineer treatment (denoted Eng treatment), where the engineer’s recommendation is always implemented. In the joint decision treatment (denoted 50−50 treatment), both employees’ jointly determine the buyer’s action, with the computer randomly picking one recommendation (with equal probability) to implement if they disagree. All subjects are informed which treatment they are in. After all players made their choices, all subjects in the group learn whether the innovation happened and if so, the supplier’s decision, the engineer’s and procurement manager’s recommendations for the scenario that happened, and which recommendation was implemented. The payoffs for the round are presented to all players and a new number is drawn to determine if the relationship between the firms continues for another round. Subjects playing as suppliers get the payoff the supplier firm and subjects playing as procurement
managers and engineers each get the payoff of the buying firm. Note that in the PM treatment, subjects playing as engineers spend a whole relationship making recommendations which are never implemented (and the same happens with procurement managers in the Eng treatment). However, since after each relationship engineers and procurement managers are randomly re-assigned a new role, most subjects get to play the role with decision authority at some point during the session. As before, the subjects know the grouping, continuation, and re-matching rules.

The experiment consists of five treatments in total, SR, LR, PM, Eng, and 50 – 50, and follows a between-subjects design (each subject is exposed to one treatment). To ensure the subjects’ understanding of the game, three examples are presented in the instructions, and the table with payoffs (Figure 4 in the appendix) is shown to participants throughout the experiment. In particular, to avoid biases relative to the continuation probabilities, in the PM, 50 – 50, Eng, and LR treatments it was made explicit that, after each round, the probability that the relationship will continue for another round remains exactly the same. To avoid reputation effects, participants only learn the outcomes and payoffs of their own relationships. In addition, since there is a minimum of four relationships playing simultaneously in any given session, it is unlikely that subjects can track their partners after random re-matching. The parameters used in the experiment match those in the numerical example (Section 3.2). For the probability of innovation we set \( \pi = 0.75 \), which allows us to get a high frequency of the interesting outcome where the innovation happens. This relatively high frequency of innovations captures for example the occurrence of small process improvements, rather than big events such as disruptive new technologies (which in reality happen less frequently). For the continuation probability, we used \( \delta = 0.75 \). A 0.75 continuation probability implies average relationship lengths of four years\(^{16}\), which is consistent for example with the automotive industry (McMillan 1990). This value guarantees that the collaborative outcome is an equilibrium of the game in the Eng and 50-50 treatments. Propositions 1 and 2 show that with the payoffs in Figure 1, cooperation can be supported as part of a subgame perfect equilibrium for values of continuation probability greater than 0.69 (for the LR and Eng settings) and 0.55 (for the 50 – 50 setting). Choosing the continuation probability, \( \delta = 0.75 \) provides an additional slack to ensure that equilibrium outcomes emerge.

### 4.1. Procedures

The experiments were conducted in z-Tree (Fischbacher 2007) between March and September of 2014 at the behavioral laboratory of the School of Information at University of Michigan. A total of 372 undergraduates participated in four sessions of each of the Buyer-as-Single-Employee

\(^{16}\) This is under the assumption that firms make supplier selection decisions on an annual basis, as is the case in the automotive industry.
treatments and six sessions of each of the Buyer-as-Two-Employees treatments. The maximum number of subjects per session was 18 and the minimum was 10 for the Buyer-as-Single-Employee treatments and 12 for the Buyer-as-Two-Employees treatments. Each session lasted approximately one hour, the SR treatment ended after 40 rounds, all other treatments ended after 50 minutes (including the time for reading the instructions) to allow some time for payment. The average number of rounds per relationship was 3.9, with a minimum of 1 and a maximum of 11. Average payoffs were $11, consisting of a $5 show up fee plus the payoffs of two randomly selected rounds at a conversion rate of $0.10 per point earned.

5. Hypotheses

We derive the following experimental hypotheses from our analysis (mainly propositions 1 and 2). The first hypothesis is derived from the equilibrium outcomes of the Buyer-as-Single-Employee setup. Propositions 1 and 2 imply that the non-collaborative outcome is the only equilibrium that can be supported in the short-term relationship while a collaborative outcome emerges as an equilibrium in the long-term relationship. Thus, we expect collaboration to be lower when the firms have a short term relationship than when they have a long term relationship.

HYPOTHESIS 1. [Buyer-as-Single-Employee Treatments] Firms collaborate less in the SR treatment than in the LR treatment. Specifically, compared to the LR treatment, the SR treatment results should show that

1.a - the supplier chooses to share less frequently,
1.b - the buyer chooses to compete (if shared) more often than in the LR treatment, and
1.c - the frequency of collaborative outcomes (both firms collaborate simultaneously) is lower.

The next hypothesis is for the Buyer-as-Two-Employees treatments. Since the procurement manager is part of the buyer-supplier pairing for only one period, his relationship with the supplier resembles a one-shot game. Thus the play in the PM treatment should map onto the SR treatment. On the other hand, the engineer remains working for the same buyer as long as the relationship with the supplier lasts. Thus, the results of the Eng treatment should be similar to the results of the LR treatment. Finally, in the 50-50 treatment, since the final decision is randomly picked, the buyer will follow the procurement manager’s decision and the engineer’s decision 50% of the time.

\[17\] We use all observations up to period 30, which is the latest period that was reached in every session. The results do not change significantly if we use the observations from all periods.

\[18\] Some previous experimental papers chose to pay for performance on randomly chosen full relationships rather than rounds. Comparing both, Sherstyuk et al. (2013) find that per-round payment slightly biases subjects towards short-term focus (present-period bias). In our setup this effect would only bias against finding treatment differences. In addition, the effect seems to be more prominent in the first round of a relationship, while our results show bigger differences in later rounds.
respectively. The theory prescribes an equilibrium where the supplier always shares, the engineer recommends to not compete and the procurement manager recommends to compete. Thus, the frequency of rounds with collaborative outcomes in the 50-50 treatment should be higher than in the SR treatment but lower than in the LR treatment.

HYPOTHESIS 2. [Buyer-as-Two-Employees Treatments] In the Firms-as-Two-Employees treatments, collaboration is in between the SR and LR benchmarks:
2.a - the PM treatment obtains the same outcomes as the SR treatment,
2.b - the Eng treatment obtains the same outcomes as the LR treatment, and
2.c - the 50-50 treatment is in between the SR and LR treatments: the supplier shares as in the LR and the buyer competes more than in the LR treatment and less than in the SR treatment.

We expect that the two treatments under the Buyer-as-Single-Employee setting will serve as benchmarks: We expect (1) the SR treatment has the lowest level of collaboration and (5) the LR treatment the highest level. In the Buyer-as-Two-Employees treatments, our theoretical results stipulate that the consideration for a long-term relationship will increase when the treatment changes from (2) the PM to (3) the 50-50 to (4) the Eng treatment. Thus, we expect to see that the more collaborative outcomes will emerge as the treatment changes from (1) to (5). Based on Hypotheses 1 and 2, if we order the treatments SR - PM - 50-50 - Eng - LR, we should see a gradient of increased collaboration from SR to LR.

