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# Can Trustworthiness in a Supply Chain Be Signaled?

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The relationship between a buyer and its suppliers is important and often relies on factors beyond the terms of a contractual agreement. Buyers can therefore benefit from identifying trustworthy suppliers. We argue that pre-contractual actions by the supplier, for example making costly buyer-specific investments without a long-term contract, can signal a supplier's trustworthiness. We develop a theoretical model to reflect supplier trustworthiness, and identify when a buyer can benefit from identifying trustworthy suppliers. We show that costly relationship-specific investments can serve as a signal of trustworthiness, and that supply chain profits increase when trustworthy suppliers are able to identify themselves in this fashion. We demonstrate the importance of the signaling mechanism using laboratory experiments. The experimental results show that relationship-specific investments lead to more collaborative transactions, with buyers offering higher prices and suppliers reciprocating with higher quality goods. This results in increased profits for both buyers and suppliers. Additionally, we show that the benefit of the relationship-specific investment depends directly on the signaling mechanism. Finally, we show that the benefits of buyer-specific investments for both suppliers and buyers are strengthened when firms interact repeatedly.

*Key words*: reciprocity, collaboration in supply chains, behavioral operations

## 1. Introduction

The relationship between a buyer and its suppliers is vital in almost every aspect of business. The operations management literature has explored in depth the problem of designing the optimal contracts for buyer-supplier relations. In many business contexts, however, it is not possible to describe every important aspect of the transaction in a contract. For example, desired quality or service level may be hard to specify (Kaya and Özer 2009). The supplier's responses to disruptions from unforeseen events, such as a natural disaster, may also be hard to determine. When a supplier fails to fulfill its obligations, the buying firm can suffer greatly. For example, Toyota's accelerator pedal quality problems in 2010 (due in part to supplier misbehavior) cost the company nearly two billion dollars and a significant decline in market share. To prevent such outcomes, many firms invest in identifying and maintaining good relationships with their business counterparts (e.g., suppliers, buyers).

In a supply chain setting, a relationship with a trustworthy supplier often results in significant benefit for a buyer. Morgan and Hunt (1994) find that when both commitment and trust are present in the buyer-supplier relationship it leads to increased efficiency, productivity and effectiveness. Piboonrungorj and Disney (2012) studied supplier relationships in the tourism industry and found that higher levels of inter-firm trust lead to better logistics performance. Doney and Cannon (1997) empirically found a positive correlation between the buying firm's trust in a supplier and the supplier's willingness to make relation-specific investments. A recent initiative by General Motors (GM) to establish strategic supplier relationships that the authors were involved in led to an improvement in the relationship with a key supplier of fascia, ultimately leading to the supplier building a new dedicated production facility. Often, supplier trustworthiness is demonstrated by the behavior of suppliers in areas not covered by the contract. Many buyers explicitly attempt to encourage this "above and beyond" behavior. Many companies including Delphi, Verizon, and AT&T have established outstanding supplier awards for the suppliers that go above and beyond their performance objectives. They reward their suppliers' efforts in terms of creative cost-reduction solutions, teamwork, customer service, response to natural disaster, sustainability, and social responsibility. For instance, a major store chain, Costco, states in its official Supplier's Code of Conduct that it encourages its suppliers to work to achieve *above and beyond goals* in excess of legal workplace requirements.

A standard argument for the emergence of a collaborative relationship under an incomplete contract is that long-term relationships between buyers and suppliers and concerns about reputation will limit opportunistic behavior. That is, if the expected long-term benefits of good behavior outweigh the immediate gratification of engaging in opportunistic behavior, then self-interested suppliers will perform collaboratively even in areas where the contract is silent. While relational and reputational incentives are certainly important, there are many cases where the incentives they provide are absent or insufficient to fully explain behavior. For example, many transactions are difficult for outsiders to monitor so that reputational incentives can steer supplier's behavior. The transactions may also be inherently one-time exchanges that fail to induce relational incentives. In these cases it is important for a buyer to identify suppliers that are trustworthy before signing a contract.

Trust can be generally defined as "a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another" (Rousseau et al. 1998) [1]. In the context under study, a trusting buyer offers a generous price to a supplier when quality is non-contractible. A trustworthy supplier provides high quality when he was trusted with a high price. A natural question is what leads suppliers to be inherently trustworthy. We represent inherent trustworthiness by some suppliers as those suppliers acting reciprocally: if a supplier is treated generously by the buyers (e.g., if they are offered a high price), it will reciprocate the gesture by, for example, providing high quality products. While reciprocity has been observed in a number of settings among individuals, it is also a relevant characteristic in describing transactions between firms. As Morgan and Hunt (1994) and Piboonrungorj and Disney (2012) show, firms differ in trustworthiness and transactions between firms with higher trustworthiness benefit both parties - suggesting that trustworthiness is an intrinsic attribute that can separate firms. Why do firms differ in trustworthiness? One possible explanation could be that firms, regardless of their size or industry, execute their interactions with other firms through individuals. This is the case at GM, a large company with over two hundred thousand employees, where the relationship with each supplier is managed by a handful of people interacting with a small number of individuals from the supplier. Thus, these individuals' preferences and behavior will influence the relationship that develops between the firms. Another possible explanation is that a firm's trustworthiness is a deliberate business strategy supported by the firm's corporate culture. A firm's culture often reflects how the leadership would like employees to interact with customers and business partners. Some firms who are known to be "excellent" suppliers may try to cultivate cultures where "above and beyond" actions are rewarded. In such cases, reliability and trustworthiness will be more common in their relationships with other firms.

As suppliers may inherently differ in trustworthiness, an important question for buyers is how to identify these "good" suppliers before contracting. In this paper we propose that observing pre-contracting behavior by the supplier is one way to discern good suppliers from selfish ones. In particular, we argue that early buyer-specific investments by a supplier may signal that firm's trustworthiness. Relationship-specific investments are costly for suppliers, as investing in one particular buyer will tend to weaken the supplier's outside option and make the supplier vulnerable in negotiations with the buyer. However, these kind of relationship-specific investments are not rare. Ganesan (1994), in a study of buyer-supplier relationship in regional department store chains, found that transaction-specific marketing investments were quite common, including training the

[1] This definition is used by Özer et al. (2011) in their study of trust in forecast information sharing. In their context, a trusting supplier relies on the forecast information provided by the manufacturer to make a capacity decision and a trustworthy supplier is that who reports forecast information truthfully.

retailer's salesforce, developing product displays, providing dedicated electronic linkups for inventory control and offering information on new products. We found other examples through our own professional interaction with firms. Cosmax, an original design manufacturer which serves several of the world's largest cosmetics companies, invested in a buyer-specific equipment which, at the time, was only recommended by L'Oreal without even having a contract from L'Oreal. An Argentinean clothing manufacturer, Kayene, hired a dedicated quality assurance team to serve a specific retailer prior to having an agreement or a written contract with that firm.[2] In both cases it was feasible for the firms to make these investments after securing the contract. Why then would these firms make the costly investments in advance? We hypothesize that these kind of investments can be used as signals that trustworthy suppliers send to help the buying firm to discern trustworthy suppliers from selfish suppliers. While Cosmax anticipated that building trust with L'Oreal would lead to a long term relationship, in the case of Kayene the buying firm's objectives were focused mainly on the short run due the high volatility of the Argentinean economy, which makes future interactions highly unpredictable.

These motivations suggest several research questions that we address in this paper: What are the benefits of developing a more collaborative supplier relationship? Is it possible to identify trustworthy suppliers before contracting with them? If so, under what circumstances is it possible? Do these benefits persist in long term relationships? We hypothesize that the buyer can distinguish between trustworthy and untrustworthy suppliers based on the suppliers pre-contract investments. Specifically, we expect that suppliers who make a buyer-specific investment will be more likely to deliver higher non-contractible quality, leading to higher profits for both firms. These results should be further accentuated when firms have expectations of establishing a long term relationship.

To formalize this intuition, we develop a model in which a trustworthy supplier can make a relationship-specific investment (instead of a general investment) to signal his type to the buyer. The buyer then offers a price, and the supplier makes a non-contractible effort that determines product quality. We identify cases where a trustworthy supplier chooses the buyer-specific investment while the selfish supplier chooses the general investment in a separating equilibrium. Under this equilibrium trustworthy suppliers receive higher prices, and exert higher effort.

We test these predictions using an experimental supply chain game. Our results show that the specific investment leads to significantly higher prices and quality, and increases the profits for both the buyer and the supplier. Furthermore, the investment choice reflects persistent individual differences, with different subjects showing a preference for one investment over another. We show that there is a positive correlation between the suppliers' preference for the specific investment

[2] The authors worked with Cosmax and Kayene for several years.

and their level of reciprocity. Hence, the investment choice represents an accurate signal of the underlying type of the supplier. We demonstrate that the signaling mechanism is essential in generating the benefits of the specific investment. In additional treatments where the signaling mechanism is limited (by reducing the efficiency of the specific investment) or eliminated (by randomly assigning investments), the buyer specific investment no longer leads to higher quality or increased profits.

Finally, we analyze the case where firms interact repeatedly through several transactions after the supplier's investment decision, representing a (finite) long-term relationship between the buyer and the supplier. In the absence of reciprocal suppliers, equilibria with collaborative outcomes can never be supported with finitely repeated interactions. However, in the presence of reciprocal suppliers, we characterize two equilibria where buyers offer positive prices and suppliers offer positive effort, resulting in higher total profits. First, as with the one-shot interaction, an equilibrium exists where a reciprocal supplier chooses the specific investment and a selfish supplier chooses the general investment. In another collaborative equilibrium, the selfish supplier mimics the reciprocal suppliers by choosing the specific investment and offering high quality in all transactions except the last one. In both equilibria the specific investment generates higher effort and a greater surplus that the general investment, and, compared to the one-transaction game, the benefits of the specific investment over the general investment are magnified by the repeated interactions. To test these results, we conducted a new treatment with one investment decision and three subsequent trading periods. We find that three trading periods are enough to significantly increase the efficiency of the specific investment. Prices and effort under the specific investment are significantly higher than in the single interaction case. As a result, the profit premiums of the specific investment are significantly more prominent with repeated interactions for both buyers and suppliers.

## 2. Literature Survey

Improving buyer-supplier relations can lead to important performance gains, including enhanced supply-chain responsiveness (as a result of reduced cycle times) and higher profits (Handfield and Bechtel 2002). Additionally, these relationships can benefit from the parties' willingness to make relationship-specific investments (Dyer and Singh 1998). For example, Asanuma (1989) and Dyer (1996) have shown that firms can derive improved performance and competitive advantages when relationship-specific investments were made. However, relationship specific investments also present problems. Hold-up problems arise from the fact that, once a party has made a specific investment, the other party has an incentive to be opportunistic. In many cases it is difficult to prevent such opportunism contractually, which may necessitate vertical integration to promote efficiency (see Williamson 1971, Williamson 1975, Klein et al. 1978, Williamson 1979, and Grossman and Hart

1986 for theoretical work; see Monteverde and Teece 1982, Masten 1984, and Joskow 1985 for empirical work).

Alternative mechanisms that can limit the scope for opportunism are long run relationships and the importance of firm reputation (Larson 1992, Baker et al. 2002, Gibbons 2005). There is experimental evidence of this in the Operations Management literature. Özer et al. (2011) find that trust and cooperation can be reinforced by reputation concerns in the context of forecast information sharing. Heinrich and Brosig-Koch (2011) find that when buyers can consider the reputation of bidders in procurement auctions, bidders supply higher quality leading to higher market efficiencies [3]. We consider first a setting where complete contracting, integration and relational incentives are not present to provide clear and direct evidence for the importance of trustworthiness. Our results also apply to settings where these factors may be present, but insufficient to incentivize proper behavior by the supplier. Then, we consider the case where firms interact repeated times. This allows us to examine the role of reputation concerns on trust in the context of relationship-specific investments with hold up problems.

The importance of trust and trustworthiness has been demonstrated in a variety of settings. Berg et al. (1995) provide early experimental evidence on the importance of trust and trustworthiness in investment decisions. Glaeser et al. (2000) demonstrate that trust and trustworthiness reflects both past actions and beliefs about others. Kosfeld et al. (2005) show that trust has a biological basis. Trust varies between countries (Bohnet et al. 2008), often depending on culture and institutions (Bohnet et al. 2001, Johnson et al. 2002). The level of trust in a country has significant effects on the rate of economic growth (Zak and Knack 2001), as many economic transactions require trusting the other party.

Trustworthiness is often modeled as a preference for equity or reciprocity (Rabin 1993, Fehr and Schmidt 1999, Bolton and Ockenfels 2000, Dufwenberg and Kirchsteiger 2004), an approach that we follow. King-Casas et al. (2005) demonstrate that reciprocal actions lead to future trust and trustworthiness. Reciprocal motives have been demonstrated experimentally in a labor market setting where higher wages lead to higher effort (Fehr and Falk 1999), and a buyer-seller transaction setting where higher prices lead to higher quality goods (Fehr et al. 1993). Mutual reciprocity/trustworthiness (as in our setting) is a particularly powerful way of addressing problems of contractual incompleteness (Fehr et al. 1997). Since reciprocal counterparties are more profitable, it is a natural question how one might identify a reciprocal individual from a selfish one. A few studies have looked at signals from outside the transaction, such as the image of the other

[3] More recent research by Haruvey, Katok, Ma and Sethi (2014) also focuses on the effects of reputation on the provision of quality. They conduct an experimental study of the role of reputation building when a seller makes non-contractible effort towards the production of a good.

person's face (Scharlemann et al. 2001) or information about past charitable giving (Fehrler 2010). This paper, however, focuses on the role of investments within the context of the transaction as a potential signal of trustworthiness.

The field of Operations Management has produced a vast literature on buyer-supplier relationships. Most papers in this category focus on designing optimal contracts or comparing contracts in different settings. This attention towards contracting problems stems from the challenge of coordinating each firm's objective with that of the supply chain, particularly due to double marginalization (Cachon 2003, Spengler 1950). The most usual setting for these problems is the newsvendor model (Silver et al. 1998) for which different types of contracts have been explored, including wholesale price (Lariviere and Porteus 2001, Bresnahan and Reiss 1985), buy-back (Pasternack 1985) and revenue sharing contracts (Cachon and Lariviere 2005). Rather than investigating the quantity decision, we focus on non-contractible aspects of buyer-supplier relations such as effort and quality. While other have studied incentive problems relating to non-contractible capacity investments (Tomlin 2003) or product quality (Kaya and Özer 2009) we are unaware of other papers that examine investment as a signaling mechanism in this context.

In the behavioral operations literature, contracting theories in buyer-supplier interactions have been tested experimentally and revised to account for social preferences or decision biases, beginning with Schweitzer and Cachon (2000).[4] Several papers have identified concerns for fairness as an important influence on supply chain performance (Cui et al. 2007, Pavlov and Katok 2009). A recent paper by Özer et al. (2011) studies the importance of trust and trustworthiness in sharing forecast information within a supply chain. Loch and Wu (2008) find that forming a relationship prior to a transaction leads both parties to take more collaborative actions. Cui and Mallucci (2010) study how investment decisions are affected when the retailer can have distributive fairness concerns with respect to the manufacturer. We identify a specific action that buyers can take beforehand which can lead to more collaborative relationships. We model a situation where the supplier can signal its type by making a relationship-specific investment before the buyer offers a contract and propose that this signal allows the buyer to screen for reciprocal suppliers, which turns out into a more collaborative and profitable relationship between the parties.

## 3. Theoretical Model

We consider a three-stage game in which a buyer trades with a single supplier for a non-divisible good. In the first stage the supplier makes a pre-contractual investment. The buyer observes this and offers a take-it-or-leave-it price offer in the second stage. Then, the supplier decides if he should accept the offer, and, if so, how much effort he will exert towards generating quality. The buyer's

[4] See also Bolton and Katok (2008), Becker-Peth et al. (2011), Katok and Wu (2009) and Ho and Zhang (2008).

value of the good depends on the good's quality, which depends on the supplier's non-contractible effort and his investment choice.

At the beginning of the game, the supplier needs to choose between two different investment options: a *general investment* (denoted by $g$) and a *buyer-specific investment* (denoted by $b$). We assume that the firm has the resources available to make one investment, and that either investment would be a better use of capital than the alternatives - hence choosing one investment is the optimal decision.[5]. Both options have equal financial cost, however they benefit the supplier in different ways. The *general investment* directly increases the supplier's the outside option value (i.e., the reservation utility) which is the monetary value the supplier receives when both parties cannot strike a deal. Since the buyer has to compensate at least the outside option value in order to close a deal, the general investment benefits the supplier by improving the supplier's bargaining power. Examples of the general investment include industry standard certification (e.g., ISO 9000), building a multi-purpose automated production line, and increasing the capability and man-power in B2B marketing. On the other hand, the *buyer-specific investment* will increase the value of the good for the buyer for a given effort choice of supplier. This investment will benefit the supplier only if the buyer shares the increased value created by the supplier's investment and effort through the take-it-or-leave-it price. Examples of the buyer-specific investment include purchasing a buyer-specific machine or fixture, adopting a higher quality standard that is only requested by a particular buyer, or hiring a team for a specific buyer. Note that we are considering the case where the supplier is already about to make an investment since making either one of the investments is profitable (better than not investing at all). Thus, the supplier has already incurred in the initial cost of investing, which will be considered sunk cost. However, since the supplier can only choose one investment, the buyer-specific investment has an opportunity cost - the supplier must forgo the chance to increase the his outside option.

To formally capture this, we assume that, if the supplier chooses investment $i$ ($i = g$, or $b$) and exerts effort, $e$, the value of the good the buyer receives is $\alpha_i e$ where $\alpha_b > \alpha_g > 0$. In other words, for given effort level, $e$, the supplier who chose the buyer-specific investment provides a higher quality, and hence a higher value to the buyer, ($\alpha_b e$) than the supplier who chose the general investment

[5] We considered an alternative model where the supplier makes a decision $i$ from two options: to invest ($i = I$) or not to invest ($i = NI$). If he invests, the quality coefficient is $\alpha_I$ and if he does not invest it is $\alpha_{NI}$, with $\alpha_I > \alpha_{NI} > 0$. Under both decisions the outside option remains $\bar{u}_I = \bar{u}_{NI} = \bar{u} > 0$ and making the investment has a fixed cost $K$. We assume in this case, that a reciprocal supplier considers an offer to be generous if the price not only compensates him for his outside option but also for his investment cost, K. We find that there is no set of parameters under which a Separating Equilibrium can arise in this model. In particular, the interesting Separating Equilibrium in which the selfish supplier chooses not to invest and the reciprocal supplier chooses to make the specific investment cannot happen. This is because it is never incentive compatible for the selfish supplier not to invest for two reasons: first, because the price offered to suppliers who invest is too high since it needs to compensate for $K$, and second, not investing does not raise the supplier's outside option.

