ON THE PERFORMANCE OF WHOLESALE PRICING IN THE PRESENCE OF FAIRNESS CONCERNS AND INFORMATION ASYMMETRY

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ABSTRACT

This paper studies the performance of wholesale pricing when the supply chain partners have fairness concerns. We extend the existing literature by providing a formal analysis of a model in which preferences for fairness are private information of the players. We find that wholesale pricing proves rather robust to the information regime. Many of its properties established under complete information directly carry over to incomplete information. Most interestingly, incomplete information does not imply rejections. That is, in equilibrium, the retailer order quantity is above zero. We also show that incomplete information can have a detrimental impact on efficiency.

INTRODUCTION AND LITERATURE REVIEW

It is only relatively recently that fairness considerations have been incorporated in economic models (cf. [9]). It is even more recently that fairness has been considered in the context of supply chain management (e.g., [5]). However, most current models of fairness assume that the players have full information on each others' fairness preferences, which seems a strong abstraction of reality. Here we consider information asymmetry on players' fairness preferences within a study 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 (see, e.g., [4] for a review). The basic idea is that two players 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 known that simple wholesale price contracts do not coordinate the supply chain due to double marginalization (see, e.g., [12]). Other more sophisticated contracts, such as buy-backs and two part tariffs, have been shown to coordinate the supply chain (see, e.g., [11] and [10]).

Yet, wholesale prices continue to be widely used in practice and [5] speculate that this may be in part because when fairness is considered supply chain coordination can indeed be achieved even under simple wholesale price contracts. They consider a dyadic channel where 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 [6]. This inequity aversion occurs both if the inequality is to the player's monetary advantage (advantageous inequality) or to his/her monetary disadvantage (disadvantageous inequality), where the former is assumed to be preferred over the latter. The authors show that, in this setting, a simple wholesale contract can coordinate the supply chain so long as the retailer is sufficiently averse to advantageous inequality. Their model assumes the supplier has perfect information on the retailer's preferences with respect to inequity. However, they acknowledge that perfect information is a strong assumption in many practical settings.

Therefore, following [7] and [2] we seek to incorporate information asymmetry with respect to the player's fairness preferences. Our key contribution is a formal analysis of wholesale pricing with fairness considerations being private information. From supply chain coordination perspective, our main findings are that (i) no matter how much a particular retailer cares about fairness he always accepts the supplier's offer and, (ii) efficiency is lower than when preferences are common knowledge.

The paper is organized as follows. Section "The model" presents the basic model considered in the paper. Section "Wholesale price contract equilibrium" then presents the equilibrium. Section "An approximate characterization …" uses an approximation to examine the case where the retailer is not highly inequity adverse. Finally, Section "Conclusions and extensions" summarizes the paper and proposes possible extensions. All proofs are given in the Appendix.

THE MODEL

We consider a standard bilateral monopoly setting with a supplier, who produces an infinitely divisible good at constant cost c per unit, and a retailer, who faces a linear 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. The retailer either accepts the contract or rejects it.

Introducing fairness concerns into the model involves two modifications of the standard model, which assumes that both players care only about their own earnings. To this end, we use the two-player utility function specification proposed by [6]. This is the same as that used by [5] with the assumption that the fair outcome, which [5] allow to be an arbitrary fraction γ, is actually an equal split (i.e., $\gamma = 1$). Second, the extent to which a particular retailer is concerned with the relative outcomes is this retailer's private information. This model is chosen for its tractability, its relationship to existing work, and because it yields insights within a clean, uncomplicated setting.

