

Contracts and Capacity Investment in Supply Chains

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Suppliers are often reluctant to invest in capacity if they believe that they will be unable to recover their investment costs in subsequent transactions with buyers. In theory, a number of different contracts can solve this issue and induce first-best investment levels by the supplier. In this study, we investigate the performance of these contracts in a two-tier supply chain. We develop an experimental design where retailers and suppliers bargain over contract terms, and have the ability to make multiple back-and-forth offers, while also providing feedback on the offers they receive. One key result from our study is that an option contract and a service-level agreement are best at increasing first-best investment levels and overall supply chain profits. However, these same contracts also generate the largest inequity in expected profits between the two parties. We find that both of these results are driven by the bargaining tendencies of retailers and suppliers, which we refer to as “superficial fairness.” In particular, (1) retailers and suppliers place more emphasis on negotiating the wholesale price, while partially overlooking any secondary parameter, and (2) they make concessions over time, such that final wholesale prices end up roughly halfway between the retailer’s selling price and the supplier’s production cost. We show that this bargaining behavior contributes to higher investment levels in the option contract and service-level agreement, but also highly inequitable payoffs.

1. Introduction

Firms often face the challenge of ensuring that their suppliers develop and maintain sufficient production capacity. A classic example of this involves General Motors (GM) purchasing metal car bodies from its supplier, Fisher Body (Klein et al. 1978, Coase 2006, Klein 2007). As demand increased, GM wanted Fisher to continue expanding its plants to increase capacity. However, in an example such as this, a supplier like Fisher Body may be reluctant to make investments, such as developing capacity, if they believe that their future profits will be insufficient, either due to low bargaining power or ex post opportunism. As a result, they may invest in less capacity than what would be jointly optimal (first best). Further, Cachon and Lariviere (2001), in a related capacity investment setting with forecast sharing, highlight a number of examples where suppliers are left without returns from their capacity investments, and suggest that “suppliers may be wise to avoid spending heavily to serve assemblers” (Cachon and Lariviere 2001, pp. 630).

To increase supplier capacity investment levels, theoretical research has proposed a number of solutions. Vertical integration aligns the firms’ incentives, but can involve substantial costs

and presents additional risks and challenges (Stuckey and White 1993). Long run buyer-supplier relationships can also promote investment. However, the scope of many capacity investments, and the likelihood that market characteristics will change, can make long run relationships difficult to maintain. Formal contracts can provide direct or indirect incentives to invest, and have been highlighted in the operations management literature as a leading solution (e.g. Tomlin 2003, Özer and Wei 2006, Plambeck and Taylor 2007, Taylor and Plambeck 2007). In this study, we focus on contractual solutions to capacity investment problems. Specifically, we conduct a series of controlled human-subject experiments which determine whether different contractual solutions can increase supplier capacity investment levels and supply chain profits, when allowing human decision makers to bargain over contract parameters and make capacity investment decisions.

While there have been a number of papers analyzing capacity investment problems from a theoretical standpoint, only a few experimental studies exist on the topic (e.g. Hoppe and Schmitz 2011). Many of these assume settings with deterministic demand and simplified bargaining. In our study, we incorporate a two-stage supply chain where demand is randomly determined, and implement a unique structured bargaining protocol which allows both a retailer and supplier to make multiple, back-and-forth offers over contract parameters. Additionally, in our bargaining setting, subjects can send limited feedback, detailing whether they feel a particular contract parameter is too high or too low. Through this bargaining protocol we are able to not only mimic a more realistic environment, but also observe how offers evolve over time and the types of feedback sent.

Using this experimental design with human decision makers we evaluate the problem of supplier capacity investment, with the aim of answering the following research questions: (1) How do alternative contracts, many of which are equivalent in theory, perform at increasing first-best investment rates and overall supply chain profits? (2) Of those contracts that are effective at inducing first-best investment rates, how are supply chain profits distributed between the retailer and supplier? and (3) What is the behavioral driver which generates any observed differences across contracts?

We begin by theoretically investigating several contractual solutions to the capacity investment problem under two-point demand, and show that, in theory, many of the contracts (a price premium for higher quantities, a minimum quantity commitment, an option fee for investing in capacity, and a bonus for satisfying demand) allow for various combinations of contract parameters that can generate first-best capacity investment decisions for suppliers, and also equalize expected profits between the retailer and supplier. We then conduct a series of experiments directly testing these theoretical predictions, and find that the contracts perform quite differently than the normative benchmarks. In particular, our first main experimental result is that the option contract, where

the supplier receives a fixed option fee from the retailer that is forfeit whenever the supplier fails to invest in capacity, and service-level agreement, where the retailer awards the supplier a bonus anytime she can satisfy all of demand, both perform substantially better than the other contracts at increasing supplier investment, and thus generating higher expected supply chain profits. However, another key result is that, these same contracts, while best at inducing higher levels of first-best investment, are also tied to the most inequitable payoffs. More specifically, we observe that as certain contracts increase overall supply chain profits, these gains heavily favor the supplier.

The bargaining data from our study suggest that there are two primary reasons for these experimental results, which we collectively refer to as “superficial fairness.” In particular, (1) when retailers and suppliers bargain over multiple contract parameters, both parties, across all contracts, devote more effort towards negotiating the wholesale price, while largely overlooking the secondary parameter (such as a secondary wholesale price, quantity commitment, option fee, or bonus), and (2) subjects make concessions while bargaining, that is, they first make an initial wholesale price offer that greatly favors themselves, and then each make concessions until the final wholesale price is roughly in the middle of the supplier’s production cost per unit and the retailer’s revenue per unit. We show that these behavioral tendencies can account not only for the favorable performance of the option contract and service-level agreement, in terms of overall investment rates and supply chain profits, but also the observed distribution of expected profits between the two parties.

In an effort to determine whether the results from our main study are sensitive to our experimental setting, we conduct two additional robustness studies. The first considers a slightly altered demand setting where superficial fairness, if present, should lead to increased investment rates (which we do observe). The second robustness study incorporates a slightly richer environment, by assuming that demand is continuous. In both of these robustness checks, we find support for each of our main experimental results. For instance, we find that the option contract continues to perform best at increasing supply chain profits, but also, tends to significantly favor the supplier. Furthermore, in both studies, we continue to find evidence of superficial fairness.

In Section 2 we summarize the relevant literature. In Section 3, we outline the theoretical details of our contractual solutions. In Section 4, we summarize the experimental design, and present our results in Section 5. We then detail two separate robustness studies in Section 6, and then conclude with a discussion of our results, managerial implications, and future research in Section 7.

2. Related Literature

The general problem of under-investment over a relation-specific investment, when the returns are expropriable by another party, has been extensively studied in the economics literature. The

most prominent theoretical solutions to this problem include vertical integration, contracting, and repeated interaction (e.g. Klein et al. 1978, Williamson 1979, Grossman and Hart 1986, Hart and Moore 1990, Chung 1991, Klein and Leffler 1981, Baker et al. 2002). From an experimental economics standpoint, Sloof et al. (2004), Ellingsen and Johannesson (2004) and Sloof (2008) test whether investment decisions respond to the structure of the situation as theory predicts in certain settings. Most relevant to our study are experimental economics works which test the role of contracts and organizational form as solutions to capacity investment problems. In particular, Hoppe and Schmitz (2011) study whether contracts can improve decisions when renegotiation is possible. Fehr et al. (2008) and Dufwenberg et al. (2013) examine how the allocation of control rights affects results. In general, a majority of these studies focus on settings with deterministic outcomes from decisions, and one-shot ultimatum offers, whereas our work attempts to extend this literature by incorporating random demand, and allowing for dynamic structured bargaining.

In terms of bargaining research, the theoretical literature is quite rich, including process-free bargaining solutions (such as the Nash Bargaining Solution, Nash 1950), game-theoretic analyses of sequential bargaining games (Rubenstein 1982), and many other approaches (see Muthoo 1999 for a comprehensive summary). From an experimental perspective, studies exploring bargaining typically apply one of two extreme structures; ultimatum one-shot take-it-or-leave-it offers or complete free form negotiation. The former is useful in that theoretical benchmarks are more easily derived and tested (e.g. Davis et al. 2014), however, an ultimatum environment may stray from a back-and-forth negotiation where both players have similar bargaining power. On the other hand, complete free form negotiation is attractive in capturing a more realistic bargaining process (e.g. Leider and Lovejoy 2016), however, there is a risk of losing control in the laboratory (i.e. participants revealing personal information or making appeals to context not present in the experiment). In our study, we develop and implement a bargaining protocol that lies in between these two extreme structures. In particular, our study allows both players to make multiple offers, and also permits players to send limited feedback about offers received. Thus, we attempt take a step towards representing a more natural bargaining process, while still having the ability to observe offers, including rejected ones, and the types of feedback sent. Both ultimatum and free-form negotiation experiments reliably show that fairness is a major concern (e.g. Güth et al. 1982, Güth and Tietz 1990, Leider and Lovejoy 2016), and therefore we expect fairness to play an important role in our setting.

Our paper also draws on the extensive literature in economics and psychology on biases in bargaining (see Bazerman and Neale 1994 and Bazerman et al. 2000 for excellent surveys of the psychology literature on negotiation biases, and Roth 1995 and Camerer 2003 Ch. 4 for surveys

of the experimental economics literature on bargaining). One prominent bias that is particularly relevant in our setting is the “fixed-pie bias” - i.e. the (incorrect) belief by negotiators that they should primarily focus on bargaining over how to divide a fixed surplus, and a failure to recognize opportunities for joint gain (Thompson and Hastie 1990, Thompson and DeHarpport 1990, Fukuno and Ohbuchi 1997). Thompson and Hastie (1990) show that one source of the bias is that negotiators typically enter a bargaining setting presuming that the other party’s preferences are diametrically opposed to their own. Thompson and DeHarpport (1990) show that this is primarily a judgement problem, as accurate feedback on the other party’s true interests can significantly mitigate the bias. Thompson and Hrebec (1996) show that joint agreements in an interdependent decision-making setting similarly fail to recognize opportunities for mutual gain.

A second prominent bias is that negotiators often have subjective and self-serving perceptions of what outcomes are fair (Thompson and Loewenstein 1992, Babcock and Loewenstein 1997). Bargaining, therefore, does not always converge to equalizing (expected) outcomes between parties in the way that more traditional social preference models of fairness would suggest (Fehr and Schmidt 1999, Bolton and Ockenfels 2000). For example, in a series of binary lottery bargaining experiments (Roth and Malouf 1979, Roth et al. 1981, Roth and Malouf 1982), Roth, Malouf and Murnighan (1981) show that when the negotiating subjects have asymmetric payoffs for winning the lottery, they will tend to disagree over whether the “fair” outcome involves giving each party an equal number of tickets (favored by the subject with the larger payoff for winning) or an equal expected value (favored by the subject with the lower payoff for winning).