HYPOTHESIS 3. [Trends across treatments] There is a trend of increasing collaboration from SR to LR:
3.a - the frequency of sharing increases,
3.b - the frequency of compete (if shared) decreases, and
3.c - the frequency of collaborative outcomes increases.

Notice that the procurement manager engages in a relationship just for one round before being rotated to another firm. Thus, the procurement manager should always choose to compete, regardless of the engineer’s previous recommendation. Similarly, the engineer should not condition his recommendation on the recommendation of the previous procurement manager. Trigger strategies prescribe that the engineer’s strategy is only contingent on the supplier’s and his own previous history of play.

HYPOTHESIS 4. [Interplay between employees] The engineer’s recommendation is independent of the procurement manager’s recommendation in the previous round. The procurement manager’s recommendation is independent of the engineer’s recommendation in the previous round.
6. Experimental Results

In the first two sections, we compare the supplier’s and the buyer’s actions across the five treatments and analyze the outcomes and resulting profits. In the third section, we analyze in depth each of the Buyer-as-Two-Employees treatments and analyze the interplay between engineers and procurement managers.

6.1. Descriptive Results

Our hypotheses in the previous section imply that both suppliers and buyers are more likely to choose collaborative actions (hence the stage-game results in a collaborative outcome) as the prospect of a long-term relationship becomes more explicit. Specifically, we expect that the supplier will be least collaborative in (1) SR and (2) PM treatments and most collaborative in (4) Eng and (5) LR treatments. Hypothesis 2 predicts that in (3) the 50-50 treatment the supplier shares as in (4) and (5). Likewise, we expect to see that buyers are most likely to choose “compete” in (1) SR and (2) PM treatments, and least likely to choose “compete” in (4) Eng and (5) LR treatments.

For the buyer’s decision, we expect that the result in (3) the 50-50 treatment falls in between (1-2) and (4-5). From Hypothesis 3, we expect to see an increasing trend of collaboration as we examine the results from treatment (1) to treatment (5) in an increasing order.

Table 1 shows the frequency of “share” and “compete” actions and the frequency of the collaborative outcome in each treatment. Table 2 presents probit regression results estimating for each treatment the probabilities of suppliers choosing “share”, buyers choosing “compete” in case the supplier chose “share”, buyers implementing the “compete” decision, and both firms choosing the collaborative action. In all cases we control for round within a relationship, period of play in the session, and subject fixed effects. Recall that our experiment uses the strategy method, which asks suppliers and buyers to choose an action for each contingency. Thus, we are able to collect the data on all the dependent variables in every period.

### Table 1: General Results - Frequency of Collaborative Outcomes

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Supplier’s Decision (%)</th>
<th>Buyer’s Decision (%)</th>
<th>Collaborative Outcome (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR</td>
<td>18.2</td>
<td>77.6</td>
<td>5.3</td>
</tr>
<tr>
<td>PM</td>
<td>29.2</td>
<td>71</td>
<td>9.5</td>
</tr>
<tr>
<td>50 – 50</td>
<td>33.5</td>
<td>74.6</td>
<td>10.8</td>
</tr>
<tr>
<td>Eng</td>
<td>40.2</td>
<td>62.7</td>
<td>24.6</td>
</tr>
<tr>
<td>LR</td>
<td>38.5</td>
<td>58.5</td>
<td>21.3</td>
</tr>
</tbody>
</table>

The results presented in Table 1 show that suppliers’ decision to “share” becomes more frequent as we go from the SR treatment to the LR treatment. A non-parametric test for trends shows that
Table 2 General Results

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Supplier’s Decision (Share)</th>
<th>Buyer’s Decision (Compete if Shared)</th>
<th>Buyer’s Decision (Compete)</th>
<th>Collaborative Outcomes (Share/Not Compete)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM</td>
<td>0.624***</td>
<td>-0.192</td>
<td>-0.247**</td>
<td>0.389*</td>
</tr>
<tr>
<td>(50 – 50)</td>
<td>(0.206)</td>
<td>(0.150)</td>
<td>(0.126)</td>
<td>(0.233)</td>
</tr>
<tr>
<td>Eng</td>
<td>0.964***</td>
<td>-0.571***</td>
<td>-0.102</td>
<td>0.462**</td>
</tr>
<tr>
<td>(0.201)</td>
<td>(0.156)</td>
<td>(0.124)</td>
<td>(0.227)</td>
<td></td>
</tr>
<tr>
<td>LR</td>
<td>0.897***</td>
<td>-0.315**</td>
<td>-0.574***</td>
<td>0.849***</td>
</tr>
<tr>
<td>(0.201)</td>
<td>(0.147)</td>
<td>(0.123)</td>
<td>(0.225)</td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>-0.008***</td>
<td>-0.018***</td>
<td>-0.017**</td>
<td>0.013***</td>
</tr>
<tr>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td></td>
</tr>
<tr>
<td>Round</td>
<td>-0.064***</td>
<td>0.041***</td>
<td>0.013</td>
<td>-0.009</td>
</tr>
<tr>
<td>(0.012)</td>
<td>(0.012)</td>
<td>(0.011)</td>
<td>(0.014)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-0.938***</td>
<td>0.734***</td>
<td>1.045***</td>
<td>-2.085***</td>
</tr>
<tr>
<td></td>
<td>(0.154)</td>
<td>(0.114)</td>
<td>(0.098)</td>
<td>(0.181)</td>
</tr>
</tbody>
</table>

Observations | 4286 | 4286 | 4286 | 4286 |

Nr. of Subjects | 143 | 143 | 143 | 143 |

Probit regression with subject random effects. Standard errors reported in parentheses. Significance is denoted: * p < 0.10 ** p < 0.05 *** p < 0.01.

Sharing increases from SR to LR (p < 0.001). However, pair-wise comparisons across treatments show that the only significant difference is between all treatments and the SR treatment (Wilcoxon rank-sum test p < 0.05 for all comparisons to the SR treatment). Average sharing is not significantly different across the PM, 50 – 50, Eng, and LR treatments. We observe similar results in the regression presented on Table 2. We observe that all the treatments (including the PM treatment) have higher frequency of sharing than the SR treatment baseline. The coefficients for all treatment dummies are not significantly different. Therefore, it appears that the supplier’s decision to share the innovation depends primarily on the length of the firm-level relationship, and does not differ significantly based on the allocation of decision rights within the buyer firm.