($\alpha_g e$). We will refer to $\alpha_i$ as the *quality coefficient* from now onwards. We assume that the outside option value from the general investment ($\bar{u}_g$) is higher than that from the specific investment ($\bar{u}_b$): $\bar{u}_g > \bar{u}_b \geq 0$.

After observing the supplier's investment, the buyer offers a take-it-or-leave-it price contract, $p$, to a supplier. In the final stage of the game, the supplier evaluates the contract and determines whether to accept the buyer's offer or not. If the supplier rejects the buyer's offer, the buyer receives zero payoff and the supplier receives the outside option value ($\bar{u}_g$ or $\bar{u}_b$), depending on the supplier's pre-contract investment. If the supplier accepts the contract, the supplier then chooses an effort level, $e$, which incurs cost $c(e)$, which we assume to be strictly increasing and strictly convex in $e$.

We assume that there are two types of suppliers–*selfish* and *reciprocal*– in the market place, where reciprocity reflects inherent trustworthiness of the supplier. The selfish supplier cares about his own monetary payoff exclusively. Thus, he only aims to maximize its own profit. If the selfish supplier with investment type $i$ accepts the buyer's contract ($p$) and chooses effort level $e$, his utility is simply his monetary payoff and is defined as follows

$$U^s(e|i,p) = p - c(e). \tag{1}$$

When offered a contract, the selfish supplier will compare the maximum utility he can receive from accepting the buyer's offer to his outside option ($\bar{u}_i$), and will choose the option that yields a higher monetary payoff.

On the other hand, if the buyer's offer is sufficiently generous, the reciprocal supplier's utility depends on both total supply chain profits as well as his own monetary payoff. To capture this, let $\gamma > 0$ be the minimum premium that the reciprocal supplier needs to receive in order to perceive that the buyer's offer is generous. If the buyer's offer to the supplier with investment type $i$ is not generous, that is, $p < \gamma + \bar{u}_i$, then the reciprocal supplier will act selfishly and will maximize his monetary payoff, $p - c(e)$. On the other hand, if the buyer's offer, $p$, is generous, then the supplier with investment $i$ who accepts the contract will maximize a utility function that accounts for both his monetary payoff and the total surplus of the supply chain: $(1-\phi)[p - c(e)] + \phi[\alpha_i e - c(e)]$ for some $\phi \in [0,1]$. We define $\phi$ to be the coefficient of reciprocity, which represents the degree of the supplier's reciprocity toward the buyer. Note than when $\phi = 0$, then this payoff is identical to that of the selfish supplier. On the other hand, when $\phi = 1$, the supplier becomes totally altruistic and interested in maximizing the total surplus. Thus, the higher $\phi$ is, the more reciprocal the supplier is. This notion of reciprocity is similar in spirit to *perceived kindness* used in Rabin (1993) in simultaneous move games, and Dufwenberg and Kirchsteiger (2004) and Falk and Fischbacher (2006) in sequential games, or *inequity aversion* used in Fehr and Schmidt (1999). However, our model is a stylized simplification of other models of reciprocity in two respects. First, our reciprocal supplier cares about total surplus, rather than the buyer's profit. Surplus maximization is more intuitive and prevents inefficient over-provision of quality, which in the context of buyer-supplier relations would be unrealistic. [6] Second, reciprocity is binary, depending on whether the offer is sufficiently generous. [7]

Combining these two cases, the utility that the reciprocal supplier with investment $i$ gains when he accepts the buyer's price offer, $p$ and exerts an effort level, $e$ is

$$U^r(e|i,p) = \begin{cases} p - c(e) & \text{if } p - \bar{u}_i < \gamma \\ (1-\phi)(p - c(e)) + \phi(\alpha_i e - c(e)) & \text{if } p - \bar{u}_i \geq \gamma \end{cases} \tag{2}$$

The supplier compares the maximum utility that he can receive from accepting the offer and the outside option ($\bar{u}_i$), and chooses the option with a higher value.

The buyer's utility from offering a price, $p$ to the supplier with investment type $i$ ($i = b$ or $g$) is [8]

$$U^B(p|e,i) = \begin{cases} \alpha_i e - p & \text{if the supplier accepts the offer and exert an effort level, } e \\ 0 & \text{if the supplier rejects the offer.} \end{cases} \tag{3}$$

We first study the full information case, in which the supplier's type is common knowledge and we then study the case where the supplier's type is private information.

### 3.1. Full Information Case

We begin by analyzing the case where the buyer has full information about the supplier type – *reciprocal* or *selfish*– as a benchmark. We first characterize the supplier's action in the third stage: whether the supplier should accept the buyer's offer and, if so, how much effort he should exert. We then apply backward induction and analyze the buyer's offer problem (2nd stage) and the supplier's choice of pre-contractual investment (1st stage).

In the third stage, a supplier decides between accepting the buyer's offer and rejecting the offer for an outside option. If the supplier accepts the offer, he must decide how much effort he exerts. We first consider a selfish supplier who chose type-$i$ investment in the first stage and received the

[6] If the surplus is replaced by buyer's profit (with the adjustment that the reciprocity coefficient, $\phi$, needs to range between $[0, \frac{1}{2}]$) behavior does not change.

[7] This simplification provides modeling tractability, however none of our main results depend on this assumption. The assumption is similar to that in Englmaier and Leider (2012) where, in a principal-agent context, a "generous" contract is one that provides the agent with an expected monetary utility in excess of his outside option. We consider a binary version of that model and introduce the additional individual-specific parameter $\gamma$, which reflects how generous the offer needs to be.

[8] We consider the simpler case where the buyer is modeled as selfish, which is sufficient to derive separating equilibrium results. Because the supplier moves last, if the supplier is reciprocal then even a selfish buyer has strategic reasons to offer a high price. A reciprocal buyer would have an even greater incentive to offer high prices to suppliers choosing the specific investment, strengthening our results. This setting is similar to Englmaier and Leider (2012) where, in a principal-agent context, the agent is modeled as reciprocal and the principal as selfish when solving for the optimal contract.

buyer's offer, $p$. If he rejects the offer, then he would receive the utility from his outside option, $\overline{u}_i$. If he accepts the offer, from (1), it is easy to observe that the optimal effort for the selfish supplier is always zero regardless of the price, $p$.

Now, consider a reciprocal supplier with type-$i$ investment. As in the selfish supplier case, if the reciprocal supplier rejects the offer, he earns his outside option, $\overline{u}_i$. On the other hand, if he accepts, his optimal effort depends on whether he perceives the buyer's contract to be generous. If $p-\overline{u}<\gamma$, then the offer is not considered to be generous. Thus, the supplier will act selfish and will maximize the utility function, $p-c(e)$ by exerting zero effort. If $p-\overline{u}\geq\gamma$, then the supplier finds the offer generous. Then, his best effort is derived from the following optimization problem:

$$\max_{e\geq 0} \quad (1-\phi)(p-c(e))+\phi(\alpha_i e-c(e)) \quad \text{ s.t. } p-\bar{u}_i\geq\gamma.$$

The solution to this problem is $c'(e)=\phi\alpha_i$. Note that, because c(e) is a strictly increasing convex function of e, $c'(e)$ is always positive, increasing in $e$, and invertible. Additionally, since $c'(e)$ is strictly increasing in $e$, $c'^{-1}(\phi\alpha_i)$ is also increasing. As a result, the solution to the above problem can also be written as $e^{r*}(p,i)=c'^{-1}(\phi\alpha_i)$. After combining both cases, it can be shown that the reciprocal supplier's optimal effort, denoted by $e^{r*}(p,\hat{e},i)$, is

$$e^{r*}(p,i)=\begin{cases}0 & \text{if } p<\bar{u}_i+\gamma\\ c'^{-1}(\alpha_i\phi) & \text{otherwise.}\end{cases} \tag{4}$$

We then compare the two options– accepting and rejecting– and characterize the supplier's optimal action in the following lemma.

LEMMA 1. *Consider a supplier who chose type-i investment and faces the buyer's price offer, p.*

*(i) If $p>\bar{u}_i$, the selfish supplier accepts the offer and exerts zero effort: $e^{s*}(p,i)=0$. If $p\leq\overline{u}_i$, he rejects the offer and earns $\bar{u}_i$.*
*(ii) If $p\geq\gamma+\bar{u}_i$, the reciprocal supplier accepts the offer and exerts $e^{r*}(p,i)=c'^{-1}(\alpha_i\phi)$. If $\bar{u}_i< p\leq\gamma+\bar{u}_i$, he accepts the offer and exerts zero effort, $e^{r*}(p,i)=0$. If $p\leq\bar{u}_i$, he rejects the buyer's offer and earns $\overline{u}_i$.*

Lemma 1.(i) implies that the selfish supplier will never choose strictly positive effort. Since the buyer will never earn positive profit from a selfish supplier, it is optimal for the buyer to offer $p=0$, and induce the supplier to reject. [9] On the other hand, facing the reciprocal supplier, the buyer must compare the two options – offering a generous contract that makes the supplier exert strictly positive effort and offering a very low offer so that the supplier rejects the contract. In order to

[9] Although any price $p<\bar{u}_i$ can be an equilibrium, we focus on the case of $p=0$ for expositional purpose.

characterize the optimal offer, we denote an offer, $p=0$, as a *null contract*. Similarly, if the buyer offers $p=(\bar{u}_i+\gamma)$ to the supplier with type-$i$ investment, we call this a *reciprocal contract* and denote by $R_i$, $i=b,g$.

In preparation for our following Lemma, let us define $\underline{\alpha_i} = min\{\alpha_i|\alpha_i(c'^{-1}(\alpha_i\phi)) - \bar{u}_i - \gamma \geq 0\}$ as the minimum value of $\alpha_i$ that satisfies $\alpha_i(c'^{-1}(\alpha_i\phi)) - \bar{u}_i - \gamma \geq 0$. Because $c'^{-1}()$ is strictly increasing in $\alpha$, there exists some threshold $\underline{\alpha_i} > 0$ above which the buyer finds it profitable to offer a reciprocal contract.

Lemma 2. *Suppose the supplier chose type-i investment in the first stage. Then, offering the null contract is optimal when the buyer faces either the selfish supplier or the reciprocal supplier with low quality coefficient: $\alpha_i \leq \underline{\alpha_i}$. Offering the reciprocal contract, $R_i$, is optimal if the buyer faces a reciprocal supplier with high quality coefficient, $\alpha_i > \underline{\alpha_i}$.*

Lemma 2 implies that the buyer offers a reciprocal contract to the supplier when the supplier can provide sufficiently high value when type-$i$ investment is made: $\alpha_i(c'^{-1}(\alpha_i\phi)) - \bar{u}_i - \gamma \geq 0$. Rewriting the condition for both types of investment, the condition in Lemma 2 can be expressed as follows:

$$\text{Condition } C_b: \quad \alpha_b \geq \underline{\alpha_b} \quad \text{and} \quad \text{Condition } C_g: \quad \alpha_g \geq \underline{\alpha_g} \tag{5}$$

Now consider the supplier's investment in the first stage. From Lemma 2, the selfish supplier will receive the null contract no matter what he chose in the first stage. Since the supplier will always reject the null contract, it is optimal for the selfish supplier to choose the general investment to raise his outside option value to $\overline{u}_g$. On the other hand, the optimal action for the reciprocal supplier depends on which of the two conditions – $C_b$ and $C_g$ is met. Since $\alpha_b \geq \alpha_g$ and $\overline{u}_b < \overline{u}_g$, it suffices to consider the following three cases (the fourth case, condition $C_g$ is met and $C_b$ is not, cannot occur). The next result characterizes the equilibrium under the full information.

Theorem 1. *In equilibrium, the following statements hold.*
*a) The selfish supplier chooses the general investment, the buyer offers the null contract, and the supplier then rejects the offer.*

*(Parts b) to d) apply to the reciprocal supplier:)*
*b) Suppose that both $C_b$ and $C_g$ hold. If $(1-\phi)(\bar{u}_b+\gamma) - c(c'^{-1}(\alpha_b\phi)) + \phi\alpha_b c'^{-1}(\alpha_b\phi) \geq (1-\phi)(\bar{u}_g + \gamma) - c(c'^{-1}(\alpha_g\phi)) + \phi\alpha_g c'^{-1}(\alpha_g\phi)$, then the supplier chooses the buyer-specific investment, the buyer offers the reciprocal contract, $R_b$, and the supplier chooses the effort level: $e_b^{r*} = c'^{-1}(\alpha_b\phi)$. Otherwise, the supplier chooses the general investment, the buyer offers $R_g$, and the supplier chooses $e_g^{R*} = \alpha_g\phi$.*

*c) Suppose that only condition $C_b$ holds. If $(1-\phi)(\bar{u}_b+\gamma)-c(c'^{-1}(\alpha_b\phi))+\phi\alpha_b c'^{-1}(\alpha_b\phi)\geq\bar{u}_g$, then the supplier chooses the buyer-specific investment, the buyer offers $R_b$, and the supplier chooses the effort level: $e_b^{r*}$. Otherwise, the supplier chooses the general investment, the buyer offers the null contract, and the supplier rejects the buyer's offer.*

*d) Suppose that neither $C_b$ nor $C_g$ holds. Then, the supplier chooses the general investment, the buyer offers the null contract, and the supplier rejects the buyer's offer.*

### 3.2. Asymmetric Information Case

We now analyze the case where the supplier's type is private information. As in Spence (1973), we use the perfect Bayesian equilibrium (PBE) as our solution concept, imposing the restriction that the buyer's belief is consistent with the buyer's knowledge of the supplier's behavior in equilibrium. In particular, we characterize a separating equilibrium under which the supplier's investment acts as a signal. We also derive pooling equilibria in which neither supplier reveals his type.[10]

**3.2.1. Separating Equilibrium** We first claim that the selfish supplier chooses the general investment and the reciprocal supplier chooses the buyer-specific investment in a separating equilibrium. To see why this must be the case, suppose that there exists a separating equilibrium in which the selfish supplier chooses the buyer-specific investment and the reciprocal supplier chooses the general investment. From Lemma 2, the buyer will offer the null contract to the selfish supplier, who rejects the offer and earns the outside option payoff $\bar{u}_b$. Since $\bar{u}_g\geq\bar{u}_b$, the selfish supplier is better off by deviating and making a general investment, and this contradicts the equilibrium. We also note that, in a separating equilibrium, the buyer should offer the null contract to the selfish supplier and contract $R_b$ to the reciprocal supplier. Consequently, the selfish supplier rejects the offer and the reciprocal supplier accepts the offer and exerts effort $e_b^*=c'^{-1}(\alpha_b\phi)$.

We characterize a sufficient condition under which the separating equilibrium exists in the next lemma. In preparation, let $\theta$ be the real fraction of reciprocal suppliers in the marketplace, $\theta_j\in[0,1]$ be the buyer's prior belief that the supplier's type is $j$, $j\in\{r=\text{reciprocal}, s=\text{selfish}\}$, and $\theta(j|i)$ be the buyer's updated belief about the supplier's type when the supplier chooses investment $i$, $i\in\{b,g\}$.

Theorem 2. *There exists a separating equilibrium in which the selfish supplier chooses the general investment and the reciprocal supplier chooses the buyer-specific investment, the buyer offers the null contract to the selfish supplier and contract $R_b$ to the reciprocal supplier, and the selfish supplier rejects the offer and the reciprocal supplier accepts the offer and exerts effort $e_b^*=c'^{-1}(\alpha_b\phi)$, resulting in $\theta(r|b)=1$ and $\theta(r|g)=0$ if and only if the following condition holds:*

[10] Under certain conditions, semi-pooling equilibria may arise in which one type of supplier chooses a pure strategy and the other uses a mixed strategy when choosing the investment type. We focus on the separating and pooling equilibria as they are most relevant to our experimental results.

*i)* $\bar{u}_g \geq \bar{u}_b + \gamma$,

*ii)* $(1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r*}) + \alpha_b \phi e_b^{r*} \geq \bar{u}_g$.

The first condition guarantees that the selfish supplier's outside option is greater than what he would get by choosing the buyer-specific investment and exerting zero effort. The second condition guarantees that the reciprocal supplier's utility with the buyer-specific investment is greater than his profit when he mimicks to be selfish. We note that i) and ii) together imply $(1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r*}) + \alpha_b \phi e_b^{r*} \geq \bar{u}_b + \gamma$, which means that condition $C_b$ holds. The result implies that pre-contractual investment can be a signal when $\overline{u}_g$ is high enough so that the selfish supplier is incentivized to choose the general investment, and, at the same time, $\alpha_b$ is high enough that fulfilling the buyer's contract is more attractive to the reciprocal supplier.

Under the buyer-specific investment, the supplier exerts effort $e_b^{r*}$ and the buyer pays price $\bar{u}_b + \gamma$, so the buyer's profit is $\alpha_b e_b^{r*} - \bar{u}_b - \gamma$, which is greater than zero by condition $C_b$. Under the general investment the buyer earns zero profits. Under the buyer-specific investment, reciprocal suppliers earn a monetary profit of $\bar{u}_b + \gamma - c(e_b^{r*})$, and derive utility $(1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r*}) + \alpha_b \phi e_b^{r*}$ (note that, if everything is held constant, the reciprocal suppliers' utility increases more than their monetary profits as effort increases). Under the general investment, selfish suppliers earn $\bar{u}_g$. Condition i) in Theorem 2 means that suppliers' monetary profits are higher under the general investment. Finally, total profits are $\alpha_b e_b^{r*} - c(e_b^{r*})$ under the specific investment and $\bar{u}_g$ under the general investment. Because of the convexity of $c(e)$, $\alpha_b e_b^{r*} - c(e_b^{r*})$ exceeds $\bar{u}_g$ if $e_b^{r*}$ is large enough.