Finally, negotiators often address a multi-issue negotiation by addressing each issue separately and sequentially (Mannix et al. 1989, Weingart et al. 1993). This can lead negotiators to overemphasize certain issues, and to fail to appreciate how multiple issues interact to generate joint gains. Together, these biases suggest several things for our setting. First, during the negotiations subjects are likely to focus on the contractual terms separately, rather than on how they work together to affect outcomes. Second, they are likely to focus on claiming value, rather than finding ways to increase joint surplus (especially since the retail price is fixed, so the only way to increase the surplus is to affect the capacity decision) or equalize expected payoffs. We might then expect subjects to primarily focus on bargaining over the wholesale price, as it is a salient contract term that (on the surface) divides the fixed per-unit revenue.

If indeed subjects during bargaining fail to appreciate how the contractual terms work together to provide incentives, the structure and directness of the incentives under different contractual forms may be particularly important. Both theoretical (Kerr 1975, Holmstrom and Milgrom 1991,

Baker 1992) and experimental (Philipson and Lawless 1997, Fehr and Schmidt 2004, Scheele et al. 2014, Al-Ubaydli et al. 2015) evidence suggests that incentives that are partial, indirect or misaligned with the ultimate goal will likely perform worse. This intuition is often called the “folly of rewarding A, while hoping for B” (Kerr 1975). In our setting the option contract provides the most direct incentives towards capacity investment, while the incentives of other coordinating contracts (quantity premium and quantity commitment) are more indirect. Hence, if negotiation biases cause subjects not to fine-tune contract parameters, these results would suggest that the contract with the most direct incentives, the option contract, will achieve the best performance.

From an operations management standpoint, there are a number of theoretical studies on capacity investment decisions in various settings. The most relevant are those which evaluate how contracts can induce a supplier to invest in capacity for a retailer. For example, Cachon and Lariviere (2001) investigate an asymmetric information setting where a manufacturer can share its forecast demand information with a sole-source supplier, and the supplier makes a decision about how much capacity to install. Tomlin (2003) extends Cachon and Lariviere (2001), in that both a manufacturer and supplier invest in capacity. Özer and Wei (2006) also extend Cachon and Lariviere (2001) by examining how a supplier can screen buyers, under asymmetric information, by offering a menu of contracts. Plambeck and Taylor (2005) evaluate a scenario with original equipment manufacturers selling production to contract manufacturers, and identify how pooling and bargaining power affect investments in innovation and capacity. Taylor and Plambeck (2007), in a classic capacity investment decision setting, derive optimal price, and price with quantity, contracts and explore which contract is best under different production and capacity costs. There has also been some work in operations that considers how human decision makers set various contract terms, such as Becker-Peth and Thonemann (2016). We believe our work is unique to this rich literature by taking a behavioral standpoint, and identifying contractual solutions to capacity investment problems with human decision makers interacting under a more natural bargaining setting.

3. Theory

One common solution to the capacity investment problem is to allow the parties to negotiate a contract prior to any supplier investment decision. In this section, we present a theoretical review of five contracts (wholesale price, quantity premium, quantity commitment, option, and a service-level agreement), which are all used in practice (Lovejoy 2010, Plambeck and Taylor 2007, Oblicore 2007), and can induce the supplier to invest in capacity through different mechanisms. For example, the quantity premium contract can lead to first-best investment through the use of multiple prices,

whereas the quantity commitment contract makes investment attractive through a minimum order quantity by retailers.

For all contracts, assume demand follows a two-point distribution, with high demand D , low demand d , and difference in demand $\delta = (D - d)$. High demand D occurs with probability p , and low demand d occurs with probability $(1 - p)$. The supplier (S) manufactures products instantaneously, begins with sufficient capacity to make d units, and can incur a fixed cost of K to increase capacity to D units. We assume that the supplier's capacity is only useful to satisfy demand for the retailer's (R) product, that is, capacity is relationship-specific to the retailer.

There is full information for both parties about the model parameters. Let r represent the retailer's revenue per unit, and $c = 0$ denote the supplier's marginal cost of production per unit. The retailer and supplier agree ex ante, before the supplier's investment decision, to buy and sell units at a wholesale price w , $0 \leq w \leq r$, plus any additional contract terms. We assume that investment in capacity is beneficial for the overall supply chain $K \leq rp\delta$.

Let $\pi_i^j(x)$ denote the expected profit function of party i , $i \in \{R, S\}$, in contract j , $j \in \{WP, QP, QC, OP, SL\}$, where x is the supplier's investment decision, $x \in \{\text{Yes}, \text{No}\}$. We will refer to any set of contract terms where it is expected-profit maximizing for the supplier to invest in capacity as an incentive compatible contract. Also, because renegotiation is not a focus of our study, we assume that renegotiation is not possible, and hence incentive compatibility depends on the initial terms of the contract, however, we discuss renegotiation-proofness in an online Appendix.

Because fairness is likely to be a concern during bargaining, we will discuss for each contract whether fairness and incentive compatibility is jointly possible. First, we will identify the parameters that both satisfy incentive compatibility and allow for equal expected profits. Second, since the bargaining literature suggests that the wholesale price is likely to be salient and that negotiators may have biased notions of fairness, we will specifically note what is possible when $w = \frac{r}{2}$, i.e. the wholesale price is at the midpoint between revenue and marginal cost. Table 1 in the next section will show the specific contractual terms required given the parameters used in the experiment.

3.1 Wholesale Price Contract

Under a wholesale price (WP) contract, the retailer and supplier agree to buy and sell units at wholesale price w , where the expected profit functions are:

$$\pi_R^{WP}(x) = \begin{cases} (r - w)d & \text{if } x = \text{No}, \\ (r - w)(d + p\delta) & \text{if } x = \text{Yes}, \end{cases} \quad \pi_S^{WP}(x) = \begin{cases} wd & \text{if } x = \text{No}, \\ w(d + p\delta) - K & \text{if } x = \text{Yes}. \end{cases}$$

The WP contract is incentive compatible for the supplier if $w \geq \frac{K}{p\delta}$. However, note that this is equivalent to $\frac{w}{r} \geq \frac{K}{rp\delta}$, implying that as $K \rightarrow rp\delta$, then $w \rightarrow r$, leading to investment but requiring unequal profit shares between the two parties. Equalizing expected profits further requires that $\frac{w}{r} = \frac{1}{2} + \frac{K}{2r(d+p\delta)}$. To jointly have incentive compatibility and equal expected profits requires $rp\delta \geq \left(\frac{2d+p\delta}{d+p\delta}\right)K$, i.e. the surplus increase from the investment has to be large relative to the cost of the investment and the amount of demand that can be covered without the investment. Additionally, note that with $w = \frac{r}{2}$ for incentive compatibility one would need $\frac{K}{rp\delta} \leq \frac{1}{2}$, again requiring an inexpensive investment. Equalizing expected profits is not possible with $w = \frac{r}{2}$. Our main experiment will use parameters such that K is not large enough to satisfy the conditions for equal profits or the conditions for incentive compatibility with $w = \frac{r}{2}$, however we will conduct an additional experiment as a robustness check that uses different parameters that satisfy both conditions.

3.2 Quantity Premium Contract

A quantity premium (QP) contract states that the retailer and supplier agree to buy and sell units at wholesale price w_1 , $0 \leq w_1 \leq r$, for the first d units, and wholesale price w_2 , $0 \leq w_2 \leq r$, for any units sold above d . In this contract the expected profit functions are as follows:

$$\pi_R^{QP}(x) = \begin{cases} (r - w_1)d & \text{if } x = \text{No}, \\ (r - w_1)d + (r - w_2)p\delta & \text{if } x = \text{Yes}, \end{cases} \quad \pi_S^{QP}(x) = \begin{cases} w_1d & \text{if } x = \text{No}, \\ w_1d + w_2p\delta - K & \text{if } x = \text{Yes}. \end{cases}$$

The QP contract is incentive compatible when $w_2 \geq \frac{K}{p\delta} = \bar{w}_2$. In addition, there are a range of QP contracts that are both incentive compatible and generate equal expected profits. In order for this to be true, $w_2 = \frac{(r-2w_1)d+rp\delta+K}{2p\delta}$, must hold. Additionally, we must have $w_2 \geq \bar{w}_2$ (for incentive compatibility), as well as $r \geq w_2$. Therefore the following two conditions are required on w_1 : (1) $w_2 \geq \bar{w}_2$, if $w_1 \leq \frac{r(d+p\delta)-K}{2d}$, and (2) $r \geq w_2$, if $w_1 \geq \frac{r(d-p\delta)+K}{2d}$. Thus, a QP contract is incentive compatible and equalizes expected profits when the following two conditions are satisfied:

$$\left\{ w_2 = \frac{(r - 2w_1)d + rp\delta + K}{2p\delta}, \frac{r(d - p\delta) + K}{2d} \leq w_1 \leq \frac{r(d + p\delta) - K}{2d} \right\}.$$

For $w_1 = \frac{r}{2}$, the incentive compatibility conditions are the same. Incentive compatibility and equal expected profits can be jointly achieved with $w_2 = \frac{rp\delta+K}{2p\delta}$.

3.3 Quantity Commitment Contract

Under a quantity commitment (QC) contract the retailer and supplier agree to buy and sell units at a wholesale price of w , with a commitment that the retailer buy at least q units, $d \leq q \leq D$, regardless of demand. If the supplier does not invest, and is therefore unable to deliver q units,

then the retailer is released from the commitment and is free to order any amount. In the QC contract the expected profit functions are given by:

$$\pi_R^{QC}(x) = \begin{cases} (r-w)d & \text{if } x = \text{No}, \\ (1-p)(rd-wq) + p(r-w)D & \text{if } x = \text{Yes}, \end{cases} \quad \pi_S^{QC}(x) = \begin{cases} wd & \text{if } x = \text{No}, \\ w(q+p(D-q)) - K & \text{if } x = \text{Yes}. \end{cases}$$

The QC contract is incentive compatible when $q \geq \frac{w(d-pD)+K}{w(1-p)} = \bar{q}$. As with the QP contract, in the QC contract, there are a range of possible contracts that are incentive compatible and equalize expected profits. To ensure this, $q = \frac{(r-2w)pD+r(1-p)d+K}{2w(1-p)}$, must hold. Additionally, we must have $q \geq \bar{q}$, as well as $d \leq q \leq D$, leading to three conditions on w : (1) $q \geq \bar{q}$, if $w \leq \frac{r(d+p\delta)-K}{2d}$, (2) $q \geq d$, if $w \leq \frac{r(d+p\delta)+K}{2(d+p\delta)}$, and (3) $D \geq q$, if $w \geq \frac{r(d+p\delta)+K}{2D}$. Therefore a QC contract is incentive compatible and equalizes expected profits between the two parties when the following conditions are satisfied:

$$\left\{ q = \frac{(r-2w)pD+r(1-p)d+K}{2w(1-p)}, \frac{r(d+p\delta)+K}{2D} \leq w \leq \min \left\{ \frac{r(d+p\delta)-K}{2d}, \frac{r(d+p\delta)+K}{2(d+p\delta)} \right\} \right\}.$$

For $w = \frac{r}{2}$ the incentive compatibility condition becomes $q \geq \frac{r(d-pD)+2K}{r(1-p)}$. Equal expected profits requires $q = \frac{r(1-p)d+K}{r(1-p)}$, which also satisfies incentive compatibility.