The frequency of the buyer’s choice to “compete if the supplier shared” presents a decreasing trend from SR to LR, as predicted in Hypothesis 3.b. As shown in column 2 of Table 2, only the Eng and LR treatments present a significant decrease relative to the SR benchmark (marginal effects Eng: −0.209, LR: −0.112). We also observe that in the 50 – 50 treatment, “compete if the supplier shared” is chosen significantly more often than expected. This deviation from our predictions is analyzed further in the following sections. We then look at the frequency of outcomes where the buyer competes (columns 2 in Table 1, and 3 in Table 2). We observe a significant trend of reduced competition (increased collaboration) from SR to LR (test for trends: p < 0.001),

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19 The non-parametric test for trends across ordered groups is an extension of the Wilcoxon rank-sum test. We consider subject level data (each subject’s average share decision across all rounds is considered as one observation for the test).
which supports Hypothesis 3.b. Table 1 shows that, while buyers compete in 77.6% of the outcomes in the SR treatment, they do so 71% of the times in the PM treatment \( (p = 0.009) \). As in the case of the suppliers’ sharing decisions, this suggests that the PM treatment presents increased collaboration relative to the SR benchmark. Nonetheless, the largest difference relative to the SR benchmark in the Eng and LR treatments (as predicted by Hypotheses 1.b and 2.b). Table 1 shows that the probability that a buyer will “compete” drops to 62.7% and 58.5% in the Eng and LR treatments respectively. Similarly, Table 2 shows that the frequency of outcomes where the buyer chose “compete” is lower in the PM treatment than in the SR benchmark (marginal effects: \(-0.087\)) and even lower in the Eng and LR treatments (marginal effects: \(-0.171\) and \(-0.212\) for Eng and LR respectively). Therefore, the buyer’s decision depends not just on the firm-level relationship length, but also on the decision rights within the firm.

The results described above indicate that suppliers’ and buyers’ actions deviate from the predictions in opposite ways. Hypothesis 2 predicts that the frequency with which suppliers choose “share” in the PM treatment will be as low as in the SR benchmark, and that in the 50 – 50 and Eng treatments it will be as high as in the LR treatment. We observe that the probability that suppliers choose “share” actually increases even sooner than expected. Even in the PM treatment suppliers share significantly more frequently than in the SR benchmark. On the other hand, the frequency with which buyers choose “compete” decreases later than predicted. Hypothesis 2 predicts that in the 50 – 50 treatment competition should be lower than in the SR benchmark and higher than in the LR treatment. We find that in the 50 – 50 treatment buyers choose “compete if the supplier shared” even more frequently than in the PM treatment \( (p = 0.094) \). It is only in the Eng and LR treatments that buyers choose “compete if the supplier shared” significantly less often than in the SR benchmark.

Lastly, we analyze the frequency with which collaborative outcomes occur in each treatment. Recall that we defined a collaborative outcome as a play of the stage game where the supplier chooses to share and the buyer chooses not to compete. A test for trends shows that the frequency of collaborative outcomes increases from SR to LR \( (p < 0.001) \), as predicted by Hypothesis 3.c. Table 1 shows that the frequency with which collaborative outcomes occur is not statistically different across the SR, PM, and 50 – 50 treatments. In the Eng treatment, it is significantly higher than in the previous three (Eng vs. 50 – 50: \( p = 0.007 \)) and not significantly different from the LR treatment. The regression presented in Table 2 shows that all treatments present a higher frequency of collaborative outcomes than the SR baseline (PM marginal effects: 0.072). In particular, the Eng and LR treatments have an even higher frequency of collaborative outcomes (Eng and LR marginal effects: 0.249 and 0.183 respectively). The results confirm the hypotheses, for the most part. They depart from the hypotheses in two ways: First, the frequency of collaborative outcomes in the PM
treatment is (marginally) higher than in the SR treatment, while they should be equivalent. Second, the frequency of collaborative outcomes in the 50−50 treatment is not significantly higher than in the PM treatment, while both buyers and suppliers are expected to be more collaborative. We explore these results in the following sections by analyzing each of the Buyer-as-Two-Employees treatments in more detail.

6.2. Profits
Table 3 presents average profits for suppliers, buyers, and the total profits of both players combined. A test for trends shows that all three present an increasing trend from SR to LR ($p = 0.001, 0.009,$ and $< 0.001$ for suppliers’, buyers’, and total profits respectively). The results also show that in the PM treatment, suppliers’ profits are slightly higher than the theoretical expected profits from non-collaborative strategies (16.14 vs. 15.25, one sided t-test $p = 0.077$). However, suppliers only earn significantly higher profits than in the SR benchmark in the Eng and LR treatments. On the other hand, buyers benefit from all Buyer-as-Two-Employees treatments. Buyers’ profits are significantly higher than in the SR benchmark, in all the other treatments – PM, 50−50, Eng, and LR. This is consistent with the previous findings about suppliers’ and buyer’s actions. While suppliers share more frequently in all the Firms-as-Employees treatments than in the SR benchmark, the frequency with which buyers choose “compete” only decreases significantly relative to the SR benchmark in the Eng treatment (where the engineer’s recommendation is the one that is always implemented).

Table 4 confirms the previous results with a regression of suppliers’, buyers’, and total profits on treatment dummies controlling for period, round and subject fixed effects. Suppliers’ profits only increase relative to the SR benchmark in the Eng and LR treatments, while buyers’ profits increase in all the Firms-as-Employees treatments, as well as in the LR treatment. Total profits are higher in the PM and 50−50 treatments than in the SR benchmark, and even higher in the Eng and LR treatments. Recall that total surplus increases if the innovation occurs and, it increases even further, if the supplier shares the innovation. The buyer’s decision affects only the allocation of total surplus between the supplier and the buyer. Since the innovation occurs with the same probability in all treatments, the difference in total profits across treatments reflects the pattern of increased frequency of suppliers’ sharing from SR to LR.

6.3. Employee decisions in the Buyer-as-Two-Employees treatments
The previous results show that the trends of increased collaboration are present for the supplier’s decision to share, the buyer’s decision to compete, and the frequency of collaborative outcomes. We next describe the results for the employee recommendations in the Buyer-as-Two-Employees treatments. We will show in this section that: (1) the PM treatment does not exactly map onto the SR treatment, (2) the 50−50 treatment is not exactly “in between” the PM and Eng treatments as
Table 3  General Results - Profits

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Supplier</th>
<th>Buyer</th>
<th>Total</th>
<th>Supplier’s Fraction of Total Surplus (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR</td>
<td>15.48</td>
<td>30.68</td>
<td>46.16</td>
<td>34</td>
</tr>
<tr>
<td>PM</td>
<td>16.14</td>
<td>35.23</td>
<td>51.37</td>
<td>31</td>
</tr>
<tr>
<td>50 – 50</td>
<td>15.63</td>
<td>36.93</td>
<td>52.55</td>
<td>30</td>
</tr>
<tr>
<td>Eng</td>
<td>21.83</td>
<td>37.60</td>
<td>59.43</td>
<td>38</td>
</tr>
<tr>
<td>LR</td>
<td>19.93</td>
<td>36.97</td>
<td>56.90</td>
<td>35</td>
</tr>
</tbody>
</table>

Expected profit from non-collaborative strategies (*) 15.25 20.75 36 42.4

(*) Refers to the outcome of the strategies where suppliers never choose “share” and buyers always choose “compete”.

