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To share or withhold? contract negotiation in buyer-supplier-supplier triads

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Abstract:

Purpose

This paper seeks to fill the literature gap that lacks of exploring negotiation strategy with competing partners under asymmetric production-cost information. We examine firms' optimal contract negotiation strategies in buyer-supplier-supplier triads where there are concurrent negotiations between the retailer and two competing manufacturers.

Design/methodology/approach

We consider a two-echelon supply chain, in which, the retailer has the option of segmented or unified negotiation policy, whereas the two competing manufacturers can withhold or share production-cost information in the negotiation. Based on game theory, we derive the manufacturers' optimal wholesale prices and the retailer's optimal retail prices with eight possible scenarios. Optimal strategic choices and operational decisions are then explored through the comparative analysis of equilibriums of eight possible scenarios.

Findings

We find that the retailer will adopt different negotiation strategies depending on manufacturers' decisions on sharing or withholding their production-cost information. When both manufacturers share their production-cost information, the retailer will adopt a unified negotiation policy. The high-efficiency manufacturer should adopt the same information-sharing strategy as the low-efficiency manufacturer in order to gain more profit.

Originality/value

Our modelling helps to bring further clarity in supply chain contract negotiation by offering a conceptual framework to enhance our understanding of the effects of information-sharing strategy and negotiation policy in the negotiation process form the perspectives of all engaging parties. Managerial insights derived from our research will enable retailers and manufacturers to make informed and better strategic and operational decisions to improve market competitiveness.

Keywords: Negotiation policy; Asymmetric information; Buyer-supplier-supplier triads; Game theory

1. Introduction

Over the past few decades there has been a growing body of research on negotiation strategy and the effects of symmetric and asymmetric information in supply chain management (Dwyer and Walker, 1981; Feng and Lu, 2013; Gurnani and Shi, 2006; Mishra and Prasad, 2005). The stream of research on supply chain contract negotiation strategy has demonstrated that negotiation power enables stronger firms to compel other firms to accept their terms of trade and even win concessions (Emerson, 1962; Crook and Combs, 2007; El Ouardighi and Kogan 2013; Maglaras et al. 2015). Although scholars have recognised for some time that exchange relationships are often characterised by an unequal access to information and power distribution between the parties (Dwyer, 1984; Shang et al., 2016, Luo et a. 2017), our understanding of negotiation under asymmetric information conditions remains limited. Indeed, in spite of the growing recognition of the importance of negotiation power and access to information in supply chain interactions (Frazier *et al.*, 2009; Li et al. 2019), scholars have failed to offer a comprehensive model to explain negotiation strategy with competing partners under asymmetric production-cost information.

Our study seeks to fill this gap in our understanding by examining firms' optimal contract negotiation strategies in buyer-supplier-supplier triads. We explore the issue in the context of a retailer and manufacturers' interactions where there are concurrent negotiations between the retailer and two competing manufacturers. Under this setting, the retailer is the dominant player in the supply chain, which becomes more and more common. The Stackelberg games are widely used to model the supply chain and bestow unequal negotiation powers on players (Kim and Kwak 2007; Nagarajan and Bassok, 2008; Feng and Lu, 2013; Xiao et al. 2015). The retailer, as the Stackelberg leader, has two normal negotiation policies which are used to negotiate wholesale prices with the manufacturers: segmented negotiation policy and unified negotiation policy. In a segmented negotiation policy, the retailer negotiates with manufacturers separately on the basis of their production costs and the two manufacturers set different wholesale prices to the retailer. In a unified negotiation policy, the retailer negotiates with both manufacturers simultaneously according to their production costs and the two manufacturers set a single wholesale price to the retailer.

Furthermore, manufacturers have private information regarding their own production-cost. They can choose to withhold or share their production-cost information with the retailer in the contract negotiation. From the manufacturers' perspective, withholding the production-cost information may enable them to gain higher profit margin in the negotiation of wholesale prices with the retailer. In contrast, sharing production-cost information with the retailer will help manufacturers to secure wholesale prices that protect profit gain but with lower margins. In addition, a presence of a competing manufacturer brings further complexity to the problem. To help firms make the optimal strategic and operational decisions in the contract negotiations in the context of buyer-supplier-supplier triads, it is essential to have a comprehensive understanding of how the retailer's negotiation policy (segmented negotiation policy vs. unified negotiation policy) and the manufacturers' production-cost information strategy (withholding vs. sharing) affect their financial performances.

The rest of this paper is organised as follows. In the next section, we present a comprehensive overview of the literature on negotiation strategy and asymmetric information. This is then followed by Section 3 which explicates the contours of our proposed unified model and assumptions and derives the manufacturers' optimal wholesale prices and the retailer's optimal retail prices. Based on these results, the penultimate section discusses the choice of retailer's negotiation policies and the choices of the manufacturers' production-cost information-sharing strategies in Section 4. The section also highlights the effect of manufacturers' production efficiency on their decisions and performance. The final section concludes by outlining the research contributions, managerial implications, and a number of promising avenues for future research.

2. Literature Review

Our study is mainly related to two streams of the literature: (1) supply chain contract negotiation, and (2) power in supply chain contract negotiation. Now we discuss how our research relates to these two streams of the literature.

2.1 Supply chain contract negotiation

One of the distinctive features of supply chains is the contract negotiation that occurs between manufacturers and retailers (Iyer and Villas-Boas, 2003). Negotiation behaviour entails haggling over the terms and conditions by channel members (Dwyer, 1984). This is a kind of "give and take" interaction shaped by the quality of information held by each party (Dwyer, 1984; Feng *et al.*, 2015; Fu et al. 2017). Since many critical components are negotiated between supply chain parties, it is important to understand the impact of negotiation strategy on collaborative intentions in buyer–supplier relationships (Thomas et al. 2013).

Thomas et al. (2018) argued that supply chain firms should select their negotiation strategy carefully as the decision on negotiation strategy can have long-term effects on the overall relationship between them extending beyond the single negotiation encounter.

Many factors need to be considered in the supply chain contract negotiation. Interestingly, a well-developed line of research suggests that the negotiation processes and eventual agreement between supply chain members are shaped by factors such as quality of information, level of expertise and ability to bargain for favourable deals (Dwyer and Walker, 1981). Shang and Wang (2015) stated that risk aversion and negotiation power have a profound effect on the selection of optimal parameters in the profit-sharing contract negotiation. Chen et al. (2019) found that along with the external market characteristics and internal operational capabilities, negotiation power plays a significant role in the supply contract negotiation with a supplier, who is also its market rival.

2.2 Power in supply chain negotiation

Negotiation power can be defined as the channel member's ability to favourably alter his or her negotiating position to win concessions from the other parties involved in a negotiation and thereby, change the outcome of a negotiation (Yan and Gray, 1994). Negotiation is an essential element in a firm's ability to minimise the possibility of conflict in channel interactions (see Morton and Zettelmeyer, 2004). Prior to negotiation, some channel members are more likely to hold better information about production costs, packaging and design, which may influence and shape their negotiation position. Under conditions of unequal power and unequal access to information, a powerful party in a negotiation is more likely to dictate the terms and win concessions (Dwyer and Walker, 1981). This line of research has suggested that the availability of alternatives not only influences the negotiation power of the channel members, but also how the power is utilised in the negotiation (Bacharach and Lawler, 1984).

One strand of related literature contends that a negotiation partner with more alternatives is more likely to be powerful due to his or her ability and willingness to threaten and walk away from a deal (Yan and Gray, 1994; Fisher and Ury, 1981). This position enhances the channel members' negotiation power and thereby squeezes better deals from the negotiating partner. In an unbalanced power structure with a retailer and two competing manufacturers, each manufacturer may be forced to come to a deal quickly to mitigate the chances of losing to the rival. In an attempt to enhance his or her negotiation position, mitigate the risk of opportunism and protect sensitive information, some channel members may opt against sharing cost information with other partners (Frazier *et al.*, 2009). Therefore, such negotiations are characterised by both information withholding and information sharing between channel partners.

Another relevant stream of research is the power dependence perspective (Emerson, 1962). The theory notes that "the power of A over B is equal to and based upon the dependence of B upon A" (Emerson, 1962). This theory contends that access to critical information (information power) about a product or cost by a party reduces his or her dependence on others (Emerson, 1962; Hickson *et al.*, 1971). The information power strengthens his or her position in business negotiations. Scholars have long recognised negotiation as one of the effective strategies that channel members can employ to deal with other members' power (Dwyer and Walker, 1981). Firms with weak market power may form a coalition to counterbalance the clout and effect of a dominant channel member (Nagarajan and Bassok, 2008). Another related line of research has suggested that a less powerful party may also seek additional information to counterbalance or strengthen his or her negotiating position (Cook and Emerson, 1978; Dwyer and Walker, 1981).

A growing number of studies have looked at the impact of the supply chain power structure on firms' decisions and performances covering various topics such as channel selection in the mobile phone supply chain (Chen and Wang 2015), pricing and effort decisions in a closed-loop supply chain (Gao et al. 2016) supply chain coordination for environmental improvement (Chen et al. 2017), and retail supply chain product choice and pricing decisions (Luo et al. 2018). These studies show that different power structures have significant impact on the firms' strategic and operational decisions as well as firms' individual and collective profits.

2.3 *Contribution to the literature*

In this paper, we examine this important but largely unexplored issue of a retailer's negotiation strategy and two competing manufacturers' production-cost information strategy in the wholesale contract negotiation under the setting of buyer-supplier-supplier triads. Our study makes two main contributions to the literature. First, despite the accumulating body of literature on supply chain negotiation and the seeming importance of the issue (Crook and Combs, 2007), past studies have largely failed to identify manufacturers' optimal strategy in supply chain wholesales contract negotiation, where there is a retailer and two competing manufacturers. Based on game theory, we derive the manufacturers' optimal wholesale prices and the retailer's optimal retailer prices. In addition, we also shed light on the retailer's optimal negotiation strategy under different production-cost information strategies adopted by manufacturers. Second, in spite of a growing body of literature on negotiation power in supply chains (Dwyer and Walker, 1981; Crook and Combs, 2007; Sheu and Gao 2014) and information asymmetry (Xu *et al.,* 2010; Boeh, 2011; Li and Li 2016; Tong and Crosno 2016), there has been little attempt to integrate these streams of research. Consequently, our understanding of retailer's negotiation strategy under asymmetric production-cost information is limited. This study fills this void in our understanding by integrating a retailer's negotiation strategy and manufacturers' production-cost information strategy to develop a new perspective on supply chain decisions.

3. The models and equilibrium analysis

We consider a two-echelon supply chain that is composed of two competitive manufacturers and a common retailer. Figure 1 illustrates our conceptual approach to the issue. The retailer is assumed as the Stackelberg leader and the two manufacturers are assumed as Stackelberg followers.

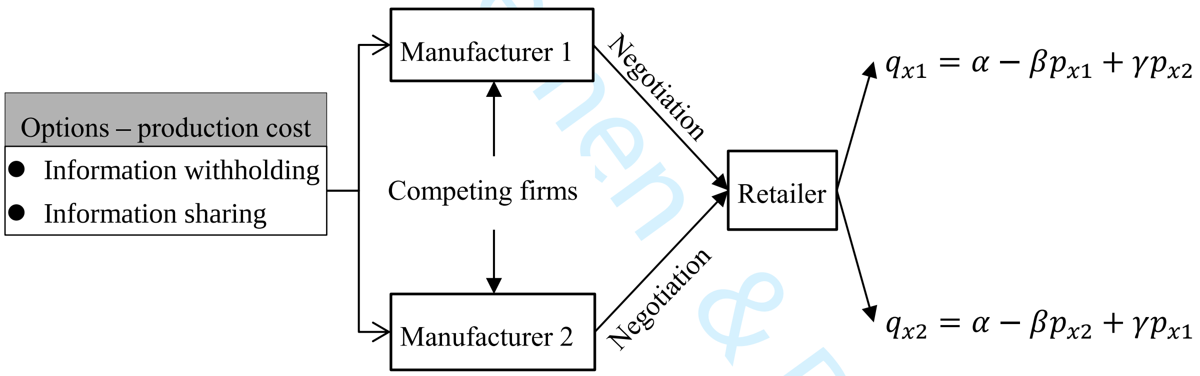

Figure 1 Two-echelon supply chain with two manufacturers and a retailer

The manufacturers produce a substitutable product with different production efficiencies. Without loss of generalisability, we assume that the relationship between manufacturer i's unit production cost, c_i ($i = 1,2$), is $c_1 < c_2$, that is, manufacturer 1 has higher production efficiency as compared to manufacturer 2. The retailer orders products from the manufacturers and then sells them to end customers. If the manufacturers withhold their production-cost information, the retailer will negotiate with manufacturers on the basis of industry-average production cost, that is $\frac{c_1+c_2}{2}$. According to the manufacturers' information-sharing strategies (withholding or sharing production-cost information strategy) and the retailer's negotiation strategy (segmented or unified negotiation policy), there are eight possible scenarios (x=1, 2, 3, 4, 5, 6, 7, 8) as described in Table 1.

