PRODUCTION AND OPERATIONS MANAGEMENT

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Vol. 23, No. 2, February 2014, pp. 285–302
ISSN 1059-1478 | EISSN 1937-5956 | 14 | 2302 | 0285
DOI 10.1111/j.1937-5956.2012.01388.x
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Wholesale Pricing under Mild and Privately Known Concerns for Fairness*

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This article studies the performance of wholesale pricing when the supply chain partners' fairness concerns are private information. We find that some properties of wholesale pricing established under complete information hold under incomplete information as well. First, wholesale pricing can coordinate the supply chain, despite the information asymmetry, when fairness concerns are strong enough. Second, in the case when an equitable profit split does not imply that the retailers profit must be higher than that of the supplier, the suppliers' equilibrium offer is never rejected. Overall, the study makes two primary contributions. First, it provides a partial characterization of the equilibrium when the conditions required for coordination do not hold, that is, when fairness concerns are mild. In this case, the model predicts that the expected market price must be exactly the same as under complete information. The channel efficiency, nevertheless, is strictly lower than under complete information. The distribution-free lower bound on channel efficiency suggests that this efficiency loss should be quite small, though. Second, it provides an experimental test of the models' predictions as well as a direct validation of the assumptions of preferences heterogeneity and mildness by obtaining the empirical distribution of the preferences.

Key words: fairness; preferences heterogeneity; supply chain coordination; wholesale pricing; behavioral operations
History: Received: February 2011; Accepted: May 2012, after 2 revisions.

1. Introduction

"It's not fair!" While every parent knows a young child's instinctive need for fairness, it is only relatively recently that fairness considerations have been incorporated in economic models (cf. Kahneman et al. 1986). It is even more recently that fairness has been considered in the context of supply chain management (e.g., Cui et al. 2007). However, most current models of fairness assume that the players have full information on each other's fairness preferences, which seems a strong abstraction of reality. In this study, we consider information asymmetry on players' fairness preferences within the context of supply chain coordination under wholesale pricing.

Supply chain coordination has been an important area of research within supply chain management for over a decade (for a review, see Cachon 2003). The basic idea is that the supply chain partners operating in their own best interests do not necessarily do what is best for the supply chain as a whole. However, if the supply chain can be *coordinated*, then the maximal system profits are available for splitting between the parties, ideally creating win–win scenarios. For example, in the absence of fairness or other behavioral considerations, it is well established that simple wholesale price contracts do not coordinate the supply chain due to double marginalization (e.g., Spengler 1950). Other more sophisticated contracts, such as buy-backs and two part tariffs, have been shown to coordinate the supply chain (Moorthy 1987, Pasternack 1985).

Yet, wholesale prices continue to be widely used in practice. Cui et al. (2007) speculate that this may be partially because when fairness is considered, supply chain coordination can be achieved even under simple wholesale price contracts. They consider a dyadic channel in which a single supplier (she) sets a wholesale price for a single retailer (he). The retailer faces a linear deterministic demand function and decides market price. In the first model, only the retailer has fairness concerns, whereas, in the second, both the supplier and retailer have fairness concerns. Fairness is modeled using an additive disutility due to inequity, where the form for the disutility follows that of Fehr and Schmidt (1999). This inequity aversion occurs both if the inequality is to the player's monetary advantage (advantageous inequality) and to his/her monetary disadvantage (disadvantageous inequality). The authors show that, in this setting, a simple wholesale contract can coordinate the channel as long as the retailer is sufficiently averse to advantageous inequality. In this case, the supplier coordinates the channel by setting the wholesale price above the production cost, yet still sufficiently low to induce the inequality-averse retailer to set the market price below its own expected profit maximizing level. In essence, the retailer rewards the supplier's generosity by forgoing some of its own profits to split the channel profit equitably.

Some evidence of this positive reciprocity emerges from laboratory settings. Loch and Wu (2008) show that in an experimental game in which a supplier and a retailer play repeatedly and are primed for a positive relationship, 95% of the supplier's offers are below the theory predictions for profit-maximizing players and, similarly, the retailers respond with market prices below the profit-maximizing value. That is, they reward suppliers for low wholesale prices. But even though channel efficiency increases to 81% against 72% in the control condition, such a priming for a positive relationship is clearly not enough to coordinate the channel. Either retailers are not sufficiently averse to the advantageous inequality or suppliers are unable to recognize that they can improve their earnings through lower wholesale prices. Fairness preferences in the field may be stronger than in the laboratory. Scheer et al. (2003) find that aversion to advantageous inequity, which is necessary for wholesale pricing to coordinate the channel, is much stronger among Dutch auto dealers than among US auto dealers, but inequity in the channels they studied was commonplace. This suggests that the channels surveyed were not coordinated.

In the light of this empirical evidence, from the lab and the field, researchers in behavioral operations management continue to test the performance of more complex contracting mechanisms in the laboratory. Ho and Zhang (2008) test the two-part tariff mechanism, as well as a mathematically equivalent quantity discount mechanism, and find that neither arrangement improves channel efficiency relative to the wholesale price contract, though the quantity discount contract performs better than the two-part tariff. They also report that loss aversion, in conjunction with bounded rationality conceptualized as the quantal response equilibrium (QRE) (Mckelvey et al. 1995), can explain the difference in performance between two mathematically equivalent mechanisms.

Lim and Ho (2007) compare the wholesale price contract to two other contracts, two- and three-block tariffs, that in theory should result in the same outcome and find that adding an extra block increases efficiency, though it does not bring it close to 100%. According to Lim and Ho (2007, p. 324), "…the results can be better explained by a QRE model that allows for noisy best response by retailers and also accounts for the retailers sensitivity to counterfactual payoffs." They conclude that retailers experience disutility from paying radically different marginal prices in different blocks. Because contracts with more blocks include a finer gradation of marginal prices, retailers find them more palatable.

The main focus of the cited work in behavioral operations management regards extending the standard theory to include behavioral dimensions and, in the case of Lim and Ho (2007) and Ho and Zhang (2008), estimating these models using laboratory data. The work centers on trying to understand why coordinating contracts perform very differently in the laboratory than in theory. A very robust finding from these laboratory experiments, however, is that a major cause of efficiency losses in the laboratory is retailer rejections.

Rejections in the bilateral monopoly contracting game are related to rejections in a much-studied game in economics, called the Ultimatum Game. In this simple two-player game, the proposer offers a split of a fixed sum of money, and a responder can either accept the split or reject it. A rejection results in both players earning 0. The ultimatum game was first reported by Guth et al. (1982), and since then it has become a fundamental building block used to understand other-regarding preferences in economics. We refer the reader to Guth and Tietz (1990), Roth and Erev (1995), Camerer (2003), Cooper and Kagel (2007), and Cooper and Dutcher (2011), for comprehensive reviews of this literature. Retailer rejections in coordinating contracts experiments may be due to the retailers' demand to be treated fairly, just like responders in the Ultimatum Game. Retailers derive sufficient disutility from a contract that allocates most of the profits to the supplier to make a rejection preferable, because a rejection results in a fair split of 0-0. An early model of bargaining that incorporated fairness concerns is by Bolton (1991); he proposes a utility function with an asymmetric loss component that includes only a disutility from receiving less than an equal share. Fehr and Schmidt (1999) extended the model to include disutility from advantageous inequality, and Bolton and Ockenfels (2000) include more general utility functions and incomplete information. In a meta-analysis, De Bruyn and Bolton (2008) estimate the asymmetric loss component utility function from Bolton (1991) and find that a specification of a utility function incorporating fairness and bounded rationality fits many different data sets from bargaining experiments and has significant predictive power out-of-sample.

Cui et al. (2007) apply a version of the Fehr and Schmidt (1999) model to the wholesale price contract. As in Fehr and Schmidt (1999), the Cui et al. (2007) model assumes that the supplier has complete information on the retailer's preferences with respect to inequity. While Cui et al. (2007) do acknowledge that complete information is a strong assumption in many practical settings, another critical point is that a model with complete information cannot (ever) explain rejections. A supplier, fully aware of the retailer's strength of inequality aversion, will offer the retailer a contract that this retailer will (just barely) accept. Thus, rejections can be due either to errors (or bounded rationality, see Su 2008)[1] or to incomplete information about inequality aversion preferences.

The idea that incomplete information is important in explaining rejections was initially suggested by Roth et al. (1991). Forsythe et al. (1994) also mention in the conclusion of their study that proposers in the ultimatum game behave in a way that is consistent with them not knowing the responder type. Neither of those early studies, however, develops a formal model. Bloton and Ockenfels's (2000) study was one of the first to develop a model of social preferences that assumes that these preferences are private information.

Our key contributions to the literature are the following. The theory part of the article presents the first formal analysis of wholesale pricing when fairness preferences are private information. The main results relate to the setting when fairness concerns are relatively mild such that the conditions required for coordination are not satisfied. Our analysis shows that (i) if the "fair" profit split does not require the retailer's profit to be larger than the supplier's profit, then the optimal contract designed by the supplier (given the supplier's beliefs about strength of the retailer's aversion to inequity) is acceptable for the retailer no matter if the supplier's beliefs are correct or not, and (ii) the supply chain efficiency is strictly lower under incomplete information than when preferences are common knowledge.

Using an experiment, we obtain several new results. First, we find that the retailers overwhelmingly respond to the proffered wholesale prices by choosing a market price at or above the profit-maximizing level. That is, we observe (i) the retailers experience disadvantageous inequality, hence, (ii) there is coordination failure. Second, the data show the heterogeneity of the retailers' preferences for fairness, which justifies the need for the incomplete information model, and our study seems to be the first reporting the empirical distribution of preferences from the contracting experiments. Finally, this distribution, jointly with the reference point, which we found to be not equal profit split but the retailer's profit being 83% of the supplier's, largely satisfy our definition of "mild" fairness concerns.

