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Alliance or no alliance—Bargaining power in competing reverse supply chains

Jiuh-Biing Sheu [a,*], Xiao-Qin Gao [b]

[a] Department of Business Administration, National Taiwan University, No.1, Sec. 4, Roosevelt Road, Taipei 10617, Taiwan, ROC
[b] Institute of Traffic and Transportation, National Chiao Tung University, 4F, 118 Chung Hsiao W. Road, Sec. 1, Taipei 10012, Taiwan, ROC

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ABSTRACT

This work investigates how bargaining power affects negotiations between manufacturers and reverse logistics providers in reverse supply chains under government intervention using a novel three-stage reverse supply chain model for two scenarios, a reverse logistics provider alliance and no reverse logistics provider alliance. Utilizing the asymmetric Nash bargaining game, this work seeks equilibrium negotiation solutions. Analytical results indicate that the reverse logistics provider alliance increases the bargaining power of reverse logistics providers when negotiating with a manufacturer for a profitable recycled-component supply contract; however, manufacturer profits are often reduced. Particularly in the case of an recycled-component vender-dominated market, a reverse logistics alliance with extreme bargaining power may cause a counter-profit effect that results in the decreases of profits for all players involved, including buyers (*i.e.*, manufacturers) and allied recycled-component venders (*i.e.*, reverse logistics providers). Additional managerial insights are provided for discussion.

1. Introduction

As the concept of extended producer responsibility (EPR) has emerged along with government intervention, interactions between manufacturers and reverse logistics (RL) providers are unavoidable in cooperative reverse supply chains. Practical cases in various manufacturing industries, such as the high-tech manufacturing, automobile, iron and steel, textile, and garment industries, further demonstrate the increasing importance of cooperating with RL providers in reverse supply chains, particularly under government intervention. For example, China consumes over 200 million tons of steel annually, including 20 million tons of steel made from steel scrap, 26 million tons of iron recycled by society, and 13 million tons from productive and non-productive recycling of steel scrap. Most Chinese iron and steel manufacturers rely on RL providers to recycle iron and steel scrap at low operational costs and with high efficiency, such that the steel manufacturers can focus on their core businesses. Another example is the electronics manufacturing industry. For instance, ASUS, a well-known global branded computer manufacturer, has recently has adopted green practices (*e.g.*, green procurement, green design, and green manufacturing) to carry out its so-called "Green ASUS" strategy. In terms of green procurement, ASUS uses Acrylonitrile–Butadiene-Styrene plastic for the housing of its notebook computers. Nevertheless, the Regulations on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products are now enforced in China (Ministry of Environmental Protection, China, 2011), as are the Restriction on Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) directives in European Union nations. To comply with these new green regulations, ASUS must increase its purchase of recycled Acrylonitrile–Butadiene-Styrene plastic, which is produced by RL providers through reprocessing shredded transfusion tubes, plastic products, and plastic housings of discarded electronics products. Not surprisingly, as a global manufacturer of green notebook computers, ASUS must negotiate with RL providers to procure recycled Acrylonitrile–Butadiene-Styrene plastic.

Typically, via negotiation between a manufacturer and an RL provider, a contract is established for recycled material price and amount. The RL providers include recyclers that provide recycled components by recycling end-of-life products for the production of green products by manufacturers. Such a producer-RL provider negotiation process toward a contractual agreement is indispensible, particularly for those highly profitable recycled-materials, *e.g.*, gold, aluminum, copper, palladium, and other precious metals, that can be reused through recovery and recycling processes from electronic wastes (Chen, Sheu, & Lirn, 2012; Kang & Schoenung, 2005). Thus, RL providers play an important role in cooperative reverse supply chains by providing end-customers with opportunities to return defective products for repair (Tuğba, Semih, & Elif, 2008) and by collecting and recycling end-of-life products for

* Corresponding author. Tel.: +886 2 3366 1069.
E-mail addresses: jbsheu@ntu.edu.tw (J.-B. Sheu), carrollgxq@126.com (X.-Q. Gao).