Let π_R and π_S denote the retailer's and the supplier's profit resulting from the retailer's acceptance or rejection of a contract. Then, the retailer's utility (the supplier's utility is analogous) is

$$U(\pi_R, \pi_S \mid \alpha, \beta) = U_R = \pi_R - \alpha \left[\max(\pi_S - \pi_R, 0)\right] - \beta \left[\max(\pi_R - \pi_S, 0)\right] \qquad (1)$$

Here, $\alpha \geq 0$ measures the retailer's disutility from earning less than the supplier (the disadvantageous inequality) and $\beta \geq 0$ measures the retailer's disutility from earning more than the supplier (the advantageous inequality). Previous research ([1], [7], [6] and [3]) strongly suggest that amount of positive reciprocity is very small so that it is sufficient to consider a limiting case of $\beta = 0$. Also, the data from experiments testing performance of wholesale pricing, for example from [8], indicates that the suppliers are earning notably more than the retailers. That is, the retailers are experiencing disadvantageous inequity and, therefore, the retailer's β is simply irrelevant. Overall, the previous research suggests that the most relevant setting is when the supplier is a profit-maximizer and the retailer is averse to advantageous inequity. However, keeping in mind importance positive reciprocity (see [5]) on supply chain performance, we allow for the retailer's β and our model can be generalized to allow for the supplier's β as well.

Following the approach of [2] to model bargaining as a Bayesian game, where players' types reflect their social preferences, we assume that when the supplier offers a contract she knows only distributions of α and β but not their realizations, which are private information of the retailer. Because the retailer moves second, it is irrelevant what he knows about the supplier's preferences. He makes his decision under complete information. As is common in the information asymmetry literature, we refer to the pair of individual characteristics of a player (α,β) as a type. Yet, for brevity, most of our statements refer to only α or β, implying that the other can be anything.

Under a wholesale price contract the supplier offers a uniform price w per unit, the retailer chooses market price p and orders $q = d(p)$. As a result, the supplier earns $\pi_S = (w-c)d(p)$ and the retailer earns $\pi_R = (p-w)d(p)$. If the retailer rejects (i.e., $q=0$), both earn zero. For the time being we assume that neither party has an outside option but we will later relax this assumption.

WHOLESALE PRICE CONTRACT EQUILIBRIUM

To characterize equilibrium of this sequential-moves game, we use backward induction. That is, we need to look at the retailer's decision first and then analyze the supplier's decision in the light of the retailer's best-response. For the retailer, since she makes the decision under complete information, one can directly apply results of [5] without re-deriving them (and using $\gamma = 1$). Thus,

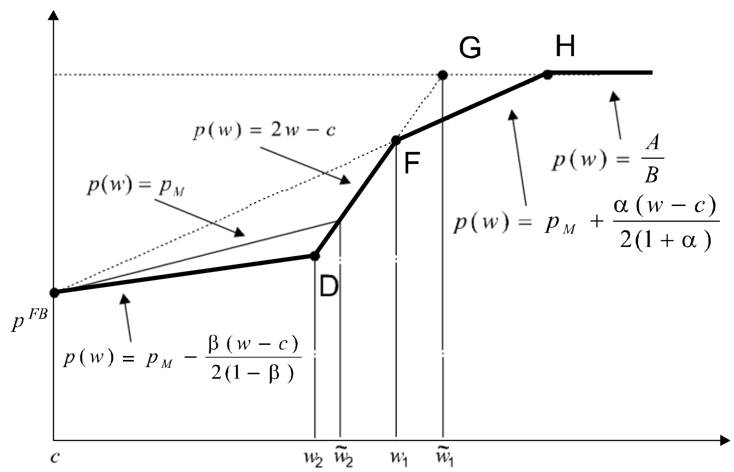
$$p(w) = \begin{cases} \frac{A+Bw}{2B} - \frac{\beta(w-c)}{2(1-\beta)} & if \quad w \le w_2 \\ 2w - c & if \quad w_2 < w \le w_1 \\ \frac{A+Bw}{2B} + \frac{\alpha(w-c)}{2(1+\alpha)} & if \quad w_1 < w \le w_0 \\ \frac{A}{B} & if \quad w_0 < w \end{cases}, \tag{2}$$

where

$$w_0 = \frac{A+\alpha(A+Bc)}{B(1+2\alpha)} > w_1 = \frac{A+\alpha(A+Bc)+2Bc}{B(3+2\alpha)} > w_2 = \frac{A+2Bc-\beta(A+Bc)}{B(3-2\beta)}$$