The rest of the article is organized as follows. Section 2 introduces the model and analyzes the case where fairness concerns are private information. Section 3 provides analysis of the case where fairness concerns are not sufficient to coordinate the channel. Section 4 describes the laboratory experiment we conducted to test some of the model predictions and verify the appropriateness of its assumptions. Section 5 concludes the article and suggests possible extensions and directions for future research. All proofs are provided in the Appendix.

2. The Model

This section is organized as follows. Subsection 2.1 sets up the model and discusses the underlying assumptions. Subsection 2.2 presents the results and some insights coming from the previous literature that our model builds upon, allowing us to use them throughout the article and in the proofs. Subsection 2.3 demonstrates how some important properties of wholesale pricing, established under complete information, generalize into the incomplete information setting.

2.1. The Economic Environment and Behavioral Assumptions

We consider a dyadic channel composed of a supplier and a retailer. The supplier produces an infinitely divisible good at a constant cost c per unit. The retailer, if he buys an amount of the product from the supplier, can sell it on a market. The market is characterized by the demand function $q = d(p) = A - Bp$, where q is the amount of product sold, p is the market price, and A and B are market constants. The supplier moves first and makes a take-it-or-leave-it offer to the retailer. Because we are considering wholesale pricing, there is only one parameter in the contract proposed by the supplier, namely, the wholesale price w. The retailer can order a positive amount of the product or nothing, the latter meaning the contract is rejected and both parties make zero profit. This model is chosen for its tractability, for its relationship to existing work, and because it yields insights within a clean, uncomplicated setting.

To allow for fairness concerns, we follow the same route as Cui et al. (2007). Let $\pi_R(w,p)$ and $\pi_S(w,p)$ denote the retailer's and the supplier's profits, respectively, given the parties' choices of w and p. For ease of exposition we will typically drop the parameters and write π_R and π_S for these profit functions. The retailer's rejection of a contract is modeled as an order of $q = 0$ or, equivalently, the retailer choosing $p = \frac{A}{B}$. The retailer's utility (similarly for the supplier) is

$$U_R(\cdot) = \pi_R - \alpha[\max(\gamma\pi_S - \pi_R, 0)] - \beta[\max(\pi_R - \gamma\pi_S, 0)], \tag{1}$$

where α measures the retailer's disutility from earning less than the value of an equitable outcome (disadvantageous inequality), β measures the retailer's disutility from earning more than the value of an equitable outcome (advantageous inequality), and γ is a scaling coefficient that yields the retailer's reference point of a "fair" outcome. That is, the retailer considers the outcome "fair" if $\pi_R = \gamma\pi_S$, "disadvantageous inequality" if $\pi_R < \gamma\pi_S$, and "advantageous inequality" if $\pi_R > \gamma\pi_S$. Note that although the data from experiments testing the performance of wholesale pricing, for example from Ho and Zhang (2008), show that suppliers made notably higher profit than the retailers, this does not imply the retailers were experiencing disadvantageous inequality, as the retailer's equitable payoff is $\gamma\pi_S$. Consistent with the literature, we assume $\alpha \geq 0$ and $0 \leq \beta < 1$ (some of our claims are stated for $\beta \geq 1$ because in the latter case Equation (1) implies the retailer avoids advantageous inequity by choosing $\pi_R = \gamma\pi_S$ and the results relevant to $0 \leq \beta < 1$ straightforwardly extend). In practice, we believe β is likely to be small (e.g., see Bolton 1991, De Bruyn and Bolton 2008, Fehr and Schmidt 1999, Forsythe et al. 1994). We do not make any specific assumptions on γ except that it is positive, the same for both players, exogenous to the model, and common knowledge for the players. Cui et al. (2007) propose, referring to previous studies, that γ broadly captures the channel members' contributions, and it may also depend on other factors such as outside options that are available for them. Depending on context, the factors can be very different. Moreover, some of them, such as horizontal and vertical competition may be driving γ in different directions. Therefore because all those factors are outside of the present model, we believe it is important to keep γ exogenous as well and not to make any specific assumptions. Further, having too many "moving parts" is likely to obscure the whole picture rather than bring deeper insights.

A novel and key feature of our model of wholesale pricing is private information. We assume that when the players make their moves they do not know the realizations of each other's α and β but only their distributions. As is common in the information asymmetry literature, we refer to the pair of individual characteristics of a player (α,β) as a type.[2] This game is similar to the standard Principal-Agent problem in that (Laffont and Martimort, 2002, p. 39, second paragraph.): "…the principal is a Bayesian expected utility maximizer. He moves first as a Stackelberg leader under asymmetric information anticipating the agent's subsequent behavior and optimizes accordingly within the set of available contracts." The difference is that we focus on characterizing the performance of wholesale pricing rather that the performance of an optimal direct mechanism. Hence, we are not using incentive-compatibility constraints.[3] Formally, the solution concept we apply is Perfect Bayesian Equilibrium (PBE) (see Fundenberg and Tirole, 1991, p. 321, and the footnote therein).

LEMMA 1. *The players' strategies in a Perfect Bayesian Equilibrium of the wholesale pricing game under incomplete information are the following:*

$$w^* = \arg\max_w E_{(\alpha_R,\beta_R)}[U_S(w, p^*(w) \mid \alpha_S, \beta_S)], \tag{2}$$

where

$$p^*(w) = \arg\max_p U_R(w, p \mid \alpha_R, \beta_R). \tag{3}$$

Intuitively, Lemma 1 simply reflects the fact that the retailer's utility does not explicitly depend on the supplier's type. Therefore, the retailer's best-response is not affected by the retailer's beliefs (both on and off the equilibrium path) and they can be ignored as redundant.

2.2. The Retailer's Best-Response

To keep the article concise we use the complete-information results (Cui et al. 2007, Equation, 12):

$$p(w) = \begin{cases} \frac{A+Bw}{2B} - \frac{\beta(w-c)}{2(1-\beta)}\gamma & \text{if } w \leq w_2 \\ w + \gamma(w-c) & \text{if } w_2 < w \leq w_1 \\ \frac{A+Bw}{2B} + \frac{\alpha(w-c)}{2(1+\alpha)}\gamma & \text{if } w_1 < w \leq w_0 \\ \frac{A}{B} & \text{if } w_0 < w \end{cases}, \tag{4}$$

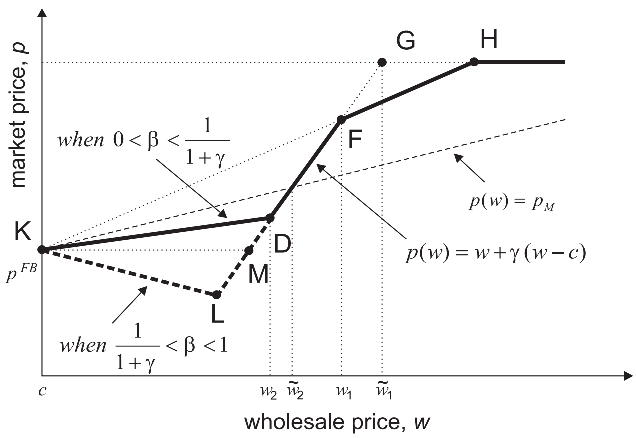
where

$$\begin{aligned} w_0 &= \frac{A + \alpha(A + Bc\gamma)}{B(1 + \alpha + \alpha\gamma)} \\ > w_1 &= \frac{A + 2Bc\gamma + \alpha(A + Bc\gamma)}{B(1 + \alpha + \alpha\gamma + 2\gamma)} \\ > w_2 &= \frac{A + 2Bc\gamma - \beta(A + Bc\gamma)}{B(1 - \beta - \beta\gamma + 2\gamma)}. \end{aligned} \tag{5}$$

To make Equation (4) more intuitive we provide a graphical representation for the case $\gamma = 1$ (see also Pavlov and Olsen, 2011).

Figure 1 plots this best-response price of a retailer for some arbitrary $\alpha > 0$, $0 < \beta < \frac{1}{2}$, and $\gamma = 1$ with a thick solid line, which is piecewise linear and consists of several parts. Due to limited space on the chart we

Figure 1 The Retailer's Best-Response



use $p_M = (A + Bw)/2B$, which denotes the best-response of a profit-maximizing retailer and p^{FB}, which stands for the "first-best price," maximizing the total profit of the channel. For $w < w_2$, the best-response price is lower than that of a retailer without fairness concerns because the retailer acts under advantageous inequality and rewards the supplier for offering a low wholesale price. Segment *DF* corresponds to a fair (i.e., 50/50 when $\gamma = 1$) split between the two players. On the *FH* segment the retailer chooses a price above what a profit-maximizing retailer would choose because he is suffering from disadvantageous inequality. Finally, the line to the right of point *H* corresponds to a zero order quantity. When w is above the w-coordinate of the point *H*, the retailer is better off rejecting such offers because a rejection results in zero utility, whereas any $q > 0$ results in negative utility. Note that the locations of points *F* and *H* depend on α. As α goes from zero to infinity, point *F* moves along the fair split line from point *D* to point *G* and point *H* moves to *G* as well. Denote the w-coordinate of point *D* when $\beta = 0$ and the w-coordinate of point *G* as

$$\tilde{w}_2 \equiv w_2|_{\beta=0} = w_1|_{\alpha=0} = \frac{A + 2Bc\gamma}{t(1 + 2\gamma)B} \quad \text{and} \quad \tilde{w}_1 \equiv w_1|_{\alpha=\infty} = \frac{A + Bc\gamma}{B(1 + \gamma)}, \tag{6}$$

respectively.