Table 1. Scenario of retailer's negotiation policies and manufacturers' information sharing strategy

x	**Description**
1	Segmented negotiation and both manufacturers sharing their cost information.
2	Unified negotiation and both manufacturers sharing their cost information.
3	Segmented negotiation and both manufacturers withholding their cost information.
4	Unified negotiation and both manufacturers withholding their cost information.
5	Segmented negotiation and only manufacturer 1 sharing his cost information.
6	Unified negotiation and only manufacturer 1 sharing his cost information.
7	Segmented negotiation and only manufacturer 2 sharing his cost information.
8	Unified negotiation and only manufacturer 2 sharing his cost information.

For the retailer's negotiation strategy x, manufacturer i's wholesale price is w_{xi}, the retailer's corresponding retail price is p_{xi}, and the demand for product i is q_{xi}. Similar to the conventional demand function (Choi, 1991; Chen and Wang, 2017; Chen *et al.*, 2016), the demand function is defined as $q_{xi} = \alpha - \beta p_{xi} + \gamma p_{xj}$ $(i,j = 1,2,\ i \neq j)$, where α represents the potential market scale of product, β means the self-price sensitivity and γ means the cross-price sensitivity. $\beta > \gamma$ indicates that the self-price sensitivity is higher than the cross-price sensitivity. We assume that the retailer's marginal profit of product i is m_{xi}, that is, $m_{xi} = p_{xi} - w_{xi}$.

If manufacturer 1 shares his production cost, the actual cost c_1 is used in the negotiation, then manufacturer 1's profit with retailer's negotiation strategy x, denoted as $\pi_{x1}^m(w_{x1})$, is:

$$\pi_{x1}^m(w_{x1}) = (w_{x1} - c_1)[\alpha - \beta(m_{x1} + w_{x1}) + \gamma(m_{x2} + w_{x2})] \quad (1)$$

The first term is manufacturer 1's unit product profit, and the second term is the retailer's order quantity.

Similarly, if manufacturer 2 shares his production cost, the actual cost c_2 is used in the negotiation, then manufacturer 2's profit with retailer's negotiation strategy x, denoted as $\pi_{x2}^m(w_{x2})$, is:

$$\pi_{x2}^m(w_{x2}) = (w_{x2} - c_2)[\alpha - \beta(m_{x2} + w_{x2}) + \gamma(m_{x1} + w_{x1})] \quad (2)$$

The first term is manufacturer 2's unit product profit and the second term is the retailer's order quantity.

If manufacturer 1 withholds his production cost, the industry average cost $\frac{c_1+c_2}{2}$ is used in the negotiation, then manufacturer 1's profit with retailer's negotiation strategy x, denoted as $\bar{\pi}_{x1}^{m}(w_{x1})$, is:

$$\bar{\pi}_{x1}^{m}(w_{x1}) = \left(w_{x1} - \frac{c_1+c_2}{2}\right)[\alpha - \beta(m_{x1} + w_{x1}) + \gamma(m_{x2} + w_{x2})] \quad (3)$$

Similarly, if manufacturer 2 withholds his profit, the industry average cost $\frac{c_1+c_2}{2}$ is used in the negotiation, then manufacturer 2's profit with retailer's negotiation strategy x, denoted as $\bar{\pi}_{x2}^{m}(w_{x2})$, is:

$$\bar{\pi}_{x2}^{m}(w_{x2}) = \left(w_{x2} - \frac{c_1+c_2}{2}\right)[\alpha - \beta(m_{x2} + w_{x2}) + \gamma(m_{x1} + w_{x1})] \quad (4)$$

The retailer's profit with retailer's negotiation strategy x, denoted as $\pi_x^r(p_{x1}, p_{x2})$, is:

$$\pi_x^r(p_{x1}, p_{x2}) = (p_{x1} - w_{x1})(\alpha - \beta p_{x1} + \gamma p_{x2}) + (p_{x2} - w_{x2})(\alpha - \beta p_{x2} + \gamma p_{x1}) \quad (5)$$

The first term is the retailer's profit from product 1 and the second term is the retailer's profit from product 2.

With retailer's different negotiation strategies, the manufacturers' optimal wholesale prices and the retailer's optimal retail prices are derived as Table 2. The derivation of these optimal solutions is provided in the Appendix

Table 2A. Optimal wholesale prices for possible negotiation scenarios

<table>
<tr><th>Negotiation scenarios</th><th>w_{x1}^{*}</th><th>w_{x2}^{*}</th></tr>
<tr><td>Scenario 1</td><td>$\frac{\alpha(2\beta+\gamma)+(6\beta^2-\gamma^2)c_1+\beta\gamma c_2}{2(2\beta+\gamma)(2\beta-\gamma)}$</td><td>$\frac{\alpha(2\beta+\gamma)+(6\beta^2-\gamma^2)c_2+\beta\gamma c_1}{2(2\beta+\gamma)(2\beta-\gamma)}$</td></tr>
<tr><td>Scenario 2</td><td colspan="2">$\frac{3(c_1+c_2)}{8}+\frac{\alpha}{4(\beta-\gamma)}$</td></tr>
<tr><td>Scenario 3</td><td>$\frac{2\alpha+(3\beta-\gamma)(c_1+c_2)}{8\beta-4\gamma}$</td><td>$\frac{2\alpha+(3\beta-\gamma)(c_1+c_2)}{8\beta-4\gamma}$</td></tr>
<tr><td>Scenario 4</td><td colspan="2">$\frac{2\alpha+3(\beta-\gamma)(c_1+c_2)}{8(\beta-\gamma)}$</td></tr>
<tr><td>Scenario 5</td><td>$\frac{2\alpha(2\beta+\gamma)+\beta\gamma c_2+(12\beta^2+\beta\gamma-2\gamma^2)c_1}{16\beta^2-4\gamma^2}$</td><td>$\frac{2\alpha(2\beta+\gamma)+(6\beta^2-\gamma^2)c_2+(6\beta^2+2\beta\gamma-\gamma^2)c_1}{16\beta^2-4\gamma^2}$</td></tr>
<tr><td>Scenario 6</td><td colspan="2">$\frac{4\alpha+3(3c_1+c_2)(\beta-\gamma)}{16(\beta-\gamma)}$</td></tr>
<tr><td>Scenario 7</td><td>$\frac{2\alpha(2\beta+\gamma)+(6\beta^2-\gamma^2)c_1+(6\beta^2+2\beta\gamma-\gamma^2)c_2}{16\beta^2-4\gamma^2}$</td><td>$\frac{2\alpha(2\beta+\gamma)+(12\beta^2+\beta\gamma-2\gamma^2)c_2+\beta\gamma c_1}{16\beta^2-4\gamma^2}$</td></tr>
<tr><td>Scenario 8</td><td colspan="2">$\frac{4\alpha+3(3c_1+c_2)(\beta-\gamma)}{16(\beta-\gamma)}$</td></tr>
</table>

Table 2B. Optimal retail prices for possible negotiation scenarios

Negotiation scenarios	$\boldsymbol{p_{x1}^{*}}$	$\boldsymbol{p_{x2}^{*}}$
Scenario 1	$\frac{\alpha(2\beta+\gamma)(3\beta-2\gamma)+2\beta^2(\beta-\gamma)c_1+\beta\gamma(\beta-\gamma)c_2}{2(2\beta+\gamma)(2\beta-\gamma)(\beta-\gamma)}$	$\frac{\alpha(2\beta+\gamma)(3\beta-2\gamma)+2\beta^2(\beta-\gamma)c_2+\beta\gamma(\beta-\gamma)c_1}{2(2\beta+\gamma)(2\beta-\gamma)(\beta-\gamma)}$
Scenario 2	$\frac{3\alpha}{4(\beta-\gamma)}+\frac{\beta(c_1-c_2)}{\beta+\gamma}+\frac{5c_2-3c_1}{8}$	$\frac{3\alpha}{4(\beta-\gamma)}+\frac{\beta(c_2-c_1)}{\beta+\gamma}+\frac{5c_1-3c_2}{8}$
Scenario 3	$\frac{2\alpha(3\beta-2\gamma)+\beta(\beta-\gamma)(c_1+c_2)}{4(2\beta-\gamma)(\beta-\gamma)}$	$\frac{2\alpha(3\beta-2\gamma)+\beta(\beta-\gamma)(c_1+c_2)}{4(2\beta-\gamma)(\beta-\gamma)}$
Scenario 4	$\frac{6\alpha+(\beta-\gamma)(c_1+c_2)}{8(\beta-\gamma)}$	$\frac{6\alpha+(\beta-\gamma)(c_1+c_2)}{8(\beta-\gamma)}$
Scenario 5	$\frac{2\alpha(3\beta-2\gamma)(2\beta+\gamma)+(\beta^2\gamma-\beta\gamma^2)c_2+(4\beta^3-3\beta^2\gamma-\beta\gamma^2)c_1}{4(\beta-\gamma)(2\beta-\gamma)(2\beta+\gamma)}$	$\frac{\alpha(3\beta-2\gamma)(2\beta+\gamma)+(\beta^3-\beta^2\gamma)c_2+(\beta^3-\beta^2\gamma+\gamma)c_1}{2(\beta-\gamma)(2\beta-\gamma)(2\beta+\gamma)}$
Scenario 6	$\frac{12\alpha(\beta+\gamma)+(\beta-\gamma)[\beta(7c_1-3c_2)-\gamma(c_1-5c_2)]}{16(\beta+\gamma)(\beta-\gamma)}$	$\frac{12\alpha(\beta+\gamma)-(\beta-\gamma)[\beta(c_1-5c_2)-\gamma(7c_1-3c_2)]}{16(\beta+\gamma)(\beta-\gamma)}$
Scenario 7	$\frac{\alpha(3\beta-2\gamma)(2\beta+\gamma)+(\beta^3-\beta^2\gamma)c_1+(\beta^3-\beta\gamma^2)c_2}{2(\beta-\gamma)(2\beta-\gamma)(2\beta+\gamma)}$	$\frac{2\alpha(3\beta-2\gamma)(2\beta+\gamma)+(\beta^2\gamma-\beta\gamma^2)c_1+(4\beta^3-3\beta^2\gamma-\beta\gamma^2)c_1}{4(\beta-\gamma)(2\beta-\gamma)(2\beta+\gamma)}$
Scenario 8	$\frac{12\alpha(\beta+\gamma)+(\beta-\gamma)[\beta(5c_1-c_2)-\gamma(3c_1-7c_2)]}{16(\beta+\gamma)(\beta-\gamma)}$	$\frac{12\alpha(\beta+\gamma)-(\beta-\gamma)[\beta(3c_1-7c_2)-\gamma(5c_1-c_2)]}{16(\beta+\gamma)(\beta-\gamma)}$

4 Firms' strategic choices

In this section, we discuss the effect of production efficiency, the choice of retailer's negotiation strategy and the choices of manufacturers' information-sharing strategies on the supply chain performance.

4.1 The choice of retailer's negotiation strategy

From the retailer's perspective, we discuss the choice of negotiation strategy under manufacturers' different production-cost information-sharing strategies and deduce the following proposition:

Proposition 1: ***When both manufacturers share their production-cost information, the retailer will adopt a unified negotiation policy; otherwise, the retailer will adopt a segmented negotiation policy.***

This proposition indicates that manufacturers' decision on whether to share their production cost information has a significant impact on the retailer's optimal decision on negotiation policy. A unified negotiation policy should be adopted only when the retailer has the production-cost information of both manufacturers. To maximize the profit, the retailer should choose the optimal negotiation strategy according to the manufacturers' production-cost information-sharing strategy.

In terms of the relationship between the retailer's maximum profits from the adopted negotiation strategy under the manufacturers' different production-cost information strategies, the following proposition is obtained:

Proposition 2: $\boldsymbol{\pi_2^r(p_{21}^*, p_{22}^*) > \pi_5^r(p_{51}^*, p_{52}^*) > \pi_3^r(p_{31}^*, p_{32}^*) > \pi_7^r(p_{71}^*, p_{72}^*)}$**.**

From this proposition, we know that when the low-efficiency manufacturer (manufacturer 2) shares his production-cost information strategy, the retailer gains less profit than that with both manufacturers withholding their production-cost information strategy. On the contrary, when the high-efficiency manufacturer (manufacturer 1) shares his production-cost information strategy, the retailer gains more profit than that with both manufacturers withholding their production-cost information strategy. Specifically, compared with both manufacturers withholding their production-cost information strategy, one manufacturer sharing his production-cost information will not always benefit the retailer. The retailer will ignore manufacturer 2's actual production-cost information and will negotiate with the manufacturers according to the industry average production cost. From the retailer's perspective, only the scenario of the low-efficiency manufacturer sharing his production-cost information will not be taken into consideration. The ordering between the retailer's maximum profits follows that $\pi_2^r(p_{21}^*, p_{22}^*) > \pi_5^r(p_{51}^*, p_{52}^*) > \pi_3^r(p_{31}^*, p_{32}^*)$. The above relationship means that the retailer's maximum profit with both manufacturers sharing their production-cost information strategy is higher than that with only the high-efficiency manufacturer sharing his production-cost information strategy, and the retailer's maximum profit with only the high-efficiency manufacturer sharing his production-cost information strategy is in turn higher than that with both manufacturers withholding their production-cost information strategy. Therefore, the above analysis further demonstrates that the manufacturer's production-cost information-sharing strategy plays an important role in the retailer's maximum profit, supporting the view of Dwyer and Walker (1981) that the negotiation processes and eventual agreement between supply chain members are shaped by factors including quality of information and ability to bargain for favourable deals.