**3.2.2. Pooling Equilibrium** In a pooling equilibrium, both suppliers will choose the same investment, thus the buyer is unable to discern the supplier type. In our setting, two pooling equilibria can exist– both types choosing the general investment and both types choosing the specific investment. To avoid a potentially large number of equilibria, we refine multiple equilibria with the *intuitive criterion* (Cho and Kreps 1987). The intuitive criterion states that for any belief the uninformed player may have after seeing a deviation, if one type of player receives a worse payoff by deviating than his equilibrium payoff and the other type does not, then the deviation should not be attributed to the player whose payoff decreases.

In the next result, we characterize three pooling equilibria that survive the intuitive criterion. In preparation, define a threshold $\tilde{\theta}_i = \frac{\bar{u}_i + \gamma}{\alpha_i c'^{-1}(\alpha_i \phi)}$ for $i = b$ and $g$. Since $\bar{u}_b \leq \bar{u}_g$ and $c'^{-1}()$ is increasing in $\alpha$ and $\alpha_b > \alpha_g$, then $\tilde{\theta}_g \geq \tilde{\theta}_b$.

THEOREM 3. *There are three pooling equilibria that survive the intuitive criterion.*
*a) If* $\theta \geq \tilde{\theta}_b$*, a pooling equilibrium under which both suppliers choose the buyer-specific investment arises. In this equilibrium, the buyer offers a reciprocal contract* $R_b$*, and both suppliers accept the offer, the selfish supplier exerts zero effort and the reciprocal supplier exerts effort* $e_b^{r*} = c'^{-1}(\alpha_b \phi)$*.*

*b) If $\theta \geq \tilde{\theta}_g$, a pooling equilibrium under which both suppliers choose the general investment arises. In this equilibrium, the buyer offers a reciprocal contract $R_g$, both suppliers accept the offer, the selfish supplier exerts zero effort and the reciprocal supplier exerts effort $e_g^{r*} = c'^{-1}(\alpha_g \phi)$.*
*c) If $\theta < \tilde{\theta}_g$, a pooling equilibrium under which both suppliers choose the general investment arises. In this equilibrium, the buyer offers the null contract and both suppliers reject the buyer's offer.*

Intuitively, if the buyer believes that the supplier is likely to be reciprocal after observing the supplier's investment, the buyer offers the corresponding reciprocal contract: $R_b$ for the buyer-specific investment and $R_g$ for the general investment. Otherwise, the buyer offers the null contract. From an earlier result, the selfish supplier always exerts zero effort. However, the reciprocal supplier exerts positive effort in response to the reciprocal contract, and zero effort in response to the null contract. The detailed condition under which each of the three equilibrium exists is relegated to the appendix.

In all three pooling equilibria described in Theorem 3 buyers' expected profits depend on the probability the buyer is facing a reciprocal supplier, $\theta$. In the pooling equilibrium described in parts a) and b), buyers' expected profits are $\theta(\alpha_i e_i^{r*}) - \bar{u}_i - \gamma$, selfish suppliers earn profit $\bar{u}_i + \gamma$ and reciprocal suppliers earn profit $\bar{u}_i + \gamma - c(e_i^{r*})$ and get utility $(1-\phi)(\bar{u}_i + \gamma) - c(e_i^{r*}) + \alpha_i \phi e_i^{r*}$. Thus, expected total surplus in the pooling equilibria described in a) and b) is $\theta(\alpha_i e_i^{r*}) - c(e_i^{r*})$. In the pooling equilibrium described in part c) the buyer earns zero profits and both types of suppliers earn $\bar{u}_g$, so total surplus is $\bar{u}_g$.

### 3.3. Theoretical Predictions

Our model predicts that a separating equilibrium can exist when the following two conditions are met. First, the quality improvement under the buyer-specific investment must be large enough so that the reciprocal supplier has enough incentive to exert effort on behalf of the buyer. Second, the outside option payoff under the general investment should be large enough so that the selfish supplier is incentivized to choose the general investment in order to improve his outside option value when the transaction does not close, but not too large so that the reciprocal supplier is not tempted to choose the general investment. If at least one of these two conditions is not met, the separating equilibrium breaks down. For example, if $\alpha_b$ is very low, both suppliers will choose the general investment. On the other hand, if $\bar{u}_g$ is very low, both suppliers prefer to choose the buyer-specific investment.

In the experiment, we conduct a main treatment where the parameters of each investment are such that the separating equilibrium is likely to occur for reasonable values of individual-specific parameters ($\phi$ and $\gamma$). In order to test that the underlying mechanism that leads to these results is in fact the separating equilibrium, we conduct two additional treatments. The first one is the *low* *benefit treatment*, where we reduce the value of $\alpha_b$, leaving all other parameters constant. As shown in Theorem 2, reducing $\alpha_b$ decreases the set of parameters $\phi$ and $\gamma$ under which the separating equilibrium can arise and increases the probability that both types of supplier choose the general investment. The second is the *random treatment*, where suppliers are randomly assigned an investment. This treatment allows us to test whether the underlying mechanism driving the results is that in a separating equilibrium suppliers choose the buyer-specific investment to signal reciprocity. Because the investment is randomly assigned to suppliers, the fraction of reciprocal suppliers is the same under both investments and the differences in the outcome across investments can only be attributed to the specific investment having a higher quality coefficient. Thus, comparing the differences across investments in the random treatment relative to the main treatment allows to measure the impact of the separating mechanism.

## 4. Experimental Design

Our experiment consisted of ten rounds of the supply chain game and, after the supply chain ended, one round of each of two additional tasks: an investment game (Berg et al. 1995) to measure trust and reciprocity and a lottery task (Dohmen and Falk 2011) to measure risk attitudes.

### 4.1. The Supply Chain Game

Subjects were randomly assigned to the role of supplier or buyer, which they kept for all ten periods. In each period subjects were randomly and anonymously matched. This setup rules out reputation or repeated game effects. The supply chain game proceeded as described in our theoretical model: the supplier chooses between the buyer-specific or general investment, the buyer makes a price offer, and finally the supplier accepts or rejects the offer and makes an effort choice. For the buyer-specific investment, we set $\alpha_b = 12$, $\bar{u}_b = 0$. For the general investment, we set $\alpha_g = 3$, $\bar{u}_g = 15$. We also assume that the supplier incurs costs for his effort according to the canonical form, $c(e) = \frac{1}{2}e^2$. In order to simplify the subjects' task, they were presented with the following table:

**Table 1 Cost of Effort Function**

| $e$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $c(e)$ | 0 | 0.5 | 2 | 4.5 | 8 | 12.5 | 18 | 24.5 | 32 | 40.5 | 50 |

In order to rule out negative payoffs, we added 60 points to the payoff of suppliers and 100 points to the payoff of buyers. Hence, the suppliers' payoff was $\pi^S = 60 + p - c(e)$ if he accepted the offer or $\pi^S = 60 + \bar{u}$ if he rejected, while the buyers' payoff was $\pi^R = 100 + \alpha * e - p$ if the supplier accepted the offer or $\pi^R = 100$ if the supplier rejected. At the end of each round, subjects were informed about what their payoff was and what the other subject made.

### 4.2. Two Additional Tasks

The lottery task gave subjects fifteen choices between a fixed payoff, which ranges from 2.5 to 37.5 in increments of 2.5, or a 50-50 lottery between a payoff of 40 points and a payoff of zero points. One decision was randomly selected for payment. The number of choices of the fixed payoff provides a measure of risk aversion.

The investment game has two roles: senders and receivers. Both senders and receivers are initially endowed with twenty points. The sender can transfer a portion of his endowment to the receiver, with any amount transfer being tripled. The receiver can then make a return transfer (without tripling) to the sender. We use the strategy method, with each subject choosing how much to send if they are the sender, and how much to return for each possible transfer amount if they are the receiver. [11] Subjects were then randomly assigned a role and matched to another subject for payment.

### 4.3. Additional Treatments

We conducted two additional treatments of the supply chain game [12]. In the "low benefit" treatment we reduce $\alpha_b$ from 12 to 6, making the specific investment less attractive and therefore reducing the range of individual parameters, $\phi$ and $\gamma$, within which the separating equilibrium arises. In the "random" treatment suppliers were randomly assigned to an investment. By assigning investments exogenously, we eliminate the signaling mechanism.

### 4.4. Hypotheses

In the main treatment of the experiment we expect to observe behavior consistent with the separating equilibrium. We set the values of the investment parameters such that the separating equilibrium can arise at moderate values of $\phi$ and $\gamma$. For instance, a moderate range of $\phi$ (between 0.25 and 0.45) can sustain the separating equilibrium for $\gamma$ between 0 and 10. To derive hypotheses for the main treatment, we examine the comparative statics of the equilibrium outcomes from the model. We also derive hypotheses from the underlying cognitive mechanisms of reciprocity that generates those equilibrium results.

Recall that in the separating equilibrium reciprocal suppliers choose the buyer-specific investment and are offered a positive price, which they accept and exert positive effort, and selfish suppliers choose the general investment and are offered a null contract, which they reject. Thus, we expect to

[11] Using the strategy method means that the receiver, instead of being asked how much he would like to send back given the amount he received, was asked how much to return for each possible transfer amount. In this way, we are able to elicit his complete strategy rather than his action in one particular case.

[12] We conducted a third additional treatment which was equivalent to the main treatment but with higher $\alpha_b$ (18, versus 12 in the main treatment). All the results we present for the main treatment also hold for the treatment with $\alpha_b = 18$. Because the results are similar to those in the main treatment, we excluded them from the paper except for minor comments.

see higher price, higher acceptance and higher effort under the specific investment. Buyers' profits under the buyer-specific investment are $\alpha_b e_b^{r*} - \bar{u}_b - \gamma$ and are zero under the general investment and suppliers earn $\bar{u}_b + \gamma - c(e_b^{r*})$ under the buyer-specific investment and $\bar{u}_g$ under the general investment. Total profits should be higher under the buyer-specific investment once a certain level of effort is reached. For the values of the parameters adopted in our experiment, this should be true for any effort greater than 1.33. Thus, the buyer-specific investment should lead to higher prices, higher acceptance, higher quality, higher buyer profits, and higher total surplus than the general investment.

We can also observe the separation mechanism based on reciprocity in how suppliers respond to different price offers. Note that while the equilibrium makes specific point predictions for prices, the experimental data is likely to have a range of price offers. Lemma 1 describes how we should expect subjects to respond to different price offers. Because subjects who choose the general investment are predicted to be selfish, they will provide the same (low) effort for any price offer. However, subjects who choose the specific investment reciprocate high price offers. Hence we would expect that under the specific investment low prices will receive low effort, while high prices will receive high effort.[13] Therefore, there should be a strong positive correlation between price and effort in the specific investment, and a weak or zero correlation under the general investment. Therefore, our theory predicts:

HYPOTHESIS 1. [Transaction Outcomes] *In the main treatment, we expect the relationship between supplier and buyer in the main treatment to become more collaborative under the buyer-specific investment: (a) buyers will offer higher prices, (b) suppliers will accept offers more often and exert higher effort, (c) the price-effort relationship will increase, and (d) buyers' profits and total profits will increase.*

Additionally, our model assumes that investment decisions are driven by suppliers separating based on intrinsic characteristics. That is, intrinsically reciprocal suppliers choose the specific investment and intrinsically selfish suppliers choose the general investment. As a result, we expect that at the individual level subjects will differ in their propensity to choose the buyer-specific investment. In particular, we expect that there will be a positive correlation between subjects choosing the specific investment more often and subjects demonstrating a more "reciprocal" behavior in our experiment. We will identify "reciprocal" behavior in two ways. First, we measure subjects' price-effort correlation when they choose the specific investment and use the slope of the effort-price regression as a measure of reciprocity. This is common in the experimental reciprocity literature.

[13] Additionally, we have simplified things theoretically by assuming that all reciprocal suppliers have the same $\phi$ and $\gamma$. This additional heterogeneity will further enhance and smooth out the price-effort correlation we describe.

For example Fehr et al. (1993) use the wage-effort relationship in the gift exchange game, while Berg et al. (1995) use the ratio of amount sent to amount returned in an investment game. Second, we create a measure of reciprocity based on the subject's return transfer decisions in the investment game. We therefore expect:

HYPOTHESIS 2. [Reciprocal Suppliers] *In the main treatment, the frequency of choosing the specific investment is positively correlated with suppliers being more reciprocal as measured by:*
*2.a - a higher effort-price correlation in the supply chain game, and*
*2.b - more reciprocal behavior in the additional investment game.*

In the low benefit treatment, we reduce the quality coefficient of the buyer-specific investment (making the specific investment less attractive) and expect that the separating equilibrium will be less likely to occur. Specifically, the set of values of $\phi$ and $\gamma$ that allow for the separating equilibrium to occur is considerably smaller that in the main treatment. In the low benefit treatment, a separating equilibrium arises only when $\phi$ is between 0.84 and 0.91 and $\gamma$ is between 0 and 2.

Lower levels of the quality coefficient result in greater incentives for the reciprocal suppliers to choose the general investment. Thus, we expect to find results that are consistent with a pooling equilibrium on the general investment. From Theorem 3, the buyer offers a reciprocal contract if he believes there are a sufficient share of reciprocal suppliers, and offers a null contract otherwise. Reciprocal suppliers exert positive effort if they are offered a reciprocal contract and reject the offer and get the outside option if they are offered a null contract. Selfish suppliers accept a reciprocal contract and exert zero effort and reject a null contract. The overall effort (under the specific and general investments combined) exerted in the low benefit treatment is at most $e_g^{r*}$ and will be offered by at most a fraction $\theta$ of suppliers (i.e. reciprocal suppliers when offered a reciprocal contract). Thus, the overall expected effort in the low benefit treatment should be lower than in the main treatment, where all reciprocal suppliers exert effort $e_b^{r*}$.

In our experiment, the general investment provides suppliers with a higher outside option than the specific investment (15 vs. 0). Thus, in a pooling equilibrium on the general investment, suppliers will be more likely to reject low price offers. Assuming prices are high enough to trigger reciprocity, buyers can expect effort $e_b^{r*}$ from all reciprocal suppliers under the main treatment, and at most $e_g^{r*}$ from reciprocal suppliers who are offered a reciprocal contract under the low benefit treatment. Thus, the average effort in offers with price greater or equal to 15, should be higher in the main treatment.

The transaction efficiency should also be lower in the low benefit treatment relative to the main treatment. The expected total surplus (the profits of buyers and suppliers combined) in the separating equilibrium is $\theta[\alpha_b e_b^{r*} - c(e_b^{r*})] + (1-\theta)\bar{u}_g$ as we expect that the proportion of reciprocal suppliers is $\theta$. In the pooling equilibrium on the general investment where the buyer offers a reciprocal contract, reciprocal suppliers accept the offer and choose effort $e_g^{r*}$ and selfish suppliers accept the offer and exert zero effort. In this case, the expected total surplus is $\theta[\alpha_g e_b^{r*} - c(e_b^{r*})]$, which is lower than the expected total surplus of the separating equilibrium. Likewise, in the pooling equilibrium on the general investment where the buyer offers a null contract, the expected total surplus is $\bar{u}_g$. When Hypothesis 1 is supported and total surplus is higher under the specific investment than under the general investment in the main treatment, then the expected total surplus should be higher in the main treatment than in the low benefit treatment, as $\alpha_b e_b^{r*} - c(e_b^{r*}) \geq \bar{u}_g$.

HYPOTHESIS 3. [Low benefit treatment] *Under the low benefit treatment, results are consistent with those of pooling equilibria on the general investment.*
*3.a - The overall effort provided by suppliers and total profits are lower than in the main treatment.*
*3.b - Considering only accepted high price offers, effort is lower than in the main treatment.*

Similarly to the low benefit treatment, the random treatment also makes the separating equilibrium less likely to occur. Suppliers are randomly assigned to an investment, which severs the connection between investment choice and the supplier's underlying preferences. To represent the random treatment we adapt our theoretical model by adding an initial move by nature that randomly assigns an investment to the supplier. Building on previous results, we identified three possible cases: If the buyer believes that the probability that the supplier is reciprocal is high enough, then he offers a reciprocal contract regardless of the investment. If the belief is moderate, he only offers a reciprocal contract under the buyer-specific investment and, if the belief is low, he does not offer a reciprocal contract in any case. The model is described in the appendix.

The expected overall effort and total profits should be lower in the random treatment than in the main treatment. The expected overall effort is $\theta e_b^{r*}$ in the main treatment and at most $\frac{1}{2}\theta e_b^{r*} + \frac{1}{2}\theta e_g^{r*}$ in the random treatment. The expected total profit is $\theta[\alpha_b e_b^{r*} - c(e_b^{r*})] + (1-\theta)\bar{u}_g$ in the main treatment and $\frac{1}{2}\theta[\alpha_b e_b^{r*} - c(e_b^{r*})] + \frac{1}{2}\bar{u}_g$ in the random treatment (assuming that case 2 arises, which is the most consistent with our results). Thus, if $\alpha_b e_b^{r*} - c(e_b^{r*}) > \bar{u}_g$, as predicted by Hypothesis 1, then expected total profits should be lower in the random treatment.

Additionally, the difference in expected effort and expected total profit across investments should be smaller in the random treatment relative to the main treatment. When the investment is randomly assigned we expect the reciprocal effort $e_b^{r*}$ to be exerted by a fraction $\theta$ of the suppliers with the specific investment (i.e. when buyers offer a reciprocal contract to a reciprocal supplier). Additionally, with the random investment, the expected effort under the general investment can be greater than zero since reciprocal suppliers exert positive effort when offered a reciprocal contract even under the general investment. By the same argument, the difference in the total profit between the two investments should also be smaller in the random treatment than in the main treatment. Assuming case 2 arises in the random treatment, expected total profit under the specific investment is $\theta[\alpha_b e_b^{r*} - c(e_b^{r*})]$ and under the general investment it is $\bar{u}_g$.

Finally, since in the random treatment the investment is no longer related to the the supplier's inherent type, we do not expect the specific investment to be positively correlated with the subject's reciprocity. These predictions are presented in our last hypothesis.