One can verify that $\tilde{w}_2$ is the only wholesale price that induces any retailer, regardless of α and β, to order the quantity resulting in a fair (50/50, when $\gamma = 1$) profit split, whereas $\tilde{w}_1$ is the wholesale price resulting in a zero order from a retailer who is infinitely averse to disadvantageous inequity. Further, $\tilde{w}_1$ also turns out to be the optimal wholesale price when the retailer's $\alpha = 0$ (again, assuming $\gamma = 1$). Note that because the prices when the best-response experiences a kink, w_1 and w_2, are monotone in α and β, respectively, it is always the case that $w_2 \leq \tilde{w}_2 \leq w_1 \leq \tilde{w}_1$.

2.3. Properties that Carry Over to Incomplete Information

The complete information equilibrium has several important properties. One is that the supplier's optimal contract never gets rejected. Of course, this is a trivial implication of the complete information regime. Clearly, knowing the retailer's α, the supplier can always propose a contract which the retailer accepts. Interestingly, this property holds under incomplete information as well, provided $\gamma \leq 1$.

Proposition 1. *If $\gamma \leq 1$, then for any distribution of (α_R, β_R) the equilibrium wholesale price does not exceed $\tilde{w}_1$ and, therefore, the contract is never rejected.*

First, note that this is a sufficient condition and there may be no rejections even if $\gamma > 1$. Second, although this property seems interesting *per se*, its robustness is more surprising. The proof does not rely on knowledge of the type distribution. As a result, it does not matter whether the supplier knows the objective distribution of the retailer's fairness parameter α or holds an incorrect belief and offers the wholesale price based on this erroneous belief. Either way the contract will not get rejected.

However, this lack of rejections is not absolute. In reality, the rejection rate may be positive because of various factors left outside the model. For example, there usually exists some minimum tradable amount (e.g., a box, a pallet, etc.) so that when w is close enough to $\tilde{w}_1$ the retailer's best-response order quantity may be smaller than the minimum tradable amount and rejection results.

Another reason for rejections may be the retailer's outside option.

Proposition 2. *If the retailer has an outside option $R > 0$, then, due to incomplete information, the rejection rate can be positive.*

The most striking property of wholesale pricing under complete information, in our opinion, is its ability to coordinate the channel. Coordination results under complete information if and only if the retailer is sufficiently averse to both advantageous and disadvantageous inequities (Cui et al. 2007, Proposition 1, p. 1307):

$$\alpha_R \geq \max\left(\frac{\gamma - 1}{\gamma + 1}, \beta_R\right) \quad \text{and} \quad \beta_R \geq \frac{1}{1 + \gamma}. \tag{7}$$

This property also turns out to be quite robust to the information regime. The conditions required for coordination under incomplete information we provide below are as simple as Equation (7). At the same time, the downside of simplicity is that we have to provide the necessary condition separately from the sufficient one. In what follows, we use S_α and S_β to denote the supports of the marginal probability density functions of α and β, respectively.

LEMMA 2. *If the channel is coordinated, then*

$$S_{\beta_R} \subseteq \left[\frac{1}{1+\gamma}, \infty\right). \tag{8}$$

The intuition behind this result can be conveniently demonstrated using Figure 1. Coordination implies that the retailer, regardless of her type, orders the first-best quantity. The supplier can trivially induce that by charging $w = c$, but the supplier's profit would then be zero, and so the supplier will not make this offer. However, $1/(1+\gamma) < \beta < 1$ makes the slope of the segment left of point D negative (and when $\beta \geq 1$ the retailer responds on the fair-split line). In this case, the retailer's best response crosses the horizontal line $p = p^{FB}$ not only when $w = c$ but also at point M on the fair split line that can be simply found from $p^{FB} = w^* + \gamma(w^* - c)$. Thus, the supplier can induce the first-best outcome and make positive profit. Notice also that the location of this point does not depend on β and, once it is known that $\beta > 1/(1+\gamma)$, no extra information is required. Therefore, it becomes possible to make a distribution-free statement, specified only in terms of the distribution support. Note that Equation (8) is not the only necessary condition. A complementary condition is needed stating that the supplier must not gain more from setting a higher wholesale price, so that at least some retailer types experience disadvantageous inequity. Together, these conditions would be necessary and sufficient. Unfortunately, the second condition turns out to be too generic and not easy to use, as it involves the distribution function. Instead, we propose a much simpler and more specific distribution-free sufficient condition. Although it is, of course, stronger than the necessary condition in question, we believe it is the weakest possible of the distribution-free conditions.

PROPOSITION 3. *The channel is coordinated with a wholesale price contract regardless of the functional form of the probability distributions of the retailer fairness parameters α and β if condition (8) is satisfied and*

$$S_{\alpha_R} \subseteq \left[\max\left(\frac{\gamma-1}{\gamma+1}, 1\right), \infty\right). \tag{9}$$

The supplier chooses to coordinate the channel only if there are no gains from charging a higher wholesale price (charging a smaller price cannot be optimal because it reduces both the channel profit and the supplier's share). If the α's are mostly small, then the supplier may find it worthwhile to charge a higher wholesale price. However, when it is known that the least fair-minded type has $\alpha_R = \max((\gamma-1)/(\gamma+1), 1)$ then even in the best-case scenario, when this type is the only type the supplier deals with (i.e., under complete information), it is not possible to derive higher utility than that obtained from inducing the first-best. That is, supply chain coordination results. Note that although the conditions specified in Proposition 3 are fairly strong, our point is that due to the structural properties of this problem, private information *per se* does not preclude coordination. The supplier does not need to know α and β once they are known to exceed the given thresholds.

Despite coordination being possible in theory, it is yet to be observed empirically. In a controlled laboratory experiment, Loch and Wu (2008) manipulate preferences for fairness but, even in the treatment with the highest degree of induced reciprocity, average efficiency did not improve over the standard theory benchmark. Such a coordination failure in the treatment which gives theory "the best shot" renders the possibility of using wholesale pricing for channel coordination perhaps of limited practicality. In the light of empirical evidence it appears that the most realistic setting is when conditions required for coordination are not satisfied. The remainder of our study, therefore, is focused on the most ubiquitous case, when coordination fails.

3. "Mild" Fairness Concerns

In the previous section we discussed that if the retailer is strongly fair-minded, then supply-chain coordination can result, regardless of information asymmetry. However, this leaves open the question of what happens under information asymmetry when the retailers are not sufficiently fair-minded. This section seeks to shed more light on the performance of wholesale pricing under incomplete information when the retailer is most likely to hold mild fairness concerns. Specifically, we derive an approximate characterization of the equilibrium when "almost all" density of the type distribution is concentrated around zero (see Lemma 3 and its corollary below for the exact specifications). Sections 3.1 and 3.2 consider the cases of retailers experiencing disadvantageous and advantageous inequity, respectively, when the supplier is a profit-maximizer. Our results are not exhaustive. In particular, we could not characterize the equilibrium in all the regions of the parameter space. Section 3.3 discusses our results and gives a few caveats about their interpretation. Section 3.4 introduces a fair-minded supplier and shows the direction in which the previous results change.

3.1. Disadvantageous Inequality

Intuitively, when the retailer's fairness concerns are known to be mostly "mild," as, for example, in the second case of Equation (A10) in Cui et al. (2007), the equilibrium wholesale price should be close to $\tilde{w}_1$, the equilibrium price in the standard model without fairness. Referring to Figure 1, this means that the optimal wholesale price chosen from $[\tilde{w}_2, \infty)$ will be such that most of the retailer types respond on the *FH* segment. However, there may be sufficiently high types that respond either on *FG* or *GH*, depending on whether the offered price is higher or lower than $\tilde{w}_1$. Consider how the shape of the retailer's best response changes as the sensitivity to disadvantageous inequity increases. The points *F* and *H* move closer to the point *G* and, at the limit, merge with it. Therefore, if α can be infinitely large, then for any wholesale price (unless it is equal to the w-coordinate of point *G*) there will be sufficiently high types whose best-response falls outside *FH*. Formally, "sufficiently high" are those types that do not satisfy the following assumption.

ASSUMPTION 1. *The reference point, γ, and the distribution of the retailer's fairness parameter α satisfy the following:*

$$0 \le 1 + \alpha - \alpha\gamma + 2\gamma(\alpha + 1)E\left[\frac{\alpha}{\alpha + 1}\right] \le 2\gamma, \quad \forall \alpha \in S_\alpha. \tag{10}$$

Although this condition does not look very intuitive by itself, it becomes clear in the context of the following lemma.

LEMMA 3. *The equilibrium strategies are given by*

$$p_D(w_D) = \frac{A + Bw_D}{2B} + \frac{\alpha(w_D - c)}{2(1 + \alpha)}\gamma, \quad \forall \alpha \in S_\alpha \tag{11}$$

and

$$w_D = \frac{A + Bc}{2B} - \frac{A - Bc}{2B}\frac{\gamma E\left[\frac{\alpha}{\alpha+1}\right]}{1 + \gamma E\left[\frac{\alpha}{\alpha+1}\right]} \tag{12}$$

if and only if Assumption 1 holds.

Regarding w_D, it seems intuitive that it decreases in γ and in $E[\alpha/(\alpha + 1)]$; the more the retailer is averse to inequity the lower the optimal wholesale price. Although the reasoning underlying this condition is intuitive, as it is simply a requirement that most types find $w_1 \le w_D \le w_0$, the resulting inequality does not seem very intuitive to us. One reason is that it implicitly contains a density function. Another is that the expression that appears between the inequality signs is neither monotone nor jointly convex/concave in γ and α; that is, it is lacking those structural properties that usually help in building intuition. At the same time, it is relatively easy to identify some extreme cases when Equation (10) does not hold. First, it cannot be satisfied for $\gamma \le \frac{1}{2}$ (notice that $\gamma = \frac{1}{2}$ implies $\alpha \equiv 0$). An intuition that we believe is plausible is that when γ approaches zero, it is better for the supplier to not force the retailer to be under disadvantageous inequality because, by choosing a wholesale price such that the retailer responds on the fair profit split line, the supplier basically avoids double marginalization as $p(w) \approx w$ (for small γ). Second, it cannot be satisfied when α is distributed such that it is "mostly large." To see this, notice that in this case $E[\alpha/(\alpha + 1)] \approx 1$ and so Equation (10) simplifies to $-2\gamma \le 1 + \alpha + \alpha\gamma \le 0$, but the right-hand inequality cannot be satisfied because the middle part is strictly positive. Considering the cases when Equation (10) holds, we offer the following example.