4.2 The choice of the manufacturers' production-cost information-sharing strategy

In this section, we discuss the choice of two competing manufacturers' production-cost information-sharing strategies on the basis of retailer's different negotiation policies. In terms of the relationship between manufacturer 1's maximum profits and the retailer's negotiation policies, the following proposition is obtained:

Proposition 3: $\boldsymbol{\pi_{21}^{m}(w_{21}^{*}) > \pi_{31}^{m}(w_{31}^{*}) > \pi_{51}^{m}(w_{51}^{*})}$.

This proposition means that the maximum profit of the high-efficiency manufacturer (manufacturer 1) with both manufacturers sharing their production-cost information strategy is higher than that with both manufacturers withholding their production-cost information strategy, and the high-efficiency manufacturer's maximum profit with both manufacturers withholding their production-cost information strategy is in turn higher than that with only manufacturer 1 sharing his production-cost information strategy.

More specifically, the high-efficiency manufacturer's maximum profit is affected by both the manufacturers' production-cost-sharing strategies. Compared with both manufacturers withholding their production-cost information strategy, only one manufacturer sharing his production-cost information strategy will not benefit the high-efficiency manufacturer. The high-efficiency manufacturer will adopt the same production-cost information-sharing strategy as that adopted by the low-efficiency manufacturer (manufacturer 2). In addition, from propositions 2 and 3, we know that both manufacturers sharing their production-cost information strategy will benefit both the retailer and the high-efficiency manufacturer.

In terms of the relationship between manufacturer 2's maximum profit with both manufacturers sharing their production-cost information and with both manufacturers withholding their production-cost information, the following proposition is obtained:

Proposition 4:

(1) If $\gamma < \beta < 2\gamma$, ***or*** $\beta > 2\gamma$ ***and*** $\alpha > \alpha_1$ ***or*** $\alpha < \alpha_2$, ***then*** $\pi_{22}^{m}(w_{22}^{*}) > \pi_{32}^{m}(w_{32}^{*})$; ***if*** $\beta > 2\gamma$ ***and*** $\alpha_2 < \alpha < \alpha_1$, ***then*** $\pi_{22}^{m}(w_{22}^{*}) < \pi_{32}^{m}(w_{32}^{*})$, ***where*** $\alpha_1 = \frac{(\beta-\gamma)[(8\beta^2-12\beta\gamma+5\gamma^2)c_2-(8\beta^2-12\beta\gamma+3\gamma^2)c_1]}{2\gamma^2} + \frac{4(c_2-c_1)(2\beta-\gamma)(\beta-\gamma)\sqrt{\beta(\beta-2\gamma)}}{2\gamma^2}$, $\alpha_2 = \frac{(\beta-\gamma)[(8\beta^2-12\beta\gamma+5\gamma^2)c_2-(8\beta^2-12\beta\gamma+3\gamma^2)c_1]}{2\gamma^2} - \frac{4(c_2-c_1)(2\beta-\gamma)(\beta-\gamma)\sqrt{\beta(\beta-2\gamma)}}{2\gamma^2}$.

(2) If $\beta > 2\gamma$, ***then*** $\Delta\alpha$ ***increases in*** β ***and decreases in*** γ, ***where*** $\Delta\alpha = \alpha_1 - \alpha_2$.

This proposition means that the low-efficiency manufacturer's (manufacturer 2) production-cost information-sharing strategy is decided by the potential market scale of the product (α), self-price sensitivity (β) and cross-price sensitivity (γ). If the manufacturers' self-price sensitivity is low ($\gamma < \beta < 2\gamma$), or the manufacturers' self-price sensitivity is high and the potential market scale of product is to some extent large or some extent small ($\beta > 2\gamma$ and $\alpha > \alpha_1$ or $\alpha < \alpha_2$), then the low-efficiency manufacturer's maximum profit with both manufacturers sharing their production-cost information strategy is higher than that with both manufacturers withholding their production-cost information strategy; both manufacturers will also share their production-cost information.

Otherwise, if the manufacturers' self-price sensitivity is high and the potential market scale of product is medium size ($\beta > 2\gamma$ and $\alpha_2 < \alpha < \alpha_1$), then the low-efficiency manufacturer's maximum profit with both manufacturers sharing their production-cost information strategy is lower than that with both manufacturers withholding their production-cost information strategy; both manufacturers will withhold their production-cost information. That is, compared to both manufacturers withholding their production-cost information strategy, manufacturers sharing their production-cost information will not always hurt the manufacturers. From the view of the low-efficiency manufacturer (manufacturer 2), if the potential market scale of product is to some extent large, he will prefer to share his production-cost information.

Furthermore, when the manufacturers' self-price sensitivity (β) is high or cross-price sensitivity (γ) is low, then the scope of the potential market scale of product ($\Delta\alpha$) is large, so the low-efficiency manufacturer's maximum profit with both manufacturers sharing their production-cost information strategy is more likely to be lower than that with both manufacturers withholding their production-cost information strategy; both manufacturers will prefer to withhold their production-cost information. Our analysis results support the finding of Frazier et al. (2009) that some channel members may opt against sharing cost information with other partners in order to enhance their negotiation position and gain competitive advantages.

4.3 The effect of production efficiency

In terms of the effect of the manufacturers' production efficiency on their maximum profit, the following proposition is obtained:

Proposition 5: ***The high-efficiency manufacturer's maximum profit is always higher than that of the low-efficiency manufacturer.***

This proposition means that no matter which negotiation strategy is adopted by the retailer, the high-efficiency manufacturer will always gain more profit than that of the low-efficiency manufacturer. Although whether to share or withhold production-cost information in the negotiation with the retailer has an effect on manufacturers' financial performance, fundamentally, manufacturers should improve their production efficiency and reduce production costs in order to increase profit and gain competitive market advantage despite other options such as forming a coalition (Nagarajan and Bassok, 2008) or seeking alternative information strategy (Dwyer and Walker, 1981) in the supply chain contract negotiation.

5 Discussion and Conclusion

This study explores a retailer's optimal negotiation policy and two competing manufacturers' optimal production-cost information strategies in the setting of buyer-supplier-supplier triads where with the two manufacturers have asymmetric production-cost. In the contract negotiation between a retailer and two manufacturers, the retailer, as the Stackelberg leader, has the option of segmented or unified negotiation policy, whereas the manufacturers, as the Stackelberg followers, also have the option of withholding or sharing production-cost information strategy. From both the retailer and manufacturers' perspective, we examine their optimal strategic choices and operational decisions respectively through the comparative analysis of equilibriums of eight possible scenarios. Our study indicates that the choice of retailer's negotiation policy, the manufacturers' information-sharing decisions, and manufacturers' production efficiency have significant effects on the financial performance of the retailer and the two rival manufacturers.

Our paper makes two main contributions to the literature. First, although some studies have examined negotiation in the supply chain (Crook and Combs, 2007; Nagarajan and Bassok, 2008), these studies have largely overlooked negotiation process under asymmetric production-cost information. This study complements to this stream of literature by modelling the relationship between a retailer and two manufacturers engaging in the negotiation process under asymmetric production-cost information. Whilst some studies have examined the negotiation process between a manufacturer and a retailer over the terms of trade (e.g. Iyer and Villas-Boas, 2003), they have broadly overlooked the need to consider negotiation under asymmetric production-cost information and competing manufacturers. In this respect, our study addresses this void in the existing literature. Second, the study also responds to the call issued by Feng and Lu (2013) for more negotiation-based models to examine supply chain contracting. Our modelling and conceptualisation help to bring further clarity in the area by offering a conceptual framework to enhance our understanding of the effects of information-sharing strategy and negotiation policy in the negotiation process form the perspectives of all engaging parties.

Our findings provide several important managerial implications which would enable retailers and manufacturers to make informed and better strategic and operational decisions to improve their performance. First, the analysis suggests that the retailer will adopt different negotiation strategies (either the unified negotiation policy or the segmented negotiation policy) depending on manufacturers' decisions on sharing or withholding their production-cost information. For instance, when both manufacturers share their production-cost information, the retailer will choose the unified negotiation policy. In this scenario, the retailer will gain more profit compared to any other scenarios modelled in this study. In contrast, the retailer will employ the segmented negotiation policy if both manufacturers decide to withhold their production-cost information. However, compared to the scenario mentioned above, the retailer will also get much less profit. The retailer's performance in the scenarios that only one manufacturer shares production-cost information is more complicated than the scenarios that both manufacturers share or withhold information as discussed above. In a nutshell, in order to maximise profit, the retailer should not only employ the right negotiation policy according to the manufacturers' cost information-sharing strategies, but also exercise his channel power to persuade manufacturers to share their production-cost information or at least disclose the high-efficiency manufacturer's production-cost information. These insights will be particularly beneficial for supermarkets that often negotiate supply contract with multiple suppliers.

Furthermore, as for the effect of the manufacturers' production-cost information-sharing strategy on their financial performance, the high-efficiency manufacturer performs best when both manufacturers share production-cost information and his performance is worst if only one manufacturer shares his production-cost information. Therefore, the high-efficiency manufacturer should adopt the same information-sharing strategy as the low-efficiency manufacturer in order to gain more profit. For the low-efficiency manufacturer, to optimise his performance, the production-cost information-sharing strategy should be dependent on the potential market scale of product, self-price sensitivity and cross-price sensitivity as illustrated in Proposition 4. These insights will be useful to manufacturers in the supply chains like food, fashion or electronics, where there is often fierce market competition. Unsurprisingly, our model demonstrates that the high-efficiency manufacturer's maximum profit is higher than that of the low-efficiency manufacturer. Although different negotiation and information-sharing strategies will impact individual supply chain partners' performance, fundamentally, manufacturers should develop their own capabilities and improve production efficiency in order to gain competitive advantages over their competitors.

Our work suggests a number of fruitful avenues that can be pursued to further enrich our understanding of the subject. First, given that our study considered only the negotiation strategy under conditions of asymmetrical information, future research should seek to broaden our conceptualisation to include factors such as negotiating skills, relational capital and level of expertise which can influence the outcome of the negotiation process. Future study could also model a more balanced power setting with complete information about production-cost information between a retailer and competing manufacturers. Another avenue for future research would be to explore more scenarios, where there are more than two competing manufacturers in a balanced information and power structure. More broadly, it would be useful to examine the post-negotiation effects. A manufacturer who emerges from a negotiation as not the main beneficiary is less likely to cooperate with the retailer. The "winner-take-all" attitude is more likely to drive down the morale of channel partners. Therefore, there is a need to explore this issue further to advance our understanding of the post-negotiation effects. We hope this study serves as a catalyst for more studies on negotiation in the supply chain.

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Appendix

Derivation of Table 2

(1) Retailer's negotiation strategy 1. From (1), we get $\frac{d\pi_{11}^m(w_{11})}{dw_{11}} = \alpha - \beta(w_{11}+m_{11}) + \gamma(w_{12}+m_{12}) - \beta(w_{11}-c_1)$ and $\frac{d^2\pi_{11}^m(w_{11})}{d{w_{11}}^2} = -2\beta < 0$, then $\pi_{11}^m(w_{11})$ is a concave function of w_{11}. Let $\frac{d\pi_{11}^m(w_{11})}{dw_{11}} = 0$, we get $w_{11}^* = \frac{1}{\beta}(\alpha - \beta p_{11} + \gamma p_{12} + \beta c_1)$. Similarly, from (2), we get $\frac{d\pi_{12}^m(w_{12})}{dw_{12}} = \alpha - \beta(w_{12}+m_{12}) + \gamma(w_{11}+m_{11}) -$

$\beta(w_{12}-c_2)$ and $\frac{d^2\pi_{12}^m(w_{12})}{dw_{12}{}^2}=-2\beta<0$, then $\pi_{12}^m(w_{12})$ is a concave function of w_{12}. Let $\frac{d\pi_{12}^m(w_{12})}{dw_{12}}=0$, we get $w_{12}^*=\frac{1}{\beta}(\alpha-\beta p_{12}+\gamma p_{11}+\beta c_2)$.