HYPOTHESIS 4. [Random Treatment] *Under the random treatment, expected effort and expected total profits are lower than in the main treatment, and the differences between the two investments is smaller than under the main treatment.*

*4.a - The overall effort provided by suppliers and total profits are lower than in the main treatment.*

*4.b - The difference in expected effort and expected total profits between the two investments is smaller than in the main treatment.*

*4.c - There will be no relationship between reciprocity (measured by the effort-price correlation and the behavior in the additional investment game) and the specific investment.*

### 4.5. Experimental procedure

The experiment was conducted in z-Tree (Fischbacher 2007) at the University of Michigan between June and July of 2011 and September and November of 2014. Subjects were paid for one randomly selected round of the Supply Chain game, for the investment game, and for one randomly selected choice from the lottery task. Subjects received \$0.05 per point earned plus a \$5 show up fee. Average payoffs were \$12 (including the show up fee) and each session lasted approximately one hour. [14]

## 5. Experimental Results

We conducted thirteen sessions of the main treatment of the experiment with between eight to fourteen subjects each time, who each played ten rounds of the supply chain game and one round of each additional task [15]. Overall, we had a total of 134 participants for the main treatment, 67 of which played as suppliers and 67 as buyers.

[14] The subjects were students at the University of Michigan. No subject participated in more than one session of the experiment. Average age was 21 years, 43% were female and 57% were male. When asked about ethnicity, 49% of the subjects identified themselves as white, 36% as Asian or Pacific Islander, 9% as Black/African American, and the remainder as Hispanic, Multiracial, or Other. Students were from a range of different majors: 21% from Social Sciences, 20% from Sciences, 20% from Engineering, 10% from Economics, 8% from Business Administration, 5% from Arts and humanities, 5% from Medicine, and 11% from other fields.

[15] The analysis presented in the Experimental Results section includes the data of the ten rounds. The results are qualitatively the same if we consider only the last five periods of play.

### 5.1. Differences between investments

Table 2 reports the fraction of times each investment was chosen and the average price, proportion of acceptance, average effort and average effort in accepted offers under the two investments. Since the supplier had the option of rejecting the buyer's offer and getting his outside option payoff, we distinguish the cases when the supplier accepts the offer and exerts zero effort from those when he rejects the offer. This allows us to observe in isolation the cases where the transaction did occur. Additionally, because under the general investment the supplier has an outside option of 15, we observe what happens to the proportion of acceptance and to effort when prices are greater than 15. For prices greater than 15, the outside option becomes irrelevant under both investments, making them more comparable.

Our hypotheses for the main treatment predict that the results will be consistent with a separating equilibrium where reciprocal suppliers choose the buyer-specific investment, will be offered higher prices which they will accept and will choose higher effort; while selfish suppliers will choose the general investment, will be offered lower prices which they reject, and will receive the outside option payoff.

**Table 2 Investment Comparison**

| Investment | % Chosen | Average Price | % Accept | Average Effort | Average Effort (accepted offers) | Average Effort (accepted offers) Price $\geq 15$ |
|---|---|---|---|---|---|---|
| Specific | 67.46% | 24.64 | 87% | 1.78 | 2.03 | 2.74 |
| General | 32.54% | 12.62 | 39% | 0.80 | 2.04 | 2.02 |
| Rank Sum test (p-value) | | $< 0.001$ | $< 0.001$ | $< 0.001$ | 0.90 | 0.023 |

#### 5.1.1. Price

Our model predicts that buyers will offer higher prices to suppliers who chose the specific investment. In line with this prediction, we observe that the average price offered by the buyers when the suppliers choose the specific investment is nearly double than the price offered when the suppliers choose the general investment (Wilcoxon rank-sum test: $p < 0.001$). We also verify this result by regressing price on a dummy variable for the specific investment (Table 18 in the Appendix). We find that choosing the specific investment increases the price the buyer offers by 11.29 points ($p < 0.01$), supporting Hypothesis 1.$a$. At an individual level, we find that 72% of the subjects offer a higher price under the specific investment than under the general investment (Wilcoxon signed-rank test: $p < 0.001$).

**5.1.2. Acceptance** In line with Hypothesis 1.*b*, the specific investment led to higher acceptance rates by suppliers (see Table 2). To control for price, we regress acceptance on price and investment type and present the results in Table 19. We find that, even after controlling for price, choosing the specific investment increases the probability of acceptance by 26.38 percentage points ($\beta = 1.884$, $p < 0.001$, marginal effects = 0.2638). To correctly control for the difference in the outside option value, we repeat the same regression restricting the sample to offers with a price of 15 or higher, and find that there is still a significant positive correlation between choosing the specific investment and the probability of acceptance ($\beta = 1.323$, $p = 0.003$, marginal effects = 0.071). Together these results provide support to Hypothesis 1.*b*.

**5.1.3. Effort** Table 2 shows that average effort under the specific investment more than doubled average effort under the general investment and that the difference is significant (Wilcoxon rank-sum test: $p < 0.001$). If we consider accepted offers only, we find no difference across investments. Our reciprocity model predicts not only higher effort levels under the specific investment but specifically effort that depends on price. While the general investment has an outside option of 15, the specific investment has an outside option of zero. Hence, rejections are more likely to happen under the general investment than under the specific investment for prices lower than 15 (28% rejection under specific versus 87% rejection under general, $p < 0001$), and hence the set of accepted offers for the specific investment includes more offers with a low price. Therefore, we are interested in testing whether there is a difference in effort across investments for accepted offers with price greater than 15. We find that, for prices greater or equal than 15, average effort in accepted offers under the specific investment is 2.74 and under the general investment it is 2.02 and the difference is statistically significant ($p = 0.023$). Additionally, individual-level data shows that 57% of subjects exert higher effort under the specific investment than under the general investment (Wilcoxon signed-rank test: $p = 0.016$). This result supports Hypothesis 1.*c*.

Table 3 presents the results of regressing effort on price under the two investment types. Panel A uses price as the independent variable and Panel B uses a price dummy, which takes the value of one if price is greater or equal to 15 and zero otherwise. The last four columns present only the cases when suppliers accepted the offer. The last two columns show the results of a Tobit regression for effort censored at zero. In all specifications we find a higher effort coefficient for price under the specific investment [16].

Because we expect that the response to price will not necessarily be linear, and that the differences between the specific and general investment will be greatest at the higher quantiles of the

[16] To test whether the differences in coefficients across investments are significant, we combined the data into one regression. The results are presented in Table 21 in the appendix. A Tobit regression of accepted offers shows that the difference in the price dummy coefficients between the specific and general investments is statistically significant (p-value = 0.017).

effort distribution (and associated with the corresponding higher quantiles of the price distribution), Table 4 estimates the difference between treatments at the $50th$, $75th$ and $90th$ quantiles. We also test whether the investments differ in responsiveness to price changes, and whether the total effort difference (at the corresponding price quantile) is significant. We observe that the differences are significant beyond the $75^{th}$ percentile. These results imply that effort under the specific investment is more price-sensitive throughout the right tail of the effort distribution, consistent with Hypothesis 1.$c$. Additionally, we find that higher prices lead to an increased share of higher efforts under the specific investment, consistent with the summary statistics shown in Table 2.

**Table 3 Price - Effort Relationship**

| Coefficients | Effort (Specific) | Effort (General) | Effort (Specific) (Accepted) | Effort (General) (Accepted) | Effort (Specific) (Accepted) | Effort (General) (Accepted) |
|---|---|---|---|---|---|---|
| | | | Panel A | | | |
| Price | 0.060*** | 0.052*** | 0.058*** | 0.028 | 0.0831*** | 0.055** |
| | (0.006) | (0.010) | (0.006) | (0.020) | (0.006) | (0.023) |
| Constant | 0.219* | 0.173 | 0.309** | 1.400** | -1.430*** | -0.209 |
| | (0.113) | (0.173) | (0.144) | (0.651) | (0.347) | (0.800) |
| | | | Panel B | | | |
| High Price | 2.158*** | 1.532*** | 1.938*** | 0.167 | 3.521*** | 0.798 |
| | (0.239) | (0.305) | (0.254) | (1.002) | (0.374) | (0.984) |
| Constant | 0.477*** | 0.318** | 0.678*** | 1.950** | -1.534*** | 0.544 |
| | (0.123) | (0.152) | (0.167) | (0.926) | (0.411) | (0.962) |
| Observations | 452 | 218 | 397 | 86 | 397 | 86 |
| Number of Subjects | 66 | 55 | 65 | 38 | 65 | 38 |

Columns 1 to 4: OLS with subject random effects. Robust standard errors reported in parentheses. Columns 5 and 6: Tobit regressions with subject random effects. Standard errors reported in parentheses. Panel A has Price as independent variable. Panel B has indicator variable High Price, which is equal to 1 if price is greater or equal than 15 and zero otherwise, as independent variable. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

**5.1.4. Profit** We next examine whether the buyer, the supplier and the whole supply chain benefit from the specific investment.

Hypothesis 1.$d$ predicts that buyers' profit is higher under the specific investment. Our data supports this - buyers' average profit was 96.88 under the specific investment and 92.94 under the general investment ($p = 0.02$) [17]. When we regress buyers' profit on the specific investment, we find a positive and significant effect (coefficient = 4.794, $p < 0.01$, presented in Table 20 in the Appendix). Additionally, a within-subject comparison of average profit under the two investments

[17] In the treatment where we used $\alpha_b = 18$, buyers' average profit was 101.968 (not statistically different than 100) under the specific investment and 67.333 under the general investment, a significant difference ($p < 0.01$).

**Table 4 Price-Effort Quantile Regressions - Main Treatment**

| Treatment | Main | | |
|---|---|---|---|
| Quantile | 0.50 | 0.75 | 0.90 |
| Coefficients | Effort | | |
| Price x Specific | 0.076*** | 0.093*** | 0.083*** |
| | (0.008) | (0.004) | (0.008) |
| Price x General | 0.057*** | 0.048*** | -0.040 |
| | (0.017) | (0.016) | (0.052) |
| Specific | -0.076 | -1.127* | -5.167** |
| | (0.423) | (0.671) | (2.293) |
| Constant | 0 | 1.571** | 7*** |
| | (0.413) | (0.647) | (2.263) |
| Observations | 483 | 483 | 483 |
| Difference in Price Slopes (Test Specific = General) | | | |
| $(p - value)$ | 0.323 | 0.006 | 0.020 |
| Total Investment Effects on Effort | | | |
| Specific - General | 0.300 | 0.672 | 2.233 |
| $(p - value)$ | 0.267 | 0.010 | 0.088 |

Robust standard errors reported in parentheses. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$. Total Investment Effects estimates the total difference between investments given prices at the corresponding quantiles of the price distribution.

shows that, for an individual buyer, profits were higher when he was paired with a supplier who chose the specific investment than when he was paired with a supplier who chose the general investment (Wilcoxon signed-rank test: $p = 0.016$, 61% of the subjects).

Hypothesis 1.$d$ also predicts that total profits are higher under the specific investment. A regression of total profit on a dummy variable for choosing the specific investment shows that the specific investment has a significant positive effect on total profits, consistently with Hypothesis 1.$d$ (coefficient $= 5.357$, $p < 0.01$, presented in Table 20 in the appendix) Average total profits were 177.11 under the specific investment and 169.48 under the general investment, but this difference is not statistically significant.

Our hypotheses focus on buyer's profit and total surplus, since for the supplier the positive difference from the specific investment should come from the unobservable reciprocal utility of increasing total profits. Under the separating equilibrium the suppliers monetary profits should be higher under the general investment to prevent selfish suppliers from switching their investment choice. In our data, however, suppliers' average profit under the specific investment were not significantly lower than that under the general investment (80.23 under specific vs. 76.54 under general, Wilcoxon rank-sum test: $p = 0.97$ ). Similarly, the within-subject pairwise comparison of average profit under the two investments shows that a supplier's profit was not significantly higher under the specific investment than under the general investment (Wilcoxon signed-rank test: $p =$

0.1935). A regression shows that the specific investment increases suppliers' profit by 3.215 points and the effect is significant a the 5% significance level (see Table 20 in the appendix). While this is at slight variance with our model, it suggests that selfish suppliers may separate from reciprocal suppliers even with weak monetary incentives to do so. This may suggest that the outcomes of the separating equilibrium could occur in a wider range of circumstances than the model predicts.

## 5.2. Individual Differences

We next examine whether the aggregate results discussed in the previous section are caused by all subjects behaving differently under the specific investment, or whether individuals who choose the specific investment are inherently different from those who choose the general one.

**5.2.1. Heterogeneity in Investment Choice** If investment choice is driven by sorting based on an underlying preference type, some subjects should persistently choose either the specific or the general investment. We conduct several tests to address the question of whether subjects differ in their underlying probabilities of choosing the specific investment. Figure 1 displays the fraction of subjects who chose the specific investment a given number of times. To determine whether this sorting is statistically significant, we test this result in three different ways.

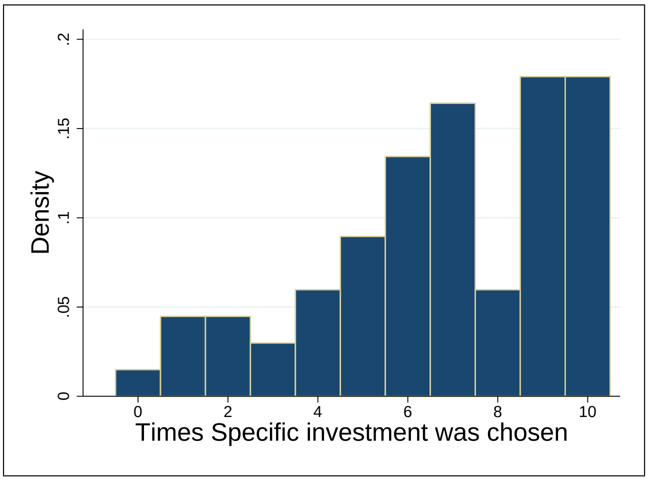


**Figure 1 Frequency of Choosing Specific Investment**

First, we look at the number of times a subject chose the specific investment in the first five periods compared to the last five periods of the game. Subjects who choose the specific investment more often in the initial periods are significantly more likely to continue to choose it in the later periods ($\rho = 0.588$, $p < 0.05$). We find similar results using a non-parametric test for trends ($p < 0.01$)[18]. Lastly, a permutation test indicates that significantly more subjects choose the specific

[18] We used a "Wilcoxon-like test for trends" introduced by Cuzick (1985). The test conducts a non-parametric test for trend across ordered groups, which is an extension of the Wilcoxon rank-sum test. It works by computing the average ranks for one group and then correlating the average ranks with the values in the other group. It tests for a trend of (increasing) values in the ranks of one group across the values of the other group.

investment at least 8 times than would be expected if all subjects chose between investments with a common probability in each period ($p < 0.01$).[19] This provides initial evidence that subjects exhibit significant heterogeneity in investment choices.

**5.2.2. Heterogeneity in Effort Choice** We next examine whether this difference in investment choice between subjects corresponds with different effort choices. We expect that subjects who choose the specific investment frequently will be inherently more reciprocal. Hence, as predicted by Hypothesis 2.$a$, we should find that these subjects have a larger price-effort relationship. To test for this, in Table 5 we regress effort on price, conditional on having the specific investment in this period, separately for subjects who frequently (infrequently) choose the specific investment across all periods.[20] The first four columns were estimated with an OLS regression and the fifth and sixth columns correspond to the Tobit regressions for effort censored at zero. We find that the effect of price on effort is approximately twice as large for subjects who frequently chose the specific investment. Table 22 in the Appendix combines the data in one regression and shows that the difference in effort-price correlation between subjects who choose the specific investment with high and low frequency is statistically significant ($p < 0.001$). This shows that suppliers who choose the specific investment more often were also more reciprocal, providing support for Hypothesis 2.$a$. Choosing the specific investment does accurately signal that the supplier is inherently more reciprocal, and will choose a higher effort if offered a high price.

**Table 5 Individual Specific Price-Effort Relationships Under Specific Investment**

| Coefficients | Effort (Specific < 8) | Effort (Specific 8+) | Effort (Specific < 8) (Accepted) | Effort (Specific 8+) (Accepted) | Effort (Specific < 8) (Accepted) | Effort (Specific 8+) (Accepted) |
|---|---|---|---|---|---|---|
| Price | 0.031*** | 0.076*** | 0.026*** | 0.076*** | 0.053*** | 0.096*** |
| | (0.008) | (0.006) | (0.008) | (0.006) | (0.012) | (0.006) |
| Constant | 0.574*** | 0.043 | 0.783*** | 0.040 | -1.263** | -1.270*** |
| | (0.157) | (0.126) | (0.201) | (0.174) | (0.547) | (0.410) |
| Observations | 192 | 260 | 165 | 232 | 165 | 232 |
| Nr. of Subjects | 38 | 28 | 37 | 28 | 37 | 28 |

Columns 1 to 4: OLS with subject random effects. Robust standard errors reported in parentheses. Columns 5 and 6 report Tobit regressions with subject random effects. Standard errors reported in parentheses. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

[19] For each period, we shuffled the investment decisions across subjects and compared the number of times subjects got the specific investment with the frequencies observed in the experimental results. We conducted 100.000 iterations of the shuffling

[20] The cutoff point of choosing the specific investment at least eight was chosen based on the results of the permutation test reported above.

**5.2.3. Heterogeneity in Trust and Risk Attitudes** We further examined two additional questions: whether other behavioral factors influence sorting, and whether other measures of reciprocity correlate with the measure obtained from the effort-price correlation in the supply chain game. After playing the supply chain game, subjects played one round of the investment game and completed a risk aversion task [21]. We measured risk aversion as the fraction of times the subject chose the fixed payoff over the $50-50$ chance lottery, yielding a distribution of subjects' risk aversion between 0 and 1. In the investment game subjects could choose to send between 0 and 20 points in increments of two points to some other subject they were randomly and anonymously paired with. Any amount sent was tripled. Subjects were then asked how much they would like to send back for different amounts they could have received, up to the total amount received. We used the amount sent as a measure of subjects' trust, therefore trust ranged between 0 and 20. We created a measure of subject's reciprocity based on their answers to how much they would return by taking the difference between the maximum and the minimum amounts they wanted to return [22]. Given that in the vast majority of the cases the amount returned was (at least weakly) increasing in the amount sent, this measure of reciprocity captured how different the subjects' response was when the sender was kind from when the sender was unkind. Reciprocity could then range between 0 and 60. Table 6 summarizes risk aversion, trust and reciprocity observed in the two additional tasks.