Table 4  Profits

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Supplier’s Profits</th>
<th>Buyer’s Profits</th>
<th>Total Profits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM Treatment</td>
<td>0.137</td>
<td>7.455***</td>
<td>7.613***</td>
</tr>
<tr>
<td>(0.773)</td>
<td>(2.675)</td>
<td>(2.794)</td>
<td></td>
</tr>
<tr>
<td>50 – 50 Treatment</td>
<td>-0.377</td>
<td>9.132***</td>
<td>8.757***</td>
</tr>
<tr>
<td>(0.725)</td>
<td>(2.596)</td>
<td>(2.758)</td>
<td></td>
</tr>
<tr>
<td>Eng Treatment</td>
<td>5.843***</td>
<td>9.801***</td>
<td>15.661***</td>
</tr>
<tr>
<td>(1.506)</td>
<td>(2.834)</td>
<td>(3.653)</td>
<td></td>
</tr>
<tr>
<td>LR Treatment</td>
<td>3.962***</td>
<td>8.993***</td>
<td>12.975***</td>
</tr>
<tr>
<td>(1.332)</td>
<td>(2.674)</td>
<td>(3.291)</td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>0.164***</td>
<td>-0.281***</td>
<td>-0.117</td>
</tr>
<tr>
<td>(0.035)</td>
<td>(0.064)</td>
<td>(0.076)</td>
<td></td>
</tr>
<tr>
<td>Round</td>
<td>0.224</td>
<td>-1.242***</td>
<td>-1.027***</td>
</tr>
<tr>
<td>(0.142)</td>
<td>(0.265)</td>
<td>(0.316)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>12.720***</td>
<td>36.278***</td>
<td>49***</td>
</tr>
<tr>
<td>(0.216)</td>
<td>(2.138)</td>
<td>(2.250)</td>
<td></td>
</tr>
</tbody>
</table>

OLS regression with subject random effects. Robust standard errors reported in parentheses. Significance is denoted: * p < 0.10  ** p < 0.05  *** p < 0.01.

predicted by Hypothesis 2, and (3) the Eng treatment presents no significant differences with the LR treatment. In the next section we show that there exists an interplay between the employees beyond what the theory predicts.

Although the theory predicts that the SR and PM treatments should be identical, the results on Table 5 show important differences. The first and second columns in Table 5 show the fraction of times buyers chose to compete when the supplier shared and when the supplier did not share respectively. The next two columns show the supplier’s expected profit from sharing and from not sharing given how the buyers responded to these two actions in the experiment. Column 5 presents the difference between columns 3 and 4. We observe that this difference is negative in the SR treatment and positive in the PM treatment. This implies that, in expectation, sharing is profitable in the PM treatment and not in the SR treatment. Table 9 in the Appendix confirms this result. In the PM treatment, a regression of the average profit per round within a relationship on the average
frequency of sharing in that relationship shows a positive correlation between the two ($\beta = 5.043$, $p = 0.01$). This means that, for example, for a supplier who shared 10% of the times, a increase in collaboration to sharing 60% of the times would be associated with an increase in expected profit of 2.52 points per round. Since the average profits for suppliers in the PM treatment is 16.59 points per round, this implies a 15% increase in profits. In the experiment, suppliers seem to acknowledge this difference: they share 18.2% of the times in the SR treatment and 29.2% of the times in the PM treatment.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Compete if shared* (%)</th>
<th>Compete if not shared* (%)</th>
<th>E[Profit from sharing]</th>
<th>E[Profit from not sharing]</th>
<th>Diff.</th>
<th>Share* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR</td>
<td>67.6</td>
<td>78.5</td>
<td>15.63</td>
<td>15.84</td>
<td>-0.22</td>
<td>18.2</td>
</tr>
<tr>
<td>PM</td>
<td>64.3</td>
<td>73.2</td>
<td>17.08</td>
<td>15.99</td>
<td>1.09</td>
<td>29.2</td>
</tr>
<tr>
<td>50 – 50</td>
<td>71.2</td>
<td>76.4</td>
<td>14.14</td>
<td>15.90</td>
<td>-1.76</td>
<td>33.4</td>
</tr>
<tr>
<td>Eng</td>
<td>50.7</td>
<td>68.6</td>
<td>22.85</td>
<td>16.11</td>
<td>6.74</td>
<td>40.3</td>
</tr>
<tr>
<td>LR</td>
<td>59.0</td>
<td>56.6</td>
<td>19.51</td>
<td>16.44</td>
<td>3.07</td>
<td>38.5</td>
</tr>
</tbody>
</table>

Note: the columns marked with (*) present data from the experiment. The others present the suppliers’ expected profits given the buyer’s choices in the experiment.

As shown in Proposition 2, in the 50 – 50 treatment an equilibrium where the supplier chooses “share” in every round, the engineer recommends “not compete if the supplier shared”, and the procurement manager recommends “compete” in every round, can be supported with the continuation probability of 0.75 used in the experiment. Since one of the two recommendations is chosen at random, collaboration should be higher than in the PM treatment and lower than in the Eng treatment. The results show that in the 50 – 50 treatment, both the engineer and the procurement managers compete more often than in the PM and Eng treatments. Figure 5 in the Appendix shows that the percentage of times when the engineer chooses “compete when the supplier shared” is higher in the 50 – 50 treatment than in the PM and Eng treatments ($p = 0.013$ for PM, $p = 0.033$ for Eng). Similarly, the procurement managers choose to “compete” significantly more often in the 50 – 50 treatment than in the PM and Eng treatments ($p = 0.055$ and $p = 0.071$ for PM and Eng respectively). In addition, a high proportion of the collaborative outcomes in the 50 – 50 treatment is generated by procurement managers (engineers’ decisions account for 63% of the collaborative outcomes and procurement managers’ for 37%).

We also study how collaboration evolves throughout a relationship in the 50 – 50 treatment relative to the PM and Eng treatments. We observe that, while in the Eng and LR treatments a relationship that starts with a collaborative outcome is likely to result in collaborative outcomes in the following rounds, in the PM and 50 – 50 treatments this is less likely to occur. This can be seen
in Figure 2, which shows how a collaborative outcome in the first round is sustained throughout the relationship in the different treatments. We also observe that in all treatments, if the collaborative outcome is not reached in the first round, it is very unlikely that it will be reached in a subsequent round. To confirm these results, Table 6 shows for each treatment the probability that a round will result in a collaborative outcome, partitioned into the following cases: (1) collaboration that happens in the first round of a relationship, (2) collaboration in rounds two and onwards where there was a collaboration in the previous round, and (3) collaboration in rounds two and onwards where there was not a collaborative outcome in the round before. First, we note that in all treatments the probability of having a collaborative outcome when there was no collaboration in the round before is very low (approximately, 0.06) and does not vary significantly by treatment. Second, the probability of a collaborative outcome in the first round of a relationship is higher in the Eng and LR treatments (0.23 and 0.21 respectively) relative to the 50–50 and PM treatments (0.12 and 0.14 respectively). However, the largest difference across treatments resides in the probability of a collaborative outcome when there was a collaborative outcome in the previous round (0.31 and 0.43 in the PM and 50–50 treatments vs. 0.77 and 0.79 in the Eng and LR treatments). This shows that the 50–50 treatment is more similar to the PM treatment than the Eng treatment in terms of sustaining collaboration in a relationship.