Replace w_{11}^* and w_{12}^* to (5), we get $\frac{\partial\pi_1^r(p_{11},p_{12})}{\partial p_{11}}=\beta c_1-4\beta p_{11}-\gamma c_2+6\gamma p_{12}-\frac{2\gamma^2 p_{11}}{\beta}+\alpha(3-\frac{2\gamma}{\beta})$, $\frac{\partial\pi_1^r(p_{11},p_{12})}{\partial p_{12}}=\beta c_2-4\beta p_{12}-\gamma c_1+6\gamma p_{11}-\frac{2\gamma^2 p_{12}}{\beta}+\alpha(3-\frac{2\gamma}{\beta})$, $\frac{\partial^2\pi_1^r(p_{11},p_{12})}{\partial p_{11}{}^2}=-4\beta-\frac{2\gamma^2}{\beta}<0$, $\frac{\partial^2\pi_1^r(p_{11},p_{12})}{\partial p_{12}{}^2}=-4\beta-\frac{2\gamma^2}{\beta}$ and $\frac{\partial^2\pi_1^r(p_{11},p_{12})}{\partial p_{11}\partial p_{12}}=\frac{\partial^2\pi_1^r(p_{11},p_{12})}{\partial p_{12}\partial p_{11}}=6\gamma$. Then $\begin{vmatrix}\frac{\partial^2\pi_1^r(p_{11},p_{12})}{\partial p_{11}{}^2} & \frac{\partial^2\pi_1^r(p_{11},p_{12})}{\partial p_{11}\partial p_{12}}\\ \frac{\partial^2\pi_1^r(p_{11},p_{12})}{\partial p_{12}\partial p_{11}} & \frac{\partial^2\pi_1^r(p_{11},p_{12})}{\partial p_{12}{}^2}\end{vmatrix}=\frac{4(4\beta^2-\gamma^2)(\beta^2-\gamma^2)}{\beta^2}>0$. That is, $\pi_1^r(p_{11},p_{12})$ is a joint concave function of p_{11} and p_{12}. From $\frac{\partial\pi_1^r(p_{11},p_{12})}{\partial p_{11}}=\frac{\partial\pi_1^r(p_{11},p_{12})}{\partial p_{12}}=0$, we get $p_{11}^*=\frac{\alpha(2\beta+\gamma)(3\beta-2\gamma)+2\beta^2(\beta-\gamma)c_1+\beta\gamma(\beta-\gamma)c_2}{2(2\beta+\gamma)(2\beta-\gamma)(\beta-\gamma)}$ and $p_{12}^*=\frac{\alpha(2\beta+\gamma)(3\beta-2\gamma)+2\beta^2(\beta-\gamma)c_2+\beta\gamma(\beta-\gamma)c_1}{2(2\beta+\gamma)(2\beta-\gamma)(\beta-\gamma)}$. Replace p_{11}^* and p_{12}^* to w_{11}^* and w_{12}^*, we get $w_{11}^*=\frac{\alpha(2\beta+\gamma)+(6\beta^2-\gamma^2)c_1+\beta\gamma c_2}{2(2\beta+\gamma)(2\beta-\gamma)}$ and $w_{12}^*=\frac{\alpha(2\beta+\gamma)+(6\beta^2-\gamma^2)c_2+\beta\gamma c_1}{2(2\beta+\gamma)(2\beta-\gamma)}$.

(2) Retailer's negotiation strategy 2. From (1), we get $\frac{d\pi_{21}^m(w_2)}{dw_2}=\alpha-\beta(w_2+m_{21})+\gamma(w_2+m_{22})-(\beta-\gamma)(w_2-c_1)$ and $\frac{d^2\pi_{21}^m(w_2)}{dw_2{}^2}=-2(\beta-\gamma)<0$, that is, $\pi_{21}^m(w_2)$ is a concave function of w_2. Similarly, from (2), we get $\frac{d\pi_{22}^m(w_2)}{dw_2}=\alpha-\beta(w_2+m_{22})+\gamma(w_2+m_{21})+(\gamma-\beta)(w_2-c_2)$ and $\frac{d^2\pi_{22}^m(w_{21})}{dw_{22}{}^2}=-2(\beta-\gamma)<0$, that is, $\pi_{22}^m(w_2)$ is a concave function of w_2. From $\frac{d\pi_{21}^m(w_2)}{dw_2}=\frac{d\pi_{22}^m(w_2)}{dw_2}=0$, we get $p_{22}=\frac{(\beta-\gamma)(c_2-c_1)}{\beta+\gamma}+p_{21}$.

Replace w_2^* and p_{22} to (5), we get $\frac{d\pi_2^r(p_{21},p_{22})}{dp_{21}}=\frac{d\pi_2^r(p_{21})}{dp_{21}}=\frac{6\alpha(\beta+\gamma)+(\beta-\gamma)[\beta(5c_1-3c_2-8p_{21})+\gamma(-3c_1+5c_2-8p_{21})]}{\beta+\gamma}$ and $\frac{d^2\pi_2^r(p_{21})}{dp_{21}{}^2}=-8(\beta-\gamma)<0$, that is, $\pi_2^r(p_{21},p_{22})$ is a concave function of p_{21}. Let $\frac{d\pi_2^r(p_{21},p_{22})}{dp_{21}}=0$, we get $p_{21}^*=\frac{3\alpha}{4(\beta-\gamma)}+\frac{\beta(c_1-c_2)}{\beta+\gamma}+\frac{5c_2-3c_1}{8}$. Replace p_{21}^* to p_{22}, we get $p_{22}^*=\frac{3\alpha}{4(\beta-\gamma)}+\frac{\beta(c_2-c_1)}{\beta+\gamma}+\frac{5c_1-3c_2}{8}$. Replace p_{21}^* and p_{22}^* to w_2^*, we get $w_2^*=\frac{3(c_1+c_2)}{8}+\frac{\alpha}{4(\beta-\gamma)}$.

(3) Retailer's negotiation strategy 3. From (3), we get $\frac{d\bar{\pi}_{31}^m(w_{31})}{dw_{31}}=\alpha-\beta(m_{31}+w_{31})+\gamma(m_{32}+w_{32})-\beta\left(w_{31}-\frac{c_1+c_2}{2}\right)$ and $\frac{d^2\bar{\pi}_{31}^m(w_{31})}{dw_{31}{}^2}=-2\beta<0$, that is, $\bar{\pi}_{31}^m(w_{31})$ is a concave function of w_{31}. Let $\frac{d\bar{\pi}_{31}^m(w_{31})}{dw_{31}}=0$, we get $w_{31}^*=\frac{\alpha-\beta p_{31}+\gamma p_{32}}{\beta}+\frac{c_1+c_2}{2}$. Similarly, from (4), we get $\frac{d\bar{\pi}_{32}^m(w_{32})}{dw_{32}}=\alpha-\beta(m_{32}+w_{32})+\gamma(m_{31}+w_{31})-\beta\left(w_{23}-\frac{c_1+c_2}{2}\right)$ and $\frac{d^2\bar{\pi}_{32}^m(w_{32})}{dw_{32}{}^2}=-2\beta<0$, that is, $\bar{\pi}_{32}^m(w_{32})$ is a concave function of w_{32}. Let $\frac{d\bar{\pi}_{32}^m(w_{32})}{dw_{32}}=0$,

we get $w_{32}^{*}=\frac{\alpha-\beta p_{32}+\gamma p_{31}}{\beta}+\frac{c_1+c_2}{2}$.

Replace w_{31}^{*} and w_{32}^{*} to (5), we get $\frac{\partial\pi_3^r(p_{31},p_{32})}{\partial p_{31}}=(\beta-\gamma)\frac{c_1+c_2}{2}-4\beta p_{31}+6\gamma p_{32}-\frac{2\gamma^2 p_{31}}{\beta}+\alpha(3-\frac{2\gamma}{\beta})$, $\frac{\partial\pi_3^r(p_{31},p_{32})}{\partial p_{32}}=(\beta-\gamma)\frac{c_1+c_2}{2}-4\beta p_{32}+6\gamma p_{31}-\frac{2\gamma^2 p_{32}}{\beta}+\alpha(3-\frac{2\gamma}{\beta})$, $\frac{\partial^2\pi_3^r(p_{31},p_{32})}{\partial {p_{31}}^2}=-4\beta-\frac{2\gamma^2}{\beta}<0$, $\frac{\partial^2\pi_3^r(p_{31},p_{32})}{\partial {p_{32}}^2}=-4\beta-\frac{2\gamma^2}{\beta}$ and $\frac{\partial^2\pi_3^r(p_{31},p_{32})}{\partial p_{31}\partial p_{32}}=\frac{\partial^2\pi_3^r(p_{31},p_{32})}{\partial p_{32}\partial p_{31}}=6\gamma$. Then $\begin{vmatrix}\frac{\partial^2\pi_3^r(p_{31},p_{32})}{\partial {p_{31}}^2} & \frac{\partial^2\pi_3^r(p_{31},p_{32})}{\partial p_{31}\partial p_{32}}\\ \frac{\partial^2\pi_3^r(p_{31},p_{32})}{\partial p_{32}\partial p_{31}} & \frac{\partial^2\pi_3^r(p_{31},p_{32})}{\partial {p_{32}}^2}\end{vmatrix}=\frac{4(4\beta^2-\gamma^2)(\beta^2-\gamma^2)}{\beta^2}>0$. That is, $\pi_3^r(p_{31},p_{32})$ is a joint concave of p_{31} and p_{32}. From $\frac{\partial\pi_3^r(p_{31},p_{32})}{\partial p_{31}}=\frac{\partial\pi_3^r(p_{31},p_{32})}{\partial p_{32}}=0$, we get $p_{31}^{*}=p_{32}^{*}=\frac{2\alpha(3\beta-2\gamma)+\beta(\beta-\gamma)(c_1+c_2)}{4(2\beta-\gamma)(\beta-\gamma)}$. Replace p_{31}^{*} and p_{32}^{*} to w_{31}^{*} and w_{32}^{*}, we get $w_{31}^{*}=w_{32}^{*}=\frac{2\alpha+(3\beta-\gamma)(c_1+c_2)}{8\beta-4\gamma}$.

(4) Retailer's negotiation strategy 4. From (3), we get $\frac{d\bar{\pi}_{41}^m(w_4)}{dw_4}=\alpha-\beta(m_{41}+w_4)+\gamma(m_{42}+w_4)-(\beta-\gamma)\left(w_4-\frac{c_1+c_2}{2}\right)$ and $\frac{d^2\bar{\pi}_{41}^m(w_4)}{d{w_4}^2}=-2(\beta-\gamma)<0$, that is, $\bar{\pi}_{41}^m(w_4)$ is a concave function of w_4. Similarly, from (4), we get $\frac{d\bar{\pi}_{42}^m(w_4)}{dw_4}=\alpha-\beta(m_{42}+w_4)+\gamma(m_{41}+w_4)-(\beta-\gamma)\left(w_4-\frac{c_1+c_2}{2}\right)$ and $\frac{d^2\bar{\pi}_{42}^m(w_4)}{d{w_4}^2}=-2(\beta-\gamma)<0$, that is, $\bar{\pi}_{42}^m(w_4)$ is a concave function of w_4. From $\frac{d\bar{\pi}_{41}^m(w_4)}{dw_4}=\frac{d\bar{\pi}_{42}^m(w_4)}{dw_4}=0$, we get $p_{41}=p_{42}$. Replace w_4^{*} and p_{42} to (5), we get $\frac{d\bar{\pi}_4^r(p_{41},p_{42})}{dp_{41}}=\frac{d\bar{\pi}_4^r(p_{41})}{dp_{41}}=6\alpha+(c_1+c_2-8p_{41})(\beta-\gamma)$ and $\frac{d^2\bar{\pi}_4^r(p_{41})}{d{p_{41}}^2}=-8(\beta-\gamma)<0$, that is, $\bar{\pi}_4^r(p_{41})$ is a concave function of p_{41}. Let $\frac{d\bar{\pi}_4^r(p_{41})}{dp_{41}}=0$, we get $p_{41}^{*}=p_{42}^{*}=\frac{6\alpha+(\beta-\gamma)(c_1+c_2)}{8(\beta-\gamma)}$. Replace p_{41}^{*} and p_{42}^{*} to (4.3-a), we get $w_4^{*}=\frac{2\alpha+3(\beta-\gamma)(c_1+c_2)}{8(\beta-\gamma)}$.

(5) Retailer's negotiation strategy 5. From (1), we get $\frac{d\pi_{51}^m(w_{51})}{dw_{51}}=\alpha-\beta(m_{51}+w_{51})+\gamma(m_{52}+w_{52})-\beta(w_{51}-c_1)$ and $\frac{d^2\pi_{51}^m(w_{51})}{d{w_{51}}^2}=-2\beta<0$, that is, $\pi_{51}^m(w_{51})$ is a concave function of w_{51}. Let $\frac{d\pi_{51}^m(w_{51})}{dw_{51}}=0$, we get $w_{51}^{*}=\frac{\alpha-\beta p_{51}+\gamma p_{52}}{\beta}+c_1$. Similarly, from (4), we get $\frac{d\bar{\pi}_{52}^m(w_{52})}{dw_{52}}=\alpha-\beta(m_{52}+w_{52})+\gamma(m_{51}+w_{51})-\beta\left(w_{52}-\frac{c_1+c_2}{2}\right)$ and $\frac{d^2\bar{\pi}_{52}^m(w_{52})}{d{w_{52}}^2}=-2\beta<0$, that is, $\bar{\pi}_{52}^m(w_{52})$ is a concave function of w_{52}. Let $\frac{d\bar{\pi}_{52}^m(w_{52})}{dw_{52}}=0$, we get $w_{52}^{*}=\frac{\alpha-\beta p_{52}+\gamma p_{51}}{\beta}+\frac{c_1+c_2}{2}$.