**Table 6 Risk and Trust Summary Statistics**

| Variable | Mean | Median | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Trust | 8.104 | 4 | 7.399 | 0 | 20 |
| Reciprocity | 16.515 | 18 | 13.111 | 0 | 40 |
| Risk aversion | 0.518 | 0.533 | 0.145 | 0 | 1 |

In columns 1 through 6 of Table 7, we regress investment choice (for suppliers) and price (for buyers) on three dummy variables which were set equal to one if the subject's measure of trust,

[21] One potential concern is that the course of play in the preceding supply chain game influenced subjects choices in the the additional tasks. While we cannot fully rule out this form of reverse-causality, we tried to minimize the connections by using contextualized instructions for the supply chain game and abstract instructions for the additional tasks. Additionally, if there were substantial spill-over effects from the supply chain game, one might expect that subjects who had been playing different roles would make different choices in the additional tasks. However, we do not find a significant difference between suppliers and buyers ($p > 0.20$ for risk aversion and reciprocity, $p > 0.10$ for trust). Additionally, subjects who were randomly assigned the specific investment more or less often in the random treatment (described below) do not make significantly different choices in the additional tasks.

[22] We considered two other measures of reciprocity, one was the difference between the minimum and maximum amount returned as a fraction of the amount received and the other one was the sum of all the net returns. All the main results remained the same regardless of which measure of reciprocity was used.

reciprocity or risk aversion was above the median value, and equal to zero otherwise. We find that reciprocity in the investment game is a good predictor of sorting in the investment choice of the supply chain game. Specifically, having an investment game measure of reciprocity above the median is correlated with a higher likelihood of choosing the specific investment. This provides support for Hypothesis 2.*b*. Additionally, suppliers who are more trusting (i.e. sent more in the trust game) are significantly more likely to choose the specific investment eight times or more. This suggests that suppliers sort not only on their willingness to repay high prices within the supply chain game and their reciprocity measure in the investment game, but also on their propensity to trust in others. Similarly, we find that trust also predicts buyers' willingness to offer high prices. Lastly, in columns 7 to 9 we present the interaction effects of the suppliers' trust, reciprocity and risk aversion measures and price on effort. We find that higher levels of trust and reciprocity in the investment game are associated with a higher effort-price correlation in the supply chain game (when we test the difference in coefficients for high versus low trust, reciprocity, and risk aversion we get $p = 0.013, 0.061$, and $0.228$ respectively).

**Table 7 Effect of Risk and Trust Measures**

| Coefficients | Chose Specific 8+ | | | Price | | | Effort | | |
|---|---|---|---|---|---|---|---|---|---|
| High Trust | 1.298*** | | | 9.920*** | | | -1.049 | | |
| | (0.357) | | | (3.773) | | | (0.646) | | |
| High Reciprocity | | 0.630** | | | 4.909 | | | -0.501 | |
| | | (0.314) | | | (3.603) | | | (0.641) | |
| High Risk Aversion | | | -0.047 | | | -1.729 | | | 0.495 |
| | | | (0.313) | | | (4.587) | | | (0.655) |
| Price*High Trust | | | | | | | 0.092*** | | |
| | | | | | | | (0.007) | | |
| Price*Low Trust | | | | | | | 0.062*** | | |
| | | | | | | | (0.010) | | |
| Price*High Reciprocity | | | | | | | | 0.094*** | |
| | | | | | | | | (0.009) | |
| Price*Low Reciprocity | | | | | | | | 0.072*** | |
| | | | | | | | | (0.008) | |
| Price*High Risk Aversion | | | | | | | | | 0.076*** |
| | | | | | | | | | (0.008) |
| Price*Low Risk Aversion | | | | | | | | | 0.090*** |
| | | | | | | | | | (0.009) |
| Constant | -1.044*** | -0.508** | -0.180 | 16.880*** | 18.458*** | 21.968*** | -0.619 | -1.058** | -1.576*** |
| | (0.297) | (0.219) | (0.238) | (1.830) | (2.252) | (4.179) | (0.502) | (0.442) | (0.512) |
| Observations | 67 | 67 | 67 | 670 | 670 | 670 | 483 | 483 | 483 |
| Nr. of Subjects | 67 | 67 | 67 | 67 | 67 | 67 | 66 | 66 | 66 |

Columns 1 to 3: Probit regression. Standard errors reported in parentheses. Columns 4 to 6: OLS with subject random effects. Robust standard errors reported in parentheses. Columns 7 to 9: Tobit with subject random effects, accepted offers only. Standard errors reported in parentheses. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

### 5.3. Additional Treatments

To provide additional evidence for investment choice as a signal of reciprocity, we conduct two treatments that diminish the signaling mechanism. The *low benefit treatment*, which decreases the quality coefficient $\alpha_b$ of the specific investment, should lead to results corresponding to a pooling equilibrium on the general investment. Hypothesis 3 predicts that the expected overall effort and expected total profits under the low benefit treatment should be lower than under the main treatment. The *random treatment*, which randomly allocates an investment to the supplier, eliminates the signaling component in investment choice. Hypothesis 4 predicts that expected effort and total profits and their differences across investments should be lower than under the main treatment. It also predicts that we should no longer see a relationship between reciprocity and the specific investment.

We conducted five sessions of each additional treatment, with 56 participants in the low benefit treatment and 54 participants in the random treatment. Table 8 reports summary statistics from the two additional treatments.

**Table 8 Investment Comparison - Additional Treatments**

| Treatment | Investment | % Chosen | Average Price | % Accept | Average Effort | Average Effort (Accepted) | Average Effort (Accepted) Price $\geq 15$ |
|---|---|---|---|---|---|---|---|
| Low Benefit | Specific | 40% | 19.86 | 87% | 1.78 | 2.041 | 2.87 |
| | General | 60% | 12.72 | 32% | 0.85 | 2.667 | 2.98 |
| | Rank Sum test (p-value)* | | $< 0.001$ | $< 0.001$ | $< 0.001$ | 0.0760 | 0.74 |
| Random | Specific | | 21.52 | 84% | 1.040 | 1.236 | 1.63 |
| | General | | 14.00 | 40% | 0.479 | 1.213 | 1.33 |
| | Rank Sum test (p-value)* | | $< 0.01$ | $< 0.001$ | $< 0.001$ | 0.815 | 0.64 |

* Non-parametric test of difference in average price, acceptance, effort and total profit between general and specific investments.

**5.3.1. Price** In the low benefit treatment we find that the general investment is chosen more often than the specific investment, consistently with a pooling equilibrium on the general investment. Table 8 shows that average price is significantly higher under the specific investment than under the general investment. At an individual level, we find that 78% of buyers offer higher prices under the specific investment than under the general investment (Wilcoxon signed-rank test: $p < 0.01$). There is no significant difference with the main treatment in price under the specific investment (19.86 in the low benefit treatment vs 24.64 in the main treatment, $p = 0.319$) or under the general investment (12.72 in the low benefit treatment versus 12.62 in the main treatment, $p = 0.659$).

In the random treatment, we observe that the difference in average price under the two investments is smaller than in the main treatment (7.52 versus 12.02). Since both treatments have the same quality coefficients, the higher price premium under the specific investment in the main treatment is attributed to the separating mechanism, which is not present in the random treatment. In Table 9 we confirm that the additional treatments led to a smaller price premium for the specific investment by estimating a separate coefficient of the effect of investment on price for each treatment. We find that the price premium in the low benefit treatment is significantly smaller than in the main treatment ($p = 0.01$) while the price premium in the random treatment is directionally smaller but not statistically significant ($p = 0.56$). At the individual level results show that in the random treatment, 67% of buyers choose higher price under the specific investment than under the general investment (Wilcoxon signed-rank test: $p < 0.01$).

**Table 9 Differential Effect of Investment on Price and Effort by Treatment**

| Coefficients | Price | Effort |
|---|---|---|
| Specific x Main Treatment | 10.495*** | 0.632*** |
| | (2.129) | (0.176 ) |
| Specific x Low Benefit Treatment | 5.130*** | 0.739*** |
| | (1.575) | (0.239) |
| Specific x Random Treatment | 8.974*** | 0.599*** |
| | (2.749) | (0.214) |
| Low Benefit Treatment | -0.133 | -0.111 |
| | (2.887) | (0.256) |
| Random Treatment | -0.453 | -0.581*** |
| | (2.325) | (0.189) |
| Constant | 13.649*** | 1.039*** |
| | (1.525) | (0.151) |
| Observations | 1220 | 1220 |
| Number of Subjects | 122 | 122 |

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

**5.3.2. Effort** Hypothesis 3.$a$ predicts that in the low benefit treatment, overall effort is lower than in the main treatment. In our data overall effort is 1.22 in the low benefit treatment and 1.47 in the main treatment ($p = 0.069$) [23]. When we restrict the data to accepted offers with price greater or equal to 15, we do not find statistical differences with the main treatment. Average effort is higher under the specific investment than under the general investment and at the individual

[23] When we look at trends across the treatments with $\alpha_b = 6$, 12 and 18, the hypothesis-consistent result gets stronger. A non parametric test for trends shows that expected effort presents a positive trend as $\alpha_b$ increases ($p = 0.001$).

level we find that 68% of suppliers choose higher effort under the specific investment than under the general investment (Wilcoxon signed-rank test: $p < 0.05$).

In the random treatment, overall effort is significantly lower than in the main treatment (0.79 vs. 1.47, $p = 0.0001$), as predicted by Hypothesis 4.$a$. Furthermore, a regression of total effort on treatment dummies (presented in Table 23 in the Appendix) shows that the random treatment has a negative effect on overall effort relative to the main treatment ($\beta = -0.673$, $p < 0.001$). Hypothesis 4.$b$ predicts that the difference in effort across investments is smaller in the random treatment than in the main treatment. The difference in average effort levels was 0.561 in the random treatment, versus 0.98 in the main treatment. While the difference in average effort across treatments is not significant under the general investment, (0.807 for the main treatment and 0.479 for the random treatment, $p = 0.223$), the difference is significant under the specific investment (1.783 and 1.040 respectively, $p < 0.001$). Additionally, if we consider only accepted offers with price greater or equal to 15, we find that in the random treatment there is no difference across investments(while in the main treatment the difference was significant). Individual level results show that in the random treatment, 82% of suppliers choose higher effort under the specific investment than under the general investment (Wilcoxon signed-rank test: $p < 0.01$).

In Table 10 we regress effort on price for the specific and general investments for each of the additional treatments. The regression presented in Panel A has price as the independent variable and the regression presented in Panel B has a price dummy (which is equal to 1 if the price is greater or equal to 15 and zero otherwise) as the independent variable. Panel A shows that in the low benefit treatment, the effort-price correlation is higher under the specific investment than under the general investment (as in the main treatment), however Panel B shows the contrary. In the random treatment, the price-effort relationship is much smaller under the specific investment, and the difference between investments is smaller than in the main treatment. In Table 21 we present a regression with the data from all three treatments pooled together. We find that in both, the low benefit and random treatments, the difference in coefficients across investments is not significant ($p = 0.428$ and $p = 0.974$ respectively). The difference in effort-price correlation across investments for each treatment is also presented for different price quantiles. Table 11 shows the effort-price correlation for price offers in the $50^{th}$, $75^{th}$, and $90^{th}$ percentiles. We find that, while the difference across investments is statistically significant in the $75^{th}$ and $90^{th}$ quantiles of the main treatment, in the two additional treatments the difference across investments is not significant at any quantile. This shows that while in the main treatment the specific investment led to significantly more high effort choices (corresponding to high price offers), there was not a corresponding difference in the effort distribution in the additional treatments.

**Table 10 Price - Effort Relationship - Additional Treatments**

| | Panel A | | | | Panel B | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | Low Benefit | | Random | | Low Benefit | | Random | |
| Coefficients | Effort (Specific) | Effort (General) | Effort (Specific) | Effort (General) | Effort (Specific) | Effort (General) | Effort (Specific) | Effort (General) |
| Price | 0.094*** | 0.058*** | 0.048*** | 0.039* | 2.974*** | 3.983*** | 1.995*** | 2.549 |
| | (0.013) | (0.016) | (0.011) | (0.023) | (0.629) | (1.224) | (0.601) | (1.604) |
| Constant | -0.961 | 0.677 | -1.293** | -1.054 | -0.684 | -1.233 | -1.451** | -2.177 |
| | (0.600) | (0.665) | (0.615) | (1.025) | (0.636) | (1.240) | (0.682) | (1.639) |
| Observations | 97 | 54 | 127 | 47 | 97 | 54 | 127 | 47 |
| Nr. of Subjects | 25 | 22 | 27 | 22 | 25 | 22 | 27 | 22 |

Panel A has price as the independent variable, Panel B has a price dummy (which is equal to 1 if the price is greater or equal to 15 and zero otherwise) as the independent variable. Tobit regressions (accepted offers only) with subject random effects. Standard errors reported in parentheses. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

**Table 11 Price-Effort Quantile Regressions - Additional Treatments**

| Treatment | Low Benefit | | | Random | | |
|---|---|---|---|---|---|---|
| Quantile | 0.50 | 0.75 | 0.90 | 0.50 | 0.75 | 0.90 |
| Coefficients | Effort | | | Effort | | |
| Price x Specific | 0.088*** | 0.109*** | 0.133*** | 0.030** | 0.077*** | 0.075*** |
| | (0.027) | (0.013) | (0.030) | (0.015) | (0.016) | (0.018) |
| Price x General | 0.040 | 0.083*** | 0.121*** | 0.011 | 0 | 0.067 |
| | (0.030) | (0.021) | (0.031) | (0.022) | (0.053) | (0.063) |
| Specific | -1.088 | -0.758 | -0.273 | 0.0526 | -1.769 | -1.417 |
| | (0.918) | (0.497) | (0.618) | (0.516) | (1.293) | (1.628) |
| Constant | 1 | 1.667*** | 1.939*** | -0.053 | 2 | 2.667* |
| | (0.840) | (0.156) | (0.504) | (0.503) | (1.234) | (1.416) |
| Observations | 151 | 151 | 151 | 174 | 174 | 174 |
| Difference in Price Slopes (Test Specific = General) | | | | | | |
| ($p-value$) | 0.234 | 0.286 | 0.780 | 0.463 | 0.163 | 0.899 |
| Total Investment Effects on Effort | | | | | | |
| Specific - General | -0.124 | 0.144 | 0.333 | 0.442 | 0.538 | -0.975 |
| ($p-value$) | 0.833 | 0.834 | 0.839 | 0.167 | 0.522 | 0.665 |

Robust standard errors reported in parentheses. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$. Total Investment Effects estimates the total difference between investments given prices at the corresponding quantiles of the price distribution.

**5.3.3. Profits** We next analyze the effect of the specific investment on total profits. Hypothesis 3.*a* predicts that total profits are lower in the low benefit treatment relative to the main treatment, and Hypothesis 4.*a* predicts that total profits are lower in the random treatment relative to the main treatment. Average values are presented in Table 12. Average total profits in the low benefit and random treatments were 169.17 and 170.10, compared to the main treatment 174.63 (rank-sum test: LB vs Main $p > 0.20$, Random vs Main $p = 0.005$)[24]. When we regress total profit

[24] A non parametric test for trends shows that total profit presents a positive trend as $\alpha_b$ increases ($p-value < 0.001$) for the treatments with $\alpha_b = 6$, 12 and 18, providing support for Hypothesis 3.a.

on treatment dummies (presented in Table 23 in the Appendix), we observe that both the low benefit and random treatments have significant negative effects on total profit relative to the main treatment (coefficients:$-5.46$ with $p < 0.001$ and $-4.53$ with $p = 0.003$ respectively), consistent with our hypotheses. Hypothesis 4.$b$ predicts that the difference in total profits across investments is lower in the random treatment than in the main treatment. The difference in average total profit across investments is 0.69 in the random treatment and 7.63 in the main treatment. Additionally, in Table 13 we regress profits on separate indicator variables for the specific investment for each treatment, as well as treatment dummies. We find that the effect of the specific investment on total profit in the main treatment is greater than in the random treatment ($p = 0.0992$).

Similar results hold for buyers' profits. Average buyer profit is 92.24 in the low benefit treatment and 91.17 in the random treatment, both significantly lower than the profit of 95.6 in the main treatment ($p = 0.03$ and $p = 0.005$ respectively). The difference in average buyer's profit across the two investments is smaller in the random treatment than in the main treatment (0.67 in the random treatment vs. 3.94 in the main treatment). We also find that, at individual level, in the low benefit and random treatments a buyer does not make a significantly higher profit under the specific investment than under the general investment, as was the case in the main treatment (Wilcoxon signed-rank test: $p > 0.020$ for both the low benefit and random treatments).

Table 13 presents the interaction effects of the specific investment and treatment on profits. While under the main treatment the specific investment leads to increased profits (both jointly and individually), in the low benefit treatment it consistently leads to lower profits. In the random treatment we find that there is no effect on profits from the specific investment. The strong connection between the main treatment and the higher benefits of the specific investment, support the argument that it is the separating equilibrium which favors the profit premiums of the specific investment.

**5.3.4. Individual Differences** In the main treatment, we identified the mechanism driving our results: a positive correlation between the supplier being more reciprocal and choosing the specific investment more often. When we examine the subject-level behavior in the additional treatments we find that this mechanism is no longer present.