Expression (2) is piecewise linear and consists of several parts. For $w < w_2$, the best-response price is lower than that of a profit-maximizing retailer. When $w_2 < w < w_1$ the retailer chooses a market price that results in a 50-50 profit split. If $w > w_1$ then the retailer sets a price higher than a profit-maximizer would do. This offer may even get rejected (if $w > w_0$). An observation to be used later is that the behavior of the best response when $w > w_1$ as well as the value of w_1 itself do not depend on β and, similarly neither w_2 nor the behavior of the best-response when $w < w_2$ depends on α .

Figure 1. The retailer's best response.



Horizontal axis: wholesale price, *w*
Vertical axis: market price, *p*

Figure 1 plots this best-response price of a retailer for arbitrary α and β with a thick solid line, which is piecewise linear and consists of several parts. It is worth reviewing some of the insights behind this curve. 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 her low wholesale price. Segment D to F corresponds to a $50/50$ split between the two players. On the F to H segment the retailer chooses a price above the price that a profit-maximizing retailer would choose because he is suffering from the disadvantageous inequality. Finally, the line to the right of point H corresponds to 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 (when fairness is considered).

Note that the locations of points F and H depend on α. As α goes from zero to infinity, point F moves along the 50/50 line from point D to point G and point H moves to G. Denote the $w-$coordinate of point D when $\beta = 0$ and the $w-$coordinate of point G as

$$\tilde{w}_2 \equiv w_2\big|_{\beta=0} = w_1\big|_{\alpha=0} = \frac{A+2Bc}{3B} \text{ and } \tilde{w}_1 \equiv w_1\big|_{\alpha=\infty} = \frac{A+Bc}{2B}. \tag{4}$$

One can verify that $\tilde{w}_2$ is the only wholesale price that induces any retailer, regardless of α and β, to respond with a 50-50 profit split, whereas $\tilde{w}_1$ is the supplier's optimal price if the retailer were a pure profit-maximizer.

Notice, [5] assume $\beta \in [0,1)$. However, extending the analysis to $\beta \geq 1$ is straightforward and, although (2) assumes $\beta \in [0,1)$, all further statements made regarding big values of β, for example $\beta \geq \frac{1}{2}$, mean $\frac{1}{2} \leq \beta \leq \infty$.

The complete information equilibrium has several important properties. First, it is never optimal for the supplier to set $w > \tilde{w}_1$. Second, the retailer's profit share is at least as big as when the retailer is a pure profit-maximizer. Third, [5] show that as soon as the retailer is sufficiently averse to the advantageous inequality ($\beta \geq \frac{1}{2}$), the wholesale contract coordinates the channel. And, of course, there are no rejections since the supplier, knowing the retailer's preferences, proposes a contract that the retailer accepts. Interestingly, as we prove below, these properties generalize and hold under incomplete information as well.

Proposition 1. *The wholesale price contract coordinates the channel under incomplete information if and only if all the retailer's types are sufficiently averse to the advantageous inequity:* $\beta \geq \frac{1}{2}$.

Another important property of the wholesale price contract, that is of interest on its own, is its robustness to the supplier's ignorance. As the next proposition shows, regardless of whether the supplier knows the true distribution of the retailer's type or holds an absolutely wrong belief, the price she sets according to her belief incurs no rejections.

Proposition 2. *Incomplete information does not affect the rejection rate. In equilibrium, the supplier charges* $w \leq \tilde{w}_1$ *and sees no rejections.*

This property is not absolute, though. In reality, the rejection rate may be positive because of various factors left outside of 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 the rejection results. Another reason for rejections can be the retailer's outside option.