EXAMPLE 1. When $\gamma = 1$, which corresponds to the case when fair profit split is 50/50, condition (10) holds for any distribution of α as long as the upper bound of the distribution support does not exceed $\frac{1}{2}$. To see this, first notice that the left-hand inequality is trivially satisfied because with $\gamma = 1$ the only negative term cancels out and the expression between the inequality signs simplifies to $1 + 2(\alpha + 1)E[\alpha/(\alpha + 1)]$. It remains to find the "worst-case" distribution that makes the right-hand inequality tight. To this end, notice that this expression is maximized in the degenerate case when all the mass is located at the upper bound of the support, implying $E[\alpha/(\alpha + 1)] = \alpha/(\alpha + 1)$. This simplifies Equation (10) to $1 + 2\alpha \le 2$, resulting in $\alpha = \frac{1}{2}$ for the highest type such that Equation (10) still holds. Since this was the worst-case scenario, Equation (10) holds for any distribution with the upper bound of support not exceeding $\frac{1}{2}$.

The reasoning we used in this example, particularly the recognition that the worst-case is the one of complete information, immediately relates this part of our analysis to Equation (A9) on page 1311 in Cui et al. (2007), bringing us the following distribution-free sufficient condition.

COROLLARY 1 (TO LEMMA 3). *Condition (10) holds if*

$$S_\alpha \subseteq \left[0, \frac{2\gamma - 1}{1+\gamma}\right], \quad when\ \frac{1}{2} \le \gamma \le 2$$
$$S_\alpha \subseteq \left[0, \frac{1}{\gamma - 1}\right], \quad when\ \gamma > 2 \tag{13}$$

This condition, although stronger than Equation (10), is notably more convenient to work with. For example, to verify if Equation (10) is consistent with the experimental observations one has to first obtain the empirical distribution of α whereas Equation (13) can be verified by much simpler means.

We can now characterize the channel performance in the equilibrium. Note that, from the players' perspectives, it is their utilities that matter rather than profits. However, utilities are unobservable, and therefore in order to obtain testable predictions, our characterization concerns values that can be measured directly.

PROPOSITION 4. *When Equation (1) holds, the equilibrium is characterized as follows. The wholesale price is given by Equation (12), the expected market price is*

$$E[p_D(w_D)] = \frac{1}{4B}(3A + Bc), \tag{14}$$

the expected channel profit is

$$E[\pi_C] = \frac{3(A - Bc)^2}{16B}\left(1 - \frac{\gamma^2 \mathrm{Var}[\frac{\alpha}{1+\alpha}]}{3\left(1 + \gamma E[\frac{\alpha}{1+\alpha}]\right)^2}\right) \tag{15}$$

and the supplier's expected profit is

$$E[\pi_S] = \frac{(A - Bc)^2}{8B\left(1 + \gamma E[\frac{\alpha}{1+\alpha}]\right)}. \tag{16}$$

Note that wholesale pricing once again proves quite robust to fairness concerns and private information. However, unlike the result of Proposition 1, the last proposition requires that the supplier knows correctly not just the support of the distribution of α but $E[\alpha/(1+\alpha)]$. Interestingly, the expected market price is the same here as under complete information. The expected profit of the channel is therefore smaller because it is a strictly concave function of the market price and so $E[\pi_C(p_D)] < \pi_C(E[p_D])$ by Jensen's inequality. Equation (16) is an incomplete information counterpart of the supplier's profit under complete information (see p. 1311 in Cui et al. 2007) and contains the latter as the extreme case of a degenerate distribution of α.

Regarding Equation (15), notice that the fraction in front of the round parentheses is the channel profit under complete information. Therefore, the expected profit of the channel proves strictly lower than its complete information counterpart. However, it appears that in situations when γ is not too big, the second factor will be close to unity. Intuitively, $\mathrm{Var}[\alpha/(1+\alpha)]$ should be small as compared with $1 + \gamma E[\alpha/(1+\alpha)]$ either because α is small (when it is small) or because $\alpha \approx \alpha + 1$ when α is big. The following proposition makes this intuition more precise by providing the lower bound on the channel efficiency.

PROPOSITION 5. *Under the conditions specified in Corollary 1 the following holds:*

$$1 - \frac{\gamma^2 Var[\frac{\alpha}{1+\alpha}]}{3\left(1 + \gamma E[\frac{\alpha}{1+\alpha}]\right)^2} \ge 1 - \frac{1}{12}\frac{\gamma^2(2\gamma - 1)^2}{(2\gamma^2 + 1)(\gamma + 1)} \quad if\ \frac{1}{2} \le \gamma \le 2,\ and \tag{17}$$

$$1 - \frac{\gamma^2 Var[\frac{\alpha}{1+\alpha}]}{3\left(1 + \gamma E[\frac{\alpha}{1+\alpha}]\right)^2} \ge 1 - \frac{1}{12}\frac{\gamma^2}{(2\gamma - 1)(\gamma - 1)} \quad if\ \gamma > 2. \tag{18}$$

Regarding this result, note first that both lower bounds are tight because we derived them using the worst-case distributions. Therefore, they should be "equal" (the value of one equals to the limit of another) at $\gamma = 2$. Second under the worst case scenario ($\gamma = 2$) the channel efficiency is 89% of its complete information counterpart. In practical situations, the worst-case scenario need not be the most likely one, and many times efficiency loss may be barely noticeable. Lastly, it is worth reiterating that, for example, the relative efficiency approaches 100% when $\gamma \to \frac{1}{2}$ not only due to the direct effect of γ on the retailer's best-response (4) but also because of an indirect effect through Equation (13).

3.2. Advantageous Inequality

While the retailer's aversion to advantageous inequality may not be strong enough for channel coordination, the supplier still needs to evaluate the option of offering a wholesale price low enough, so that the retailer will be under advantageous inequity. Our approach to analyzing this case is similar to what we used in the analysis of disadvantageous inequity. We begin with an analogous assumption (the subscript A stands for "advantageous"). Notice that the assumption is silent with regard to α. However, similarly to the above case of disadvantageous inequality, it implies the equilibrium wholesale price will place the retailer under advantageous inequality.

ASSUMPTION 2. *The reference point, γ, and the distribution of the retailer's fairness parameter β satisfy the following:*

$$1-\beta+\beta\gamma-2\gamma(1-\beta)E\left[\frac{\beta}{1-\beta}\right]\leq 2\gamma,\quad \forall\beta\in S_\beta. \tag{19}$$

The following proposition characterizes the equilibrium, providing results parallel to those obtained in our analysis of disadvantageous inequality.

PROPOSITION 6. *If*

$$S_\beta\in\left[0,\frac{1-2\gamma}{1+\gamma}\right], \tag{20}$$

then Assumption 2 holds and the equilibrium is characterized as follows:

$$w_A=\frac{A+Bc}{2B}+\frac{A-Bc}{2B}\frac{\gamma E\left[\frac{\beta}{1-\beta}\right]}{1-\gamma E\left[\frac{\beta}{1-\beta}\right]}, \tag{21}$$

$$E[p_A(w_A)]=\frac{3A+Bc}{4B}, \tag{22}$$

$$E[\pi_S]=\frac{(A-Bc)^2}{8B\left(1-\gamma E\left[\frac{\beta}{1-\beta}\right]\right)}, \tag{23}$$

$$E[\pi_C]=\frac{3(A-Bc)^2}{16B}\left(1-\frac{\gamma^2 Var[\frac{\beta}{1-\beta}]}{3\left(1-\gamma E[\frac{\beta}{1-\beta}]\right)^2}\right),\ \textit{and} \tag{24}$$

$$1-\frac{\gamma^2 Var[\frac{\alpha}{1+\alpha}]}{3\left(1+\gamma E[\frac{\alpha}{1+\alpha}]\right)^2}\geq 1 -\frac{1}{12}\frac{\gamma^2(2\gamma-1)^2}{(2\gamma^2+1)(\gamma+1)}\ \textit{if}\ 0\leq\gamma\leq\frac{1}{2}. \tag{25}$$

We omit the proof because it is fully analogous to those that appeared before. The only exception was Equation (20) because here it only requires analysis of a single inequality rather than a double one. From a technical perspective, these results are full analogues of their counterparts obtained under disadvantageous inequity, and their similarity is not surprising.

3.3. Limitations of the Analysis and the Results Interpretation

The preceding analysis has a number of limitations. To start, a comparison of the intervals given by Equations (8) and (20) reveals a gap in between, and our analysis provides no guidance as to what to expect if S_β falls into this gap. The reason is that (we believe) the problem is analytically intractable in that region of the parameter space. However, whether this is a significant limitation or not is an empirical question, and the results of our experiment reported in section 4 suggest that it may be not. Regarding the interpretation of the analytical results that we do manage to obtain, notice that the problems formulations that arise in case of advantageous and disadvantageous inequalities are structurally identical and, not surprisingly, so are the results. The most robust prediction is that the expected market price in both the advantageous and disadvantageous cases is the same as the standard model without fairness concerns. However, a comparison of Equations (12) and (21) shows not just that the optimal wholesale prices are different but something that may seem counterintuitive: $w_A > w_D$. How can it be that the retailer falls under disadvantageous inequity when offered a wholesale price lower than under advantageous inequity? The reason for this seemingly surprising result is that the two prices were derived for different ranges of γ. Assumption 1 does not hold for $\gamma < \frac{1}{2}$ whereas Assumption 2 does not hold when $\gamma > \frac{1}{2}$. That is, the two prices refer to the retailers having very different reference points. To see why $w_A > w_D$ consider what happens to the retailer's best-response function as γ decreases. Referring to Figure 1, the fair-split line becomes flatter and the whole graph shifts to the right. This can be best seen by inspecting w_1 and w_2—they both decrease in γ.