In the low benefit treatment, we find that there is still sorting - with some subjects choosing the specific investment more often than others. Subjects who choose the specific investment more often in the first five periods also choose it more often in the last five periods, both as measured by correlation ($\rho = 0.526$, $p < 0.05$), and a non-parametric trend test($p = 0.007$). Similarly, the permutation test also indicates a significantly larger number of subjects choosing the specific investment frequently ($p < 0.05$ for frequencies greater than seven). However, we do not find a difference in

**Table 12 Profit Comparison - Additional Treatments**

| Treatment | Investment | Average Supplier's Profit | Average Buyer's Profit | Average Total Profit |
|---|---|---|---|---|
| Main | Specific | 80.23 | 96.88 | 177.11 |
| | General | 76.54 | 92.94 | 169.48 |
| | Rank Sum test (p-value)* | 0.97 | 0.02 | 0.99 |
| Low Benefit | Specific | 75.68 | 91.03 | 166.70 |
| | General | 77.75 | 93.04 | 170.79 |
| | Rank Sum test (p-value)* | 0.001 | 0.038 | $< 0.001$ |
| Random | Specific | 78.94 | 91.46 | 170.40 |
| | General | 78.91 | 90.80 | 169.71 |
| | Rank Sum test (p-value)* | 0.067 | 0.943 | $< 0.001$ |

* Non-parametric test of difference in average profits between general and specific investments.

**Table 13 Interaction Effects of Specific Investment and Treatment on Profit**

| Coefficients | Suppliers' Profit | Buyers' Profit | Total Profit |
|---|---|---|---|
| Specific x Main Treatment | 3.167** | 4.863*** | 5.357*** |
| | (1.346) | (1.589) | (1.680) |
| Specific x Low Benefit Treatment | -2.806* | -1.170 | -3.682** |
| | (1.691) | (1.440) | (1.481) |
| Specific x Random Treatment | -0.202 | 0.263 | 1.131 |
| | (1.960) | (2.048) | (1.937) |
| Low Benefit Treatment | 1.145 | 0.388 | -0.387 |
| | (1.401) | (2.116) | (1.028) |
| Random Treatment | 2.147 | -1.296 | -1.550 |
| | (1.443) | (1.858) | (1.059) |
| Constant | 76.892*** | 92.319*** | 171.014*** |
| | (0.865) | (1.072) | (0.766) |
| Observations | 1220 | 1220 | 1220 |
| Nr. of Subjects | 122 | 122 | 122 |

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

supply chain game play between subjects who choose the specific investment five or more times and subjects who choose it four of fewer times.[25] In Table 14 we regress effort on price (with the specific investment) separately for these two groups. Unlike the main treatment, we find very similar price coefficients for high- and low-frequency subjects. When we pool the data in one regression, the difference in coefficients is not significant ($p = 0.904$), as shown in Table 22 in the Appendix. Additionally, neither trust nor reciprocity in the trust game are correlated with choosing the specific investment at least five times in the low benefit treatment (Table 24). Hypothesis 4.*c.* predicts that

[25] The cutoff point of five was chosen so that the fraction of suppliers above and below the cutoff point is the closest to that in the main treatment, where the cutoff point was eight. If we use the cutoff points derived from the permutation test, 6 (marginally significant) or 7 (significant), the results do not change.

there is no relation between the specific investment and reciprocity in the random treatment. When we compare the price-effort relationships of subjects that were assigned the specific investment six times or more to those assigned it five or fewer times, we find that high-frequency subjects actually have a lower price coefficient than low-frequency subjects with only marginal significant difference ($p = 0.097$ presented in Table 22) [26]. Additionally, as predicted by Hypothesis 4.$d$, neither trust nor reciprocity in the trust game are correlated with a high frequency of the specific investment (see Table 24).

**Table 14 Individual Specific Price-Effort Relationships Under Specific Investment - Additional Treatments**

| Coefficients | Low Benefit Treatment | | Random Treatment | |
|---|---|---|---|---|
| | Effort (Specific < 5) | Effort (Specific 5+) | Effort (Specific < 6) | Effort (Specific 6+) |
| Price | 0.086*** | 0.096*** | 0.077*** | 0.036** |
| | (0.015) | (0.017) | (0.017) | (0.014) |
| Constant | -0.885 | -0.979 | -1.419 | -1.546** |
| | (0.792) | (0.861) | (1.044) | (0.776) |
| Observations | 31 | 66 | 49 | 78 |
| Nr. of Subjects | 13 | 12 | 13 | 14 |

Tobit regressions (accepted offers only) with subject random effects. Standard errors reported in parentheses. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

These results explain why the specific investment is no longer more profitable under the two additional treatments. The fact that reciprocal suppliers do not consistently choose the specific investment more often shows that the investment type is no longer a good predictor of reciprocity. These results are particularly strong in the random treatment, providing support to the hypothesis that the separating equilibrium is the main driver behind our results.

## 6. Repeated Interactions

In the previous sections, we have considered the effects of reciprocity and up-front buyer specific investments on supply-chain efficiency when firms interact only once. In this section we study the impact of longer relationships on the sorting mechanism with a finitely repeated version of the supply chain game. With repeated interactions, firms may be concerned about how their actions in the current period affect the profits in subsequent periods.

The existing literature shows that repeated interactions have a positive impact on trust and trustworthiness. Özer et al. (2011) find that repeated interactions further promote cooperation in forecast information sharing. Empirical research by Doney and Cannon (1997) find that concerns

[26] The cutoff point was set at those subjects who were assigned the specific investment six times or more so that the fraction of subjects above and below the cutoff point was close to that in the main treatment.

about reputation reinforce trust and that developing trusting relationships represents an investment for the long run. This suggests that repeated interactions could enhance the benefits of buyer-specific investments in presence of reciprocal suppliers that we observed in the previous sections.

In infinitely repeated interactions it is a well-know game-theoretical result that, if players care enough about the future, collaborative outcomes can be sustained in equilibrium. On the other hand, in finitely repeated interactions these equilibria usually fall apart. Through backwards induction, players know that their counterpart will defect in the last period, so this breaks apart collaborations in previous periods. However, previous research has shown that outcomes that are not equilibria of the single shot game can be equilibria of a finitely repeated game in certain circumstances, as in the case of incomplete information. For example, Kreps and Wilson (1982) show that reputation building can be an equilibrium in a finitely repeated version of Selten's finitely repeated chain-store game. Similarly, Kreps et al. (1982) show that reputation effects due to informational asymmetries can generate cooperative behavior in finitely repeated Prisoner's Dilemma, where "finking" at each stage is the only Nash equilibrium of the finitely repeated game. We show that the existence of reciprocal suppliers (and asymmetric information about the suppliers' type) allows for collaborative outcomes to arise in a finitely repeated game.

### 6.1. Model and Experimental Design

We extended the previous model to the case where, after the supplier chooses an investment, the buyer and the supplier engage in a finite number of repeated transactions ("periods"). We first characterize a separating equilibrium, analogous to the one described in the one-period model. Under this equilibrium, the buyer offers a reciprocal contract under the specific investment and a null contract under the general investment in each transaction. The reciprocal supplier chooses the specific investment, then the buyer offers a reciprocal contract to which the supplier reciprocates by exerting effort $e_b^{r*}$. Likewise, the selfish supplier chooses the general investment and is offered a null contract, which the supplier rejects. The sufficient condition for the separating equilibrium in a one-transaction game also guarantees a separating equilibrium in the finitely repeated game. This result is summarized in Theorem 4.

Theorem 4. *In a finitely repeated interaction game; there exists a separating equilibrium that is the same as in Theorem* (2)*.*

We also characterize another equilibrium which leads to collaborative outcomes denoted "semi-separating". In this equilibrium, both types of supplier choose the buyer-specific investment, and are offered a reciprocal contract in each transaction. Both suppliers exert reciprocal effort $e_b^{r*}$ for the first $N-1$ transactions. In the last transaction, the reciprocal supplier exerts effort $e_b^{r*}$ and the selfish supplier exerts zero effort. We summarize this result in Theorem 5:

Theorem 5. *In a finitely repeated game, there exists a semi-separating equilibrium under which both suppliers choose the specific investment, and the buyer offers a reciprocal contract $R_b$ in every period. Upon receiving the contract, the reciprocal supplier exerts effort $e_b^{r*} = c'^{-1}(\alpha_b \phi)$ for all periods, and the selfish supplier exerts the same effort except in period $n$ in which he exerts zero effort.*

The detailed description of the model and the proofs are relegated to the Appendix.

We conduct a repeated interactions treatment in which subjects played six rounds of a repeated version of the supply chain game. In the repeated version of the game, the supplier makes one investment decision which is followed by three transactions. In each transaction, the buyer offers a price and the supplier decides whether he accepts the offer and, if so, a quality level. The values of the parameters are the same as those of the main treatment; $\alpha_b = 12$, $\bar{u}_b = 0$ for the buyer-specific investment, and $\alpha_g = 3$, $\bar{u}_g = 15$ for the general investment. Suppliers start the each game with 60 points and buyers with 100 points. The supplier's and buyer's payoffs from the game are given by their initial endowments plus the sum of their payoffs from all three transactions. At the end of the experiment, one of the six rounds of the repeated supply chain game is randomly selected for payment.

Based on our theoretical findings, we expect the relationships to be more collaborative under the specific investment. To see why, note that while the separating equilibrium predicts that the outcome of each transaction will be as in the single-transaction case, the semi-separating equilibrium predicts even more collaborative relationships under the specific investment (since selfish suppliers also choose the specific investment and provide high effort for at least some of the transactions). Our theoretical findings also suggest that repeated interactions should accentuate the social surplus of a specific investment in the presence of reciprocity relative to the single-transaction case. Both equilibria predict that overall effort and total surplus[27] should be at least as high as in the main treatment. The separating equilibrium predicts in each transaction the same overall effort and total surplus as in the separating equilibrium of the single-transaction game. The semi-separating equilibrium predicts effort $e_b^{r*}$ in periods 1 through $N-1$ and $\theta e_b^{r*}$ in period $N$. Additionally, it predicts a total surplus of $\alpha_b e_b^{r*} - c(e_b^{r*})$ in periods 1 though $N-1$ and $\theta[\alpha_b e_b^{r*} - c(e_b^{r*})]$ in period $N$. Note that if Hypothesis 1 is true, and $\alpha_b e_b^{r*} - c(e_b^{r*}) > \bar{u}_g$, then the total surplus in every transaction period 1 through $N-1$ in repeated interactions should be at least as high as in the main treatment. In the last period, the separating equilibrium predicts the same total surplus, and the semi-pooling predicts a lower total surplus than in the main treatment. We summarize these predictions in Hypothesis 5:

[27] We define "surplus in transaction $i$" as the net profit a subject gets from that particular transaction (it does not include the initial endowment).

HYPOTHESIS 5. [Repeated Interactions Treatment]
*The relationship between supplier and buyer is more collaborative under the buyer-specific investment.*
*5.a - Buyers offer higher prices, suppliers accept offers more often and exert higher effort under the specific investment. Buyers' profits and total profits are higher under the specific investment than under the general investment.*
*5.b - In each transaction, expected overall effort is at least as high as in the main treatment. Expected total surplus is at least as high as in the main treatment in every transaction except in the last one, where it can be higher or lower than in the main treatment.*

### 6.2. Experimental Results

We conducted five sessions of the repeated interactions treatment, with a total of 50 subjects. Total payoffs from the experiment include the payoff from the Supply Chain Game, the payoffs from the two additional tasks and a $7 participation fee. The average payoff was $15 and each session lasted approximately 90 minutes.

As predicted by Hypothesis 5.$a$, Table 15 shows that average price, acceptance rate, and effort are higher under the specific investment than under the general investment in all three periods, and the differences are significant. Table 17 shows that the effort-price correlation is also higher under the specific investment in every transaction. Buyers make higher profits[28] when the buyer-specific investment is chosen than when the general investment is chosen (Table 16, Rank-sum test p-value: $< 0.0001$). This is the result of a higher surplus in every transaction (see Table 15). Table 16 shows that total profits are also significantly higher under the specific investment, as predicted by Hypothesis 5.$a$. This result is confirmed by the regression of buyers' profits and total profits on a specific investment indicator variable presented in Table 25 in the Appendix.

Hypothesis 5.$b$ predicts that in each transaction, expected overall effort is at least as high as in the main treatment and that expected total surplus is at least as high as in the main treatment in every transaction except in the last one, where it can be higher or lower than in the main treatment. Total effort is 1.466 in the main treatment and 3.2 and 2.733 in transactions 1 and 2 of the repeated interactions treatment respectively (both differences are significant, $p < 0.001$). In transaction 3, the difference with the main treatment is not significant (1.593, $p = 0.182$). Similarly, total surplus is 14.628 in the main treatment and 27.813 and 24.48 in transaction 1 and 2 of the repeated interactions treatment respectively (both differences have $p < 0.001$). In transaction

[28] Buyers' and suppliers' profits are defined as their initial endowment plus the sum of their surplus in all three trading periods.

3, total surplus is 16.577, which is not significantly different from the total surplus in the main treatment ($p = 0.857$).

Buyers' surplus under the specific investment in transactions 1 and 2 are significantly higher than in the main treatment (6.127 and 9.608 respectively versus −3.12, both with $p < 0.001$) and not different in transaction 3 (−4.77 versus −3.12, $p = 0.214$). While buyers' profits under the specific investment increase relative to the main treatment, buyers' profits under the general investment significantly decrease relative to the main treatment. As a result, the difference in buyers' profits across the two investments increases in repeated interactions relative to the main treatment (47.211 versus 4.44). Similarly, the difference in total profits across investments is significantly larger under the repeated interactions treatment than in the main treatment (58.25 in repeated interactions vs. 7.63 in the main treatment). We report that a further statistical analysis confirms these results (c.f., Table 26 in the Appendix).

We find two additional important results. First, there is strong evidence that the buyers' profit under the buyer-specific investment is greater than the initial endowment of 100. That is, the increase in buyers' surplus in transactions 1 and 2 more than compensates for the drop in transaction 3. We conduct a pair-wise comparison of each retailer's profit observation with a variable that has all its values equal to 100, and reject the hypothesis that the two variables are equivalent with p-value of 0.015. Additionally, we regress buyers' profit on a dummy variable for the buyer-specific investment (the results are presented on Table 25 in the Appendix). A 95% confidence interval for buyers' profit under the specific investment is $[100.97; 120.22]$. Therefore at $\alpha = 0.05$, it confirms that buyers' profits are greater than 100. This result stresses the impact of buyer-specific investments on buyers' profits in repeated interactions. Buyers can expect to make positive profits even in a context of non-contractible quality. Second, we observe that both price and effort do not drop entirely in the third (last) transaction. In fact, both price and effort remain relatively high under the specific investment (average price is 31.569 and average effort is 3.139). Similarly, Table 17 shows that the effort-price correlation is higher under the specific investment than under the general investment and the difference is even higher than in previous periods. These results provide support for the existence of a fairly high number of reciprocal suppliers, which is a requirement for the semi-separating equilibrium to arise.

## 7. Discussion

The experimental results largely confirm our hypotheses based on a signaling model. First, we show that the upfront choice of a specific investment results in a more collaborative relationship between buyers and suppliers. Buyers offer higher prices, suppliers accept offers more often, the overall provision of effort is higher, and this results in higher total profits. We show that this is

**Table 15 Average Price, Acceptance, Effort, and Surplus**

| | Investment | Transaction 1 | Transaction 2 | Transaction 3 |
|---|---|---|---|---|
| Price | General | 20.708 | 18.167 | 10.958 |
| (all offers) | Specific | 42.863*** | 33.020*** | 31.569*** |
| Price | General | 38.541 | 35.818 | 36.546 |
| (accepted offers) | Specific | 45.021 | 37.798 | 44.431 |
| Acceptance | General | 0.5 | 0.458 | 0.229 |
| | Specific | 0.951*** | 0.873*** | 0.706*** |
| Effort | General | 2.667 | 2.182 | 1.182 |
| (accepted offers) | Specific | 4.289*** | 4.067*** | 3.139*** |
| Supplier's Surplus | General | 24.083 | 22.125 | 19.302 |
| | Specific | 30.627** | 22.294 | 23.627 |
| Buyer's Surplus | General | −15.271 | −13.427 | −7.562 |
| | Specific | 6.127*** | 9.608*** | −4.774* |

Note: Surplus refers to the net profit from a transactions and does not include the initial endowment. Significant differences across investments is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

**Table 16 Profit Comparison - Main vs. Repeated Interactions**

| Treatment | Main | | | Repeated Interactions | | |
|---|---|---|---|---|---|---|
| Investment | Average Supplier's Profit | Average Buyer's Profit | Average Total Profit | Average Supplier's Profit | Average Buyer's Profit | Average Total Profit |
| Specific | 80.23 | 96.88 | 177.11 | 136.549 | 110.961 | 247.51 |
| General | 76.54 | 92.94 | 169.48 | 125.510 | 63.75 | 189.26 |
| Rank Sum test (p-value)* | 0.97 | 0.02 | 0.996 | 0.024 | < 0.0001 | < 0.0001 |

* Non-parametric test of difference in average profits between general and specific investments. Note: Profits include initial endowment.

**Table 17 Price - Effort Relationship - Repeated Interactions**

| Coefficients | Transaction 1 | | Transaction 2 | | Transaction 3 | |
|---|---|---|---|---|---|---|
| | Effort Specific | Effort General | Effort Specific | Effort General | Effort Specific | Effort General |
| Price | 0.091*** | 0.051** | 0.108*** | 0.078** | 0.080*** | -0.051 |
| | (0.008) | (0.025) | (0.006) | (0.036) | (0.014) | (0.071) |
| Constant | -0.360 | 0.540 | -0.223 | -1.619 | -1.546 | 1.243 |
| | (0.566) | (1.110) | (0.322) | (1.701) | (0.969) | (2.671) |
| Observations | 97 | 24 | 89 | 22 | 72 | 11 |
| Nr. of Subjects | 24 | 15 | 22 | 12 | 21 | 10 |

Tobit regressions (accepted offers only) with subject random effects, except in column 6 which has 11 observations and 10 subjects. Standard errors reported in parentheses. Robust standard errors reported in parentheses. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

possible because there exists a positive correlation between choosing the specific investment and the supplier being reciprocal. Therefore, the investment choice can help buyers identify reciprocal suppliers before contracting. We also find that when the specific investment is not efficient enough, the positive correlation between investment choice and reciprocity falls apart resulting in lower levels of effort and total surplus. When suppliers are randomly assigned an investment, the efficiency premium of the specific investment disappears. This supports the hypothesis that it is the signaling effect of the investment choice what drives the specific investments efficiency enhancement. Finally, we show that repeated interactions magnify the benefits of the specific investment, leading to even more collaborative relationships. This could be either attributed to a scenario where reciprocal suppliers choose the specific investment and selfish suppliers choose the general investment, or a scenario where both types of suppliers choose the specific investment and selfish suppliers mimic reciprocal suppliers for some number of periods.