3.4 Option Contract

In the option (OP) contract, the retailer and supplier agree to buy and sell units at a wholesale price of w , and the retailer pays a lump sum option fee p_o to the supplier. If the supplier does not invest, he will be unable to execute the terms of the contract (i.e. unable to deliver all units the buyer has an option for), and forfeits the option fee. Note that, given our two-point demand setting, this is a special case of the more general option contract, where the retailer buys $d \leq q_o \leq D$ options for an option fee of p_o , giving the retailer the right to buy up to q_o units at a certain price w_o (and a higher price for any additional units), and if the retailer exercises more units than the supplier can deliver, the supplier must refund the option fee p_o . Since this more general contract has four parameters (and would be more complex than the other contracts) our special case effectively fixes the number of options at $q_o = D$. In a later robustness study, we will investigate this more general case, by incorporating continuous demand. In the OP contract the expected profit functions are:

$$\pi_R^{OP}(x) = \begin{cases} (r-w)d & \text{if } x = \text{No}, \\ (r-w)(d+p\delta) - p_o & \text{if } x = \text{Yes}, \end{cases} \quad \pi_S^{OP}(x) = \begin{cases} wd & \text{if } x = \text{No}, \\ w(d+p\delta) + p_o - K & \text{if } x = \text{Yes}. \end{cases}$$

The OP contract is incentive compatible when $p_o \geq (K - wp\delta) = \bar{p}_o$. Turning to the distribution of expected profits, and incentive compatibility, $p_o = \frac{(r-2w)(d+p\delta)+K}{2}$, must hold to equalize expected profits. We also must have $p_o \geq \bar{p}_o$ for incentive compatibility, as well as $p_o \geq 0$, and therefore require the following conditions on w : (1) $p_o \geq \bar{p}_o$, if $w \leq \frac{r(d+p\delta)-K}{2d}$, and (2) $p_o \geq 0$, if $w \leq \frac{r(d+p\delta)+K}{2(d+p\delta)}$. Thus,

an *OP* contract is incentive compatible and equalizes expected profits between the two parties when the following two conditions are satisfied:

$$\left\{ p_o = \frac{(r-2w)(d+p\delta) + K}{2}, w \leq \min \left\{ \frac{r(d+p\delta) - K}{2d}, \frac{r(d+p\delta) + K}{2(d+p\delta)} \right\} \right\}.$$

For $w = \frac{r}{2}$ the incentive compatibility constraint is $p_o \geq (K - rp\delta/2)$. The requirement for equalizing expected profits is $p_o = \frac{K}{2}$, which also satisfies incentive compatibility.

3.5 Service-Level Agreement

Under a service-level (*SL*) agreement, the retailer and supplier agree to buy and sell units at a wholesale price of w , and the retailer promises to pay the supplier a lump sum bonus B , anytime the supplier can satisfy 100% of the retailer's demand. Therefore, the investment decision by the supplier is unobservable to the retailer, and the supplier may receive the bonus if they neglected to invest in capacity and demand is low. In the *SL* agreement the expected profit functions are:

$$\pi_R^{SL}(x) = \begin{cases} (r-w)d - (1-p)B & \text{if } x = \text{No}, \\ (r-w)(d+p\delta) - B & \text{if } x = \text{Yes}, \end{cases} \quad \pi_S^{SL}(x) = \begin{cases} wd + (1-p)B & \text{if } x = \text{No}, \\ w(d+p\delta) + B - K & \text{if } x = \text{Yes}. \end{cases}$$

The *SL* agreement is incentive compatible when $B \geq (K/p - w\delta) = \bar{B}$. To equalize expected profits between the parties, $B = \frac{(r-2w)(d+p\delta) + K}{2}$, must hold. Furthermore, we need $B \geq \bar{B}$ for incentive compatibility, and $B \geq 0$, leading to the following conditions on w : (1) $B \geq \bar{B}$, if $w \leq \frac{rp(d+p\delta) - K(2-p)}{2p(d-(1-p)\delta)}$, and (2) $B \geq 0$, if $w \leq \frac{r(d+p\delta) + K}{2(d+p\delta)}$. Therefore, an *SL* contract is incentive compatible and equalizes expected profits between the two parties when the following three conditions are satisfied:

$$\left\{ B = \frac{(r-2w)(d+p\delta) + K}{2}, w \leq \frac{r(d+p\delta) + K}{2(d+p\delta)}, w \leq \frac{rp(d+p\delta) - K(2-p)}{2p(d-(1-p)\delta)} \right\}.$$

For $w = \frac{r}{2}$ we need $B \geq (\frac{K}{p} - \frac{r\delta}{2})$ for incentive compatibility. For equal expected profits we need $B = \frac{K}{2}$. To have both incentive compatibility and equal expected profits, requires the parameters to be such that $rp\delta \geq K(2-p)$, i.e. the surplus increase from investment must be sufficiently large relative to the cost of the investment. The parameters in our main experiment do not satisfy this condition, although they are such that nearly equal expected profits are possible.

3.6 Other Psychological Biases

The results from the previous sections describe how a sophisticated designer could set the contract parameters to achieve surplus maximization and payoff equalization. From this perspective all four of the coordinating contracts are in some sense "equivalent." However, the interplay between the contractual terms can be fairly complex and/or subtle, and therefore one might expect that human

decision makers may not be able to fine tune the parameters. How might unsophisticated subjects view the coordinating contracts differently?

The option contract is in many ways the least complicated and provides incentives directly towards the desired goal: capacity investment. Unlike the other four contracts, the incentives do not depend on the realization of demand. Furthermore, the intuitive parameters of $w = \frac{r}{2}$ and $p_o = \frac{K}{2}$ achieve both first best efficiency and equity. The service level agreement is somewhat more complex than the option contract. While it too has incentives directly dependent on the capacity investment decision, the impact of those incentives depends on the demand realization. The quantity commitment contract adds complexity in a different way by providing indirect incentives to invest. Subjects must realize that a larger order commitment gives the supplier greater incentive to invest. Like the service level agreement the effect of these incentives depend on the demand realization - although from the supplier's perspective the commitment mutes the differences between demand states. On the other hand, from the retailer's perspective he takes on additional risk from potentially buying "worthless" units in the low demand state. Additionally, retailers may be disinclined to set high quantity commitments if they compare outcomes in the low demand state to what they would have earned without the commitment (either due to loss aversion or regret aversion). Finally, the quantity premium contract may be the least intuitive for many subjects. First, they need to realize that only w_2 matters for the incentives to invest. Additionally, they must recognize that they should provide a price *premium* for high quantities, rather than a price discount.

Table 1, in the following section, provides another way of thinking about how the contracts differ when subjects are unsophisticated or boundedly rational. Often we model the choices of boundedly rational individuals as involving random errors around the optimal or desired outcome (e.g. McFadden 1974, McKelvey and Palfrey 1995). We can then compare for each contract how large a set of parameters allow for incentive compatibility and equal expected payoffs. This essentially captures how large a choice error it would take to disrupt the desired outcomes. Note that we make a similar comparison in Table 5 in the context of superficial fairness, and reach similar conclusions. Aligning with our intuition from above, we see that the option contract and service level agreement allow for the largest range of parameters, while the quantity premium and quantity commitment contracts have the smallest. This suggests that choice errors would be least likely to disrupt the option-like contracts, and most likely to disrupt the more indirect contracts.

Finally, concerns with the true fairness of the contract (as captured by social preference models like Fehr and Schmidt 1999 and Bolton and Ockenfels 2000) do not suggest that the coordinating contracts should perform differently. If the supplier does not invest, the two parties will only have

equal expected payoffs if $w = \frac{r}{2}$. In contrast, when the supplier invests, all four contracts can equalize expected payoffs for a range of parameters. Therefore, concerns for fairness should only further increase the supplier's incentives to invest in all four coordinating contracts.

4. Experimental Design

Our experimental design included five treatments, one for each of the five contracts, with each treatment consisting of 10 rounds. In every round, a participant was first assigned the role of a retailer or supplier, who was then randomly matched, anonymously, with someone of the opposite role. Following this, each pair then participated in a bargaining stage (details below). In the *WP* contract, the retailer and supplier bargained over a wholesale price w . In the remaining contracts they bargained over two terms simultaneously: (w_1, w_2) in the *QP* contract, (w, q) in the *QC* contract, (w, p_o) in the *OP* contract, and (w, B) in the *SL* agreement. After an agreement was reached in this bargaining stage, the supplier then made the decision of whether to incur a fixed cost and invest in capacity (if an agreement was not reached, both parties earned a profit of zero). Following the supplier's investment decision, random remand was then realized, each party earned their respective private profits, and the round ended.

Consistent with the theory outlined in Section 3, we set demand to follow a two-point distribution, with high demand $D = 20$ and low demand $d = 10$, where the probability of high demand was $p = 1/2$. The supplier's cost to invest in capacity was $K = 35$, allowing them to increase their capacity from $d = 10$ units to $D = 20$ units. The retailer's revenue per unit was $r = 10$, and the supplier's production cost per unit was $c = 0$. Given these parameters, if the supplier does not invest in capacity, then the total supply chain surplus and profit are 100. Whereas if the supplier chooses to invest in capacity, then the expected supply chain profit is 115.

For all treatments, we developed a bargaining protocol that permitted players to bargain with each other dynamically, allowing us to monitor offers over time. In particular, there were no restrictions as to how many offers could be made by either player, nor who had to make an initial offer. Additionally, when either player received an offer, they could accept it, or provide the proposer with limited feedback. For instance, consider the *QC* treatment. In the *QC* treatment, both players could propose different combinations of the wholesale price and quantity commitment at any point in time (w, q) , with no restrictions on the number of offers, and no rules requiring alternating offers. When either player received an offer, they could either accept it, or, provide feedback to the proposer with respect to the contract parameters. Specifically, in the *QC* treatment, someone receiving an offer could let the proposer know whether they felt the wholesale price was too high

or too low, and/or whether they felt that the quantity commitment was too high or too low. No communication beyond these “too high” or “too low” messages was permitted.