Finally, our results concerning efficiency state that it will be below its counterpart when players are profit-maximizers. The exact value depends on the distribution of the retailer's parameter α. However, the lower bounds of the channel efficiency, provided by Equations (18) and (25), shows that the efficiency loss can be quite small. For example, when $\gamma = 1$ the channel efficiency drops by less than 2%.

3.4. A Fair-Minded Supplier

The analysis of wholesale pricing when the retailer is fair-minded but the supplier is a profit-maximizer delivers clean and easy to interpret results. The next question is whether these results hold more generally when the supplier is fair-minded as well. In this regard, Cui et al. (2007) observe that the supplier's fairness concerns, if they are strong enough, hinder coordination. It is straightforward to show that this result carries over to the incomplete information environment by extending our Proposition 3 in parallel to Cui et al.'s (2007) Proposition 3.

PROPOSITION 7. *When the supplier is fair-minded, such that $\beta_S \leq 1/(1+\gamma)$ and $\alpha_S \geq 0$, and Equation (13) holds, then the supplier's optimal wholesale price is lower than w_D when the optimal contract puts the retailer under disadvantageous inequality and higher than w_A when it puts the retailer under advantageous inequality.*

These results formally convey very simple intuition: The supplier's fairness concerns push the wholesale price toward mitigating the supplier's disutility. Less obvious, perhaps, is the fact that the supplier's fairness concerns improve the channel profitability when the retailer is acting under disadvantageous inequality, whereas they decrease the total profit of the channel when the retailer is acting under advantageous inequality.

4. Laboratory Experiment

In this section we report on a small laboratory experiment that is useful in checking the predictions of our model (2, 4, and 5), verifying the assumption of "mild" fairness concerns (Assumptions 1 and 2) and, importantly, in showing heterogeneity of the preferences for fairness directly.

4.1. Experiment Design

Our experiment consisted of two treatments. In each treatment half of the human participants were randomly assigned to the role of the supplier and the other half to the role of the retailer. Suppliers moved first, offering the wholesale price w, and retailers moved second, setting the market price p or rejecting the contract. In both treatments the market demand was linear $q = d(p) = 100 - p$ and suppliers' production cost was $c = 20$. In one of the treatments, which we labeled WP-out, retailers earned 200 laboratory tokens if they rejected—it was their outside option. In the other treatment, which we labeled simply WP, retailers had the outside option of 0. Suppliers had the outside option of 0 in both treatments. In both treatments the supplier's profit-maximizing wholesale price for a retailer with $\alpha = 0$ is 60, and the retailer's profit-maximizing market price is $p_M = 80$. This results in the order quantity of $q = 100 - p_M = 20$, supplier's profit of $(60 - 20)\times 20 = 800$, the retailer's profit of $(80 - 60)\times 20 = 400$, and the total channel profit of 1200. The first-best channel profit is 1600, so without fairness concerns the efficiency should be 75%.

Each treatment included three sessions in which eight participants played for 40 rounds. They kept the same role, supplier or retailer, for the entire session, and were randomly matched with a player in the other role each period. We conducted all three sessions concurrently in the same laboratory, and participants were not told that the session size was 8. In total, our experiment included 48 participants. Participants were students, mostly undergraduates, recruited through a on-line recruitment system. Earning money was the only incentive they were offered. Their earnings in US dollars were proportional to their earning from the experiment, and they also received $5 participation fee on top of those earnings. Sessions lasted approximately 75 minutes, and average earnings were $20.

4.2. Experiment Results

Table 1 summarizes average market prices, efficiency levels, and rejection rates, as well as their standard errors (using session as a unit of analysis) in the two treatments of our study. A simple comparison using a t-test allows us to conclude that market prices are no different (two-sided $p > 0.1$) between the treatments, perfectly matching the predictions of Proposition 4 and that the efficiency level in the WP treatment is below the complete information benchmark of 75%, also in accord with Proposition 4. The rejection rates are higher in the WP-out treatment (one-sided $p = 0.0395$), in line with the directional result of Proposition 2.[4] These observations are also consistent with the findings of the studies cited earlier. We note that there are a few rejections in the WP treatment, while theoretically there should be none (if $\gamma \leq 1$). About half of those rejections result from wholesale prices above 60. The other half result from wholesale prices that average 56.43, so they may be explained by bounded rationality and/or high γ.

In order to proceed with analysis of the data we need to know γ, as most of our analytical results, including the model assumptions, are stated in terms of γ. Although it is exogenous in the model and, in principle, can take on any value, it is endogenous in the experiment[5] and can be inferred from the data. It cannot be measured directly, and, therefore, we structurally estimate it using a random choice model. The data from M observations comes in a form of (w_i, p_i) pairs—the supplier-offered wholesale price and the retailer's chosen market price. In the experiment, both w_i and p_i were discrete, and to the offered wholesale price w_i the retailer could respond by choosing one of 101 market prices ($p_i = 0, 1, \ldots, 100$) with the

Table 1 Average Market Prices, Efficiency Levels, and Rejection Rates in the Two Treatments

	WP	WP-out
Market price (p)	81.08	80.08
	(7.30)	(7.90)
Efficiency (%)	68.91	72.16
	(6.50)	(5.21)
Rejection rate (%)	3.61	10.00
	(3.37)	(3.31)

resulting utility defined by Equation (1) with an added error term drawn from the extreme value distribution. The latter assumption results in a multinomial logit model with the following likelihood of the model parameters conditional on the data:

$$f(\alpha,\beta,\gamma,\lambda\,|\,w_i,p_i)=\frac{e^{\frac{1}{\lambda}U_R(w_i,p_i\,|\,\alpha,\beta,\gamma)}}{\sum_{j=1}^{101}e^{\frac{1}{\lambda}U_R(w_i,p_j\,|\,\alpha,\beta,\gamma)}},$$

where λ is a precision parameter capturing the amount of "noise" in the retailers' decisions. Higher values of λ reflect more randomness in the choice, and at the limit when $\lambda = 0$ the decision-maker chooses the option of the highest utility with certainty. The likelihood function for the given M observations is, therefore,

$$L(\alpha,\beta,\gamma,\lambda\,|\,\{w_i,p_i\}_{i=1}^{M})=\prod_{i=1}^{M}\frac{e^{\frac{1}{\lambda}U_R(w_i,p_i\,|\,\alpha,\beta,\gamma)}}{\sum_{j=1}^{N}e^{\frac{1}{\lambda}U_R(w_i,p_j\,|\,\alpha,\beta,\gamma)}}. \qquad (26)$$

This model is commonly used in contracting studies (e.g., Ho and Zhang 2008, Lim and Ho 2007) and although it does not allow for possible heterogeneity of α and β we believe it provides a good sense of the magnitude of the parameters and their importance. We find the maximum likelihood estimates (MLEs) by numerically maximizing the log-likelihood function, $LL = ln(L)$. We used the standard optimization routines in MATLAB.

Table 2 reports the MLE obtained using the whole data set from both treatments. The value of β is small but it is not statistically significant. Removing it from the full model does not affect the likelihood. At the same time, removing α from the full model results in a model that is only as good as the null model.

It is interesting to compare the parameter estimates obtained by using WP and WP-out data separately. First, most importantly, γ is the same in both cases. Somewhat surprisingly, the retailer's outside option does not affect it. However, the estimates of λ, α, and particularly β differ substantively. Apparently, some observations can be better explained by much higher β jointly with much higher noise. The latter, however, suggests that high β may not be robust. For example, the number of outcomes when the retailer experienced advantageous inequity may be very small in WP. Here is where our WP-out data proves particularly useful. In contrast with WP treatment, rejections provide information not only about the retailer's α but also about β. In case of a rejection the retailer earns the outside option of 200 and the supplier gets nothing, Therefore, according to Equation (1), the retailer's utility is $200 - \beta(200 - 0\gamma) = 200(1 - \beta)$. The smaller β, the higher utility, the more likely the retailer rejects an offer. Therefore, even a relatively small number of rejections (compared to the total number of observations) coming from the WP-out data immediately drives the estimate of β practically to zero (Table 3).

We did not observe any instance when the channel was coordinated although the suppliers did provide the retailers such opportunities. Figure 2 shows the distribution of the ratios of the parties' profits that would be obtained, given the wholesale prices offered by the suppliers, if the retailers were profit-maximizers. Although the wholesale prices were generally too high to coordinate the channel, more than 5% of offered prices were low enough so that the retailers, were they sufficiently averse to advantageous inequality, would set the market prices close to the channel optimal one. However, in all these cases the retailers showed virtually no aversion to advantageous inequity.

Now, the established value of γ allows us to obtain the empirical distribution of α. To this end, we can use Equation (4) to calculate the retailers' α's from the retail prices we observe.[6] Assumption 1 implies that

Table 2 Maximum Likelihood Estimates Obtained Using the Data from Both WP and WP-Out Treatments

Both (1200 obs)	Full model	w/o β	w/o α	Null model
α	0.4296	0.4228	–	–
β	0.0438	–	0.9854	–
γ	0.8333	0.8333	0	0
λ	79.178	78.3641	1.2	81.71
LL	−3666.3	−3666.7	−3925.5	−3926.9
p-value	1.00e-16	1.00e-16	0.09	

The likelihood-ratio (LR) test on the difference between the full model and the nested model with $\beta = 0$ gives p-value of 0.37.