We also study how collaboration evolves throughout a relationship in the 50–50 treatment relative to the PM and Eng treatments. We observe that, while in the Eng and LR treatments a relationship that starts with a collaborative outcome is likely to result in collaborative outcomes in the following rounds, in the PM and 50–50 treatments this is less likely to occur. This can be seen in Figure 2, which shows how a collaborative outcome in the first round is sustained throughout the relationship in the different treatments. We also observe that in all treatments, if the collaborative outcome is not reached in the first round, it is very unlikely that it will be reached in a subsequent round. To confirm these results, Table 6 shows the probability that any round will result in a collaborative outcome for each treatment, partitioned into the following cases: collaboration that happens in the first round of a relationship, collaboration that happens in any round after the first one of a relationship when there was a collaboration in the immediate previous round, and collaboration that happens in any round after the first one of a relationship when there was not a collaborative outcome in the round immediate before. First, we note that in all treatments the probability of having a collaborative outcome when there was no collaboration in the period immediate before is very low (approximately, 0.06) and does not vary significantly by treatment. Second, the probability of a collaborative outcome in the first round of a relationship is higher in the Eng and LR treatments (0.23 and 0.21 respectively) relative to the 50–50 and PM treatments (0.12 and 0.14 respectively). However, the largest difference across treatments resides in
the probability of a collaborative outcome when there was a collaborative outcome in the previous round (0.31 and 0.43 in the PM and 50 – 50 treatments vs. 0.77 and 0.79 in the Eng and LR treatments). As a result, the 50 – 50 treatment is more similar to the PM treatment than the Eng treatment in term of sustaining collaboration in a relationship.

### Table 6  Collaboration throughout Relationships

<table>
<thead>
<tr>
<th></th>
<th>SR</th>
<th>PM</th>
<th>50 – 50</th>
<th>Eng</th>
<th>LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pr (CO)*</td>
<td>0.053</td>
<td>0.095</td>
<td>0.108</td>
<td>0.246</td>
<td>0.213</td>
</tr>
<tr>
<td>Pr (CO</td>
<td>R = 1)</td>
<td>0.053</td>
<td>0.14</td>
<td>0.12</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>(37%)</td>
<td>(30%)</td>
<td>(24%)</td>
<td>(25%)</td>
<td></td>
</tr>
<tr>
<td>Pr (CO</td>
<td>CO prev round, R &gt; 1)</td>
<td>0.31</td>
<td>0.43</td>
<td>0.77</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>(24%)</td>
<td>(33%)</td>
<td>(59%)</td>
<td>(58%)</td>
<td></td>
</tr>
<tr>
<td>Pr (CO</td>
<td>no CO prev round, R &gt; 1)</td>
<td>0.06</td>
<td>0.06</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(39%)</td>
<td>(37%)</td>
<td>(17%)</td>
<td>(17%)</td>
<td></td>
</tr>
</tbody>
</table>

Note: (*) CO refers to collaborative outcome. (%) represents the percentage of all collaborative outcomes that occur in a particular treatment corresponding to cases (A), (B), and (C). R = 1 represents the first round of a relationship, R > 1 represents all rounds other than the first one in a relationship.

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**Figure 2**  Effect of first round collaboration of subsequent rounds
In the Eng treatment the engineers recommendation is implemented in every period. Since the
engineer is matched with the supplier as long as the relationship between the firms lasts, the Eng
treatment should resemble the play in the LR treatment (hypothesis 2). The results show that
there are no significant differences between the two treatments in terms of either the suppliers’
(“share”) or the buyers’ (“compete”) decisions.

6.3.1. Interplay between employees Figure 3 shows how the engineer’s play in the Eng
treatment correlates with his own previous play and with the play of the previous procurement
manager he interacted with. The bar chart on the left shows the engineer’s choice to “compete if
the supplier shared” in every round of the relationship (except the first one) with two columns,
one for the case where he chose to compete in the previous round and another for the case where
he chose not to compete in the previous round. We observe that if an engineer competed in one
round, he is more likely to compete again in the following round within the same relationship
than if he did not compete in the previous round. This difference in behavior is present even in
later rounds within a relationship. This result is not surprising; it is consistent with hypothesis
2.b, which was derived assuming trigger strategies, but it can also be the result of other common
strategies such as “tit-for-tat” and “always compete”. The bar chart on the right of Figure 3 shows
a more surprising result: engineers seem to be more likely to compete if the previous procurement
manager in the relationship chose to compete than if the previous procurement manager chose not
to compete. Since this result can be intertwined with the engineer’s own choice in the previous
round, we conduct the regression presented in Table 7. Column 6 shows that, the engineer’s decision
is correlated with the previous procurement manager’s decision in the round immediate before,
even after controlling for the engineer’s own decision in the previous round. This suggests that in
the Eng treatment, where the procurement manager has no say in the final decision, the engineer
takes into account the procurement manager and incorporates it into his own decision making.

On the contrary, procurement managers do not consider the engineer’s previous recommendation
in the PM treatment (column 4). Procurement managers ignore the previous round play in the
relationship and are only consistent with their own previous actions (note that the regression only
considers the cases where in the previous round the innovation did occur, so that the procurement
manager is informed of all the players’ actions in the previous round). Columns 5 and 7 show
that in the 50−50 treatment, where both the engineer and the procurement manager have input
on the final decision, both players ignore the previous recommendation of the player in the other
role. Finally, columns 1, 2, and 3 show the supplier’s actions in each of the Firms-as-Employees

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20 We considered the first six rounds of a relationship since it is the longest relationship that every supplier got to
play. Thus, for this particular plot, we eliminated the observations from rounds 7 onwards.
treatments. We find that the suppliers, as the engineers, care about the actions of the previous procurement manager even after he has left the relationship – but only do so when the procurement manager has a say in the final decision (PM and 50 – 50 treatments). We therefore see both suppliers and engineers deviate from the collaborative equilibria described in Propositions 1 and 2, where in the 50 – 50 and Eng treatments the supplier’s and engineer’s choices should depend only each other.