Replace w_{51}^{*} and w_{52}^{*} to (5), we get that $\frac{\partial\pi_5^r(p_{51},p_{52})}{\partial p_{51}}=\frac{1}{2\beta}[2\alpha(3\beta-2\gamma)+(2\beta^2-\beta\gamma)c_1-\beta\gamma c_2+$

$12\beta\gamma p_{52} - 4(2\beta^2+\gamma^2)p_{51}]$, $\frac{\partial \pi_5^r(p_{51},p_{52})}{\partial p_{52}} = \frac{1}{2\beta}[2\alpha(3\beta-2\gamma)+(\beta^2-2\beta\gamma)c_1-\beta^2 c_2+12\beta\gamma p_{51}-4(2\beta^2+\gamma^2)p_{52}]$, $\frac{\partial^2 \pi_5^r(p_{51},p_{52})}{\partial {p_{51}}^2} = -4\beta-\frac{2\gamma^2}{\beta} < 0$, $\frac{\partial^2 \pi_5^r(p_{51},p_{52})}{\partial {p_{52}}^2} = -4\beta-\frac{2\gamma^2}{\beta}$ and $\frac{\partial^2 \pi_5^r(p_{51},p_{52})}{\partial p_{51}\partial p_{52}} = \frac{\partial^2 \pi_5^r(p_{51},p_{52})}{\partial p_{52}\partial p_{51}} = 6\gamma$. Then $\begin{vmatrix} \frac{\partial^2 \pi_5^r(p_{51},p_{52})}{\partial {p_{51}}^2} & \frac{\partial^2 \pi_5^r(p_{51},p_{52})}{\partial p_{51}\partial p_{52}} \\ \frac{\partial^2 \pi_5^r(p_{51},p_{52})}{\partial p_{52}\partial p_{51}} & \frac{\partial^2 \pi_5^r(p_{51},p_{52})}{\partial {p_{52}}^2} \end{vmatrix} = \frac{4(4\beta^2-\gamma^2)(\beta^2-\gamma^2)}{\beta^2} > 0$. That is, $\pi_5^r(p_{51},p_{52})$ is a joint concave function of p_{51} and p_{52}. From $\frac{\partial \pi_5^r(p_{51},p_{52})}{\partial p_{51}} = \frac{\partial \pi_5^r(p_{51},p_{52})}{\partial p_{52}} = 0$, we get $p_{51}^* = \frac{2\alpha(3\beta-2\gamma)(2\beta+\gamma)+(\beta^2\gamma-\beta\gamma^2)c_2+(4\beta^3-3\beta^2\gamma-\beta\gamma^2)c_1}{4(\beta-\gamma)(2\beta-\gamma)(2\beta+\gamma)}$ and $p_{52}^* = \frac{\alpha(3\beta-2\gamma)(2\beta+\gamma)+(\beta^3-\beta^2\gamma)c_2+(\beta^3-\beta^2\gamma+\gamma)c_1}{2(\beta-\gamma)(2\beta-\gamma)(2\beta+\gamma)}$. Replace p_{51}^* and p_{52}^* to w_{51}^* and w_{52}^* , we get $w_{51}^* = \frac{2\alpha(2\beta+\gamma)+\beta\gamma c_2+(12\beta^2+\beta\gamma-2\gamma^2)c_1}{16\beta^2-4\gamma^2}$ and $w_{52}^* = \frac{2\alpha(2\beta+\gamma)+(6\beta^2-\gamma^2)c_2+(6\beta^2+2\beta\gamma-\gamma^2)c_1}{16\beta^2-4\gamma^2}$.

(6) Retailer's negotiation strategy 6. From (1), we get $\frac{d\pi_{61}^m(w_6)}{dw_6} = \alpha-\beta(m_{61}+w_6)+\gamma(m_{62}+w_6)-(\beta-\gamma)(w_6-c_1)$ and $\frac{d^2\pi_{61}^m(w_6)}{d{w_6}^2} = -2(\beta-\gamma) < 0$, that is, $\pi_{61}^m(w_6)$ is a concave function of w_6. Similarly, from (4), we get $\frac{d\bar{\pi}_{62}^m(w_6)}{dw_6} = \alpha-\beta(m_{62}+w_6)+\gamma(m_{61}+w_6)-(\beta-\gamma)\left(w_6-\frac{c_1+c_2}{2}\right)$ and $\frac{d^2\bar{\pi}_{62}^m(w_6)}{d{w_6}^2} = -2(\beta-\gamma) < 0$, that is, $\bar{\pi}_{62}^m(w_6)$ is a concave function of w_6. From $\frac{d\pi_{61}^m(w_6)}{dw_6} = \frac{d\bar{\pi}_{62}^m(w_6)}{dw_6} = 0$, we get $p_{61} = \frac{c_2-c_1}{2}-\frac{\beta(c_2-c_1)}{\beta+\gamma}+p_{62}$. Replace w_6^* and p_{62} to (5), we get that $\frac{d\pi_6^r(p_{61},p_{62})}{dw_6} = \frac{d\pi_6^r(p_{62})}{dp_{62}} = \frac{12\alpha(\beta+\gamma)-(\beta-\gamma)[\beta(c_1-5c_2+16p_{62})-\gamma(7c_1-3c_2-16p_{62})]}{2(\beta+\gamma)}$ and $\frac{d^2\pi_6^r(p_{62})}{d{p_{62}}^2} = -8(\beta-\gamma) < 0$, that is, $\pi_6^r(p_{62})$ is a concave function of p_{62}. Let $\frac{d\pi_6^r(p_{61},p_{62})}{dp_{62}} = 0$, we get $p_{62}^* = \frac{12\alpha(\beta+\gamma)-(\beta-\gamma)[\beta(c_1-5c_2)-\gamma(7c_1-3c_2)]}{16(\beta+\gamma)(\beta-\gamma)}$. Then, $p_{61}^* = \frac{12\alpha(\beta+\gamma)+(\beta-\gamma)[\beta(7c_1-3c_2)-\gamma(c_1-5c_2)]}{16(\beta+\gamma)(\beta-\gamma)}$. Replace p_{61}^* and p_{62}^* to w_6^*, we get $w_6^* = \frac{4\alpha+3(3c_1+c_2)(\beta-\gamma)}{16(\beta-\gamma)}$.

(7) Retailer's negotiation strategy 7. From (3), we get $\frac{d\bar{\pi}_{71}^m(w_{71})}{dw_{71}} = \alpha-\beta(m_{71}+w_{71})+\gamma(m_{72}+w_{72})-\beta\left(w_{71}-\frac{c_1+c_2}{2}\right)$ and $\frac{d^2\bar{\pi}_{71}^m(w_{71})}{d{w_{71}}^2} = -2\beta < 0$, that is, $\bar{\pi}_{71}^m(w_{71})$ is a concave function of w_{71}. Let $\frac{d\bar{\pi}_{71}^m(w_{71})}{dw_{71}} = 0$, we get $w_{71}^* = \frac{\alpha-\beta p_{71}+\gamma p_{72}}{\beta}+\frac{c_1+c_2}{2}$. Similarly, from (2), we get $\frac{d\pi_{72}^m(w_{72})}{dw_{72}} = \alpha-\beta(m_{72}+w_{72})+\gamma(m_{71}+w_{71})-\beta(w_{72}-c_2)$ and $\frac{d^2\pi_{72}^m(w_{72})}{d{w_{72}}^2} = -2\beta < 0$, that is, $\pi_{72}^m(w_{72})$ is a concave function of w_{72}. Let $\frac{d\pi_{72}^m(w_{72})}{dw_{72}} = 0$, we get $w_{72}^* = \frac{\alpha-\beta p_{72}+\gamma p_{71}}{\beta}+c_2$. Replace w_{71}^* and w_{72}^* to (5), we get $\frac{\partial \pi_7^r(p_{71},p_{72})}{\partial p_{71}} = \frac{1}{2\beta}[2\alpha(3\beta-2\gamma)+\beta^2 c_1+(\beta^2-2\beta\gamma)c_2+12\beta\gamma p_{72}-4(2\beta^2+\gamma^2)p_{71}]$, $\frac{\partial \pi_7^r(p_{71},p_{72})}{\partial p_{72}} = \frac{1}{2\beta}[2\alpha(3\beta-2\gamma)-\beta\gamma c_1+(2\beta^2-\beta\gamma)c_2+$

$12\beta\gamma p_{71} - 4(2\beta^2+\gamma^2)p_{72}]$, $\frac{\partial^2\pi_7^r(p_{71},p_{72})}{\partial p_{71}{}^2} = -4\beta - \frac{2\gamma^2}{\beta} < 0$, $\frac{\partial^2\pi_7^r(p_{71},p_{72})}{\partial p_{72}{}^2} = -4\beta - \frac{2\gamma^2}{\beta}$ and $\frac{\partial^2\pi_7^r(p_{71},p_{72})}{\partial p_{71}\partial p_{72}} = \frac{\partial^2\pi_7^r(p_{71},p_{72})}{\partial p_{72}\partial p_{71}} = 6\gamma$. Then $\begin{vmatrix} \frac{\partial^2\pi_7^r(p_{71},p_{72})}{\partial p_{71}{}^2} & \frac{\partial^2\pi_7^r(p_{71},p_{72})}{\partial p_{71}\partial p_{72}} \\ \frac{\partial^2\pi_7^r(p_{71},p_{72})}{\partial p_{72}\partial p_{71}} & \frac{\partial^2\pi_7^r(p_{71},p_{72})}{\partial p_{72}{}^2} \end{vmatrix} = \frac{4(4\beta^2-\gamma^2)(\beta^2-\gamma^2)}{\beta^2} > 0$, that is, $\pi_7^r(p_{71},p_{72})$ is a joint concave function of p_{71} and p_{72}. From $\frac{\partial\pi_7^r(p_{71},p_{72})}{\partial p_{71}} = \frac{\partial\pi_7^r(p_{71},p_{72})}{\partial p_{72}} = 0$, we get $p_{71}^* = \frac{\alpha(3\beta-2\gamma)(2\beta+\gamma)+(\beta^3-\beta^2\gamma)c_1+(\beta^3-\beta\gamma^2)c_2}{2(\beta-\gamma)(2\beta-\gamma)(2\beta+\gamma)}$ and $p_{72}^* = \frac{2\alpha(3\beta-2\gamma)(2\beta+\gamma)+(\beta^2\gamma-\beta\gamma^2)c_1+(4\beta^3-3\beta^2\gamma-\beta\gamma^2)c_1}{4(\beta-\gamma)(2\beta-\gamma)(2\beta+\gamma)}$. Replace p_{71}^* and p_{72}^* to w_{71}^* and w_{72}^*, we get $w_{71}^* = \frac{2\alpha(2\beta+\gamma)+(6\beta^2-\gamma^2)c_1+(6\beta^2+2\beta\gamma-\gamma^2)c_2}{16\beta^2-4\gamma^2}$ and $w_{72}^* = \frac{2\alpha(2\beta+\gamma)+(12\beta^2+\beta\gamma-2\gamma^2)c_2+\beta\gamma c_1}{16\beta^2-4\gamma^2}$.