Table 3 WP Data Suggest that β Is Large and Significant. WP-out, Instead, Shows that It Is Identically Zero

	Full model	w/o β	w/o α	Null model
WP (720 obs)				
α	0.5755	0.473	–	–
β	0.898	–	1.4388	–
γ	0.8395	0.8333	1	–
λ	108.0049	94.6968	103.7562	96.7377
LL	−2216.8	−2249.1	−2388.8	−2412.3
p-value	4.00E-16			
WP-out (480 obs)				
α	0.3485	0.3485	–	–
β	0	–	0	–
γ	0.8333	0.8333	0.0012	–
λ	56.0018	56.0018	60.0872	60.087
LL	−1400.9	−1400.9	−1499.1	−1499.1
p-value	1.00e-16			

Figure 2 Distribution of π_R/π_S Based on Offers

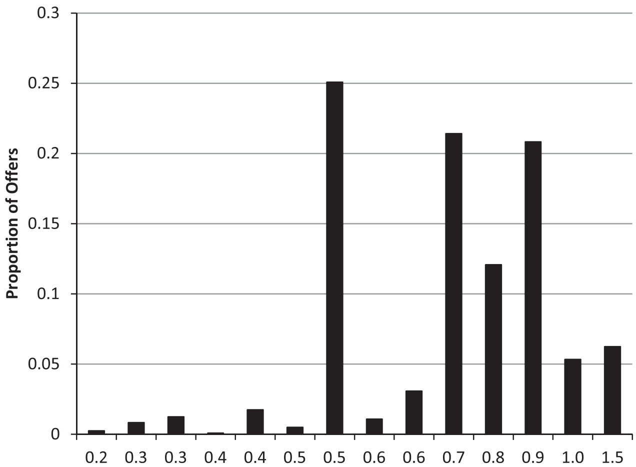
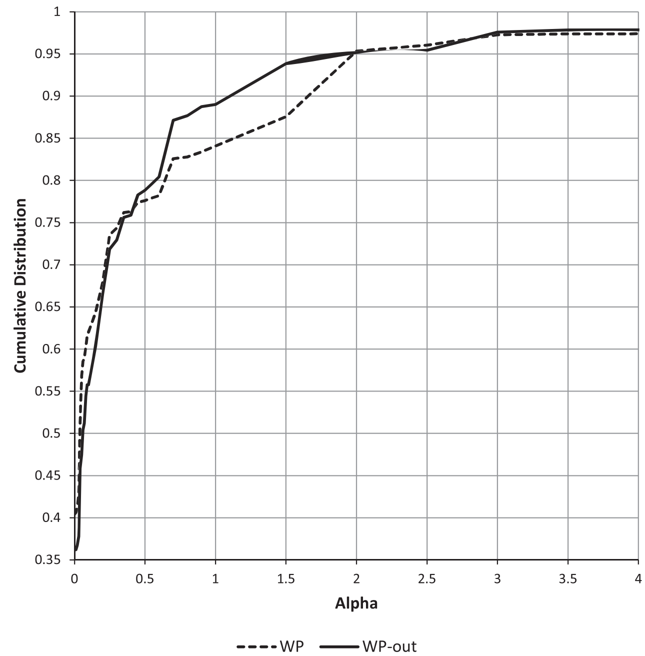


Figure 3 Cumulative Distribution of α's in Our Experiment



most of the data should correspond to the *FG* segment in Figure 1. Figure 3 shows the cumulative distributions of α's in our study, using, as a robustness check, the data from both treatments separately. The two distributions are nearly identical visually, and there is no statistically significant difference as well.

Close to 40% of α's are 0 and about 75% are at 0.36 or lower, satisfying the sufficient condition (1). Recall that the latter is fairly strong, designed using a "worst case" approach. This shows that qualitatively, our assumption of "mild" fairness concerns is reasonably justified. A final important fact demonstrated in Figure 3 is heterogeneity of the retailers' preferences, one of the primary motivations of our study.

5. Conclusions and Extensions

This study extends the existing literature on supply chain coordination by studying wholesale pricing in the presence of fairness concerns, treating the latter as private information. Overall, we find that wholesale pricing proves rather robust to this type of information asymmetry. Some of its properties established under complete information continue to hold (yet, under certain conditions) and some admit intuitive generalizations. Interestingly, many of them are distribution-free, as long as the distributional support falls in a certain specified range.

In particular, this contract can still coordinate the channel under sufficient fairness concerns. Despite incomplete information, and, moreover, even when the supplier's knowledge of the distribution is incorrect, the contract gets never rejected, provided the retailer perceives fairness as making, at most, as much profit as the supplier.

The focus of this study is characterizing the performance of wholesale pricing when the conditions required for coordination are not satisfied, that is, when fairness concerns are "mild." The results we obtained in the analyses of advantageous and disadvantageous cases are structurally similar.

Interestingly, despite private information about the retailer's preferences, when the supplier is not averse to advantageous inequality, the expected market price in equilibrium turns out to be exactly the same as in the standard model of profit-maximizing players. However, we do find that when fairness concerns are not strong they can actually make the supply chain *less* efficient. We derive distribution-free lower bounds on the channel efficiency and, based on them, believe that in practice this efficiency loss is likely to be small.

We tested the model predictions in an experiment and found that the data supported them. In addition, we also validated the main assumption of our model directly. In this regard, our study appears to be the first to obtain an estimate of the reference point, γ, and an empirical distribution of the retailer's fairness parameter α used in the Fehr and Schmidt (1999) specification. Interestingly, the retailer's equitable payoff turned out to be lower that the supplier's profit, and we also observed that it was the same with and without an outside option. Jointly, the observed value of the reference point and the distribution of α constitute what we call "mild" fairness concerns. Lastly, the empirical distribution allowed us to demonstrate heterogeneity of the preferences for fairness directly from the subjects' decisions.

This study suggests several venues for future research. First, different models of fairness have been proposed in the literature, and, despite the differences, they all perform well in a variety of settings.

Although our model is supported by the data, it still seems important to know whether results similar to ours can be obtained using different models. Second, the most significant limitation of our model is that the assumptions required for tractability partitioned the parameter space in a way that it is not possible to directly compare performance of wholesale pricing, when the retailer experiences disadvantageous inequity, with that of when the retailer experiences advantageous inequity. Overcoming intractability, possibly by obtaining approximations, is certainly desirable but definitely challenging as well. Third, the model of wholesale pricing in the presence of fairness concerns proves very sensitive to the reference point. Our intuition suggests that some interesting results can be obtained in a model with players making investments (that establish the reference point) prior to playing a contracting game. Finally, a different direction that we believe can be very fruitful as well is whether modeling the bargaining process as a take-it-or-leave-it offer is reasonable. Real negotiations are more complex, and the effect of the bargaining process may well have an effect on the contract performance of both wholesale pricing and more flexible contracts. Such topics are left as the subject of future research.

Acknowledgments

The authors thank Nadine France for help with proofediting the manuscript as well as the special issue editors and reviewers for their thorough reviews and helpful suggestions that greatly improved the paper. Katok gratefully acknowledges the support from the National Science Foundation (NSF) award SES0849054, the Die Deutsche Forschungsgemeinschaft (DFG) Research Group Design & Behavior, and the Smeal College of Business at Penn State.

Appendix: Proofs

Proof of Lemma 1. By definition, in order to completely characterize a Perfect Bayesian Equilibrium one needs to specify each player's beliefs at her information sets and the players' sequentially rational strategies and ensure that her beliefs are consistent with the equilibrium strategies and derived by Bayes' rule when possible. We proceed by first characterizing the retailer's part and then the supplier's part.

(i) The retailer's utility (1) does not directly depend on the supplier's type, and, therefore, the latter becomes payoff-irrelevant once the supplier offers w. Therefore, at the retailer's information set, sequential rationality requires the retailer to ignore beliefs and choose the strategy according to Equation (3) both on and off the equilibrium path. Because any beliefs are consistent with this strategy, the equilibrium requirement is trivially satisfied.

(ii) At the supplier's information set, since the retailer has not moved yet and could not possibly affect the supplier's beliefs, they are given by the objective distribution of the retailer's type both on and off the equilibrium path. Therefore, sequential rationality implies Equation (2). □

Proof of Proposition 1. As follows from Equations (4) and (6), the lowest wholesale price such that the contract can be rejected (by the infinitely inequity-averse types) is $\tilde{w}_1$. If the supplier offers $w > \tilde{w}_1$ then sufficiently averse types will reject the contract (for them $w > w_0$), so that the supplier cannot gain by this price increase from those types. All lower types respond with the $p(w) = ((A + Bw)/(2B) + ((\alpha_R(w - c))/(2(1 + \alpha + R)))\gamma$. To prove that the supplier cannot gain from these types by choosing $\tilde{w}_1 < w < \tilde{w}_0$ it suffices to show that there does not exist $\alpha_R \geq 0$ such that the supplier might want to charge $w > \tilde{w}_1$ if α_R were the only type. We establish this by demonstrating that regardless of α_R the supplier's utility is decreasing in w when $\tilde{w}_1 < w < \tilde{w}_0$ and, therefore, the optimal w cannot exceed $\tilde{w}_1$. In what follows, we omit the details of lengthy algebraic manipulations because they are purely technical and do not provide any valuable insights.