To help subjects keep track of the contract offers, we provided them with two tables, one which displayed all of the proposed offers, and one which displayed all of the received offers, along with any feedback. The bargaining stage in each round lasted up to four minutes. If either party chose to accept a contract proposal at any time, the bargaining stage ended for that dyad. If an agreement was not reached within the allotted time, both parties earned a profit of zero. By utilizing this type of bargaining structure, we are able to capture some of the features existing in more realistic negotiations, while maintaining our ability to directly monitor the bargaining dynamics.

There were 36-48 participants in each treatment, for a total of 228 subjects. Based on our experimental parameters and the theory outlined in Section 3, one can calculate contract parameters necessary for incentive compatibility, along with conditions which generate equal expected payoffs (and incentive compatibility). This information is shown in Table 1, which depicts our experimental design, number of participating subjects, and contract details. Note that it also includes conditions in which a wholesale price of $5 = \frac{r}{2}$ is incentive compatible (IC) and equalizes expected profits.

Table 1 Experimental design, number of participating subjects, and contract details.

Contract	Participants	Incentive Compatibility	Equalize Expected Profits	
			Given IC	Given $w = 5$ and IC
<i>WP</i>	48	$w \geq 7.00$	-	-
<i>QP</i>	48	$w_2 \geq 7.00$	$\{w_2 = (18.5 - 2w_1), 4.25 \leq w_1 \leq 5.75\}$	$w_2 = 8.5$
<i>QC</i>	48	$q \geq 70/w$	$\{q = (\frac{185}{w} - 20), 4.63 \leq w \leq 5.75\}$	$q = 17$
<i>OP</i>	48	$p_o \geq (35 - 5w)$	$\{p_o = (92.5 - 15w), w \leq 5.75\}$	$p_o = 17.5$
<i>SL</i>	36	$B \geq (70 - 10w)$	$\{B = (92.5 - 15w), w \leq 4.5\}$	-

We ran all treatments at a university, where participants were mostly students. Subjects first read the instructions themselves. Following this, we then read the instructions out loud and answered any questions. Roughly 30 minutes were spent reviewing the game. We recruited participants through an online system where cash was the only incentive offered. Subjects were paid a \$5 show-up fee plus an amount based on their performance. Average compensation for the participants was just over \$26, which was based on the profits from all 10 rounds. Each session lasted approximately 80 minutes, and the experimental interface was programmed using zTree (Fischbacher 2007).

5. Results

In this section, we first provide a summary of the outcomes of each treatment: investment rates, incentive compatibility, distribution of expected profits, and contract parameters. We then detail

the bargaining dynamics, including offers made and feedback sent. Because each treatment was comprised of reasonably large cohorts of 14-18 subjects, we use the individual subject as our main unit of statistical analysis. Unless otherwise noted, we use non-parametric hypothesis tests, and all regressions include clustered standard errors at the subject or subject-pair level. Also, as mentioned previously, whenever a supplier's best response is to invest in capacity (i.e. it is expected profit maximizing for the supplier to invest), we refer to this as incentive compatible (IC).

5.1 Outcomes

Retailer-supplier dyads successfully reached an agreement at similar rates across all five treatments, overall average of 88.86%, with the exception of the *WP* contract, which yielded an agreement rate of 81.25%. Thus, any observed differences in outcomes are unlikely to be due to agreement rates, so we focus on outcomes and decisions conditional on agreements.

Figure 1a depicts the average investment rates by suppliers for each of the five contract treatments, given an agreement. As one can see in the first column of Figure 1a, the *WP* contract leads to an investment rate of 35.38%. However, a different result emerges when considering the remaining contracts. The *QP*, *QC*, and *OP* contracts, and *SL* agreement, generate higher investment levels than in the baseline *WP* contract treatment, where these differences are significant in all but one comparison (rank-sum tests: $p = 0.1202$ for *WP* vs *QP*, $p = 0.0335$ for *WP* vs *QC*, and $p < 0.01$ for *WP* vs *OP* and *WP* vs *SL*). The *OP* contract achieves the best investment rate of 86.85%, and the *SL* agreement achieves the second best, 71.01%, both of which are significantly higher than the remaining contracts (rank-sum tests: all $p < 0.01$). If we compare these two more contracts directly to each other, *OP* and *SL*, the *OP* contract's investment rate is significantly higher than the *SL* agreement (rank-sum test: $p < 0.01$).

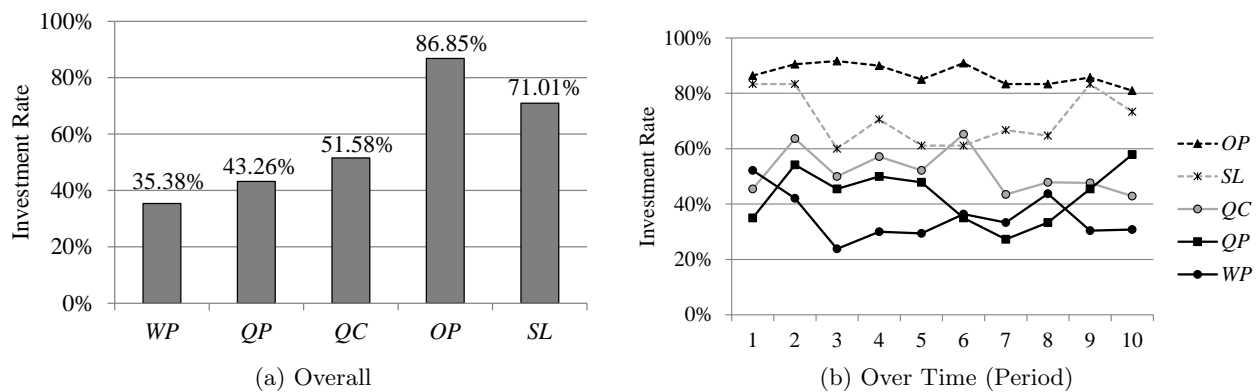


Figure 1 Average investment rates for each contract, overall and over time, conditional on agreement.

The favorable investment rates of the *OP* contract and *SL* agreement appear to persist over time, observed in Figure 1b. To formally check for any experience effects, we ran five Logit regressions with clustered standard errors, with the supplier investment decision as the dependent variable, and the decision period as the independent variable. The coefficient on the period variable was not significantly different from zero in any of the five regressions (smallest $p = 0.288$).

Table 2 provides a summary of additional results. Beginning with incentive compatibility rates, in Table 2, one can immediately recognize a difference between the *OP* contract and *SL* agreement, compared to the remaining three contracts. That is, 91.55% of agreements in the *OP* contract were incentive compatible, and 72.78% of the agreements in the *SL* agreement were incentive compatible, compared to roughly half in the *QC* contract and only a minority in the *WP* and *QP* contracts. Thus, the favorable investment rates of the *OP* contract and *SL* agreement may be attributed to their ability to generate incentive compatible agreements.

Table 2 Summary of experimental results for each contract, outcomes conditional on agreement.

Contract	% Agreement	% IC	Retailer Profit	Supplier Profit	Contract Terms					IC w
					w/w_1	w_2	q	p_o	B	
<i>WP</i>	81.25% [2.70]	12.82% [3.80]	50.84 [1.62]	54.47 [1.36]	5.61 [0.11]	-	-	-	-	-
<i>QP</i>	89.58% [2.23]	21.86% [4.01]	49.75 [1.51]	56.74 [1.45]	5.79 [0.13]	5.43 [0.16]	-	-	-	$w_2 \geq 7.00$
<i>QC</i>	92.08% [1.85]	51.58% [4.21]	49.50 [1.65]	58.24 [1.83]	5.29 [0.10]	-	14.34 [0.31]	-	-	$q \geq 13.97$
<i>OP</i>	88.75% [2.61]	91.55% [2.52]	42.98 [3.72]	70.05 [3.79]	5.19 [0.14]	-	-	27.55 [2.45]	-	$p_o \geq 9.03$
<i>SL</i>	93.89% [1.81]	72.78% [4.55]	43.54 [2.09]	67.11 [1.89]	5.09 [0.16]	-	-	-	25.90 [1.81]	$B \geq 19.06$

Note: Standard errors across subjects reported in square brackets. IC| w reports the average threshold for the second parameter for incentive compatibility, given the observed wholesale prices in the data.

Turning to retailer and supplier expected profits, in Table 2, there appears to be a correlation between investment rates and distribution of expected profits. For instance, the *WP* contract, while yielding a relatively low level of investment, provides the most equitable payoffs between the retailer and supplier: suppliers make roughly 3.63 more in expected profit than retailers. As we move down the table, to those coordinating contracts which lead to higher investment rates, this difference in expected profits only increases, from 3.63 in the *WP* contract, to 6.99 in the *QP* contract, to 8.74 in the *QC* contract, to 27.07 in the *OP* contract, and 23.57 in the *SL* agreement. These data suggest that contracts which increase overall supply chain profits disproportionately favor the supplier. Indeed, compared to the *WP* contract, while suppliers earn considerably more in the contracts generating higher investment, retailers actually begin to earn less in expected profit.

Table 2 also delineates the average contract parameters for agreements in each treatment, and the average required condition on any secondary term for incentive compatibility, given the observed wholesale price. Starting with the *WP* contract, the average agreed upon wholesale price was 5.61, below the required threshold for incentive compatibility ($w \geq 7.00$). A similar result exists in the *QP* contract, where subjects agreed on wholesale price of 5.79, but a secondary wholesale price of only 5.43, considerably lower than the condition for incentive compatibility ($w_2 \geq 7.00$). The *QC* contract performs a bit better in this regard, in that the average quantity commitment was 14.34, which, given the observed wholesale prices (average 5.29), is higher than the average quantity commitment required for incentive compatibility ($q \geq 13.97$). In the *OP* contract and *SL* agreement, given the observed wholesale prices (average 5.19 in *OP* and 5.09 in *SL*), the agreed secondary terms, the option fee and bonus, are far above the thresholds for incentive compatibility; 27.55 in the *OP* contract ($p_o \geq 9.03$), and 25.90 in the *SL* agreement ($B \geq 19.06$).