(8) Retailer's negotiation strategy 8. From (3), we get $\frac{d\bar{\pi}_{81}^m(w_8)}{dw_8} = \alpha - \beta(m_{81}+w_8) + \gamma(m_{82}+w_8) - (\beta-\gamma)\left(w_8 - \frac{c_1+c_2}{2}\right)$ and $\frac{d^2\bar{\pi}_{81}^m(w_8)}{dw_8{}^2} = -2(\beta-\gamma) < 0$, so $\bar{\pi}_{81}^m(w_8)$ is a concave function of w_8. Similarly, from (2), we get $\frac{d\pi_{82}^m(w_8)}{dw_8} = \alpha - \beta(m_{82}+w_8) + \gamma(m_{81}+w_8) - (\beta-\gamma)(w_8-c_2)$ and $\frac{d^2\pi_{82}^m(w_8)}{dw_8{}^2} = -2(\beta-\gamma) < 0$, so $\pi_{82}^m(w_8)$ is a concave function of w_8. From $\frac{d\bar{\pi}_{81}^m(w_8)}{dw_8} = \frac{d\pi_{82}^m(w_8)}{dw_8} = 0$, we get $p_{81} = \frac{c_2-c_1}{2} - \frac{\beta(c_2-c_1)}{\beta+\gamma} + p_{82}$. Replace w_8^* and p_{82} to (5), we get $\frac{d\pi_8^r(p_{81},p_{82})}{dp_{82}} = \frac{d\pi_8^r(p_{82})}{dp_{82}} = \frac{12\alpha(\beta+\gamma)-(\beta-\gamma)[\beta(3c_1-7c_2+16p_{82})-\gamma(5c_1+c_2+16p_{82})]}{2(\beta+\gamma)}$ and $\frac{d^2\pi_8^r(p_{82})}{dp_{82}{}^2} = -8(\beta-\gamma) < 0$, so $\bar{\pi}_8^r(p_{81},p_{82})$ is a concave function of p_{82}. Let $\frac{d\pi_8^r(p_{81},p_{82})}{dp_{82}} = 0$, we get $p_{82}^* = \frac{12\alpha(\beta+\gamma)-(\beta-\gamma)[\beta(3c_1-7c_2)-\gamma(5c_1-c_2)]}{16(\beta+\gamma)(\beta-\gamma)}$. Replace p_{82}^* to p_{81}, we get $p_{81}^* = \frac{12\alpha(\beta+\gamma)+(\beta-\gamma)[\beta(5c_1-c_2)-\gamma(3c_1-7c_2)]}{16(\beta+\gamma)(\beta-\gamma)}$. Replace p_{81}^* and p_{82}^* to w_8^*, we get $w_8^* = \frac{4\alpha+3(c_1+3c_2)(\beta-\gamma)}{16(\beta-\gamma)}$.

Proof of Proposition 1

Case 1: When both manufacturers share their cost information, from table 2 and (5), we get $\pi_1^r(p_{11}^*,p_{12}^*) = \frac{2\alpha\beta(2\beta+\gamma)[\alpha-(\beta-\gamma)(c_1+c_2)]+\beta(\beta-\gamma)[(2\beta^2-\gamma^2)(c_1^2+c_2^2)-2\beta\gamma c_1c_2]}{4(2\beta+\gamma)(2\beta-\gamma)(\beta-\gamma)}$. Similarly, from table 2 and (5), we get $\pi_2^r(p_{21}^*,p_{22}^*) = \frac{\alpha^2}{2(\beta-\gamma)} - \frac{3\alpha(c_1+c_2)}{8} - \frac{(\beta-\gamma)[\beta(7c_1{}^2-18c_1c_2+7c_2{}^2)-\gamma(9c_1{}^2-14c_1c_2+9c_2{}^2)]}{16(\beta+\gamma)}$.

Since $w_{32}^* > c_2$, from table 2, we get $2\alpha > (5\beta-3\gamma)c_2 - (3\beta-\gamma)c_1$, then $\pi_2^r(p_{21}^*,p_{22}^*) - \pi_1^r(p_{11}^*,p_{12}^*) = \frac{1}{16(2\beta+\gamma)(2\beta-\gamma)(\beta-\gamma)}[2\alpha(2\beta+\gamma)(\beta+\gamma)[4\alpha-(2\beta-3\gamma)(c_1+c_2)] - 36\beta^4(c_1-c_2)^2 + 8\beta^3\gamma(7c_1{}^2 - 15c_1c_2 + 7c2^2) + \beta^2\gamma^2(-25c_1{}^2 + 46c_1c_2 - 25c_2{}^2) - 4\beta\gamma^3(3c_1{}^2 - 8c_1c_2 + 3c_2{}^2) + \gamma^4(9c_1{}^2 - 14c_1c_2 + 9c_2{}^2)] >$

$\frac{1}{16(2\beta+\gamma)(2\beta-\gamma)(\beta-\gamma)}[(2\beta+\gamma)(\beta+\gamma)[(8\beta-3\gamma)c_2-(8\beta-5\gamma)c_1][(5\beta-3\gamma)c_2-(3\beta-\gamma)c_1]-36\beta^4(c_1-c_2)^2+8\beta^3\gamma(7{c_1}^2-15c_1c_2+7c2^2)+\beta^2\gamma^2(-25{c_1}^2+46c_1c_2-25{c_2}^2)-4\beta\gamma^3(3{c_1}^2-8c_1c_2+3{c_2}^2)+\gamma^4(9{c_1}^2-14c_1c_2+9{c_2}^2)]=\frac{1}{16(2\beta+\gamma)(2\beta-\gamma)(\beta-\gamma)}[(44\beta^4+98\beta^3\gamma-84\beta^2\gamma^2-24\beta\gamma^3+18\gamma^4){c_2}^2+(12\beta^4+82\beta^3\gamma-60\beta^2\gamma^2-20\beta\gamma^3+14\gamma^4){c_1}^2-(56\beta^4+180\beta^3\gamma-144\beta^2\gamma^2-44\beta\gamma^3+32\gamma^4)c_1c_2]$.

Set $A_1=44\beta^4+98\beta^3\gamma-84\beta^2\gamma^2-24\beta\gamma^3+18\gamma^4$ and $B_1=12\beta^4+82\beta^3\gamma-60\beta^2\gamma^2-20\beta\gamma^3+14\gamma^4$, then $\pi_2^r(p_{21}^*,p_{22}^*)-\pi_1^r(p_{11}^*,p_{12}^*)>\frac{1}{16(2\beta+\gamma)(2\beta-\gamma)(\beta-\gamma)}[A_1{c_2}^2+B_1{c_1}^2-(A_1+B_1)c_1c_2]=\frac{1}{16(2\beta+\gamma)(2\beta-\gamma)(\beta-\gamma)}[(c_2-c_1)(A_1c_2-B_1c_1)]$. Since $A_1=(44\beta^4-24\beta\gamma^3)+(98\beta^3\gamma-84\beta^2\gamma^2)+18\gamma^4>0$and $B_1=12\beta^4+(60\beta^3\gamma-60\beta^2\gamma^2)+(20\beta^3\gamma-20\beta\gamma^3)+14\gamma^4>0$, then $A_1-B_1=(32\beta^4-24\beta^2\gamma^2)+(16\beta^3\gamma-4\beta\gamma^3)+4\gamma^4>0$, that is, $A_1>B_1$. So, $(c_2-c_1)(A_1c_2-B_1c_1)>0$, that is, $\pi_2^r(p_{21}^*,p_{22}^*)>\pi_1^r(p_{11}^*,p_{12}^*)$. Hence, when both manufacturers share their cost information, the retailer will adopt unified negotiation strategy.

Case 2: When both manufacturers hide their cost information, from table 2 and (5), we get $\pi_3^r(p_{31}^*,p_{32}^*)=\frac{\beta[2\alpha-(\beta-\gamma)(c_1+c_2)]^2}{8(2\beta-\gamma)(\beta-\gamma)}$. Similarly, from table 2 and (5), we get $\pi_4^r(p_{41}^*,p_{42}^*)=\frac{[2\alpha-(\beta-\gamma)(c_1+c_2)]^2}{16(\beta-\gamma)}$. Then $\pi_3^r(p_{31}^*,p_{32}^*)-\pi_4^r(p_{41}^*,p_{42}^*)=\frac{[2\alpha-(\beta-\gamma)(c_1+c_2)]^2\gamma}{16(2\beta-\gamma)(\beta-\gamma)}>0$, that is, $\pi_3^r(p_{31}^*,p_{32}^*)>\pi_4^r(p_{41}^*,p_{42}^*)$. Hence, when both manufacturers withhold their cost information, the retailer will adopt segmented negotiation strategy.

Case 3: When only manufacturer 1 sharing his cost information, from table 2 and (5), we get $\pi_5^r(p_{51}^*,p_{52}^*)=\frac{\beta\{4\alpha(2\beta+\gamma)[2\alpha-(3c_1+c_2)(\beta-\gamma)]+(\beta-\gamma)[2\beta^2(5{c_1}^2+2c_1c_2+{c_2}^2)-4\beta\gamma c_1(c_1+c_2)-\gamma^2(5{c_1}^2+2c_1c_2+{c_2}^2)]\}}{16(\beta-\gamma)(4\beta^2-\gamma^2)}$. Similarly, from table 2 and (5), we get $\pi_6^r(p_{61}^*,p_{62}^*)=\frac{\alpha[2\alpha-(3c_1+c_2)(\beta-\gamma)]}{8(\beta-\gamma)}+\frac{(\beta-\gamma)[\beta({c_1}^2+22c_1c_2-7{c_2}^2)+\gamma(17{c_1}^2-10c_1c_2+9{c_2}^2)]}{64(\beta+\gamma)}$. $\pi_6^r(p_{61}^*,p_{62}^*)>0$ means that $8\alpha(\beta+\gamma)[2\alpha-(3c_1+c_2)(\beta-\gamma)]>-(\beta-\gamma)^2[\beta({c_1}^2+22c_1c_2-7{c_2}^2)+\gamma(17{c_1}^2-10c_1c_2+9{c_2}^2)]$. Then $\pi_5^r(p_{51}^*,p_{52}^*)-\pi_6^r(p_{61}^*,p_{62}^*)=\frac{1}{64(\beta^2-\gamma^2)(4\beta^2-\gamma^2)}\{8\alpha\gamma(\beta+\gamma)(2\beta+\gamma)[2\alpha-(3c_1+c_2)(\beta-\gamma)]+(36\beta^5-92\beta^4\gamma+81\beta^3\gamma^2-13\beta^2\gamma^3-21\beta\gamma^4+9\gamma^5){c_2}^2+(36\beta^5-76\beta^4\gamma+73\beta^3\gamma^2-37\beta^2\gamma^3-13\beta\gamma^4+17\gamma^5){c_1}^2-(72\beta^5-200\beta^4\gamma+170\beta^3\gamma^2-2\beta^2\gamma^3-50\beta\gamma^4+10\gamma^5)c_1c_2\}>\frac{1}{64(\beta^2-\gamma^2)(4\beta^2-\gamma^2)}\{-\gamma(2\beta+\gamma)(\beta-\gamma)^2[\beta({c_1}^2+22c_1c_2-7{c_2}^2)+\gamma(17{c_1}^2-10c_1c_2+9{c_2}^2)]+(36\beta^5-92\beta^4\gamma+81\beta^3\gamma^2-13\beta^2\gamma^3-21\beta\gamma^4+9\gamma^5){c_2}^2+(36\beta^5-76\beta^4\gamma+73\beta^3\gamma^2-37\beta^2\gamma^3-13\beta\gamma^4+17\gamma^5){c_1}^2-(72\beta^5-200\beta^4\gamma+170\beta^3\gamma^2-2\beta^2\gamma^3-50\beta\gamma^4+10\gamma^5)c_1c_2\}=\frac{(34\beta^3-6\beta^2\gamma-6\beta\gamma^2)(\beta-\gamma)^2+8\beta\gamma^3(\beta-\gamma)}{64(\beta^2-\gamma^2)(4\beta^2-\gamma^2)}(c_2-c_1)^2>0$, that is, $\pi_5^r(p_{51}^*,p_{52}^*)>\pi_6^r(p_{61}^*,p_{62}^*)$. Hence, when only manufacturer 1 sharing his cost information, the retailer will adopt segmented negotiation strategy.