Proposition 3. *If the retailer has an outside option* $R > 0$ *(in terms of utility), then due to incomplete information, the rejection rate can be positive.*

To illustrate this proposition, start with a standard model of the profit-maximizing retailer ($\alpha \equiv 0$, $\beta \equiv 0$). The supplier's optimal offer is $w = \tilde{w}_1$. Next, consider a two-type scenario: apart from $\alpha = 0$, there is a very (arbitrary) small $\varepsilon > 0$ mass of types close to $\alpha = \infty$. To ensure their participation the supplier would have to offer $\hat{w}$ but this is not optimal because the overwhelming majority has $\alpha = 0$. Therefore, the supplier's optimal offer is still $w = \tilde{w}_1$ and implies the rejection rate of $\varepsilon > 0$.

AN APPROXIMATE CHARACTERIZATION OF THE EQUILIBRIUM

In the previous section we observed that if the retailers are sufficiently fair-minded, then the supply-chain coordination can result. However, this leaves open the question of what happens when their retailers are not sufficiently fair-minded (i.e., $\beta < 1/2$). This section seeks to shed more light on the efficiency of wholesale pricing under incomplete information regarding preferences for fairness. Propositions presented in this section relate to the approximate characterization only but for brevity statements do not include words approximate characterization.

Moving from one extreme, when the retailers are strongly averse to disadvantageous inequality, to another, when aversion to unfair outcomes is mild, one can derive an approximate characterization of the equilibrium. To this end, consider the case when almost all density of the type distribution is concentrated around zero (see Condition 5 below for the exact specification). Intuitively, in this case, the optimal wholesale price will be close to $\tilde{w}_1$ and the proportion of types that respond to this price on the 50-50 line will be very small. That is, we make the following assumption (the subscript L indicates low aversion).

Assumption 4. Most of the retailers respond with

$$p_L(w) = \frac{A + Bw}{2B} + \frac{\alpha(w - c)}{2(1 + \alpha)} \tag{5}$$

The supplier's approximate problem is then:

$$\max_{w}(w-c)E\left[d(p(w))\right]$$
$$s.t.$$
$$p_L(w)=\frac{A+Bw}{2B}+\frac{\alpha(w-c)}{2(1+\alpha)}$$

To solve it, we first eliminate the constraint by substituting $p(w)$ into the objective function via

$$d(p_L(w))=\frac{A-Bw}{2}-\frac{B(w-c)}{2}\frac{\alpha}{\alpha+1} \tag{6}$$

so that

$$E\left[d(p_L(w))\right]=\frac{A-Bw}{2}-\frac{B(w-c)}{2}E\left[\frac{\alpha}{\alpha+1}\right]. \tag{7}$$

Now it is straightforward to find the supplier's optimal wholesale price. To suggest some additional insight, note that the preceding expression can be re-stated in terms of α' : $\frac{\alpha'}{\alpha'+1}=E\left[\frac{\alpha}{\alpha+1}\right]$, where α' can be thought of as a representative retailer's type. Notice also that, since $\alpha>0$ the ratio $\frac{\alpha}{\alpha+1}$ is concave and, by Jensen's inequality,

$$E\left[d(p_L(w))\right]=\frac{A-Bw}{2}-\frac{B(w-c)}{2}E\left[\frac{\alpha}{\alpha+1}\right]$$
$$>\frac{A-Bw}{2}-\frac{B(w-c)}{2}\frac{E\left[\alpha\right]}{E\left[\alpha\right]+1}.$$

Observe that $\alpha'<E[\alpha]$, which may be counterintuitive.

In terms of α' the optimal wholesale price is given by

$$w_L=\frac{A+Bc}{2B}-\frac{(A-Bc)\alpha'}{2B(1+2\alpha')} \tag{8}$$

and, in particular, is highest when $\alpha'=0.$ That is, the supplier charges the highest wholesale price when she thinks she is dealing with a profit-maximizing retailer.