1. From Equations (4) and (2) it follows that when $\tilde{w}_1 < w < \tilde{w}_0$ the retailer is experiencing disadvantageous inequity and the supplier is experiencing advantageous inequity. Therefore, in this range, the supplier's utility function is $U_S(w, p(w, \alpha_R) \mid \beta_S) = \pi_S - \beta_S(\gamma\pi_S - \pi_R)$, where $p(w, \alpha_R) = ((A + Bw)/2B) + (\alpha_R(w - c))/2(1 + \alpha_R)\gamma$.
2. $U_S(w, p(w, \alpha_R) \mid \beta_S)$ is concave in $w, \forall \beta_S \in \left[0, \frac{1}{1+\gamma}\right]$ because

$$\frac{d^2}{dw^2} U_S(w, p(w, \alpha_R) \mid \beta_S) = (\beta + \alpha\beta + 2\beta\gamma + \alpha\beta\gamma - 2\alpha - 2)\frac{B(\alpha + \alpha\gamma + 1)}{2(\alpha + 1)^2}$$

is increasing in β_S and the largest it can be is

$$\left(\frac{d^2}{dw^2} U_S(w, p(w, \alpha_R) \mid \beta_S)\right)\Bigg|_{\beta_S = \frac{1}{1+\gamma}} = -\frac{B(\alpha + \alpha\gamma + 1)^2}{2(\alpha + 1)^2(\gamma + 1)} < 0.$$

3. Evaluating the first derivative of $U_S(w, p(w, \alpha_R) \mid \beta_S)$ w.r.t. w at $\tilde{w}_1$ one obtains

$$\left(\frac{d}{dw} U_S(w, p(w, \alpha_R) \mid \beta_S)\right)\Big|_{w=\frac{A+Bc\gamma}{B(1+\gamma)}} = -\frac{1}{2}(2\alpha + \alpha^2 + \alpha^2\gamma + \beta\gamma^2 + 1 - \gamma)\frac{A - Bc}{(\alpha+1)^2(\gamma+1)},$$

which is non-positive negative when $\gamma \leq 1$.

We now conclude that since for $\gamma \leq 1$ the supplier's utility function is (weakly) decreasing at $\tilde{w}_1$ and concave in w, its derivative w.r.t. w cannot be larger than at $\tilde{w}_1$ if $\tilde{w}_1 < w < \tilde{w}_0$. Since this holds for any α_R setting $\tilde{w}_1 < w < \tilde{w}_0$ then it cannot be optimal regardless of the distribution of α_R. Therefore, when $\gamma \leq 1$, the highest wholesale price the supplier may want to charge is $\tilde{w}_1$. It will be rejected by the infinitely inequity-averse types but, by assumption, their mass is zero. □

Proof of Proposition 2. To prove the claim, it suffices to construct one example. To begin with, consider the case when the supplier is a profit-maximizer and there is only one retailer type (i.e. complete information environment) with $\beta = 0$ and $0 < \alpha' < \infty$. Under complete information the supplier can always design a contract that the retailer accepts. That is, the wholesale price, w', offered in equilibrium is such that $U_R(w' \mid \alpha') \geq 0$. Next, introduce incomplete information by adding a sufficiently inequity-averse type, $\alpha'' : U_R(w' \mid \alpha'') < R$. Due to Equation (4), it is always possible for any $R > 0$. Also, $\exists w'' < w' : U_R(w'' \mid \alpha'') = R$. Clearly, in this two-type case only two prices are potential candidates for the equilibrium, w' and w''. If w' is offered, only α' participates, and when w'' is offered both types participate. Let μ be the proportion of α''. Then w' will be the equilibrium price if and only if

$$(1-\mu)\pi_S(w', p(w' \mid \alpha')) \geq (1-\mu)\pi_S(w'', p(w'' \mid \alpha')) + \mu\pi_S(w'', p(w'' \mid \alpha'')).$$

However, w' is the optimal wholesale price when the supplier is dealing with type α' only and it can be shown that $\pi_S(w', p(w' \mid \alpha')) > \pi_S(w'', p(w'' \mid \alpha'))$. Therefore, when μ is low enough, w' will be offered in equilibrium and type α'' will reject it in favor of the outside option. □

Proof of Lemma 2. The retailer orders the first best quantity if and only if the best-response price equals the first-best price. This can happen only at $w = c$, which is obviously not optimal for the supplier, or at $w > c$ when the slope of the best-response left to point D on Figure 1 is non-positive. The latter implies $\beta \geq 1/(1 + \gamma)$. □

Proof of Proposition 3. As directly follows from Equation (4), when conditions (8) and (9) hold the supplier can induce the retailer to order the first-best quantity $q^{FB} = (A - Bc)/2$ by charging price $w^{FB} = \frac{1}{2}(A + Bc + 2Bc\gamma)/(B(\gamma + 1))$ (Cui et al. 2007, p. 1311, denote this price as $\overline{w}_{II}$). Since this wholesale price results in the equitable profit split ($\pi_R = \gamma\pi_S$), the supplier experiences no disutility and $U_S = \pi_S = (A - Bc)^2/(4B(1 + \gamma))$. To see whether this price will be offered in equilibrium, check the supplier's gains from possible deviations. First, the supplier cannot gain anything by charging $w < w^{FB}$ because this reduces the total profit of the channel and may also reduce the supplier's share (when $w < w_2$). Second, when $w > w^{FB}$ some retailer types may respond on the equitable profit split line. In these instances, the supplier's share is the same as under coordination but the total profit of the channel is smaller. Hence, there are no gains here. Some retailer types may also find the offered price too high and reject to offer. Obviously, the supplier is not gaining anything in such cases.

Finally, consider the retailers whose best-response places them under disadvantageous inequity, that is, the supplier offers $w_1 < w < w_0$. In this range, as it follows from Equation (4), $p(w, \alpha_R) \propto \alpha_R/(1 + \alpha_R)$, that is, for a fixed w, is strictly decreasing in α_R. Since $q(w, \alpha_R) = A - Bp(w, \alpha_R)$ it is decreasing in α_R. Therefore, for a fixed w, the supplier profit, $\pi_S = (w - c)q(w, \alpha_R)$, is non-increasing in α_R. Now consider the following sequel of inequalities, $\forall \alpha_R$:

$$\begin{aligned}U_S(w, p(w, \alpha)) &= \pi_S - \beta_S(\gamma\pi_S - \pi_R)\\ &< \pi_S(w, p(w, \alpha_R)) \text{ (the disutility term was removed)}\\ &\leq \pi_S\left(w, p\left(w, \max\left(\frac{\gamma-1}{\gamma+1}, 1\right)\right)\right) \text{(due to monotonicity in } \alpha_R)\\ &\leq \max_x \pi_S\left(x, p\left(x, \max\left(\frac{\gamma-1}{\gamma+1}, 1\right)\right)\right) \text{(since } w \text{ was not necessarily optimal).}\end{aligned}$$

Referring to Cui et al. (2007, p. 1311), the last term cannot exceed $(A - Bc)^2/(4B(1 + \gamma))$ and so the supplier's utility cannot exceed that as well. Hence, coordination follows. □

Proof of Lemma 3. "Only if" part: Notice that the functional form of Equation (11) implies, by Equation (4), that $\tilde{w}_1 \le w_D \le \tilde{w}_0$. Substituting values of the corresponding wholesale prices from Equations (12) and (5) into this double inequality results in Equation (1).

"If" part: Consider the supplier's problem of choosing the optimal wholesale price satisfying $\tilde{w}_1 \le w \le \tilde{w}_0$ for some α, γ:

$$\begin{aligned}&\max_w (w-c)E[d(p_D(w))]\\ &\text{s.t.}\\ &p_D(w) = \frac{A+Bw}{2B} + \frac{\alpha(w-c)}{2(1+\alpha)}\gamma\\ &\tilde{w}_1 \le w \le \tilde{w}_0.\end{aligned}$$

Ignore the second constraint and solve a relaxed problem. Substituting the first constraint into the objective function gives

$$w_D = \arg\max_w (w-c)\left(\frac{A-Bw}{2} - \frac{B(w-c)}{2}\gamma E\left[\frac{\alpha}{\alpha+1}\right]\right).$$

The latter is a quadratic function of w and it follows that

$$w_D = \frac{A+Bc}{2B} - \frac{A-Bc}{2B}\frac{\gamma E\left[\frac{\alpha}{\alpha+1}\right]}{1+\gamma E\left[\frac{\alpha}{\alpha+1}\right]}$$

is its unique maximizer. To verify whether this solution is optimal for the original problem, one has to check if it satisfies the second constraint of the original problem. Since Assumption 1 and

$$w_1 \le w_D \le w_0$$

are equivalent, it follows that the second constraint is satisfied. Since this section concerns with the case of disadvantageous inequality, the proof is now complete. However, note that Equation (1) also excludes a possibility of an equilibrium under advantageous inequality that would correspond to the first case in Equation (A10) in Cui et al. (2007, p. 1311). The latter requires $\beta < (1 - 2\gamma)/(1 + \gamma)$ whereas Equation (1) implies $\gamma > \frac{1}{2}$ and, consequently, $(1 - 2\gamma)/(1 + \gamma) < 0$. This leads to $0 < \beta < 0$, which is impossible. □

Proof of Corollary 1 to Lemma 3. The term $(2\gamma - 1)/(1 + \gamma)$ is derived to satisfy the second inequality of Equation (10) using exactly the same reasoning as in Example 1. The term $1/(\gamma - 1)$ is derived to satisfy the first inequality of Equation (10) by assuming $E[\alpha/(1 + \alpha)] = 0$. □

Proof of Proposition 4. First, substituting Equation (12) into Equation (11) and taking the expectation gives Equation (14). Then, substituting Equation (14) into the realized profit of the channel,

$$\pi_C = (p_D(w_D) - c)d(p_D(w_D)),$$

and taking the expectation one obtains Equation (15). The first factor on the right-hand-side is exactly the channel profit when the retailer is a profit-maximizer and the second factor, which is due to the distribution of the fairness parameter, is less than unity. Computation of the supplier's profit is analogous. □

Proof of Proposition 5. To derive a lower bound we need to find the density function $f^*(\alpha)$ that maximizes

$$\frac{\gamma^2 Var[\frac{\alpha}{1+\alpha}]}{\left(\gamma E[\frac{\alpha}{1+\alpha}] + 1\right)^2}.$$