Lastly, in Table 2, the average wholesale prices for all five contracts are roughly halfway between the retailer's revenue per unit $r = 10$ and the suppliers cost of production $c = 0$. Keeping this in mind, recall from Section 3 that the *QP*, *QC*, *OP* contracts, and *SL* agreement can all lead to first-best investment while (nearly, for *SL*) equalizing expected profits. Specifically, this is possible when $4.25 \leq w_1 \leq 5.75$ in the *QP* contract, $4.63 \leq w \leq 5.75$ in the *QC* contract, and $w \leq 5.75$ in the *OP* contract (in the *SL* agreement, $w \leq 4.5$ is necessary, but $w = 5$ can also lead to relatively equitable expected profits). Returning to Table 2, the average observed wholesale prices for these contracts are within, or near, all of these ranges, suggesting that the secondary parameters may be partly responsible for the considerable inequity we observe in certain contracts. For instance, consider the *OP* contract, where the average option fee is 27.55. In Table 1, we observed that the necessary option fee, assuming a wholesale price of 5, to induce investment and lead to equal expected profits, is only $p_o = 17.5$. Thus, secondary terms, in those contracts that contribute to higher rates of first-best investment, are one potential reason we observe the differences in expected profits. We will investigate how subjects came to these types of agreements in the next subsection.

5.2 Bargaining Dynamics

We now turn to the bargaining data. Table 3 shows the number of messages sent per subject, by minute (the average time to come to an agreement was around three minutes in each contract, with the longest being three minutes 10 seconds in the *WP* contract). Looking at Table 3, there were more messages sent about the wholesale price than the secondary parameter, particularly in the *QP* and *QC* contracts. Although this effect is weaker in the *SL* agreement, which may be due to the fact that the *SL* agreement is the only contract where the secondary parameter is potentially

paid even if the supplier does not invest (and demand is low). These data also suggest that subjects did not take a sequential nature to bargaining, and instead sent feedback over both parameters consistently over time, particularly about the wholesale price.

Table 3 Number of messages sent, per subject, per minute, for the coordinating contracts.

Contract	Term	Total	First	Second	Third	Fourth
<i>QP</i>	w_1	21.83	9.77	5.98	4.13	1.96
	w_2	9.40	5.19	2.35	1.23	0.63
<i>QC</i>	w	28.06	11.65	7.44	5.40	3.58
	q	9.79	4.21	2.79	1.92	0.88
<i>OP</i>	w	25.04	10.83	7.19	4.81	2.21
	p_0	19.33	8.13	5.56	3.77	1.88
<i>SL</i>	w	18.86	8.86	4.97	3.31	1.72
	B	17.78	6.72	5.31	3.64	2.11

In Figure 2, we provide two arrow plots that illustrate the types of feedback sent for the *QP* and *QC* contracts. In these plots the vertical axis represents the wholesale price, w or w_1 , and the horizontal axis represents the secondary parameter, w_2 or q . The origin of the arrows illustrates a contract offer, rounded, and the length of the arrows depict the frequency in which messages were sent about a parameter: longer (shorter) vertical arrows suggest many (few) messages were sent only about the wholesale price, longer (shorter) horizontal arrows indicate many (few) messages were sent only about the secondary parameter, and longer (shorter) arrows in a straight diagonal suggest many (few) messages were sent equally about both parameters. Consistent with Table 3, in Figure 2, for both plots, the majority of the arrows are vertical, and relatively long, implying that feedback for contracts frequently consisted of messages focusing on the wholesale price being too high (i.e. down arrow) or too low (i.e. up arrow). In fact, in both the *QC* and *QP* contract, it appears that a vast majority of the messages focused on driving the wholesale price to around 5 (in the *OP* contract and *SL* agreement, not depicted, similar effects persist, but are not as strong).

We now turn to how offers evolve over time. In Figure 3, we provide two sunflower density plots for the *QC* contract and the *SL* agreement, which depict the contract proposals during the bargaining stage at different moments in time (similar patterns exist for the *QP* and *OP* treatments). Specifically, the left-hand side figures show the density of contract offers during the first minute of bargaining, whereas the right-hand side figures show the density of contract offers during the fourth minute of bargaining. The vertical axis denotes the wholesale price w , and the horizontal axis represents the secondary parameter, q or B . One can immediately notice that

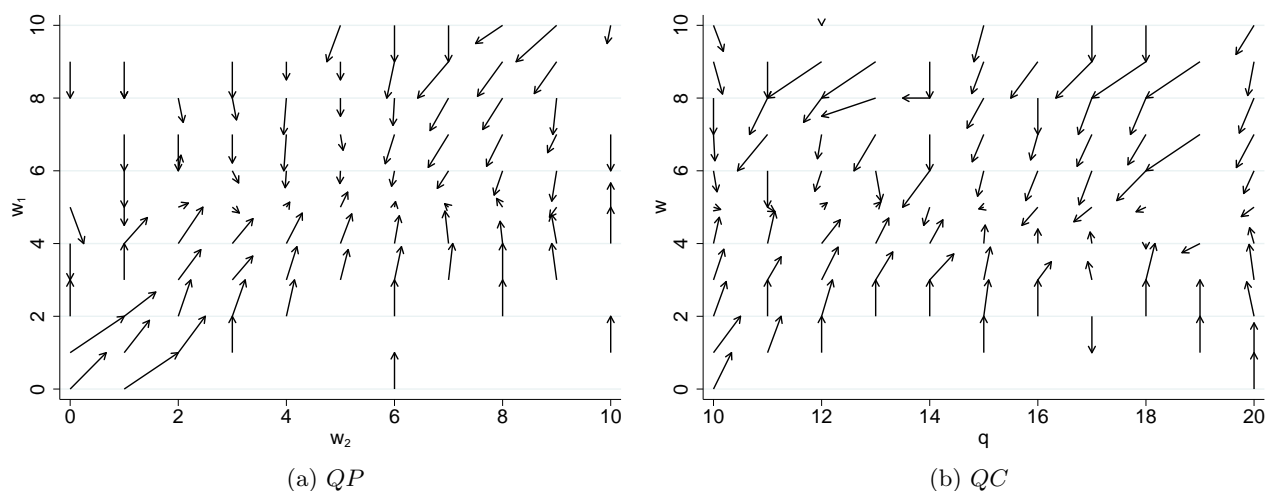


Figure 2 Arrow plots depicting the direction of contract offer feedback in the *QP* and *QC* contracts. The origin of each arrow illustrates a contract offer, rounded, and the length of the arrows depict the frequency in which messages were sent about a parameter: longer (shorter) vertical arrows suggest many (few) messages sent only about the wholesale price, longer (shorter) horizontal arrows indicate many (few) messages sent only about the secondary parameter, and longer (shorter) arrows in a straight diagonal suggest many (few) messages sent equally about both parameters.

during the first minute of bargaining, there is considerable dispersion of offers for both parameters. However, during the final minute, wholesale prices converge to around 5, whereas the secondary parameters continue to exhibit considerable variability (a similar pattern emerges if you look at the first and last two minutes). This suggests that subjects responded to the plethora of messages about the wholesale price, and that they put in considerable effort in negotiating the wholesale price, but gave relatively less attention to the secondary parameter.

In addition to the main bargaining results presented thus far, some other highlights include: initial offers by both retailers and suppliers favored themselves considerably, suppliers tended to make more incentive compatible offers than retailers, both retailers and suppliers failed to accept offers that resulted in low expected profits for themselves, and 50% of all offers were made by suppliers. None of these results are entirely surprising, and point to rational behavior in general.

5.3 “Superficial Fairness”

Thus far, one primary result is that the *OP* contract and *SL* agreement generate higher levels of incentive compatible agreements and investment, but also highly inequitable payoffs. In regards to the bargaining dynamics, we also observe that retailers and suppliers tend to (1) place more emphasis on bargaining over the wholesale price, and (2) settle on a price that is roughly halfway between the retailer’s revenue per unit and supplier’s cost of production per unit. Here, we provide

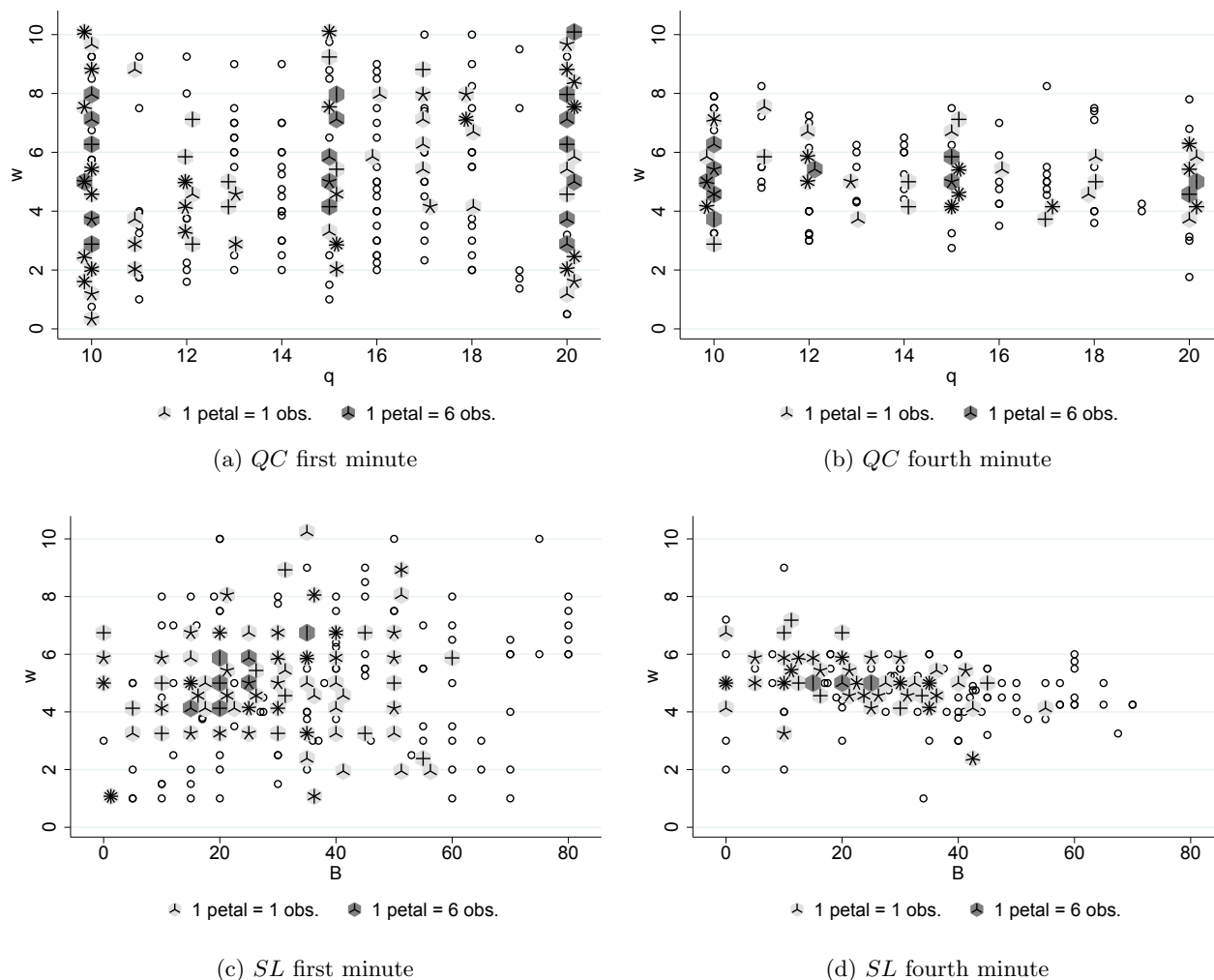


Figure 3 Sunflower density plots for the *QC* contract and *SL* agreement offers in the first and fourth minute. Each circle represents a single observation. Each line on a lightly-shaded hexagon represents one observation. Each line on a darkly-shaded hexagon represents six observations.

further support for these bargaining tendencies, and discuss how these two bargaining anomalies, which we collectively refer to as “superficial fairness,” contribute to our experimental results.