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manufacturers (Guide, Jayaraman, Srivastava, & Benton, 2000), while conforming with green laws/regulations implemented by governments.

Nevertheless, the cooperative reverse supply chain negotiations cannot ignore the issue of bargaining power (DiMatteo, Prentice, Morant, & Barnhizer, 2007). Bargaining power has been defined as the ability of one party to influence the terms and conditions in a contract or subsequent contracts in its favor due to its possession of unique and valuable resources (Argyres & Liebeskind, 1999). Inderst (2002) claimed that contractual distortions are caused typically by asymmetric bargaining power during negotiation. Crook and Combs (2007) further suggested that bargaining power differs among supply chain members. One notable example is the power-dependence relationship between Wal-Mart and its suppliers, where only large suppliers have an ability to exert countervailing power when facing Wal-Mart's "big squeeze" (Bloom & Perry, 2001).

Furthermore, a shift in bargaining power caused by either government intervention or an RL alliance may increase the complexity of such bilateral negotiations. Based on resource dependence theory (Pfeffer & Salancik, 1978; Ulrich & Barney, 1984), we propose that government intervention can increase the dependence of a manufacturer on an RL provider's resources to comply with green regulations (*e.g.*, take-back laws). According to Pfeffer and Salancik (1978), organizations are rarely self-sufficient with respect to their critical resources and, thus, are dependent upon the resources of others for survival in competitive environments. Conversely, we argue that government intervention increases the likelihood of an RL provider exerting countervailing power through an RL alliance to seek a balanced power relationship when negotiating with manufacturers. For example, government intervention via green legislation and financial incentives has altered the relative power of manufacturers and RL providers during negotiations. This argument is based on evidence from several practical cases in Europe, indicating that recyclers influence producer market share and costs for WEEE compliance (Clean Production Action. 2003; Stevels & Huisman, 2005). Particularly, strategic alliances of RL providers that have relatively less power than manufacturers seek opportunities to gain additional benefits while bargaining with manufacturers. This scenario has been observed increasingly in anecdotal evidence and real-world cases. Moreover, an RL alliance is very likely to facilitate a reduction in RL operational costs by consolidating small volumes of scattered RL tasks with similar attributes into full load tasks to attain economies of scale (Liu & Zhang, 2008).

Although the number of RL studies has grown steadily, reflecting the increasing significance of RL in the context of government intervention, these studies primarily provide a strong basis for developing general frameworks and mathematical models for analyzing RL operational performance and practices for the case of no RL alliance. Krumwiedea and Sheu (2002) established an RL decision-making model to guide the process of examining the feasibility of implementing RL for third-party providers such as transportation companies. Kim, Song, Kim, and Jeong (2006) developed a mathematical model that maximizes total cost savings by determining the equilibrium quantity of parts to be processed at each remanufacturing facility and the number of parts that should be purchased from subcontractors. Additionally, Sheu (2007) built a linear multi-objective analytical model to systematically minimize total RL operating costs and risks, and developed a prototype green supply chain negotiation model (Sheu, 2011). Du and Evans (2008) established a bi-objective optimization model that minimizes overall costs and total tardiness in RL cycle time. Kara, Rugrungruang, and Kaebernick (2007) developed a simulation model to assess the performance of RL networks in collecting end-of-life appliances in the Sydney Metropolitan Area. Min and Ko (2008) utilized a mixed-integer programming model and a genetic algorithm to solve an RL problem involving location and allocation of repair facilities for third-party logistics providers. Mitra and Webster (2008) analyzed a two-period model of a manufacturer that produces and sells a new product and a remanufacturer that competes with the manufacturer during the second period; the effects of governmental subsidies used to promote remanufacturing activities were examined. Hu, Sheu, and Huang (2002) constructed a discrete-time linear analytical model that minimizes total RL operating costs, subject to constraints that consider such internal and external factors as business operating strategies and government regulations. Aksen, Aras, and Karaarslan (2009) developed and solved two bi-level programming (BP) models describing a subsidization agreement between a government and a company engaged in end-of-life product collection and recovery. Under the same collection rate and profitability ratio, a government must provide a higher subsidy with the supportive model than with the legislative model. Chen and Sheu (2009) established a differential game model comprising the Vidale–Wolfe equation, which favors product recycling. Despite these advances for cooperative reverse supply chains, the research scope of these studies was limited to the scenario of RL operations without considering RL alliances. Conversely, this work, including the proposed model and analyses, applies to both the cases of no RL alliance and an RL alliance.