Let $\theta = \alpha/(1 + \alpha)$. As follows from the conditions specified in in Corollary 1, when $\gamma \le 2$ the upper bound on the support of α is $(2\gamma - 1)/(1 + \gamma)$ and when $\gamma > 2$ it is $1/(\gamma - 1)$. We now restate the problem in terms of θ:

$$\begin{aligned}&\max_{g(\theta)} \frac{\gamma^2 Var[\theta]}{(\gamma E[\theta]+1)^2}\\ &\text{s.t.}\\ &\int_0^{\frac{2\gamma-1}{1+\gamma}} g(\theta)d\theta = 1, \quad \text{when } \gamma \le 2 \\ &\int_0^{\frac{1}{\gamma-1}} g(\theta)d\theta = 1, \quad \text{when } \gamma > 2.\end{aligned} \tag{A1}$$

Let $g^*(\theta)$ be its solution and $\theta^* = E_{g^*(\theta)}[\theta]$. Now, consider an arbitrary distribution $g(\theta) : E_{g(\theta)}[\theta] = \theta^*$. The problem can be now considered as the one of finding the distribution with the highest variance among those having mean equal to θ^*. Clearly, any other distribution $g'(\theta)$ obtained from $g(\theta)$ using a mean-preserving spread increases the objective function of Equation (A1). Next, it is immediate that the most variance-increasing mean-preserving spread is the one that allocates all the mass to the endpoints of the interval. That is, it is sufficient to consider the two-point distributions. Now, despite not knowing θ^* we can solve Equation (A1) by restating it in terms of δ. □

Case 1: $\frac{1}{2} \leq \gamma \leq 2$

$$\max_{\delta} \frac{\gamma^2\left(\delta\left(\frac{2\gamma-1}{1+\gamma}\right)^2-\left(\delta\frac{2\gamma-1}{1+\gamma}\right)^2\right)}{\left(\gamma\delta\frac{2\gamma-1}{1+\gamma}+1\right)^2}$$
$$\text{s.t.}\ 0 \leq \delta \leq 1.$$

From the first-order and the second-order conditions it follows that the unique maximizer is

$$\delta = \frac{\gamma+1}{\gamma+2\gamma^2+2},$$

and evaluating the objective function at this point gives

$$\frac{1}{4}\frac{\gamma^2}{2\gamma^2+1}\frac{(2\gamma-1)^2}{\gamma+1}.$$

Using this result along with Equation (15) proves Equation (17).

Case 2: $\gamma > 2$

$$\max_{\delta} \frac{\gamma^2\left(\delta\left(\frac{1}{\gamma-1}\right)^2-\left(\delta\frac{1}{\gamma-1}\right)^2\right)}{\left(\gamma\delta\frac{1}{\gamma-1}+1\right)^2}$$
$$\text{s.t.}\ 0 \leq \delta \leq 1.$$

From the first-order and the second-order conditions it follows that the unique maximizer is

$$\delta = \frac{\gamma-1}{3\gamma-2},$$

and evaluating the objective function at this point gives

$$\frac{1}{4}\frac{\gamma^2}{(2\gamma-1)(\gamma-1)}.$$

Using this result along with Equation (15) proves Equation (18).

Proof of Proposition 7. To keep the expressions shorter, we use subscripts only on the supplier's fairness parameters and, on the intermediate steps, employ the following abbreviations: $x = E\left[\frac{\alpha}{1+\alpha}\right]$, $z = E\left[\left(\frac{\alpha}{1+\alpha}\right)^2\right]$.

Case 1: The retailer is under disadvantageous inequality. By taking the second derivative of the supplier's expected utility, $E_\alpha(U_S) = E_\alpha(\pi_S - \beta_S(\gamma\pi_S - \pi_R))$, one finds that

$$\begin{aligned}\frac{d^2E_\alpha(U_S)}{dw^2} &= \frac{B}{2}\{\beta - 2x\gamma + 2\beta\gamma - z\beta\gamma^2 + 2x\beta\gamma^2 - 2\}\\ &= \frac{B}{2}\{(\beta_S + 2\beta_S\gamma - 2) - 2x\gamma - z\beta_S\gamma^2\\ &\quad + (x^2\beta_S\gamma^2 - x^2\beta_S\gamma^2) + 2x\beta_S\gamma^2\}\\ &= \frac{B}{2}\left\{(\beta_S + 2\beta_S\gamma - 2) - \beta_S\gamma^2 Var\left[\frac{\alpha}{1+\alpha}\right]\right.\\ &\quad \left.+ \gamma E\left[\frac{\alpha}{1+\alpha}\right]\left(2(\beta_S\gamma - 1) - E\left[\frac{\alpha}{1+\alpha}\right]\beta_S\gamma\right)\right\}.\end{aligned}$$

In this expression, the first term is strictly negative and the other terms are negative because $\beta_S \leq 1/(1+\gamma)$. Therefore, the whole expression is strictly negative, implying that the expected utility is concave and the optimal wholesale price is unique. Next, evaluating the first derivative at w_D gives

$$\begin{aligned}\left.\frac{dE_\alpha(U_S)}{dw}\right|_{w=w_D} &= \frac{(A-Bc)}{4\left(1-E\left[\frac{\alpha}{1+\alpha}\right]\gamma\right)}\{2x\beta_S\gamma - \beta_S - z\beta_S\gamma^2\\ &\quad - 4x\gamma + 4x\beta_S\gamma^2\}.\end{aligned}$$

The conditions (13) imply the denominator is positive.

Next, rearranging the terms in the curly brackets gives

$$\begin{aligned}\{\cdot\} &= 2x\beta_S\gamma - \beta_S - z\beta_S\gamma^2 - 4x\gamma + 4x\beta_S\gamma^2\\ &= 2x\beta_S\gamma - \beta_S - z\beta_S\gamma^2 + (\beta_S\gamma^2x^2 - \beta_S\gamma^2x^2)\\ &\quad + 4x\gamma(\beta_S\gamma - 1)\\ &= -\beta_S(x\gamma-1)^2 - \beta_S\gamma^2(z - x^2) + 4x\gamma(\beta_S\gamma - 1)\\ &= -\beta_S\left(E\left[\frac{\alpha}{1+\alpha}\right]\gamma - 1\right)^2 - \beta_S\gamma^2\text{Var}\left[\frac{\alpha}{1+\alpha}\right]\\ &\quad - 4\gamma(1-\beta_S\gamma)E\left[\frac{\alpha}{1+\alpha}\right].\end{aligned}$$

However, it is immediate that the latter is strictly negative since $\beta_S < 1/(1+\gamma) < 1/\gamma$ implies $(1-\beta_S\gamma) > 0$. Hence, the optimal wholesale price is lower than w_D.

Case 2: The retailer is under advantageous inequality Similarly to the previous case, by taking the second derivative of the supplier's expected utility, $E_\beta(U_S) = E_\beta(\pi_S - \alpha_S(\pi_R - \gamma\pi_S))$, one finds that

$$\begin{aligned}\frac{d^2E_\beta(U_S)}{dw^2} = \frac{B}{2}&\left\{\alpha_S\left(E\left[\left(\frac{\beta}{1-\beta}\right)^2\right]\gamma^2 - 1\right)\right.\\ &\left.+ 2(\alpha_S\gamma + 1)\left(E\left[\frac{\beta}{1-\beta}\right]\gamma - 1\right)\right\},\end{aligned}$$

which is strictly negative since $S_\beta \subseteq [\frac{1}{1+\gamma}, \infty)$. Next, evaluating the first derivative at w_A gives

$$\left.\frac{dE_\beta(U_S)}{dw}\right|_{w=w_A} = \frac{\alpha_S}{4}\frac{A-Bc}{\left(1-\gamma E\left[\frac{\beta}{1-\beta}\right]\right)}\left(\mathrm{Var}\left[\frac{\beta}{1-\beta}\right] + \left(E\left[\frac{\beta}{1-\beta}\right]\gamma-1\right)^2\right),$$

which is clearly positive. Hence, the optimal wholesale price is higher than w_A. □

Notes

[1]The bounded rationality framework has a great deal of intuitive appeal as a potential explanation for why retailers sometimes reject contracts that allocate most of the channel profits to suppliers. The basic bounded rationality idea is that when people are faced with several options, they do not select the option with the highest utility with certainty; rather they select it only with some probability that depends on the relative utility of this option and the coefficient of certitude. The higher the utility and the precision parameter, the greater is the chance of choosing the option with the highest utility. Therefore, contracts that allocate less profit to the retailer are more likely to be rejected by that retailer. It has been shown both theoretically (Yi 2005) and experimentally (Bolton and Zwick 1995) that bounded rationality by itself cannot fully explain the magnitude of rejections.

[2]Although we are dealing with two-dimensional types, our statements may refer to only α or β, whenever the second was assumed to be in a certain range.

[3]We thank the review team for helping us to clarify these points.

[4]We also made the comparison using a regression model, controlling for individual heterogeneity with random effects. For the wholesale prices and efficiency levels we use linear regression, and for the rejection rates we use a logit. We also control for learning by including a linear trend term into the model. Wholesale prices and efficiency levels continue to not be different in the two treatments ($p = 0.324$ for wholesale prices and $p = 0.376$ for efficiency). Wholesale prices decrease over time ($p < 0.001$) and efficiency levels increase over time ($p = 0.002$). Rejection rates are higher in the WP-out treatment than in the WP treatment ($p = 0.009$), and rejection rates decrease over time ($p = 0.001$).

[5]We thank the review team for this observation.

[6]We did this by solving for α using $p(w) = p_M + \alpha(w-c)/(2(1+\alpha))\gamma$ and then using the estimated α to estimate w_1 and w_0, and checking whether $w_1 < w < w_0$. This is the case that corresponds to the FH segment in Figure 1. It accounts for 82% and 78% of our data for WP and WP-out treatments, respectively. In the other part of the data we cannot estimate α either because the retailer erroneously rejected the contract, because the data is in the DF segment in Figure 1, or because $p(w) < p_M$.

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