Condition 5. *Assumption 4 is justified when the mass of retailer types such that*

$$\alpha>\frac{1}{2E\left[\frac{\alpha}{1+\alpha}\right]}-1 \tag{9}$$

is negligible.

Although this condition is not very intuitive because it implicitly contains a density function, other, more appropriate for practical purposes conditions can be derived from it. For example, if the distribution support is such that the lowest α is $\alpha=1$ then Assumption 4 is not valid. In another extreme, of the distribution support is such that the highest α is $\alpha=\frac{1}{2}$ then Assumption 4 holds for all types, that is, the analysis is no longer approximate but exact.

We proceed with characterizing the equilibrium by computing the expected market price.

Proposition 6. *The expected market price is equal to that of the wholesale price contract when the retailer is a profit-maximizer, i.e.,*

$$E[p_L]=\frac{1}{4B}(3A+Bc). \tag{10}$$

Thus, wholesale pricing once again proves robust to fairness concerns. However, unlike the result of Proposition 2, this one does assume the supplier correctly knows at least $E\left[\frac{\alpha}{1+\alpha}\right]$.

However, knowing the expected market price is not enough to make any conclusions regarding channel efficiency. The next proposition covers the gap.

Proposition 7. *The expected channel profit equals*

$$E[\pi_C] = \frac{3(A - Bc)^2}{16B}\left(1 - \frac{Var[\frac{\alpha}{1+\alpha}]}{3(E[\frac{\alpha}{1+\alpha}]+1)^2}\right), \tag{11}$$

and hence the expected efficiency of the wholesale contract is lower when the retailer is fair-minded.

In the expression for expected channel profit, the first term is the channel profit when the retailer is a profit-maximizer and the second term, which is due to the distribution of the fairness parameter, is less than unity. We would like to make two observations at this point. First, notice that the negative term in the last expression is likely to be small. The reason is that its numerator, $Var[\frac{\alpha}{1+\alpha}]$, tends to be a small number, compared to the denominator, and, therefore, the impact of the second term, if not completely negligible, can be difficult to detect in an experiment. In numerical simulations with uniform, exponential, and truncated normal (to ensure positive values of α) typical values of the second factor are of 10^{-4} or 10^{-3} order of magnitude and we could not find a combination of parameters that would make it bigger that 0.02. In fact, it is a remarkable observation. The efficiency does depend on the distribution of the fairness coefficient but its impact on the efficiency is practically negligible regardless of the distribution form.

CONCLUSIONS AND EXTENSIONS

This paper extends the existing literature on supply chain coordination by studying wholesale pricing in the presence of fairness concerns, treating the latter as private information. We find that wholesale pricing proves extremely robust to this type of information asymmetry. In particular, many of the properties derived under the assumption of complete information indeed carry over to the setting with information asymmetry and, moreover, are almost distribution-free with respect to inequity preferences. Thus, this contract coordinates the channel when the retailer is sufficiently averse to advantageous inequity and the supplier knows this. However, we find that when aversion to advantageous inequity is not strong enough then aversion to disadvantageous inequity can actually make the supply chain *less* efficient; in practice, this efficiency loss is likely to be small. We also establish another kind of robustness of wholesale pricing: as long as the supplier chooses a wholesale price rationally, given beliefs, the retailer orders some positive amount. In other words, the contract never gets rejected no matter how strongly the retailer is concerned about fairness and, surprisingly, no matter what the supplier knows about the retailer's preferences. The supplier may hold incorrect beliefs and offer a wholesale price that is not, in fact, optimal. Nevertheless, the contract will not be rejected.

A number of extensions to this work are possible but outside the scope of this study. For example, we argued that the appropriate reference point is an equal profit split. While we believe relaxing this assumption is unlikely to change the results, this must be formally shown. Moving in this direction and treating the reference point as private information, just as we did with respect to the fairness scaling coefficients, would result in an even more general, truly incomplete information model. In another direction, the model can be generalized by relaxing the assumption of linear demand. It seems particularly important to find out if relaxing any of the assumptions will destroy the "no rejections" result.