There is a vast literature that shows when parties negotiate over a parameter with salient endpoints, the two parties often make concessions and come to an agreement that is roughly in the middle (Roth and Malouf 1979, 1982). Indeed, in our experimental data, retailers and suppliers tend to start with an initial offer which strongly favors themselves, and eventually settle on a wholesale price that appears more equitable. Specifically, the average midpoint, between the retailer’s and supplier’s first wholesale price offers, ranges from 5.01 in the *SL* agreement, to 5.73 in the *QP* contract, and the wholesale price for accepted offers is significantly correlated with the midpoint of the initial offers, in all treatments (ρ ranges from 0.377 in *OP* to 0.695 in *QP*, $p < 0.01$ for all).

The corresponding concession pattern for the secondary parameters, however, is not as strong. While the secondary parameters for the accepted contract and the midpoint of the initial offers are significantly correlated, the strength of the correlation is relatively weaker (ρ between 0.18 in *SL* to 0.53 in *QP*, $p < 0.01$ for all). Also, importantly, the secondary parameters for accepted contracts significantly differ from the midpoint of initial offers in each treatment, other than *QP* (signed-rank test: $p = 0.47$ in *QP*, $p < 0.01$ for all others).

To determine what contributes to accepting an offer, Table 4 reports the results of regressing subjects' acceptance of an offer using Logit regressions with subject-pair clustered standard errors. *IsIC* is an indicator variable equalling 1 if the offer is incentive compatible. *RiskDifference* is a risk allocation measure, where we first calculated the absolute difference in profits if demand is high or low, for both the retailer and supplier (conditional on the correct investment choice), and then took the absolute difference between the parties. This variable will be high if either the retailer or supplier is bearing the majority of the payoff uncertainty, and will be zero if they have equal payoff uncertainty. Similarly, *Inequality* captures the payoff inequality by taking the absolute difference between the retailer's and supplier's expected profits (conditional on the correct investment). Finally, $w \in [4.5, 5.5]$ is an indicator variable that equals 1 if the wholesale price is between 4.50 and 5.50, capturing the superficial fairness of the offer (we obtain qualitatively similar results if we use alternate measures of superficial fairness, such as expanding the range to $w \in [4, 6]$).

In Table 4, in all contracts, offers are significantly more likely to be accepted if the wholesale price is superficially fair. And the magnitude of the effect is considerable - increasing the likelihood of acceptance by between one-third and two-thirds of the baserate probability (*QP*: 32%, *QC*: 66%, *OP*: 59%, *SL*: 52%). In contrast, subjects do not appear to favor offers that are incentive compatible. Similarly, subjects do not seem to reject offers that are objectively unequal in either expected profits or risk allocation, the former of which is consistent with our data in that contracts with highly unequal expected profits are accepted. Finally, while not depicted, we note that there is no corresponding preference for offers near the middle value of the secondary parameter, which can directly contribute to the distribution of expected profits (in separate regressions, the coefficients on an indicator variable for the secondary characteristics are not significant in any treatment).

This emphasis on the wholesale price, combined with concessions, can account for the rates of incentive compatibility we observe, and also, qualitatively, the differences in expected profits. As previously highlighted in Section 3, when both contract parameters are unconstrained, the *QP*, *QC*, and *OP* contracts, and *SL* agreement, have considerable flexibility at inducing the supplier to invest in capacity and equalize expected profits. However, if one of the two parameters

Table 4 Logit regressions of accepting an offer, for the *QP*, *QC*, and *OP* contracts, and *SL* agreement.

	<i>QP</i>		<i>QC</i>		<i>OP</i>		<i>SL</i>	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>IsIC</i>	-0.612** [0.257]	-0.639** [0.257]	-0.0324 [0.263]	0.0719 [0.264]	0.375 [0.272]	-0.128 [0.278]	0.173 [0.207]	-0.0145 [0.206]
<i>RiskDifference</i>	0.00384 [0.00893]	0.00261 [0.00893]	0.0.00359 [0.00345]	4.02e-05 [0.00352]	-0.00824 [0.00565]	0.00464 [0.00577]	0.00878 [0.00692]	0.0250** [0.00802]
<i>Inequality</i>	-0.00437 [0.00404]	0.00238 [0.00467]	-0.00772* [0.00405]	0.00135 [0.00373]	0.00263 [0.00207]	0.00215 [0.00191]	-0.00640** [0.00254]	-0.00681*** [0.00222]
$w \in [4.5, 5.5]$		0.428** [0.180]		0.812*** [0.190]		0.782*** [0.195]		0.748*** [0.211]
<i>Time</i>	0.0115*** [0.00121]	0.0115*** [0.00122]	0.00916*** [0.00123]	0.00921*** [0.00123]	0.0125*** [0.00122]	0.0124*** [0.00125]	0.0126*** [0.00144]	0.0124*** [0.00148]
<i>Constant</i>	-3.514*** [0.229]	-3.830*** [0.252]	-3.330*** [0.247]	-3.907*** [0.277]	-4.395*** [0.317]	-4.521*** [0.321]	-3.963*** [0.278]	-4.404*** [0.317]

Note: Logit regression with standard errors clustered at the subject-pair level. Dependent variable is the contract acceptance decision. *IsIC* is a binary variable equaling 1 when an offer was incentive compatible, *RiskDifference* denotes the absolute difference in payoff risk between the retailer and supplier, *Inequality* denotes the absolute difference in average payoffs between the retailer and supplier, $w \in [4.5, 5.5]$ is a binary variable equaling 1 when the offered wholesale price was between 4.50 and 5.50, and *Time* shows the time in the round.

is restricted to a particular value, and the secondary parameter is overlooked, then the performance of these contracts may differ. Specifically, if the average wholesale price in all contracts is $w = 5$, then the proportion of the contracting space for the secondary parameter that will lead to incentive compatibility, or favor the supplier over the retailer, greatly differs across the contracts. For example, in the *QC* contract, the quantity commitment parameter must be between 10 and 20, where the requirement for incentive compatibility is $q \geq 14$, and the requirement for a supplier earning strictly more than the retailer in expected profits is $q \geq 17$. This implies that 60% of the quantity commitment parameter space, leads to incentive compatible outcomes, and 30% leads to the supplier earning more in expected profits. Table 5 shows the results from applying this approach to each of the coordinating contracts (focusing on the individually rational contract space for the *OP* contract and *SL* agreement). As one can see, the ordering of incentive compatibility rates and inequity of expected profits, is consistent with that which exists in the experimental data.

In summary, concessions indicate that during negotiations, players will tend to end up in the middle of the potential contracting space. This, combined with the fact that subjects focus most of their bargaining efforts over the wholesale price, and partially overlook the secondary parameter, suggests that the *OP* contract, and a lesser extent the *SL* agreement, have a distinct advantage in arriving at incentive compatible agreements. This, in turn leads to higher investment rates and greater expected supply chain profits, but also significantly more expected profits for the supplier. In fact, given a superficially fair agreement in our setting, we can demonstrate that for any set

Table 5 Analysis of superficial fairness on incentive compatibility rates and expected profit distribution.

Contract	Incentive Compatibility Requirement		$\pi_S \geq \pi_R$, given IC	
	% Region*	% Region*	Requirement	% Region*
<i>QP</i>	$w_2 \geq 7.00$	30%	$w_2 \geq 8.5$	15%
<i>QC</i>	$q \geq 14$	60%	$q \geq 17$	30%
<i>OP</i>	$p_o \geq 10$	87%	$p_o \geq 17.5$	77%
<i>SL</i>	$B \geq 20$	73%	$B \geq 20$	73%

Note: * For the *OP* contract and *SL* agreement, these numbers reflect the region of the individually rational contracting space (i.e. large option fees and bonuses may drive the retailer's expected profit negative).

of parameters (that leads to a non-trivial capacity investment problem) the incentive compatible region for superficially fair contracts will always be (weakly) largest for the *OP* contract. We provide the proof in an online Appendix.

PROPOSITION 1. *For superficially fair contracts ($w = r/2$), the *OP* contract has an incentive compatible region that is strictly larger than the incentive compatible region for *QP* contract and *SL* agreement, and is weakly larger than the region for the *QC* contract.*

6. Robustness Checks

In an effort to investigate the robustness of our results, we conducted two additional experimental studies, consisting of five treatments and 190 additional subjects. In this section we detail the results for these two robustness checks: one which evaluates a scenario where a superficially fair wholesale price should, in theory, induce investment, and another which considers continuous demand.

6.1 Alternative Two-Point Demand

In our first robustness study, we evaluated a scenario in which a superficially fair wholesale price is incentive compatible. To this end, we ran one treatment of the *WP* contract (42 subjects) and one treatment of the *OP* contract (40 subjects) with one subtle difference compared to our main study: the probability of high demand occurring was increased from $1/2$ to $7/10$, thus making $w = 5$ incentive compatible for the supplier. All other parameters and experimental protocols remained the same. Conducting these treatments helps determine (a) whether the favorable performance of the *OP* contract, from a supply chain perspective, persists in an alternative setting, (b) whether there continues to be a wider distribution of expected profits in the *OP* contract, and (c) more importantly, whether investment levels in the *WP* contract increase in this new scenario, relative to the main experiment, supporting the superficial fairness hypothesis.

In these two new treatments, dyads came to an agreement 83.81% of the time in the *WP* treatment and 89% in the *OP* treatment, which yields a weak statistically significant difference

(rank-sum test: $p = 0.096$). Note that these rates are virtually identical to those in the main study (previously 81.25% in the *WP* contract, and 88.75% in the *OP* contract). As with our analysis of the main experiment, we report outcome results conditional on an agreement. A summary of additional results is provided in Table 6.