Case 4: When only manufacturer 2 sharing his cost information, from table 2 and (5), we get $\pi_7^r(p_{71}^*,p_{72}^*)=$

$\frac{\beta\{4\alpha(2\beta+\gamma)[2\alpha-(c_1+3c_2)(\beta-\gamma)]+(\beta-\gamma)[2\beta^2(5{c_1}^2+2c_1c_2+{c_2}^2)-4\beta\gamma c_2(c_1+c_2)-\gamma^2({c_1}^2+2c_1c_2+5{c_2}^2)]\}}{16(\beta-\gamma)(4\beta^2-\gamma^2)}$. Similarly, from table 2 and (5), we get $\pi_8^r(p_{81}^*,p_{82}^*)=\frac{\alpha[2\alpha-(c_1+3c_2)(\beta-\gamma)]}{8(\beta-\gamma)}-\frac{(\beta-\gamma)[\beta(7{c_1}^2-22c_1c_2-{c_2}^2)-\gamma(9{c_1}^2-10c_1c_2+17{c_2}^2)]}{64(\beta+\gamma)}$. $\pi_8^r(p_{81}^*,p_{82}^*)>0$ means that $8\alpha(\beta+\gamma)[2\alpha-(c_1+3c_2)(\beta-\gamma)]>(\beta-\gamma)^2[\beta(7{c_1}^2-22c_1c_2-{c_2}^2)-\gamma(9{c_1}^2-10c_1c_2+17{c_2}^2)]$. Then we get $\pi_7^r(p_{71}^*,p_{72}^*)-\pi_8^r(p_{81}^*,p_{82}^*)=\frac{1}{64(\beta^2-\gamma^2)(4\beta^2-\gamma^2)}\{8\alpha\gamma(\beta+\gamma)(2\beta+\gamma)[2\alpha-(c_1+3c_2)(\beta-\gamma)]+(36\beta^5-76\beta^4\gamma+73\beta^3\gamma^2-37\beta^2\gamma^3-13\beta\gamma^4+17\gamma^5){c_2}^2+(36\beta^5-92\beta^4\gamma+81\beta^3\gamma^2-13\beta^2\gamma^3-21\beta\gamma^4+9\gamma^5){c_1}^2-(72\beta^5-200\beta^4\gamma+170\beta^3\gamma^2-2\beta^2\gamma^3-50\beta\gamma^4+10\gamma^5)c_1c_2\}>\frac{1}{64(\beta^2-\gamma^2)(4\beta^2-\gamma^2)}\{\gamma(2\beta+\gamma)(\beta-\gamma)^2[\beta(7{c_1}^2-22c_1c_2-{c_2}^2)-\gamma(9{c_1}^2-10c_1c_2+17{c_2}^2)]+(36\beta^5-76\beta^4\gamma+73\beta^3\gamma^2-37\beta^2\gamma^3-13\beta\gamma^4+17\gamma^5){c_2}^2+(36\beta^5-92\beta^4\gamma+81\beta^3\gamma^2-13\beta^2\gamma^3-21\beta\gamma^4+9\gamma^5){c_1}^2-(72\beta^5-200\beta^4\gamma+170\beta^3\gamma^2-2\beta^2\gamma^3-50\beta\gamma^4+10\gamma^5)c_1c_2\}=\frac{1}{64(\beta^2-\gamma^2)(4\beta^2-\gamma^2)}(36\beta^5-78\beta^4\gamma+42\beta^3\gamma^2+14\beta^2\gamma^3-14\beta\gamma^4)(c_2-c_1)^2>0$, that is, $\pi_7^r(p_{71}^*,p_{72}^*)>\pi_8^r(p_{81}^*,p_{82}^*)$. Hence, when only manufacturer 2 sharing his cost information, the retailer will adopt segmented negotiation strategy. So, when both manufacturers share their cost information, the retailer will adopt unified negotiation strategy; otherwise, the retailer will adopt segmented negotiation strategy.

Proof of Proposition 2

Since $w_{32}^*>c_2$, from table 2, we get $2\alpha>(5\beta-3\gamma)c_2-(3\beta-\gamma)c_1$. Then $\pi_2^r(p_{21}^*,p_{22}^*)-\pi_5^r(p_{51}^*,p_{52}^*)=\frac{1}{16(\beta+\gamma)(4\beta^2-\gamma^2)}[16\alpha^2\beta^2+24\alpha^2\beta\gamma+8\alpha^2\gamma^2+(-30\beta^4+62\beta^3\gamma-28\beta^2\gamma^2-15\beta\gamma^3+9\gamma^4){c_2}^2+(-38\beta^4+58\beta^3\gamma-20\beta^2\gamma^2-11\beta\gamma^3+9\gamma^4){c_1}^2-(-68\beta^4+128\beta^3\gamma-44\beta^2\gamma^2-34\beta\gamma^3+14\gamma^4)c_1c_2+\alpha(-16\beta^3-12\beta^2\gamma+10\beta\gamma^2+6\gamma^3)c_2+\alpha(12\beta^2\gamma+18\beta\gamma^2+6\gamma^3)c_1]>\frac{1}{16(\beta+\gamma)(4\beta^2-\gamma^2)}\{[(5\beta-3\gamma)c_2-(3\beta-\gamma)c_1](12\beta^3+12\beta^2\gamma+5\beta\gamma^2-3\gamma^3)c_2-[(5\beta-3\gamma)c_2-(3\beta-\gamma)c_1](12\beta^3+8\beta^2\gamma-\beta\gamma^2-5\gamma^3)c_1+(-30\beta^4+62\beta^3\gamma-28\beta^2\gamma^2-15\beta\gamma^3+9\gamma^4){c_2}^2+(-38\beta^4+58\beta^3\gamma-20\beta^2\gamma^2-11\beta\gamma^3+9\gamma^4){c_1}^2-(-68\beta^4+128\beta^3\gamma-44\beta^2\gamma^2-34\beta\gamma^3+14\gamma^4)c_1c_2\}=\frac{c_2-c_1}{16(\beta+\gamma)(4\beta^2-\gamma^2)}[(30\beta^4+86\beta^3\gamma-79\beta^2\gamma^2-21\beta\gamma^3+18\gamma^4)c_2-(-2\beta^4+70\beta^3\gamma-55\beta^2\gamma^2-17\beta\gamma^3+14\gamma^4)c_1]>0$, that is, $\pi_2^r(p_{21}^*,p_{22}^*)>\pi_5^r(p_{51}^*,p_{52}^*)$.

$\pi_5^r(p_{51}^*,p_{52}^*)-\pi_3^r(p_{31}^*,p_{32}^*)=\frac{\beta(c_2-c_1)[4\alpha(2\beta+\gamma)-2\beta^2(3c_1+c_2)+2\beta\gamma(c_1+c_2)+\gamma^2(3c_1+c_2)]}{16(4\beta^2-\gamma^2)}>\frac{\beta(c_2-c_1)\{2(2\beta+\gamma)[(5\beta-3\gamma)c_2-(3\beta-\gamma)c_1]+(\gamma^2-2\beta^2)(3c_1+c_2)+2\beta\gamma(c_1+c_2)\}}{16(4\beta^2-\gamma^2)}=\frac{\beta(c_2-c_1)^2(18\beta^2-5\gamma^2)}{16(4\beta^2-\gamma^2)}>0$, that is, $\pi_5^r(p_{51}^*,p_{52}^*)>\pi_3^r(p_{31}^*,p_{32}^*)$.

$\pi_3^r(p_{31}^*,p_{32}^*)-\pi_7^r(p_{71}^*,p_{72}^*)=\frac{\beta(c_2-c_1)[4\alpha(2\beta+\gamma)-2\beta^2(c_1+3c_2)+2\beta\gamma(c_1+c_2)+\gamma^2(c_1+3c_2)]}{16(4\beta^2-\gamma^2)}>$

$\frac{\beta(c_2-c_1)\{(4\beta+2\gamma)[(5\beta-3\gamma)c_2-(3\beta-\gamma)c_1]+(\gamma^2-2\beta^2)(c_1+3c_2)+2\beta\gamma(c_1+c_2)\}}{16(4\beta^2-\gamma^2)} = \frac{\beta(c_2-c_1)^2(14\beta^2-3\gamma^2)}{16(4\beta^2-\gamma^2)} > 0$, that is, $\pi_3^r(p_{31}^*, p_{32}^*) - \pi_7^r(p_{71}^*, p_{72}^*)$. So, $\pi_2^r(p_{21}^*, p_{22}^*) > \pi_5^r(p_{51}^*, p_{52}^*) > \pi_3^r(p_{31}^*, p_{32}^*) > \pi_7^r(p_{71}^*, p_{72}^*)$.

Proof of Proposition 3

Since $w_{32}^* > c_2$, from table 2, we get $2\alpha > (5\beta-3\gamma)c_2 - (3\beta-\gamma)c_1$.

$\pi_{21}^m(w_{21}^*) - \pi_{31}^m(w_{31}^*) = \frac{1}{64(\beta-\gamma)(2\beta-\gamma)^2}\{(48\beta^4 - 136\beta^3\gamma + 133\beta^2\gamma^2 - 50\beta\gamma^3 + 5\gamma^4){c_2}^2 + (80\beta^4 - 248\beta^3\gamma + 281\beta^2\gamma^2 - 138\beta\gamma^3 + 25\gamma^4){c_1}^2 - (128\beta^4 - 384\beta^3\gamma + 414\beta^2\gamma^2 - 188\beta\gamma^3 + 30\gamma^4)c_1c_2 + 4\gamma^2[(\alpha^2 + (\beta-\gamma)^2{c_2}^2] + 4\alpha(\beta-\gamma)[(8\beta^2 - 12\beta\gamma + 3\gamma^2)c_2 - (8\beta^2 - 12\beta\gamma + 5\gamma^2)c_1]\} > \frac{1}{64(\beta-\gamma)(2\beta-\gamma)^2}[(128\beta^4 - 384\beta^3\gamma + 432\beta^2\gamma^2 - 208\beta\gamma^3 + 36\gamma^4){c_2}^2 + (128\beta^4 - 384\beta^3\gamma + 432\beta^2\gamma^2 - 208\beta\gamma^3 + 36\gamma^4){c_1}^2 - 2(128\beta^4 - 384\beta^3\gamma + 432\beta^2\gamma^2 - 208\beta\gamma^3 + 36\gamma^4)c_1c_2] = \frac{1}{64(\beta-\gamma)(2\beta-\gamma)^2}(128\beta^4 - 384\beta^3\gamma + 432\beta^2\gamma^2 - 208\beta\gamma^3 + 36\gamma^4)(c_2-c_1)^2 > 0$, that is, $\pi_{21}^m(w_{21}^*) > \pi_{31}^m(w_{31}^*)$.

$\pi_{31}^m(w_{31}^*) - \pi_{51}^m(w_{51}^*) = \frac{\beta(c_2-c_1)}{16(4\beta^2-\gamma^2)^2}[8\alpha\beta^2(2\beta+\gamma) - 4\beta^4(c_1+3c_2) + 4\beta^3\gamma(c_1+c_2) + 8\beta^2\gamma^2c_2 + \gamma^4(c_1 - c_2)] > \frac{\beta(c_2-c_1)}{16(4\beta^2-\gamma^2)^2}\{4\beta^2(2\beta+\gamma)[(5\beta-3\gamma)c_2 - (3\beta-\gamma)c_1] - 4\beta^4(c_1+3c_2) + 4\beta^3\gamma(c_1+c_2) + 8\beta^2\gamma^2c_2 + \gamma^4(c_1-c_2)\} = \frac{\beta(c_2-c_1)}{16(4\beta^2-\gamma^2)^2}(28\beta^4 - 4\beta^2\gamma^2 - \gamma^4)(c_2-c_1) > 0$, that is, $\pi_{31}^m(w_{31}^*) > \pi_{51}^m(w_{51}^*)$. So, $\pi_{21}^m(w_{21}^*) > \pi_{31}^m(w_{31}^*) > \pi_{51}^m(w_{51}^*)$.

Proof of Proposition 4

Set $f(\alpha) = \pi_{22}^m(w_{22}^*) - \pi_{32}^m(w_{32}^*)$, then $f(\alpha) = \frac{[2\alpha+(\beta-\gamma)(3c_1-5c_2)]^2}{64(\beta-\gamma)} - \frac{\beta[2\alpha+(3\gamma-5\beta)c_2+(3\beta-\gamma)c_1][2\alpha-(\beta-\gamma)(c_1+c_2)]}{16(2\beta-\gamma)^2}$. So $\frac{df(\alpha)}{d\alpha} = \frac{2\gamma^2\alpha+(8\beta^3-20\beta^2\gamma+15\beta\gamma^2-3\gamma^3)c_1-(8\beta^3-20\beta^2\gamma+17\beta\gamma^2-5\gamma^3)c_2}{16(\beta-\gamma)(2\beta-\gamma)^2}$ and $\frac{d^2f(\alpha)}{d\alpha^2} = \frac{\gamma^2}{8(\beta-\gamma)(2\beta-\gamma)^2} > 0$, that is, $f(\alpha)$ is convex function of α. Let $\frac{df(\alpha)}{d\alpha} = 0$, we get $\alpha_0 = \frac{(\beta-\gamma)[(8\beta^2-12\beta\gamma+5\gamma^2)c_2-(8\beta^2-12\beta\gamma+3\gamma^2)c_1]}{2\gamma^2}$. Then, $Min\ f(\alpha) = f(\alpha_0) = \frac{\beta(c_2-c_1)^2(\beta-\gamma)(2\gamma-\beta)}{4\gamma^2}$.