7. Discussion
One of the most interesting observations is that the results of the 50 – 50 treatment substantially deviate from the theoretical predictions. The theory predicts that in the PM and 50 – 50 treatments the procurement manager always recommends “compete”, and that in the Eng and 50 – 50 treatments the engineer always recommends “not compete”. The experimental results show that procurement managers choose “compete” more often in the 50 – 50 treatment than in the PM treatment, and engineers choose “compete” more often in the 50 – 50 treatment than in the Eng treatment. That is, both procurement managers and engineers choose “compete” more often in a setup where the probability that their recommendation will be implemented is 0.5, than when it will be implemented for sure. The results show that the frequency with which suppliers choose “share” is not significantly different across the PM, 50 – 50, and Eng treatments (the average frequency is 0.29, 0.34, and 0.40 respectively). One could expect that suppliers would punish the procurement managers and engineers for choosing “compete” more often in the 50 – 50 treatment. However, suppliers do not share less often in the 50 – 50 treatment than in the PM or Eng treatments (subject level average differences $p = 0.301$ and $p = 0.391$ respectively). This explains why the suppliers’ profits and share of the total surplus are the low in the 50 – 50 treatment (Table 3)
We also observe that, among the rounds where collaborative outcomes arise in the 50 – 50 treatment, a relatively high proportion of those collaborative outcomes (37%) occur when the procurement manager’s recommendation is implemented. This result seems to be driven by a number of procurement managers who often choose “not compete” when the supplier shared. While 50% of the procurement managers in the 50 – 50 treatment choose to compete in more than 90% of the rounds they played, another 23% choose to compete only 50% of the times or less. This is surprising since procurement managers change partners in every round, even if the relationship between the firms continues. A potential explanation for this can be found in Kandori (1992b) and Kandori (1992a), who have shown that collaboration can be supported in a sub-game perfect equilibrium in a setting where subjects change partners over time. They show that a “community” can sustain collaboration if defection against one subject triggers punishment by other subjects, or if the subject who leaves overlaps with his successor for a long enough period of time. This would explain why some procurement manager’s chose not to “compete if shared” in the 50 – 50 treatment. The subjects in a session may constitute a “community” where, if all procurement managers choose “compete”, they ultimately get punished in the future relationships they join. This can provide enough incentives for procurement managers to collaborate\textsuperscript{21}.

\textsuperscript{21}With the same explanation, their result could also explain why in the PM treatment procurement managers’ decision to “compete if the supplier shared” is lower than 100%, and why in the SR treatment buyers’ decision to “compete if the supplier shared” is lower than 100% (they are 64% and 68% respectively).
Another surprising result is that procurement managers influence the future buying team’s (the engineer and the successor of the procurement manager) actions after they have left a relationship. Previous experimental literature on group decision making has found somehow related results. Ambrus et al. (2013) study how the preferences of individuals get aggregated when they make decisions as a group, where the decision is how much to reciprocate as a second mover in a sequential gift exchange game (Fehr et al. 1993, Brandts and Charness 2004). In their setup, subjects freely discuss in groups of five individuals before making a group decision. Their results show that the relative position of an individual in a group is correlated with his influence on the other members of the group: members whose decision is at the median or closer to the mean of the distribution of all the group members’ individual decisions have significant influence on others. Interestingly, they find that deliberation causes that individual opinions move towards the decision of the previous group she/he was in, even after moving to the next group. In our setting, previous procurement managers influence the actions of suppliers and engineers after the procurement managers leave. Note that in our setting, social influence is less likely to occur than in their setting. First, because our setting does not allow for discussion and deliberation. Second, because they consider symmetric games while in our setting procurement mangers and engineers have different different matching rules and therefore different monetary incentives to collaborate.

8. Conclusions

We analyze a case where a supplier has to decide whether to share an innovation with a buyer when sharing the innovation increases supply chain efficiency but makes the supplier vulnerable if the buyer re-shares the innovation with the supplier’s competitors. The buyer decides what type of procurement policy he will follow: single source, which protects the suppliers’ intellectual property rights for the innovation and distributes total profits more evenly between the firms, or to open

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22 The gift exchange game is similar in structure and incentives to the trust game. It captures the dynamics of an incomplete labor contract where the employee’s effort is non-contractible or verifiable. Both players start with an initial endowment. The first mover sends a gift to the second mover where the gift is deducted from the first mover’s endowment and is tripled by the experimenter. The second mover then decides whether to send a gift to the first mover under the same conditions.

23 Ambrus et al. (2013) reference two social psychology mechanisms which explain why subjects may behave different in group contexts. Social comparison theory proposes that individuals want to perceive and present themselves in a socially desirable way, and therefore they react in a way that is closer to a social norm. The identifiability explanation proposes that in a group setting others’ ability to assign responsibility is more limited, allowing them to behave more selfishly.

24 Related to this point, Kocher and Sutter (2007) find that results of a one-shot gift exchange game are closer to the standard game-theoretic prediction when the experiment is computerized and group members anonymously reach consensus by voting on proposals, than when group members can discuss face to face.

25 Further literature on group decision making in trust games has focused for the most part in comparing how individuals and groups make decisions as senders and as receivers. Cox (2002) finds that groups in the role of responders send back smaller amounts than individuals, while Kugler et al. (2007) find that groups are just as trustworthy as individuals.
up competition among suppliers, which takes advantage of the supplier’s innovation sharing and gives the buyer a larger share of total profits. As it is common in the automotive industry, the buyer may allocate decision rights to short-run and long-run focused employees. Anecdotal evidence from automotive suppliers tells that in different occasions it is either the short-run or the long-run focused employees that has more power in the decision making process. To study how this impacts firms’ decisions, we conduct a laboratory experiment where both an engineer and a procurement manager make recommendations for what the buyer should do. We observe that, in addition to the length of the relationship between the firms, the allocation of decision rights to employees also matters. Having both short- and long-run focused employees involved in the decision increases collaboration and efficiency, even if it is the short-run focused employee who has the final decision rights or if there is uncertainty about which recommendation will be chosen. However, the highest increase in collaboration and efficiency is reached when the decision rights are allocated to the long-run focused employee. When we analyze separately suppliers’ and buyers’ profits, we find that suppliers benefit only from long-run focused employees, while buyers benefit from any of the dual decision cases.

Most importantly, our results show that subjects’ may be influenced by their peers’ recommendations. In particular, it is the short run focused employee who has the strongest impact on the future play within the relationship: his actions are correlated with those of both the supplier and the long-run focused employee, but not those of his short-run focused successor. Understanding this interplay between employees is important for a buyer deciding whether (and how) to build teams to manage his supplier relations. Our experimental results suggest that: first, if the relationship is being managed by a short-run focused procurement manager, the buyer can benefit from introducing a long-run focused employee to the team. This can lead to increased efficiency without hurting the supplier. Second, if the long-run focused employee is in charge of making the decision, introducing a short-run focused employee may influence the decision maker’s actions but does not lead to significantly worse outcomes in terms of efficiency or buyer’s profits. Lastly, our results show that introducing uncertainty about which employee will be the final decision maker, leads to significantly lower collaboration by both types of employees. This is particularly detrimental for suppliers’ profits.

References


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Kugler, Tamar, Gary Bornstein, Martin G Kocher, Matthias Sutter. 2007. Trust between individuals and groups: Groups are less trusting than individuals but just as trustworthy. *Journal of Economic psychology* **28**(6) 646–657.