Table 6 Summary of results for the two-point demand robustness study, outcomes conditional on agreement.

	% Agreement	% Investment	% IC	Retailer	Supplier	Terms		Messages	
				Profit	Profit	w	p_0	w	p_0
<i>WP</i>	83.81%	68.18%	80.11%	59.89	63.97	5.86	-	52.38	-
	[3.32]	[4.91]	[4.22]	[3.02]	[2.65]	[0.17]			
<i>OP</i>	89.00%	93.82%	98.31%	48.31	84.52	5.23	32.60	26.83	22.50
	[3.26]	[3.80]	[1.08]	[4.75]	[4.96]	[0.19]	[5.07]		

Note: Standard errors across subjects reported in square brackets.

One observation from Table 6 is that, consistent with the main experiment, the *OP* contract yields higher investment levels and more incentive compatible agreements than the *WP* contract (93.82% versus 68.18% investment, and 98.31% versus 80.11% incentive compatibility, both rank sum tests: $p < 0.01$). In addition, we see a significant improvement in investment and incentive compatibility rates over the main experiment. Specifically, average investment rates in the *WP* contract double from 35.38% previously to 68.18%, and incentive compatibility rates increase from 12.82% previously to 80.11%. This result is qualitatively in line with superficial fairness, since $w = 5$ is now incentive compatible. The *OP* contract also has higher investment rates (93.82% versus 86.85% previously, rank sum $p = 0.04$) and more frequent incentive compatible agreements (98.31% versus 91.55% previously, rank sum $p = 0.07$). Overall, the *OP* contract still yields the best outcomes for the supply chain, but the relative advantage of *OP* over *WP* is greatly diminished.

Turning to the distribution of expected profits between retailers and suppliers, in Table 6 it appears that the *OP* contract provides more inequitable payoffs, despite its favorable performance at inducing investment from suppliers, which is consistent with the main study.

Continuing in Table 6, wholesale prices are similar to those in the main study: 5.86 versus 5.61 previously in the *WP* contract, and 5.23 versus 5.19 previously in the *OP* contract. There is a small difference in the option fee, which increases to 32.60 from 27.55 previously. Lastly, the bargaining dynamics are consistent with the main study, in that the number of messages sent about each parameter only slightly favored the wholesale price in the *OP* contract, 26.83, compared to the option fee, 22.50 (previously 25.04 for the wholesale price and 19.33 for the option fee).

To summarize this robustness study, we find that when a superficially fair wholesale price is incentive compatible, investment rates increase significantly for both contracts. Strikingly, compared to our main study, average investment rates in the *WP* contract nearly double in this new scenario. Furthermore, the qualitative results from the main study continue to hold: the *OP* contract still yields the most incentive compatible agreements and achieves high investment levels, nearly 94% given an agreement, and these supply chain benefits continue to entirely favor the supplier.

6.2 Continuous Demand

In our second robustness study, we consider a scenario in which demand is continuous. To this end, we implemented the same experimental protocols as in our main study, but allow for demand to be uniformly distributed from 10 to 20, and set the cost of increasing supply capacity, $k \in [10, 20]$, by one unit, to 3.5 (thus, as in our main study, an investment of 35 would increase capacity from 10 to 20). Under this continuous demand scenario we explored the *WP*, *QC*, and *OP* contracts, where each treatment consisted of three sessions (42, 32, and 34 subjects).

6.2.1 Continuous Demand Theory Before presenting our experimental results, we first review some of the theoretical details of the *WP*, *QC*, and *OP* contracts for demand following a continuous distribution over $[a, b]$, and $k \in [a, b]$, along with some comments pertaining to our experimental implementation of continuous demand (i.e. uniformly distributed between 10 and 20). Before turning to each individual contract, we note that the supply chain expected profit under continuous demand is given by:

$$\hat{\pi}_{SC}(k) = \int_a^k r x dF(x) + rk(1 - F(k)) - 3.5(k - a).$$

Which, for our continuous implementation, leads to a first-best investment level of $k_{FB}^* = 16.5$, with expected supply chain profit increasing from 100 (absent any investment, $k = 10$) to 121.125 ($k = 16.5$).

Let $\hat{\pi}_i^j(x)$ denote the expected profit function of party i , $i \in \{R, S\}$, in contract j , $j \in \{WP, QC, OP\}$ under continuous demand, where decision k is the supplier's investment decision, $k \in [a, b]$. Let k_S^* denote the supplier's optimal investment decision, conditional on the contract parameters. Turning to the *WP* contract, each party's expected profits are given by:

$$\begin{aligned} \hat{\pi}_R^{WP}(k) &= \int_a^k (r - w)x dF(x) + (r - w)k(1 - F(k)), \\ \hat{\pi}_S^{WP}(k) &= \int_a^k w x dF(x) + wk(1 - F(k)) - 3.5(k - a). \end{aligned}$$

For our experimental continuous parameters, in the *WP* contract the supplier's optimal investment $k_s^*(w) = \max[20 - 35/w, 10]$, such that the first-best investment level is only achieved when $w = 10$. If we assume that superficial fairness exists, then $w = 5$ cannot lead to first-best investment, and instead will lead to investment levels of $k = 13$, and the corresponding expected profits will be $\hat{\pi}_R^{WP} = 52.25$, and $\hat{\pi}_S^{WP} = 62.75$.

In the *QC* contract under continuous demand, if the supplier invests enough in capacity to satisfy a quantity commitment $k \geq q$, then the retailer promises to purchase q units, regardless of demand. If the supplier does not invest enough to satisfy the quantity commitment, $k < q$, then the quantity commitment is not binding, and the two parties transact at the agreed upon wholesale price. Note that if $w \geq 3.5$ it is optimal for the supplier to set $k \geq q$. Assuming this, the corresponding party's expected profit functions under the *QC* contract with continuous demand are given by:

$$\begin{aligned}\hat{\pi}_R^{QC}(k) &= \int_a^q (rx - wq)dF(x) + \int_q^k (r - w)xdF(x) + (r - w)k(1 - F(k)), \\ \hat{\pi}_S^{QC}(k) &= wqF(q) + \int_q^k wxdF(x) + wk(1 - F(k)) - 3.5(k - a).\end{aligned}$$

For our continuous implementation in the *QC* contract, $k_s^*(w, q) = \max[20 - 35/w, q]$, implying that it can achieve a first-best investment level if $w \geq 3.5$ and $q = 16.5$. In terms of distributing expected profits, a number of combinations can achieve first-best capacity investment with equal expected profits. For instance, $w^* \sim 5.05$, will generate $\hat{\pi}_R^{QC} = 60.56$ and $\hat{\pi}_S^{QC} = 60.56$.

In the *OP* contract, as noted in Section 3, the level of complexity for a general contract increases considerably, compared to two-point demand. In particular, the *OP* contract under continuous demand would consist of an option fee p_o paid by the retailer for the option to buy up to q_o units at wholesale price w_o , with any additional units purchased at an increased wholesale price w . If $k < q_o$ (i.e. the supplier cannot satisfy all of the options), then the option fee is returned, and the two parties transact under a single wholesale price at w_o . Assuming that the supplier invests enough in capacity to satisfy the agreed upon number of options, $k \geq q_o$, the expected profit functions under the *OP* contract are given by:

$$\begin{aligned}\hat{\pi}_R^{OP}(k) &= \int_a^{q_o} (r - w_o)xdF(x) + \int_{q_o}^k (r - w)xdF(x) + (r - w)k(1 - F(k)) - p_o, \\ \hat{\pi}_S^{OP}(k) &= \int_a^{q_o} w_o xdF(x) + \int_{q_o}^k wxdF(x) + wk(1 - F(k)) + p_o - 3.5(k - a).\end{aligned}$$

In our implementation of the *OP* contract, to limit complexity and avoid having subjects negotiate over four contract parameters, we exogenously fix $w = 1.2w_o$. That is, the increased wholesale

price for additional units beyond the options is always 20% higher than the negotiated option wholesale price. Subjects therefore negotiate over three contract parameters: w_o , p_o , q_o . In the continuous *OP* treatment, $k_S^*(w, p_o, q_o) = \max[20 - 35/w, q_o]$. Note that $k_S^* = q_o$ is binding if $w \leq 35/(20 - q_o)$. Therefore if $q_o = 16.5$ then $k_S^* = 16.5$, which is the first-best investment level, for any $w \leq 10$. Many combinations of parameters exist such that the expected profits of the two parties are equalized. For example, if $w_o = 5$, $q_o = 16.5$, and $p_o = 5.6$, then both parties earn expected profits of 60.56.

As with our two-point demand setting, in the continuous demand case we expect the wholesale price contract to lead to sub-optimal investment. Both the quantity commitment and option contracts can, with the appropriate parameters, generate first best investment and equalize expected profits. Additionally, both contracts can perform very well with the intuitive contract parameters of a (discounted) wholesale price of 5 and a quantity commitment/number of options of 16.5. This setting therefore provides a natural extension and robustness check of the findings of our main experiment in a more general and realistic setting.

Lastly, in our experimental implementation, given the additional complexity of these contracts with continuous demand, we provided subjects with a decision support tool during negotiations and when making capacity decisions. During bargaining they could enter in potential contract terms, and see each party's expected profits for each level of investment in capacity. They could also utilize this tool for any offers they received while bargaining. When making capacity decisions, suppliers could see the expected profits for each level of investment given the agreed upon contract.

6.2.2 Continuous Demand Results Agreement rates in the *WP*, *QC*, and *OP* contracts were 90.48%, 94.38%, and 90%, with no significant differences (all rank sum tests: $p > 0.10$). Therefore, we continue to report outcomes conditional on an agreement. Also, we define the efficiency gain from investment level k as the ratio between the increase in supply chain profit at the observed investment over no investment ($\hat{\pi}_{SC}(k) - \hat{\pi}_{SC}(10)$), relative to the potential gains under first-best investment ($\hat{\pi}_{SC}(16.5) - \hat{\pi}_{SC}(10)$). Hence, the ratio shows the percent of potential gains achieved.