If $\gamma < \beta < 2\gamma$, then $f(\alpha) > f(\alpha_0) > 0$, that is, $\pi_{22}^m(w_{22}^*) > \pi_{32}^m(w_{32}^*)$. If $\beta > 2\gamma$, then $f(\alpha_0) = \frac{\beta(c_2-c_1)^2(\beta-\gamma)(2\gamma-\beta)}{4\gamma^2} < 0$. Since $f(0) = \frac{(\beta-\gamma)[(80\beta^2-88\beta\gamma+25\gamma^2){c_2}^2+(48\beta^2-40\beta\gamma+9\gamma^2){c_1}^2-(128\beta^2-128\beta\gamma+30\gamma^2)c_1c_2}{64(2\beta-\gamma)^2} > 0$, then there are two positive solutions for $f(\alpha) = 0$. Set the two position solutions are α_1 and α_2, and $\alpha_1 > \alpha_2 > 0$, we get $\alpha_1 = \frac{(\beta-\gamma)[(8\beta^2-12\beta\gamma+5\gamma^2)c_2-(8\beta^2-12\beta\gamma+3\gamma^2)c_1]}{2\gamma^2} + \frac{4(c_2-c_1)(2\beta-\gamma)(\beta-\gamma)\sqrt{\beta(\beta-2\gamma)}}{2\gamma^2}$ and $\alpha_2 =$

$\frac{(\beta-\gamma)[(8\beta^2-12\beta\gamma+5\gamma^2)c_2-(8\beta^2-12\beta\gamma+3\gamma^2)c_1]}{2\gamma^2}-\frac{4(c_2-c_1)(2\beta-\gamma)(\beta-\gamma)\sqrt{\beta(\beta-2\gamma)}}{2\gamma^2}$. Then, if $\alpha>\alpha_1$ or $\alpha<\alpha_2$, then $f(\alpha)>0$, that is, $\pi_{22}^m(w_{22}^*)>\pi_{32}^m(w_{32}^*)$; if $\alpha_2<\alpha<\alpha_1$, then $f(\alpha)<0$, that is, $\pi_{22}^m(w_{22}^*)<\pi_{32}^m(w_{32}^*)$. Hence, if $\gamma<\beta<2\gamma$, or $\beta>2\gamma$ and $\alpha>\alpha_1$ or $\alpha<\alpha_2$, then $\pi_{22}^m(w_{22}^*)>\pi_{32}^m(w_{32}^*)$; if $\beta>2\gamma$ and $\alpha_2<\alpha<\alpha_1$, then $\pi_{22}^m(w_{22}^*)<\pi_{32}^m(w_{32}^*)$.

If $\beta>2\gamma$, then $\Delta\alpha=\alpha_1-\alpha_2=\frac{4(c_2-c_1)(2\beta-\gamma)(\beta-\gamma)\sqrt{\beta(\beta-2\gamma)}}{\gamma^2}$. So $\frac{d\Delta\alpha}{d\beta}=\frac{4(c_2-c_1)}{\gamma^2}\left[2(\beta-\gamma)\sqrt{\beta(\beta-2\gamma)}+(2\beta-\gamma)\sqrt{\beta(\beta-2\gamma)}+\frac{(2\beta-\gamma)(\beta-\gamma)^2}{\sqrt{\beta(\beta-2\gamma)}}\right]>0$, that is, $\Delta\alpha$ increases in β. Similarly, $\frac{d\Delta\alpha}{d\gamma}=-\frac{4(c_2-c_1)}{\gamma^4}\left\{\gamma^2\left[(\beta-\gamma)\sqrt{\beta(\beta-2\gamma)}+(2\beta-\gamma)\sqrt{\beta(\beta-2\gamma)}+(2\beta-\gamma)(\beta-\gamma)\frac{\beta}{\sqrt{\beta(\beta-2\gamma)}}\right]+2\gamma(2\beta-\gamma)(\beta-\gamma)\sqrt{\beta(\beta-2\gamma)}\right\}<0$, then $\Delta\alpha$ decreases in γ. So, if $\beta>2\gamma$, then $\Delta\alpha$ increases in β and decreases in γ.

Proof of Proposition 5

(1) With retailer's negotiation strategy 1, from table 2 and (1), we get $\pi_{11}^m(w_{11}^*)=\frac{\beta[\alpha(2\beta+\gamma)-(2\beta^2-\gamma^2)c_1+\beta\gamma c_2]^2}{4(4\beta^2-\gamma^2)^2}$. Similarly, from table 2 and (2), we get $\pi_{12}^m(w_{12}^*)=\frac{\beta[\alpha(2\beta+\gamma)-(2\beta^2-\gamma^2)c_2+\beta\gamma c_1]^2}{4(4\beta^2-\gamma^2)^2}$. Then $\pi_{11}^m(w_{11}^*)-\pi_{12}^m(w_{12}^*)=\frac{\beta(\beta+\gamma)(c_2-c_1)[2\alpha-(\beta-\gamma)(c_1+c_2)]}{4(4\beta^2-\gamma^2)}>0$, that is, $\pi_{11}^m(w_{11}^*)>\pi_{12}^m(w_{12}^*)$.

(2) With retailer's negotiation strategy 2, from table 2 and (1), we get $\pi_{21}^m(w_2^*)=\frac{[2\alpha-(\beta-\gamma)(5c_1-3c_2)]^2}{64(\beta-\gamma)}$. Similarly, from table 2 and (2), we get $\pi_{22}^m(w_2^*)=\frac{[2\alpha+(\beta-\gamma)(3c_1-5c_2)]^2}{64(\beta-\gamma)}$. Then $\pi_{21}^m(w_2^*)-\pi_{22}^m(w_2^*)=\frac{1}{4}(c_2-c_1)[2\alpha-(\beta-\gamma)(c_1+c_2)]>0$, that is, $\pi_{21}^m(w_2^*)>\pi_{22}^m(w_2^*)$.

(3) With retailer's negotiation strategy 3, from table 2 and (1), we get $\pi_{31}^m(w_{31}^*)=\frac{\beta[2\alpha+(3\gamma-5\beta)c_1+(3\beta-\gamma)c_2][2\alpha-(\beta-\gamma)(c_1+c_2)]}{16(2\beta-\gamma)^2}$. Similarly, from table 2 and (2), we get $\pi_{32}^m(w_{32}^*)=\frac{\beta[2\alpha+(3\gamma-5\beta)c_2+(3\beta-\gamma)c_1][2\alpha-(\beta-\gamma)(c_1+c_2)]}{16(2\beta-\gamma)^2}$. Then $\pi_{31}^m(w_{31}^*)-\pi_{32}^m(w_{32}^*)=\frac{\beta(c_2-c_1)[2\alpha-(\beta-\gamma)(c_1+c_2)]}{4(2\beta-\gamma)}>0$, that is, $\pi_{31}^m(w_{31}^*)>\pi_{32}^m(w_{32}^*)$.

(4) With retailer's negotiation strategy 4, from table 2 and (1), we get $\pi_{41}^m(w_4^*)=\frac{[2\alpha-(\beta-\gamma)(5c_1-3c_2)][2\alpha-(\beta-\gamma)(c_1+c_2)]}{64(\beta-\gamma)}$. Similarly, from table 2 and (2), we get $\pi_{42}^m(w_4^*)=\frac{[2\alpha-(\beta-\gamma)(5c_2-3c_1)][2\alpha-(\beta-\gamma)(c_1+c_2)]}{64(\beta-\gamma)}$. Then $\pi_{41}^m(w_4^*)-\pi_{42}^m(w_4^*)=\frac{1}{8}(c_2-c_1)[2\alpha-(\beta-\gamma)(c_1+c_2)]>0$, that is, $\pi_{41}^m(w_4^*)>\pi_{42}^m(w_4^*)$.

(5) With retailer's negotiation strategy 5, from table 2 and (1), we get $\pi_{51}^m(w_{51}^*)=$

$\frac{\beta[2\alpha(2\beta+\gamma)+\beta\gamma c_2-(4\beta^2-\beta\gamma-2\gamma^2)c_1]^2}{16(4\beta^2-\gamma^2)^2}$. Similarly, from table 2 and (2), we get $\pi_{52}^m(w_{52}^*) = \frac{\beta[2\alpha(2\beta+\gamma)-(2\beta^2-2\beta\gamma-\gamma^2)c_2-(2\beta^2-\gamma^2)c_1][2\alpha(2\beta+\gamma)-(10\beta^2-3\gamma^2)c_2+(6\beta^2+2\beta\gamma-\gamma^2)c_1]}{16(4\beta^2-\gamma^2)^2}$. Since $w_{32}^* > c_2$, from table 2, we get $2\alpha > (5\beta-3\gamma)c_2-(3\beta-\gamma)c_1$, then $\pi_{51}^m(w_{51}^*) - \pi_{52}^m(w_{52}^*) = \frac{\beta(c_2-c_1)}{16(4\beta^2-\gamma^2)}[2\alpha(6\beta+4\gamma)-(5\beta^2-3\gamma^2)c_2-(7\beta^2-4\beta\gamma-5\gamma^2)c_1] > \frac{\beta(c_2-c_1)}{16(4\beta^2-\gamma^2)}[(6\beta+4\gamma)[(5\beta-3\gamma)c_2-(3\beta-\gamma)c_1]-(5\beta^2-3\gamma^2)c_2-(7\beta^2-4\beta\gamma-5\gamma^2)c_1] = \frac{\beta(c_2-c_1)}{16(4\beta^2-\gamma^2)}[(25\beta^2+2\beta\gamma-9\gamma^2)(c_2-c_1)] > 0$, that is, $\pi_{51}^m(w_{51}^*) > \pi_{52}^m(w_{52}^*)$.

(6) With retailer's negotiation strategy 6, from table 2 and (1), we get $\pi_{61}^m(w_6^*) = \frac{[4\alpha-(7c_1-3c_2)(\beta-\gamma)]^2}{256(\beta-\gamma)}$. Similarly, from table 2 and (2), we get $\pi_{62}^m(w_6^*) = \frac{[4\alpha+(9c_1-13c_2)(\beta-\gamma)][4\alpha+(c_1-5c_2)(\beta-\gamma)]}{256(\beta-\gamma)}$. Since $w_{32}^* > c_2$, from table 2, we get $2\alpha > (5\beta-3\gamma)c_2-(3\beta-\gamma)c_1$, then $\pi_{61}^m(w_6^*) - \pi_{62}^m(w_6^*) = \frac{c_2-c_1}{32}[12\alpha-(5c_1+7c_2)(\beta-\gamma)] > \frac{c_2-c_1}{32}\{6[(5\beta-3\gamma)c_2-(3\beta-\gamma)c_1]-(5c_1+7c_2)(\beta-\gamma)\} = \frac{c_2-c_1}{32}(23\beta-11\gamma) > 0$, that is, $\pi_{61}^m(w_6^*) > \pi_{62}^m(w_6^*)$.

(7) With retailer's negotiation strategy 7, from table 2 and (1), we get $\pi_{71}^m(w_{71}^*) = \frac{\beta[2\alpha(2\beta+\gamma)-(2\beta^2-2\beta\gamma-\gamma^2)c_2-(2\beta^2-\gamma^2)c_1][2\alpha(2\beta+\gamma)-(10\beta^2-3\gamma^2)c_1+(6\beta^2+2\beta\gamma-\gamma^2)c_2]}{16(4\beta^2-\gamma^2)^2}$. Similarly, from table 2 and (2), we get $\pi_{72}^m(w_{72}^*) = \frac{\beta[2\alpha(2\beta+\gamma)+\beta\gamma c_1-(4\beta^2-\beta\gamma-2\gamma^2)c_1]^2}{16(4\beta^2-\gamma^2)^2}$. Since $w_{32}^* > c_2$, from table 2, we get $2\alpha > (5\beta-3\gamma)c_2-(3\beta-\gamma)c_1$, then $\pi_{71}^m(w_{71}^*) - \pi_{72}^m(w_{72}^*) = \frac{\beta(c_2-c_1)}{16(4\beta^2-\gamma^2)}[2\alpha(6\beta+4\gamma)-(5\beta^2-3\gamma^2)c_1-(7\beta^2-4\beta\gamma-5\gamma^2)c_2] > \frac{\beta(c_2-c_1)}{16(4\beta^2-\gamma^2)}\{(6\beta+4\gamma)[(5\beta-3\gamma)c_2-(3\beta-\gamma)c_1]-(5\beta^2-3\gamma^2)c_1-(7\beta^2-4\beta\gamma-5\gamma^2)c_2\} = \frac{\beta(c_2-c_1)}{16(4\beta^2-\gamma^2)}(23\beta^2+6\beta\gamma-7\gamma^2)(c_2-c_1) > 0$, that is, $\pi_{71}^m(w_{71}^*) > \pi_{72}^m(w_{72}^*)$.

(8) With retailer's negotiation strategy 8, from table 2 and (1), we get $\pi_{81}^m(w_8^*) = \frac{[4\alpha-(13c_1-9c_2)(\beta-\gamma)][4\alpha-(5c_1-c_2)(\beta-\gamma)]}{256(\beta-\gamma)}$. Similarly, from table 2 and (2), we get $\pi_{82}^m(w_8^*) = \frac{[4\alpha+(3c_1-7c_2)(\beta-\gamma)]^2}{256(\beta-\gamma)}$. Since $w_{32}^* > c_2$, from table 2, we get $2\alpha > (5\beta-3\gamma)c_2-(3\beta-\gamma)c_1$, then $\pi_{81}^m(w_8^*) - \pi_{82}^m(w_8^*) = \frac{c_2-c_1}{32}[12\alpha-(7c_1+5c_2)(\beta-\gamma)] > \frac{c_2-c_1}{32}\{6[(5\beta-3\gamma)c_2-(3\beta-\gamma)c_1]-(7c_1+5c_2)(\beta-\gamma)\} = \frac{c_2-c_1}{32}(25\beta-13\gamma)(c_2-c_1) > 0$, that is, $\pi_{81}^m(w_8^*) > \pi_{82}^m(w_8^*)$.

So, the high-efficiency manufacturer's maximum profit is always higher than that of the low-efficiency manufacturer.