One result not anticipated by our theoretical model is the importance of trust for both buyers and suppliers. In our model, we account for the supplier's reciprocity and this is sufficient for the separating equilibrium to arise. The experimental data (presented in Table 7) shows that, suppliers must trust that buyers actually play the equilibrium and respond to their investment choice with high prices. Similarly, buyers must trust that suppliers will reciprocate high prices with high effort. By contrast, the supplier's effort choice, which has no subsequent buyer action, does not depend on trust since this choice does not make the supplier vulnerable. Since trust plays a role in subjects' decision making, a related consideration is whether subjects' decisions are influence by "betrayal aversion". Previous research on the trust game suggests that people may be averse to being betrayed (Bohnet and Zeckhauser 2004). In order to analyze this, we identify as a "betrayal" the case where a buyer offered a positive price and received zero effort. We find that the price offers in periods 6 to 10 are not correlated with the number of betrayals experienced in the first five periods. On the other hand, we find that a betrayal in the period immediate previous to the current one has a marginally significant negative effect on buyers' price offers ($\beta = -3.461$, $p = 0.066$). This further suggest that in practice buyers have some wariness about whether suppliers will in fact be trustworthy.

Another surprising result is the increase in supplier's monetary profits under the specific investment. While our theoretical model predicts that reciprocal suppliers will have higher *utility* under the specific investment, this is predicted to be entirely due to the non-monetary reciprocal utility. It is possible that the strategic uncertainty (and therefore the importance of trust) kept some selfish subjects from switching to the specific investment despite the monetary benefits.

Finally, subjects' decisions in the game could be affected other interpersonal concerns such as inequality aversion. If they perceive that their previous payoff was too low (or too high) compared to their partners' payoff, they may want to adjust their behavior in the following period to make payoffs more equitable. This could happen even if subjects play with different subjects in every round. To analyze this, we tested whether firms' profit premium (over their partner's profit) earned in the previous period affected their decision in the current period. For buyers, we find that price offers were not affected by profit inequality in the previous period. For suppliers, we find that the choice of effort is negatively correlated with his profit premium in the previous period. This suggests the opposite of inequality aversion: the more suppliers have earned over their partners in the previous period, the lower the effort they provide in the current period (which will further increase inequality). These results suggest that inequality aversion does not play an important role in this context.

## 8. Conclusion

We investigate how firms can benefit from identifying trustworthy suppliers when non-contractible factors such as quality are important. We suggest that upfront relationship-specific investments can signal that a supplier is trustworthy and will provide high quality if awarded a high price contract. This provides an explanation to why certain suppliers want to make a buyer-specific investment before contracting. We identify theoretical conditions where this signaling mechanism can generate a separating equilibrium with selfish suppliers choosing a general investment (that improves the supplier's outside option), while trustworthy suppliers choose the specific investment (that increases the efficiency of the supplier's quality-generating effort).

We test our model using a laboratory experiment. The results of our supply chain game confirm the effect of signaling on supply chain performance. Subjects who consistently choose the specific investment are significantly more trustworthy as suppliers. As a result, contracting with suppliers who made the relationship-specific investment leads to higher buyer profits and supply chain profits. Offering a price premium to suppliers who chose the specific investment leads to higher quality, as well as higher profits for the supply chain and both individual firms. Thus, buying firms facing a supplier who made an up-front specific investment should consider offering generous contracts even when quality is non-contractible. Our model determines that for the signaling mechanism to arise, the buyer-specific investment needs to be efficient enough and the general investment must provide sufficient monetary incentives to the selfish supplier. The experimental results show that, when these conditions are not present and the signaling mechanism is reduced or eliminated, the relation between the specific investment and reciprocity is no longer present. As a result, the relationship-specific investment no longer leads to higher profits.

Finally, we show that the benefits of upfront buyer-specific investments in promoting collaboration and increasing profits are further strengthened with repeated interactions. We characterize two possible equilibria: one where trustworthy supplier fully separate from the selfish suppliers, and one where selfish suppliers mimic the investment choice and initial effort decisions of the reciprocal suppliers. In both cases repeated interactions only increase the transaction surplus when there are sufficiently many reciprocal firms. Our experimental results confirm this intuition: supply chain profits are substantially increased with repeated transactions, and buyers benefit heavily from working with trustworthy suppliers.

Taken together our results show that there is great value in a buyer being able to identify a trustworthy supplier, and suggest one potential avenue for trustworthy suppliers to distinguish themselves. Future research can explore other ways that trustworthy suppliers can identify themselves, and other supply chain settings where this signaling is important.

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# Supplementary Documents

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## 1. Proofs for the Theoretical Results

**Proof of Lemma 1:** The proof is algebraic, therefore omitted.

**Proof of Lemma 2:** Notice from Lemma 1 that offering a null contract to the selfish supplier is optimal. This is because, regardless of the contract, the selfish supplier will either reject the offer or exert zero effort. For the reciprocal supplier, notice also from Lemma 1 that, if $p \geq \gamma + \bar{u}_i$, the reciprocal supplier accepts the offer and exerts $e^{r*}(p,i) = c'^{-1}(\alpha_i \phi)$. If $\bar{u}_i < p \leq \gamma + \bar{u}_i$, he accepts the offer and exerts zero effort. If $p \leq \bar{u}_i$, he rejects the buyer's offer and earns $\overline{u}_i$. Thus, if the buyer makes an offer $p$, such that $p \geq \gamma + \bar{u}_i$, he will earn $\alpha_i e_i^{r*} - p$ and if his offer is such that $p < \gamma + \bar{u}_i$, he earns zero profit. From equation 3, the minimum price that yields an effort level of $e^{r*}(p,i) = c'^{-1}(\alpha_i \phi)$ is $R_i = \bar{u}_i + \gamma$. If $\alpha_i e_i^{r*} - \bar{u}_i - \gamma \geq 0$, doing so results in a strictly positive payoff for the buyer, therefore, it is optimal. Otherwise, offering the null contract is optimal.

**Proof of Theorem 1:** The proof utilizes Lemma 1 and 2 and derives the optimal contract for both selfish and reciprocal suppliers.

**Proof of Theorem 2:** To show sufficiency, first notice that condition $i$), $\bar{u}_g \geq \bar{u}_b + \gamma$, guarantees that the selfish supplier chooses the general investment as his profit with the general investment is greater than the profit he earns when he mimics the reciprocal supplier and chooses the specific investment. Likewise, condition $ii$, $(1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r*}) + \phi \alpha_b e_b^{r*} \geq \bar{u}_g$, guarantees that the reciprocal supplier chooses the specific investment. Conditions $i$) and $ii$) together imply condition $C_b$, thus it is optimal for the buyer to offer a contract $R_b$ to the reciprocal supplier when he chooses the buyer-specific investment.

To show necessity, we show that the separating equilibrium breaks apart when any of conditions (i)-(iii) does not hold. If condition $i$) is not met, both types of suppliers choose the specific investment. If condition $ii$) does not hold, both types of suppliers choose the general investment. If condition $iii$) does not hold, the set of parameters under which the separating equilibrium exists becomes empty.

**Proof of Theorem 3:**

We show that the three pooling equilibria described in Theorem 3 exist and survive the intuitive criterion. We focus on the beliefs that give greater disincentive for deviation, except in the case where it violates the intuitive criterion. In this case, we consider alternative beliefs. Together, they characterize the full set of parameters under which the equilibrium can be supported with some beliefs.

We first prove the equilibrium described in part a) – both suppliers choose the buyer-specific investment and both suppliers accept the buyer's reciprocal contract $R_b$– exists and survives the intuitive criterion. Under this equilibrium, the selfish supplier exerts no effort, and the reciprocal supplier exerts $e_b^{r^*} = c'^{-1}(\alpha_b\phi) > 0$. We will show that this equilibrium arises if (i) $\theta \geq \tilde{\theta}_b$, with $\tilde{\theta}_b = \frac{\bar{u}_b+\gamma}{\alpha_b(c'^{-1}(\alpha_b\phi))}$; (ii) $\bar{u}_g < \bar{u}_b + \gamma$; and (iii) $\bar{u}_g < (1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r^*}) + \phi\alpha_b e_b^{r^*}$.

Note that this equilibrium cannot exist when $\theta < \tilde{\theta}_b$. This is because the selfish supplier will exert no effort regardless of the contract. Hence, at low $\theta$, the buyer finds it better off to deviate and offer a null contract. We now show that this equilibrium survives the intuitive criterion with two sets of beliefs: (1) $\theta(r|b) = \theta$ and $\theta(r|g) = 0$ and (2) $\theta(r|b) = \theta$ and $\theta(r|g) = 1$.

Suppose first that $\theta(r|b) = \theta$ and $\theta(r|g) = 0$. Condition (i) implies condition $C_b$ (in equation (5)). Hence, from Lemma 2, it is optimal for the buyer to offer a reciprocal contract, $R_b$ under the buyer-specific investment. Note that under these beliefs, it is optimal for the buyer to offer the null contract under the general investment. Both suppliers choose the buyer-specific investment, and both suppliers accept the reciprocal contract $R_b$. The selfish supplier exerts no effort and the reciprocal supplier exerts effort $e_b^{r^*} = c'^{-1}(\alpha_b\phi) > 0$. The selfish supplier gets price $\bar{u}_b + \gamma$ and exerts zero effort under the specific investment and gets $\bar{u}_g$ under the general investment. Condition (ii), $\bar{u}_g < \bar{u}_b + \gamma$, makes choosing the specific investment incentive compatible and rational for the selfish supplier. The reciprocal supplier gets price $\bar{u}_b + \gamma$ and chooses effort $e_b^{r^*}$ under the specific investment. Thus, he derives utility $(1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r^*}) + \phi\alpha_b e_b^{r^*}$ under the specific investment and $\bar{u}_g$ under the general investment. Condition (iii), $\bar{u}_g < (1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r^*}) + \phi\alpha_b e_b^{r^*}$, guarantees that choosing the specific investment is incentive compatible and rational for the reciprocal supplier.

To show that this equilibrium survives the intuitive criterion, we need to consider two cases separately depending on whether condition $C_g$ is met or not (Note that $C_b$ already holds if $\theta \geq \tilde{\theta}_b$). Suppose $C_g$ holds. Note that the intuitive criterion is violated if a deviating strategy is equilibrium-dominated [1] for the selfish supplier (i.e., $\bar{u}_b + \gamma > \bar{u}_g + \gamma$) but not for the reciprocal supplier (i.e., $(1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r^*}) + \phi\alpha_b e_b^{r^*} \leq (1-\phi)(\bar{u}_g + \gamma) - c(e_g^{r^*}) + \phi\alpha_g e_g^{r^*}$)[2]. However the first inequality

[1] For the intuitive criterion a deviating strategy is defined as *equilibrium-dominated* if it gives the player a lower payoff than his equilibrium payoff for any belief the uninformed party may have following deviation.

[2] We set these conditions using the highest off-equilibrium payoffs a supplier can earn under any belief. By doing this, we ensure that the equilibrium refinement by intuitive criterion is robust even under the highest possible incentives to deviate from equilibrium.

cannot hold for any $\gamma > 0$ since $\bar{u}_g \geq \bar{u}_b$. Thus, the equilibrium in part a) survives the intuitive criterion.

Now suppose that condition $C_g$ does not hold. Thus, it is optimal for the buyer to offer a null contract to a reciprocal supplier when he makes the general investment. Again, the intuitive criterion is violated when the deviating strategy is equilibrium-dominated for the selfish supplier (i.e., $\bar{u}_b + \gamma > \bar{u}_g$) but not for the reciprocal supplier (i.e., $(1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r^*}) + \phi\alpha_b e_b^{r^*} \leq \bar{u}_g$). But, this violates condition (iii). Thus, the equilibrium survives the intuitive criterion.

A similar reasoning can be applied to show that the same equilibrium with belief $\theta(r|b) = \theta$ and $\theta(r|g) = 1$ also survives the intuitive criterion if $(1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r^*}) + \phi\alpha_b e_b^{r^*} \leq (1-\phi)(\bar{u}_g + \gamma) - c(e_g^{r^*}) + \phi\alpha_g e_g^{r^*}$. Likewise, we can show the pooling equilibrium described in part b) arises if (i) $\theta \geq \tilde{\theta}_g$; (ii) $\bar{u}_b \leq (1-\phi)(\bar{u}_g + \gamma) - c(e_g^{r^*}) + \phi\alpha_g e_g^{r^*}$; and (iii) $(1-\phi)(\bar{u}_g + \gamma) - c(e_g^{r^*}) + \phi\alpha_g e_g^{r^*} > (1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r^*}) + \phi\alpha_b e_b^{r^*}$, and the equilibrium described in part c) arises if (i) $\theta < \tilde{\theta}_g$; (ii)$\bar{u}_g > \bar{u}_b + \gamma$ ; and (iii) $\bar{u}_g > (1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r^*}) + \phi\alpha_b e_b^{r^*}$. The proof follows a similar logic, thus it is omitted.

**Theoretical Model for Random Investment Case:**

Consider a game where nature moves first to assign investment randomly, the buyer acts second to offer a take-it-or-leave-it price offer, and the supplier acts last and decides if he should accept the offer, and, if so, selects an effort level. Because the investment is randomly chosen, the buyer does not update his prior belief about the probability of the supplier being reciprocal, $\theta$, after observing the investment. Analogous to the result found in the pooling equilibrium case, there exists a threshold $\tilde{\theta}_i = \frac{\bar{u}_i + \gamma}{\alpha_i c'^{-1}(\alpha_i \phi)}$ for $i = b, g$ (with $\tilde{\theta}_g \geq \tilde{\theta}_b$) above which the buyer offers a reciprocal contract or offers a null contract instead. When he is offered a reciprocal contract, the selfish supplier accepts and chooses $e = 0$ and when he is offered a null contract he rejects the offer. The reciprocal supplier accepts a reciprocal contract and chooses $e_i^{r*} = c'^{-1}(\alpha_i \phi)$ and rejects a null contract.

One of the following three outcomes arises:

1) If $\theta \geq \tilde{\theta}_b$ and $\theta \geq \tilde{\theta}_g$, the buyer offers a reciprocal contract $R_b$ under the specific investment and a reciprocal contract $R_b$ under the general investment. With probability $\theta$, the supplier will be reciprocal and will choose effort $e_i^{r*}$ and with probability $(1-\theta)$ the supplier will be selfish and choose $e = 0$. Under the specific investment, the reciprocal supplier earns $\bar{u}_b + \gamma - c(c'^{-1}(\alpha_b \phi))$ and the selfish supplier earns $\bar{u}_b + \gamma$. The buyer's expected profit is $\theta[\alpha_b c'^{-1}(\alpha_b \phi) - (\bar{u}_b + \gamma)] + (1 - \theta)[-(\bar{u}_b + \gamma)]$. Under the general investment, the reciprocal supplier earns $\bar{u}_g + \gamma - c(c'^{-1}(\alpha_g \phi))$ and the selfish supplier earns $\bar{u}_g + \gamma$. The buyer's expected profit is $\theta[\alpha_g c'^{-1}(\alpha_g \phi) - (\bar{u}_g + \gamma)] + (1 - \theta)[-(\bar{u}_g + \gamma)]$.

2) If $\theta \geq \tilde{\theta}_b$ and $\theta < \tilde{\theta}_g$, the buyer offers a reciprocal contract under the specific investment $p = \bar{u}_b + \gamma$ and a null contract under the general investment. Under the general investment both types of supplier reject the offer. Under the specific investment, with probability $\theta$ the supplier is reciprocal and chooses effort $e_b^{r*}$ and with probability $(1-\theta)$ the supplier is selfish and chooses $e = 0$. Under the general investment both types of supplier earn $\bar{u}_g$ and the buyer earns zero profits. Under the specific investment, the reciprocal supplier earns $\bar{u}_b + \gamma - c(c'^{-1}(\alpha_b\phi))$ and the selfish supplier earns $\bar{u}_b + \gamma$. The buyer earns $\theta[\alpha_b c'^{-1}(\alpha_b\phi) - (\bar{u}_b + \gamma)] + (1-\theta)[-(\bar{u}_b + \gamma)]$.

3) If $\theta < \tilde{\theta}_b$ and $\theta < \tilde{\theta}_g$, the buyer offers a null contract under both investments. Thus, both types of supplier reject the offer. The supplier earns $\bar{u}_b$ under the specific investment and $\bar{u}_g$ under the general investment. The buyer earns zero profits under both investments.

**Repeated Interactions Model:**

We analyze a repeated interactions model in which the supplier first makes the investment decision and then the supplier and the retailer engage in $N$ transactions. In each round of transaction, the buyer makes an offer and the supplier decides whether he accepts the offer and, if so, how much effort to make.

The buyer's utility is the sum of profits over $N$ periods:

$$U^B(p|e,i) = \sum_{t=1}^{N} \begin{cases} \alpha_i e_t - p_t & \text{if the supplier accepts the offer in period } t \text{ and exerts an effort level } e_t \\ 0 & \text{if the supplier rejects the offer in period } t. \end{cases} \tag{1}$$

The selfish supplier's utility is the total profit accrued:

$$U^s(e|i,p) = \sum_{t=1}^{N} [p_t - c(e_t)]. \tag{2}$$

The reciprocal supplier's utility is the sum of her utilities for the $N$ periods [3]:

$$\begin{aligned} U^r(e|i,p) &= \sum_{t=1}^{N} \begin{cases} [p_t - c(e_t)] & \text{if } p_t < \gamma + \bar{u}_i \\ [(1-\phi)(p_t - c(e_t)) + \phi(\alpha_i e_t - c(e_t))] & \text{if } p_t \geq \gamma + \bar{u}_i \end{cases} \\ &= \sum_{t=1}^{N} \mathbf{1}_{\{p_t < \gamma + \bar{u}_i\}})[p_t - c(e_t)] + (1 - \mathbf{1}_{\{p_t < \gamma + \bar{u}_i\}})[(1-\phi)(p_t - c(e_t)) + \phi(\alpha_i e_t - c(e_t))] \end{aligned} \tag{3}$$

We first show that the same separating equilibrium where the reciprocal supplier chooses the specific investment and the selfish supplier chooses the general investment, exists in a finitely repeated game as well. Furthermore, a sufficient condition is exactly the same as that in the single period game (Theorem 2). In this equilibrium, the buyer always offers a reciprocal contract

[3] We assume that the supplier's reciprocity concerns depend only on the latest offer received. It is not affected by offers received in previous transaction periods.

to a supplier who chose the specific investment, the reciprocal supplier accepts and exerts effort $e_b^{r*} = c'^{-1}(\alpha_b \phi)$. On the other hand, the buyer offers a null contract to a supplier who chose a general investment, which the selfish supplier rejects. This result is formalized in Theorem 4, which stipulates that in a finitely repeated interaction game; there exists a separating equilibrium that is the same as in Theorem 2.