The emergence of research in diverse public goods games used to address issues of resource sustainability in the area of evolutionary games is also noteworthy (Anderson, Goeree, & Holt, 1998; Andreoni, 1988; Hauert, De Monte, Hofbauer, & Sigmund, 2002; Helbing, Szolnoki, Perc, & Szabo, 2010; Semmann, Krambeck, & Milinski, 2003). Stemming from repeated mix-motive games, public goods games aim at the social dilemma in which individual actions enhancing personal prosperity harm the others within groups (Macy & Flache, 2002). Therein, group members are classified into different categories, *e.g.*, cooperators and defectors, interacting with each other, thus contributing to different outcomes designated with respective payoffs. Specifically, public goods games consider reward and punishment effects on the dynamics and dilemmas of collective actions of game players when moving equilibrium conditions (Helbing et al., 2010; Perc, 2012; Perc & Szolnoki, 2012; Szolnoki & Perc, 2010). Similarly, this work treats government intervention as a form of political power characterized by regulatory and financial instruments, which are embedded in the proposed three-stage game-theoretic model. Drawing from the theory of environmental economics (Dobbs, 1991; Polack & Heertje, 2000; Walls & Palmer, 2001), the ideas of external benefit and external cost are conceptualized in a social welfare objective function embedded in the first-stage game dominated by the government. Furthermore, this work considers the influences of green taxation and subsidization, mimicking the effects of punishment and reward effects in public goods games, on the decisions of producers and RL providers in negotiations and market competition, thus formulating the follow-up bargaining and market competition problems in the second- and third-stage using asymmetric Nash bargaining game. Relative to public goods games, the distinctive feature of the proposed model is noticeable in its capability of characterizing the relative bargaining power of game players (*i.e.*, competing manufacturers relative to either RL providers or RL-alliance) and its influence in the decision outcomes of game players when moving toward equilibrium conditions (*e.g.*, cooperative agreements).

Furthermore, scholars have made notable advances in addressing supply chain cooperation issues (*e.g.*, Cachon & Lariviere, 2005; Koulamas, 2006; Pasternack, 1985); however, literature is generally limited to vertical coordination of chain members, and does not discuss the phenomenon of bargaining power alteration in the case of horizontal cooperation (*e.g.*, strategic alliance of RL providers), and its effect on cooperative reverse supply chains. For instance, the closest studies to this work are those by Nagarajan and Bassok (2008) and Sheu (2011). Nagarajan and Bassok (2008) addressed the assembler-suppliers bargaining problem in a decentralized supply chain, where a single assembler buys complementary components from allied suppliers. Conversely, this work considers the threats and bidding effect from competitors, thus generating a relatively more comprehensive bargaining framework containing two competing manufacturers and allied suppliers to investigate supply chain cooperation issues. By contrast, Sheu's bargaining model (2011) is limited to one-to-one bilateral negotiation and does not consider the RL provider alliances. These shortcomings leave room for this work.

The primary objective of this work is to investigate how a manufacturer interacts with RL providers for the cases without and with RL-provider alliance under government intervention. Specifically, this work addresses the following research questions.

1. How do an alliance and no alliance among RL providers influence the bargaining power in manufacturer and RL provider negotiation?
2. How does a shift in bargaining power influence the profits of manufacturers and allied RL providers, and how should manufacturers and RL providers deal with such influence?
3. What solutions exist for decisions of all players, including governments and cooperative reverse supply chain members, under an equilibrium condition.