Murnighan, J Keith, Alvin E Roth. 1983. Expecting continued play in prisoner’s dilemma games a test of several models. *Journal of Conflict Resolution* 27(2) 279–300.


9. Appendix

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Demand parameter</td>
<td>50</td>
</tr>
<tr>
<td>b</td>
<td>Demand parameter</td>
<td>2</td>
</tr>
<tr>
<td>$C_{s1}$</td>
<td>Supplier 1’s cost before innovation</td>
<td>7</td>
</tr>
<tr>
<td>$C_{s2}$</td>
<td>Supplier 1’s cost if innovation occurs</td>
<td>5</td>
</tr>
<tr>
<td>$C_{m1}$</td>
<td>Manufacturer’s cost before supplier shares</td>
<td>11</td>
</tr>
<tr>
<td>$C_{m2}$</td>
<td>Manufacturer’s cost if innovation occurs and supplier shares</td>
<td>5</td>
</tr>
<tr>
<td>$C_{a1}$</td>
<td>Supplier 2’s cost before manufacturer shares</td>
<td>9</td>
</tr>
<tr>
<td>$C_{a2}$</td>
<td>Supplier 2’s cost if manufacturer chooses to compete</td>
<td>5</td>
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</table>

Figure 4  Payoffs table shown in the experiment

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Average profit per round (Supplier)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average sharing in a relationship</td>
<td>5.043*** (1.950)</td>
</tr>
<tr>
<td>Match</td>
<td>0.358 (0.291)</td>
</tr>
<tr>
<td>Constant</td>
<td>13.43*** (1.769)</td>
</tr>
</tbody>
</table>

Observations 220  Nr. of Subjects 28

Tobit regression with subject random effects. Standard errors reported in parentheses. Each relationship represents one observation. Significance is denoted: * p < 0.10 ** p < 0.05 *** p < 0.01.
9.1. Manufacturer chooses not to compete: Bilateral bargaining

We consider the case where both firms agree on a contract that splits profits according to some parameter $\alpha$. In the bilateral case, we assume that the total surplus in the supply chain will be split in such a way that the manufacturer earns a fraction $\alpha$ of the total surplus, $\Pi_m = Q\alpha(p - C_s - C_m)$, and the supplier earns a fraction $(1 - \alpha)$ of the total surplus $\Pi_s = Q(1 - \alpha)(p - C_s - C_m)$.

The manufacturer and the supplier simultaneously choose $p^*$ and $w^*$ that maximize total surplus while keeping the Nash Bargaining allocation of surplus between them. That is, they solve:

$$\max_{p,w} Q(p - C_m - C_s)$$

s.t. $\Pi_m(p, w) = \alpha Q(p - C_m - C_s)$

and $\Pi_s(p, w) = (1 - \alpha)Q(p - C_m - C_s)$

Taking FOC, the optimal retail price is $p^* = \frac{a+b(C_m+C_s)}{2b}$. At this retail price, the quantity sold is $Q^* = \frac{a-b(C_m+C_s)}{2b}$. The supplier’s wholesale price $w^*$, is such that earns the supplier $(1 - \alpha)$ times total surplus. That is, $w^*$ such that $Q(w - C_s) = (1 - \alpha)Q(p - C_m - C_s)$. Then $w^* = (1 - \alpha)(p - C_m) + \alpha C_s^{26}$.

It is a commonly known result that in the case where the manufacturer and the supplier have the same bargaining power and they both get zero profits in case of disagreement, the Nash Bargaining Solution predicts equal splits of the surplus, that is $\alpha = \frac{1}{2}$. Thus, replacing for the manufacturer’s and supplier’s profits with $\alpha = \frac{1}{2}$, we get:

$$\Pi_m = \Pi_s = \frac{(a - b(C_s + C_m))^2}{8b}$$

(4)

26 For more on the surplus split in case of monopolies with exogenous bargaining power, see Lovejoy (2010).
9.2. Manufacturer chooses to compete: Bargaining with supplier competition

Consider now the case where the manufacturer chooses to compete. If the supplier shared, then the
firms have costs $C_{s2} = C_{a2}$ and if the innovation did not occur or if occurs and the supplier chose
not to share, then the firms have costs $C_{a1} > C_{s1}$ and $C_{a1} > C_{s2}$ respectively. We assume that, in
either case, the original supplier wins the deal. The Nash Bargaining solution dictates that the
manufacturer and the supplier find the split $\alpha^*$ that solves

$$
\arg \max_\alpha [(u_s - ts)(um - tm)]
$$

where $u_s$ is the supplier’s agreement payoff, $(1 - \alpha)Q(p - C_s - C_m)$; $t_s$ is the supplier’s dis-
agreement payoff, 0; $u_m$ is the manufacturer’s agreement payoff $\alpha Q(p - C_s - C_m)$; and $t_m$ is the
manufacturer’s disagreement payoff, $\beta Q(p - C_a - C_m)$. We assume $\beta = 1$ since the manufacturer
can extract the whole surplus from the high-cost supplier.

Thus, Nash Bargaining dictates that the total surplus will be allocated according the $\alpha$ that solves:

$$
\arg \max_\alpha [(1 - \alpha)Q(p - C_s - C_m)] [\alpha Q(p - C_s - C_m) - Q(p - C_a - C_m)]
$$

The solution to this problem is $\alpha^* = \frac{1}{2} + \frac{(p - C_a - C_m)}{2(p - C_s - C_m)}$. Given this split of surplus, the manufacturer
and supplier simultaneously find the optimal $p^*$ and $w^*$ that result in maximum total surplus while
splitting it according to $\alpha$. They solve:

$$
\max_{p,w} \quad Q(p - C_m - C_s) \\
\text{s.t.} \quad \Pi_m(p, w) = \alpha Q(p - C_m - C_s) \\
\text{and} \quad \Pi_s(p, w) = (1 - \alpha)Q(p - C_m - C_s)
$$

Taking FOC, the optimal retail price is $p^* = \frac{a + b(C_m + C_a)}{2b}$. At this retail price, the quantity sold is
$Q^* = \frac{a - b(C_m + C_a)}{2}$. The wholesale price $w^*$, is such that earns the supplier $(1 - \alpha)$ times total surplus.
That is, such that $Q(w - C_s) = \frac{1}{2} - \frac{(p - C_a - C_m)}{2(p - C_s - C_m)}[Q(p - C_s - C_m)]$, which yields $w^* = \frac{C_a + C_s}{2}$. At this
retail price, the quantity sold is $Q^* = \frac{a - b(C_m + C_a)}{2}$.

Replacing $\alpha^*$ in the manufacturer’s and supplier’s profits, we get that the manufacturer’s profit
is:
\[ \Pi_m = \frac{[a - b(C_m + C_s)](a - b(C_m + C_a))}{4b}, \]  
(5)

and the supplier’s profit is:

\[ \Pi_s = \frac{[C_a - C_s](a - b(C_s + C_m))}{4}. \]  
(6)

9.3. Numerical Example

We fix the values of the parameters \((a, b, C_{s1}, C_{s2}, C_{m1}, C_{m2}, C_{a1}, C_{a2}, \text{ and } \pi)\) and calculate the payoffs under these conditions. Figure 1 shows the extensive form of the game with these payoffs.