Figure 4 depicts the efficiency gain for each of the contracts under continuous demand. As one can see, in Figure 4 we have the familiar ranking of relative performance from a supply chain perspective: the *WP* generates the lowest efficiency gains, the *QC* contract performs significantly better, and the *OP* contract yields the best performance (rank-sum tests: all $p < 0.01$). However, it is important to note that with continuous demand the magnitude of these differences have diminished considerably compared to the main experiment. In other words, the differences across contracts appear to be larger in a two-point demand setting, and slightly lessened with continuous

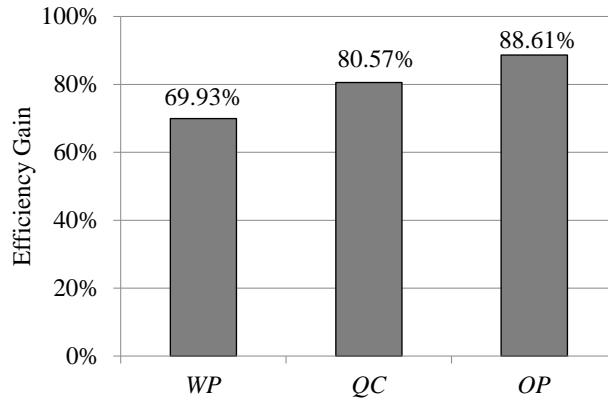


Figure 4 Average efficiency gains in the continuous demand robustness study, conditional on agreement.

demand. This is in part due to the shape of the payoff function under continuous demand, with diminishing returns as the investment approaches the first best level.

Table 7 provides a summary of additional results for the continuous robustness treatments. As with the main study and first robustness check, it appears that the contracts which perform best at achieving greater supply chain profits also yield fairly uneven expected profits between the retailer and supplier. Specifically, under continuous demand, the supplier expected profit exceeds that of the retailer by 2.24 in the *WP* contract, 3.47 in the *QC* contract, and 18.82 in the *OP* contract. The observed payoff inequality is especially interesting given that both parties could easily see both parties' expected profits under various contracts using the decision support tool. This suggests that equalizing expected payoffs was not a primary concern for many subjects.

With respect to contract terms and bargaining dynamics, in Table 7 we see a similar pattern, consistent with the salience of superficial fairness, as in the main study and first robustness check. Specifically, wholesale prices (w_o for the *OP* contract) are around, or slightly above, the superficially fair focal value of $w = 5$. Additionally, for the contracts with multiple parameters, far more messages (per subject) were sent about the wholesale price than messages about the alternative parameters.

Table 7 Summary of results for the continuous demand robustness study, outcomes conditional on agreement.

Contract	% Agreement	Investment Level	Retailer Profit	Supplier Profit	Contract Terms				Messages			
					w/w_o	q	q_o	p_o	w/w_o	q	q_o	p_o
<i>WP</i>	90.48%	13.81	56.27	58.51	5.57	-	-	-	58.69	-	-	-
	[2.12]	[0.26]	[0.88]	[0.94]	[0.07]							
<i>QC</i>	94.38%	14.30	56.78	60.25	5.37	14.65	-	-	26.50	6.06	-	-
	[1.61]	[0.22]	[1.11]	[1.29]	[0.08]	[0.18]						
<i>OP</i>	90.00%	15.38	49.95	68.77	4.98	-	15.59	16.09	14.38	-	6.91	8.29
	[2.76]	[0.24]	[1.74]	[1.91]	[0.08]		[0.19]	[1.28]				

Note: Standard errors across subjects reported in square brackets.

Together the results confirm the main results of our experiment in this more general setting. Qualitatively, we see the same performance ranking across contracts, and we see a similar pattern of bargaining and agreements. Superficial fairness seems to play an important role, and supply chain efficiency appears to be tied to payoff inequality.

7. Conclusion

In this study, we conduct an experimental investigation of capacity investment problems with bargaining. We compare five contracts that, in theory, can provide sufficient incentives and generate first-best investment in capacity by the supplier: wholesale price, quantity premium, quantity commitment, option, and service-level agreement. Further, four of these contracts can not only provide proper incentives for first-best investment, but can also equalize expected profits between the two parties. We find, however, that there are significant differences in the performance of these contracts when we allow human-decision makers to bargain over contract terms and make investment decisions. In particular, the option contract and service-level agreement significantly outperform the other contracts in terms of first-best investment levels and thus supply chain profits. These same contracts also generate the greatest inequity between the two parties in terms of expected profits; the gains they generate in supply chain profit go entirely to the supplier.

In our experiment, we introduce a form of bargaining which puts some structure on the communication, but leaves the offer process unstructured. This allows us to observe the bargaining dynamics over time. These data indicate that subjects have preferences for what we refer to as “superficial fairness.” That is, subjects focus heavily on negotiating the wholesale price and eventually agree on a wholesale price that is near the middle of the contracting space, while paying less attention to the secondary term. These biases significantly distort the incentives provided by the quantity premium and quantity commitment contracts. In contrast, the option contract and service-level agreement have incentives that are robust to an over-emphasis on superficially fair wholesale prices, in terms of first-best investment. However, these contracts are also more susceptible to superficial fairness in terms of the distribution of payoffs, and, as a result, largely favor the supplier.

The tendency to focus on bargaining over one salient term is not uncommon in the bargaining literature - often due to negotiators using sequential agendas that make joint gains hard to find (Mannix et al. 1989), or by focusing on distributing value rather than finding integrative solutions - the “mythical fixed pie” (Bazerman and Neale 1994). This behavior has also been observed in practice. For instance, Devlin et al. (2014) conduct interviews with fashion retailers and suppliers negotiating buyback contracts and find that “wholesale prices charged are similar regardless of the

presence of a buyback,” as if the buyback amount is largely overlooked. Nevertheless, while we believe that this type of bargaining behavior is useful in the organizing the data, we admit that there are undoubtedly many other dynamics taking place in the bargaining process which may drive particular results.

We believe that there are several opportunities for future research in this area. One direction would be to extend our work in a repeated setting. As mentioned previously, relational incentives in a long-term relationship is a common solution to capacity investment problems. It would also be interesting to extend our setting and results to incorporate renegotiation.

One limitation of our study is that subjects had a limited time to bargain over parameters. While we believe our contractual setting was relatively simple compared to negotiations in practice - most supply chain contracts would be significantly more complicated and deal with far greater uncertainty and ambiguity - we recognize that many supply chain negotiations would likely involve a greater length of time, and some additional level of calculations for each offer (although we provided decision support in our continuous demand treatments). However, while this may be a limitation to our study, we believe that ours is one of the first to allow both parties to make back-and-forth offers, while also allowing them to provide limited feedback, as opposed to a setting with only one-shot ultimatum offers. Thus, we believe that our work takes an important step towards understanding a more realistic bargaining setting, but admit that more work is necessary to fully understand capacity investment decisions and bargaining.

From a managerial standpoint, while we investigate a capacity investment context for the supplier, our results can apply to smaller scale settings as well, where a supplier must make a relationship-specific investment. For instance, a startup may need to invest in training, software, or hiring specialized personnel, to serve a potential buyer. In these situations, our results suggest that contracts similar to the option or service-level agreements may generate the optimal investment by the supplier, and lead to increased supply chain profits, but may disproportionately favor the supplier as well.

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Appendix A: Incentive Compatibility Region for Superficially Fair Contracts

We now consider the size of the incentive compatibility (IC) regions within our model for the OP , QC , and QP contracts, and SL agreement, that are superficially fair (i.e. where $w = r/2$). We maintain the underlying structure of the model (e.g. two-point demand, binary investment decision, etc.), but consider variations in the parameters of the model (d, D, r, p, K) . For the investment problem to be non-trivial, we maintain throughout that $K < rp\delta < 2K$ (so for example an equal split of the surplus in ex post negotiation would not be incentive compatible, similarly, a superficially fair wholesale price contract will not be incentive compatible on its own). We begin by reformulating the IC and individually rational (IR) constraints to separate out the common factors across contracts, given that $w = r/2$.

For the OP contract, the IC constraint is $p_o \geq K - pw\delta$, or $2p_o \geq 2K - rp\delta$. Define $\Theta = 2K - rp\delta$, which represents the additional incentives that the secondary term in the contract must provide, given the incentives that the wholesale price is already generating. Note that $0 < \Theta < K$. The IC constraint is therefore $p_o \geq \Theta/2$. The retailer's expected profit given the contract (and investment) is

$$(1-p)(r-w)d + p(r-w)D - p_o = (r/2)(d+p\delta) - p_o.$$

Define $\Gamma = (r/2)(d+p\delta)$, which denotes the retailer's remaining surplus given the wholesale price. Note that $\Gamma > \Theta$. The IR constraint is therefore $p_o \leq \Gamma$. The size of the IC region for the OP contract is therefore $1 - \Theta/2\Gamma$. Finally, since $\Gamma > \Theta$, the size of the IC region is at least 50%.

For the SL agreement, by similar logic the IC constraint is $p_o \geq \Theta/2p$ and the IR constraint is $p_o \leq \Gamma$. Therefore the size of the IC region is $1 - \Theta/2p\Gamma$, which is strictly smaller than the OP contract's IC region.

For the QC contract, we can rewrite the IC constraint as $pw\delta + (1-p)w(q-d) \geq K$ or $(1-p)r(q-d) \geq \Theta$. Finally, we can write the IC constraint as $(q-d) \geq \Theta/r(1-p)$. Note that $0 \leq (q-d) \leq \delta$. For the IR constraint we can write the retailer's expected profit as

$$(1-p)(r-w)d + p(r-w)D - (1-p)w(q-d) = \Gamma - (1-p)w(q-d).$$

The IR constraint is therefore $(q-d) \leq 2\Gamma/r(1-p)$. Note that there are two cases. In Case 1, this limit is larger than δ , hence the IR constraint will not bind. In Case 2, $2\Gamma/r(1-p) < \delta$, which occurs if $d < (1-2p)\delta$. In Case 1 the size of the IC region of the QC contract is $1 - \Theta/r\delta(1-p)$, while in Case 2 it is $1 - \Theta/2\Gamma$.

Is it possible for the IC region for the QC contract to be larger than the OP contract? We take the two cases in turn. For Case 1, we want to see if $1 - \Theta/r\delta(1-p) > 1 - \Theta/2\Gamma$. This would occur if $2\Gamma < r\delta(1-p)$, or $d < (1-2p)\delta$ - however this violates the assumption that we are in Case 1. Therefore, for Case 1 the OP contract always has a larger IC region than the QC contract. For Case 2, both contracts have the same size region: $1 - \Theta/2\Gamma$. Therefore, the size of the IC region for the OP contract is always at least weakly larger than the size of the IC region for the QC contract.

For the QP contract, we know that we at least need $w_2 > r/2$ (since we have assumed that the problem is not trivially solved by a superficially fair wholesale price contract). Since $w_2 \in [0, r]$ is the IR region, the IC region is no larger than 50% of the contracting space. Therefore, the OP contract always has a strictly

larger IC region than the QP contract. Taking all of these results, we can state that for superficially fair contracts ($w = r/2$), the OP contract has an incentive compatible region that is strictly larger than the incentive region for QP contract and SL agreement, and is weakly larger than the region for QC contracts.