Proof of Theorem 4: We will show that the sufficient conditions for a separating equilibrium to arise in the single period case, $i) \bar{u}_g \geq \bar{u}_b + \gamma$ and $ii) (1-\phi)(\bar{u}_b + \gamma) - c(e_b^{r*}) + \alpha_b \phi e_b^{r*} \geq \bar{u}_g$, are also sufficient for the separating equilibrium to arise in N-period games.

Condition $i)$ guarantees that the selfish supplier does not want to deviate from the equilibrium. To see why, consider first the case where the selfish supplier chooses the general investment. In this case, the buyer believes that the supplier is selfish and offers a null contract in every period. Thus, the selfish supplier rejects the contract in every period and earns a total profit of $N\bar{u}_g$.

Consider now the case where the selfish supplier deviates and chooses the specific investment. We show that one of the following two strategies will dominate any other strategy. The first strategy is to exert effort $e_b^{r*}$ for the first $N-1$ periods and exert effort $e=0$ in period N. This strategy will result in a profit of $(N-1)[\bar{u}_b + \gamma - c(e_b^{r*})] + \bar{u}_b + \gamma$. The other strategy is to exert effort $e=0$ in the first period and then reject the contract throughout, which results in a profit of $\bar{u}_b + \gamma + (N-1)\bar{u}_b$. To show this, note first that in any period the supplier's optimal effort is always one of the following two: $e=0$ or $e_b^{r*} = c'^{-1}(\alpha_b \phi)$. This is because any other effort leads the buyer to believe that the supplier is selfish and offer him a null contract, so the supplier prefers $e=0$. If $c(e_b^{r*}) > \gamma$, then $e=0$ is optimal in every period. We show this by backward induction. In the last period the selfish supplier always chooses $e=0$. In period $N-1$, choosing $e=0$ has no cost and results in a profit of $\bar{u}_b$ in the following period. On the other hand, choosing $e_b^{r*}$ has a cost of $c(e_b^{r*})$ but earns him $\bar{u}_b + \gamma$ in the following period. Thus, if $c(e_b^{r*}) > \gamma$, the supplier chooses $e=0$. The same logic applies to every period prior to $N-1$ (all the way up to period 1), so the supplier chooses $e=0$ in every period. This strategy earns the supplier a total profit of $\bar{u}_b + \gamma + (N-1)\bar{u}_b$ which, under condition i), is dominated by his payoff under the general investment. If $c(e_b^{r*}) \leq \gamma$, exerting effort $e_b^{r*}$ for the first $N-1$ periods and $e=0$ in period N, dominates any other strategy. To see why, note first that in period $N$ the selfish supplier always chooses $e=0$. In periods 1 through $N-1$ exerting effort $e_b^{r*}$ has cost $c(e_b^{r*})$ earns the supplier $\bar{u}_b + \gamma$ in the following period, and choosing $e=$ has no cost but earns the supplier $\bar{u}_b$ in the following period. Thus, if $c(e_b^{r*}) \leq \gamma$, the supplier chooses $e_b^{r*}$ in periods 1 to $N-1$. In this case, the supplier earns $(N-1)[\bar{u}_b + \gamma - c(e_b^{r*})] + \bar{u}_b + \gamma$ which, under condition i), is dominated by his payoff under the general investment.

Now we show that the reciprocal supplier does not want to deviate from the equilibrium. Consider first the case where the reciprocal supplier chooses the specific investment. In every period, the optimal effort is either $e_b^{r*}$ or $e = 0$. If in any period, the supplier chooses anything other than $e_b^{r*}$, then in every subsequent period she will be offered a null contract, which she rejects and gets utility $\bar{u}_b$. If the supplier is offered a reciprocal contract and exerts effort $e_b^{r*}$, then she gets utility $(1-\phi)(\bar{u}_b+\gamma) - c(e_b^{r*}) + \alpha_b \phi e_b^{r*}$ in that period and is offered a reciprocal contract again in the following period. Thus, if conditions i) and ii) hold, it is optimal for the supplier to exert effort $e_b^{r*}$ in every period, which gets her a total utility of $N[(1-\phi)(\bar{u}_b+\gamma) - c(e_b^{r*}) + \alpha_b \phi e_b^{r*}]$. To see why, we solve by backward induction. In the last period, the utility from exerting effort $e_b^{r*}$ is $(1-\phi)(\bar{u}_b+\gamma) - c(e_b^{r*}) + \alpha_b \phi e_b^{r*}$ and the utility from $e = 0$ is $\bar{u}_b + \gamma$. Thus, if conditions i) and ii) are met, the optimal effort is $e_b^{r*}$. In period $N-1$, if the supplier exerts effort $e_b^{r*}$, then she gets utility $(1-\phi)(\bar{u}_b+\gamma) - c(e_b^{r*}) + \alpha_b \phi e_b^{r*}$ in periods $N-1$ and $N$. If she chooses $e = 0$, she gets $\bar{u}_b + \gamma$ in period $N-1$ and $\bar{u}_b$ in period $N$. Thus, if conditions i) and ii) are met, the optimal effort is $e_b^{r*}$. If we continue solving backwards until period 1, the same logic shows that, if conditions i) and ii) are met, the optimal effort is $e_b^{r*}$ in every period.

Consider now the case where the reciprocal supplier chooses the general investment. The supplier is offered a null contract in every period and she rejects the offer in every period. Thus, she derives utility $N\bar{u}_g$. Condition *ii*) guarantees that the utility she derives from the equilibrium payoff, $N[(1-\phi)(\bar{u}_b+\gamma) - c(e_b^{r*}) + \alpha_b \phi e_b^{r*}]$, is greater or equal than $N\bar{u}_g$.

Lastly, conditions *i*) and *ii*) guarantee that the buyer does not want to deviate from equilibrium under the equilibrium beliefs. First, note that if a supplier chooses the general investment, the buyer believes the supplier is selfish and it is optimal to offer a null contract in every period. If the supplier chooses the specific investment, the buyer believes the supplier is reciprocal. Conditions *i*) and *ii*) guarantee that it is optimal for the buyer to offer a reciprocal contract to a reciprocal supplier in every period. To see why, note that conditions *i*) and *ii*) combined imply condition $C_b$, that is $\alpha_b(c'^{-1}(\alpha_b\phi)) - \bar{u}_{-}\gamma \geq 0$. If the buyer offers a reciprocal contract to a reciprocal supplier in any given period, the reciprocal supplier will exert effort $e_b^{r*}$ and the buyer gets profit $\alpha_b(c'^{-1}(\alpha_b\phi)) - \bar{u}_b - \gamma$. If he offers a null contract, the reciprocal supplier will reject it and the buyer earns zero profit in every period thereafter. Thus, if conditions i) and ii) hold, it is optimal for the buyer to offer a reciprocal contract in every period. ■

In a finitely repeated game we also find that an interesting equilibrium exists (we call it semi-separating [4]) which leads to collaborative outcomes in every period except for the last. Under this equilibrium, both types of supplier choose the specific investment. The buyer offers a reciprocal

[4] We call this equilibrium a "semi-separating equilibrium" since the selfish and reciprocal suppliers make the same investment choice and their actions coincide in all trading periods except for the last one. As a result, their actions coincide at every point where their actions affecting the buyer's beliefs has impact on the buyer's future actions. Their actions only differ in the last trading period, where they no longer affect the buyer's actions.

contract under the specific investment and a null contract under the general investment. The reciprocal supplier chooses effort $e_b^{r*} = c'^{-1}(\alpha_b \phi)$ in every period, and the selfish supplier chooses effort $e_b^{s*} = c'^{-1}(\alpha_b \phi)$ in every period, except the last period, where he accepts the offer and chooses zero effort. This result is formalized in Theorem 5, which stipulates that in a finitely repeated game, there exists a semi-separating equilibrium under which both suppliers choose the specific investment, and the buyer offers a reciprocal contract $R_b$ in every period. Upon receiving the contract, the reciprocal supplier exerts effort $e_b^{r*} = c'^{-1}(\alpha_b \phi)$ for all periods, and the selfish supplier exerts the same effort except in period $n$ in which he exerts zero effort.

The semi-separating equilibrium exists if the buyer's belief that the supplier is reciprocal, $\theta$, is high enough. In particular, it requires $\theta \geq \tilde{\theta}_b^N$. The threshold $\tilde{\theta}_b^N = \frac{\bar{u}_b + \gamma}{\alpha_b e_b^{r*}}$ is also the threshold above which a retailer offers a reciprocal contract in a pooling equilibrium of the single interaction model. Additional conditions on the parameters are necessary to guarantee that the equilibrium is incentive compatible and rational for all players. The proof is similar as in Theorem (4) and thus, omitted.

## 2. Supplementary Tables

**Table 18 Price Comparison - Main Treatment**

| Coefficients | Price |
|---|---|
| Specific | 11.29*** |
| | (1.507) |
| Constant | 13.12*** |
| | (0.919) |
| Observations | 670 |
| Number of Subjects | 67 |

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

**Table 19 Acceptance Decisions - Main Treatment**

| Coefficients | Accept | Accept (price≥ 15) |
|---|---|---|
| Specific | 1.884*** | 1.323*** |
| | (0.195) | (0.441) |
| Price | 0.107*** | 0.012 |
| | (0.011) | (0.013) |
| Constant | -1.597*** | 1.004** |
| | (0.186) | (0.454) |
| Observations | 670 | 333 |
| Number of Subjects | 67 | 67 |

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

**Table 20 Profit on Specific Investment Choice - Main Treatment**

| Coefficients | Supplier's Profit | Buyer's Profit | Total Profit |
|---|---|---|---|
| Specific | 3.215** | 4.794*** | 5.357*** |
| | (1.343) | (1.579) | (1.683) |
| Constant | 76.860*** | 92.366*** | 171.014*** |
| | (0.863) | (1.066) | (0.767) |
| Observations | 670 | 670 | 670 |
| Number of Subjects | 67 | 67 | 67 |

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

**Table 21 Price-Effort Relationship for Specific vs. General - All Treatments**

| Coefficients | Effort (Accepted) | Effort (Accepted) |
|---|---|---|
| Price x Specific x Main Treatment | 0.083*** | 3.336*** |
| | (0.006) | (0.348) |
| Price x General x Main Treatment | 0.061*** | 1.281 |
| | (0.017) | (0.782) |
| Price x Specific x Low Benefit Treatment | 0.094*** | 2.964*** |
| | (0.015) | (0.691) |
| Price x General x Low Benefit Treatment | 0.052*** | 4.236*** |
| | (0.017) | (1.470) |
| Price x Specific x Random Treatment | 0.048*** | 2.129*** |
| | (0.010) | (0.611) |
| Price x General x Random Treatment | 0.041** | 2.198 |
| | (0.020) | (1.976) |
| Specific x Main Treatment | -1.670*** | -2.050*** |
| | (0.565) | (0.752) |
| Specific x Low Benefit Treatment | -1.652** | 0.966 |
| | (0.775) | (1.509) |
| Specific x Random Treatment | 0.025 | 0.703 |
| | (0.804) | (1.999) |
| Low Benefit Treatment | 0.400 | -2.456 |
| | (0.930) | (1.629) |
| Random Treatment | -1.393 | -2.850 |
| | (1.012) | (2.102) |
| Constant | 0.153 | 0.618 |
| | (0.576) | (0.736) |
| Observations | 808 | 808 |
| Nr. of Subjects | 120 | 120 |

| Test Price x Specific Often = Price x General Often | $p-value$ | $p-value$ |
|---|---|---|
| Main Treatment | 0.19 | 0.017 |
| Low Benefit Treatment | 0.06 | 0.428 |
| Random Treatment | 0.74 | 0.974 |

Tobit regressions with subject random effects. Standard errors reported in parentheses. Column 1 has price as independent variable and column 2 has a price dummy (which takes value one if the price is greater or equal to 15 and zero otherwise) as independent variable. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

**Table 22** **Individual Specific Price-Effort Relationship Under Specific Investment - All Treatments**

| Coefficients | Effort (Accepted) |
|---|---|
| Price x Specific Often x Main Treatment | 0.100*** |
| | (0.007) |
| Price x General Often x Main Treatment | 0.048*** |
| | (0.009) |
| Price x Specific Often x Low Benefit Treatment | 0.097*** |
| | (0.018) |
| Price x General Often x Low Benefit Treatment | 0.093*** |
| | (0.026) |
| Price x Specific Often x Random Treatment | 0.034*** |
| | (0.012) |
| Price x General Often x Random Treatment | 0.068*** |
| | (0.016) |
| Specific Often x Main Treatment | -0.676 |
| | (0.642) |
| Specific Often x Low Benefit Treatment | 0.035 |
| | (1.184) |
| Specific Often x Random Treatment | -0.344 |
| | (1.050) |
| Low Benefit Treatment | -0.210 |
| | (0.980) |
| Random Treatment | -0.153 |
| | (0.901) |
| Constant | -0.847* |
| | (0.450) |
| Observations | 621 |
| Nr. of Subjects | 117 |

| Test Price x Specific Often = Price x General Often | $p-value$ |
|---|---|
| Main Treatment | $< 0.001$ |
| Low Benefit Treatment | 0.904 |
| Random Treatment | 0.097 |

Tobit regressions with subject random effects. Standard errors reported in parentheses. Specific Often is a dummy variable which takes value 1 if the supplier's frequency of the specific investment is greater or equal to 8 (5 for the low benefit treatment and 6 for the random treatment respectively). Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

**Table 23 Effect of Treatment on Overall Effort and Total Profit**

| Coefficients | Overall Effort | Total Profit |
|---|---|---|
| Low Benefit Treatment | -0.244 | -5.461*** |
| | (0.274) | (1.243) |
| Random Treatment | -0.673*** | -4.532*** |
| | (0.191) | (1.537) |
| Constant | 1.466*** | 174.628*** |
| | (0.144) | (1.093) |
| Observations | 1220 | 1220 |
| Number of Subjects | 122 | 122 |

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

**Table 24 Effect of Trust and Reciprocity on Investment Choice - Additional Treatments**

| Coefficients | Main Treatment Chose Specific 8+ | | Low Benefit Treatment Chose Specific 5+ | | Random Treatment Chose Specific 6+ | |
|---|---|---|---|---|---|---|
| High Trust | 1.298*** | | -0.053 | | -0.271 | |
| | (0.357) | | (0.482) | | (0.492) | |
| High Reciprocity | | 0.630** | | -0.275 | | -0.097 |
| | | (0.314) | | (0.492) | | (0.483) |
| Constant | -1.044*** | -0.508** | -0.157 | -0.074 | 0.157 | 0.097 |
| | (0.297) | (0.219) | (0.315) | (0.304) | (0.315) | (0.348) |
| Observations | 67 | 67 | 28 | 28 | 27 | 27 |
| Nr. of Subjects | 67 | 67 | 28 | 28 | 27 | 27 |

Probit regression. Standard errors reported in parentheses. Robust standard errors reported in parentheses. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

**Table 25 Total Profit on Specific Investment Choice - Repeated Interactions**

| Coefficients | Supplier's Profit | Buyer's Profit | Total Profit |
|---|---|---|---|
| Specific | 9.746 | 45.640*** | 44.931*** |
| | (7.429) | (12.067) | (8.645) |
| Constant | 126.389*** | 64.818*** | 198.317*** |
| | (5.267) | (10.009) | (3.883) |
| Observations | 150 | 150 | 150 |
| Number of Subjects | 25 | 25 | 25 |

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

**Table 26 Repeated Interactions vs. Main Treatments: Effects of Specific Investment on Effort and Profits**

| Transaction Period | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|---|---|
| Coefficients | Overall Effort | | | Buyers' Profit | | | Total Profit | | |
| Specific x MT | 0.699*** | 0.649*** | 0.580*** | 4.538*** | 4.651*** | 4.918*** | 5.618*** | 5.099*** | 4.618*** |
| | (0.178) | (0.177) | (0.175) | (1.535) | (1.553) | (1.601) | (1.673) | (1.692) | (1.717) |
| Specific x RIT | 2.216*** | 2.020*** | 1.342*** | 20.867*** | 22.681*** | 1.789 | 25.260*** | 20.073*** | 3.826 |
| | (0.499) | (0.577) | (0.486) | (5.564) | (5.034) | (4.274) | (2.927) | (3.895) | (3.448) |
| RIT | 0.699** | 0.332 | -0.394 | -7.448** | -5.645 | 0.835 | -0.202 | -0.358 | 2.464 |
| | (0.350) | (0.360) | (0.343) | (3.611) | (4.315) | (3.502) | (1.172) | (1.897) | (1.725) |
| Constant | 0.994*** | 1.028*** | 1.075*** | -7.461*** | -7.538*** | -7.718*** | 10.838*** | 11.188*** | 11.513*** |
| | (0.150) | (0.151) | (0.153) | (1.040) | (1.050) | (1.080) | (0.735) | (0.799) | (0.862) |
| Observations | 820 | 820 | 820 | 820 | 820 | 820 | 820 | 820 | 820 |
| Nr. of Subjects | 92 | 92 | 92 | 92 | 92 | 92 | 92 | 92 | 92 |

| Test: Specific x MT = Specific x RIT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $(p - value)$ | 0.004 | 0.023 | 0.140 | 0.005 | 0.001 | 0.493 | ¡0.001 | ¡0.001 | 0.837 |

OLS regression with subject random effects. Robust standard errors reported in parentheses. Significance is denoted:

* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.