Suppose that supplier 1 started off with production cost \(C_{s1} = 7\) and the manufacturer with a cost \(C_{m1} = 11\). If the innovation occurs, the supplier’s cost is reduced to \(C_{s2} = 5\). If the supplier chooses to share the technology with the manufacturer, the manufacturer’s cost is reduced to \(C_{m2} = 5\). If the supplier does not share the technology, the manufacturer’s cost remains \(C_{m1} = 11\).

In the second period, the manufacturer can choose to bring in another supplier, who initially has cost \(C_{a1} = 9\). In the case where the first supplier (supplier 1) shared the technology with the manufacturer, if the manufacturer chooses to bring in a new supplier (alternative supplier, ”a”), the manufacturer then shares the technology with the alternative supplier whose cost is reduced to \(C_{a2} = 5\). Otherwise, the alternative supplier’s cost remains \(C_{a1} = 9\).

We assume that the innovation occurs with probability \(\pi = 0.75\). In the case where the innovation does happen, we observe the following:

Consider first the case where the supplier shared the technology. If the manufacturer chooses to compete, then the optimal retailer price is \(p = 17.5\), the wholesale price is \(w = 5\) and the quantity sold is \(Q = 15\). This results in a total surplus of 112.5. In this case, we get \(\alpha = 1\), that is, the manufacturer keeps all the surplus and the supplier gets nothing. If the manufacturer chooses not to compete, then the optimal retailer price is \(p = 17.5\), the wholesale price is \(w = 8.75\) and the quantity sold is \(Q = 15\). This results in a total surplus of 112.5. In this case, we get \(\alpha = \frac{1}{2}\) (the manufacturer and the supplier split profits equally and earn 56 each).

Consider now the case where the supplier did not share the technology with the manufacturer. In this case, if the manufacturer chooses to compete, then the optimal retailer price is \(p = 20.5\), the wholesale price is \(w = 7\) and the quantity sold is \(Q = 9\). This results in a total surplus of 40.5. In this case, we get \(\alpha = 0.556\), that is, the manufacturer keeps 55.6% of the surplus and earns 22.5, and the supplier gets 44.4% and earns 18. If the manufacturer chooses not to compete, then the

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27 Note that this game resembles the structure of the basic Trust Game (Kreps 1990).

28 We assume that if supplier 1 and the alternative supplier have the same costs, supplier 1 wins the deal.
optimal retailer price is \( p = 20.5 \), the wholesale price is \( w = 7.25 \) and the quantity sold is \( Q = 9 \). This results in a total surplus of \( 40.5 \). In this case, we get \( \alpha = \frac{1}{2} \) (the manufacturer and the supplier split profits equally and earn \( 20.25 \) each).

In the case where the innovation does not happen, we observe the following:

If the manufacturer chooses to compete, then the optimal retailer price is \( p = 21.5 \), the wholesale price is \( w = 8 \) and the quantity sold is \( Q = 7 \). This results in a total surplus of \( 24.5 \). In this case, we get \( \alpha = 0.714 \), that is, the manufacturer keeps 71.4% of the surplus and earns 17.5, and the supplier gets 28.6% and earns 7. If the manufacturer chooses not to compete, then the optimal retailer price is \( p = 21.5 \), the wholesale price is \( w = 8.75 \) and the quantity sold is \( Q = 7 \). This results in a total surplus of \( 24.5 \). In this case, we get \( \alpha = \frac{1}{2} \) (the manufacturer and the supplier split profits equally and earn \( 12.25 \) each).

9.4. Firm’s Decisions - repeated interactions

Proof of Proposition 1: For the supplier, the strategy described in Proposition 1 is an equilibrium strategy if the present value from a perpetuity of collaborative actions when the innovation happens is greater than the payoff of a one-time “Not Share” decision plus the present value of a perpetuity of non-collaborative payoffs. That is, if \( \frac{1}{(1-\delta)}(\pi_{ISN_s} + (1 - \pi)NC_s) \geq \frac{1}{(1-\delta)}(\pi_{INC_s} + (1 - \pi)NC_s) \), or equivalently \( ISN_s \geq INC_s \). For the manufacturer the strategy described in Proposition 1 is an equilibrium strategy if his present value from a perpetuity of collaborative outcomes is greater than his profit from a one-time Share-Compete outcome plus the present value of a perpetuity of non-collaborative actions by both firms. That is, if \( ISN_m + \frac{1}{(1-\delta)}[\pi_{ISN_m} + (1 - \pi)NC_m] \geq ISC_m + \frac{1}{(1-\delta)}[\pi_{INC_m} + (1 - \pi)NC_m] \), or equivalently \( ISN_m \geq ISC_m \). In the numerical example, \( ISN_s = 56 \) is given by equation 1 with \( C_{s2} \) and \( C_{m2} \), \( ISC_s = 0 \) is given by equation 3 with \( C_{s2}, C_{m2}, \) and \( C_{a2} \), and \( INC_s = 18 \) is given by equation 3 with \( C_{s2}, C_{m1}, \) and \( C_{a1} \).

9.5. Employee’s Decisions

Proof of Proposition 2:

Analogous to the proof of Proposition 1, the supplier does not want to deviate from collaboration if \( \frac{1}{(1-\delta)}[\pi(\frac{ISN_s+ISC_s}{2}) + (1 - \pi)NC_s] \geq \frac{1}{(1-\delta)}[\pi INC_s + (1 - \pi)NC_s] \), or equivalently \( ISN_s + ISC_s \geq INC_s \). In the numerical example, \( ISN_s = 56 \) is given by equation 1 with \( C_{s2} \) and \( C_{m2} \), \( ISC_s = 0 \) is given by equation 3 with \( C_{s2}, C_{m2}, \) and \( C_{a2} \), and \( INC_s = 18 \) is given by equation 3 with \( C_{s2}, C_{m1}, \) and \( C_{a1} \).

For the engineer does not want to deviate from collaboration if \( ISN_m + \frac{1}{(1-\delta)}[\pi(\frac{ISN_m+ISC_m}{2}) + (1 - \pi)NC_m] \geq ISC_m + \frac{1}{(1-\delta)}[\pi INC_m + (1 - \pi)NC_m] \), or equivalently \( ISN_m \geq ISC_m \). In the numerical example, \( ISN_m = 56 \) is given by equation 1 with \( C_{s2} \) and \( C_{m2} \), \( ISC_m = 112 \) is given by equation 2 with \( C_{s2}, C_{m2}, C_{a2} \), and \( INC_m = 22 \) is given by equation 2 with \( C_{s2}, C_{m1}, \) and \( C_{a1} \).
Lastly, the procurement manager will always choose compete. This is because he maximizes his profit from a one-shot game, which dictates to compete regardless of the other players’ actions in the current or previous periods.