APPENDIX

Proof (Proposition 1) A well known result is that dealing with a pure profit-maximizing retailer the supplier obtains exactly $1/2$ of the channel profit. When dealing with a fair-minded retailer by setting $w = w^{FB} : (p^{FB} - w^{FB}) = (w^{FB} - c)$ the supplier induces all types $\beta \geq \frac{1}{2}$ to respond with $q = q^{FB}$ and obtains exactly a half of it. Since there are no any other types, $w = w^{FB}$ coordinates the channel. ■

Proof (Proposition 2) First, consider the supplier's profit from dealing with an arbitrary retailer's type α if the supplier raises the wholesale price from $\tilde{w}_1$ to $\tilde{w}_1 + \delta$ (where $\delta > 0$) . The retailer, if α is big enough, may reject the offer so that the supplier incurs a loss. If not, the result will be (using (2)):

$$\pi_S(\tilde{w}_1 + \delta) - \pi_S(\tilde{w}_1) = -\frac{1}{2}\frac{\delta}{\alpha + 1}\left(\alpha(A - Bc) + B\delta(1 + 2\alpha)\right). \quad (12)$$

Since the RHS is negative $\forall \alpha$, setting $w > \tilde{w}_1$ is not optimal.
Second, from (2), the retailer's best-response price is increasing in α and decreasing in β . Therefore, the type most prone to rejecting has $\alpha = \infty$ and $\beta = 0$, its best-response is increasing in w , and the lowest wholesale price that this type rejects is $w = \tilde{w}_1$. However, this is the only type that rejects $w = \tilde{w}_1$ and its measure is zero. But, as we have just proven above, in the equilibrium $w \le \tilde{w}_1$. Therefore, the equilibrium rejection rate is zero. Since this proof does not assume knowledge of the true distribution of the retailer's type, it holds for any belief the supplier may have. ■

Proof (Proposition 3) The type most prone to rejections is $\alpha = \infty$ and for any w that lies between $\tilde{w}_2$ and $\tilde{w}_1$ she chooses the market price on the 50-50 line (where $p = 2w - c$). Therefore, the retailer's utility equals to her profit and the offer gets rejected when the wholesale price is high enough so that

$$\pi_R = (A + Bc - 2Bw)(w - c) < R \quad (13)$$

The cut-off wholesale price, $\hat{w}$, is given by the larger root of the quadratic equation

$$(A + Bc - 2Bw)(w - c) = R. \quad (14)$$

However, $w > \hat{w}$ gets rejected not only by the type $\alpha = \infty$ but also, since the retailer's utility (from (1) and (2)) is continuous and decreasing in both α and w, by a non-zero measure of sufficiently high types. ■

Proof (Condition 5) For the Assumption 4 to hold, the wholesale price w_L must fall between w_0 and w_1, according to (2). First, one can immediately verify that $\forall \alpha, w_L < w_0$. Second, since w_1 as a function of α is monotone increasing, there exist a highest (cut-off) type for which (4) is still true. This type can be found by setting $w_1 = w_L$. By rearranging the terms and simplifying one obtains (5). ■

Proof (Proposition 6) Substituting (8) into (5) and taking the expectation gives $E[p_L]$, which can be recognized as the retail price under the wholesale price contract without fairness considerations. ■

Proof (Proposition 7) The realized channel profit is given by

$$\pi_C = (p_L(w_L) - c)d(p_L(w_L)). \quad (15)$$

Taking the expectation one obtains expected channel profit as given. In this product, the first term (factor) is exactly the channel profit when the retailer is a profit-maximizer and the second term (factor), which is due to the distribution of the fairness parameter, is less than unity. ■

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