Noticeably, this work adds to literature on green supply chain management (GSCM) in the following two ways. First, this work addresses the interplay between competing manufacturers and RL providers in cases with and without an RL alliance under governmental intervention of tack-back legislation and financial measures. We hypothesize that the altered relative bargaining power of manufacturers and RL providers due to an RL provider alliance will influence the equilibrium solutions of these green supply chain members for cooperative agreements. Thus, this work conceptualizes the influence of such a shift in bargaining power in the proposed manufacturer and RL supplier interplay model for an alliance and no alliance cases. Such a bargaining conceptualization and equilibrium solutions are rarely investigated in literature. Second, given an RL provider alliance, heterogeneity in the bargaining power of competitive manufacturers relative to that of an RL provider alliance is considered. Under the condition of competing manufacturers seeking the same RL provider alliance as a chain partner, manufacturers encounter threats from competitors and increasing breakdown risks resulting from altered bargaining power when negotiating with an RL provider alliance. The proposed model solves the specified manufacturers and RL provider alliance interplay problem by characterizing heterogeneity in competitors' bargaining power in a two-to-allied one bargaining framework. To the best of our knowledge, the investigation of such a bargaining framework characterizing the antecedents and outcomes of negotiations between two competing manufacturers and one RL provider alliance is limited to the works by Nagarajan and Bassok (2008) and Sheu (2011).

Additionally, although EPR systems vary worldwide (Kahhat et al., 2008), this work concentrates on individual EPR systems that regulate manufacturers as entirely responsible for, but allow them to contact RL providers individually for end-of-life product collection, recycling, and disposal. Such an individual-based EPR system is particularly common in the consumer electronics product manufacturing industry. Under either challenges of global green organizations or the spontaneous green branding strategies of enterprises, an increasing number of consumer electronics product manufacturers (*e.g.*, Apple, ASUS, ACER, and SONY) have incorporated green design into green manufacturing to improve product recyclability. One striking example is the Guide to Greener Electronics, a quarterly publication issued by Greenpeace International, which ranks the top 18 global brands of personal computers, mobile phones, televisions, and games consoles based on their policies for toxic chemicals, recycling, and climate change (Greenpeace International., 2010). This ranking has pressured top manufacturers to be responsible for the entire lifecycle of their products, including electronic waste generated and energy used. Therefore, global consumer electronics brands (*e.g.*, ASUS and ACER) prefer to control and manage their collection and recycling systems.

Briefly, this work aims at the issue of power shifting and restructuring in green supply chain negotiation and collaboration under socio-political power intervention. Such an issue, differing from typical supply chain management issues, requires interdisciplinary research for investigation. Specifically, we have extended the research aim and scope from the "power shifts" in supplier–buyer to supplier alliance-buyer negotiations of green supply chains under the third-party power intervention, which has never been addressed in either supply chain management or green supply chain management.

2. Model framework and assumptions

The focal story in this work is the interplay of reverse supply chain members under government intervention; two scenarios are considered—an RL alliance and no alliance. Motivated by advances in literature, this work proposes a three-stage reverse supply chain bargaining model for these two scenarios to analyze the effects of bargaining power on the interplay between manufacturers and RL providers as they negotiate toward cooperative agreements under government intervention. Specifically, this work focuses on symmetric Cournot's duopoly competition, which assumes firms are as similar as possible in all economic aspects and compete for the same buyers in an industry producing a storable, homogeneous product. Symmetric competition posits that competitors have the same production and inventory costs, charge the same price, and face symmetric demand functions (Schemalensee, 1976). Therefore, we assume all comparable parameters are equal and firms have similar market share. In numerous economic studies, competition results in a symmetric oligopoly, and duopoly competition from Cournot models have been proven to be the same under equilibrium conditions (Kreps & Sheinkman, 1983; Schemalensee, 1976).

2.1. Framework

Negotiation between a manufacturer and an RL provider is primary focus in this work. Subject to government green policies, a transaction concerning the recycled component supply through negotiations over recycled component prices between a manufacturer and an RL provider is indispensable. Therefore, this work conceptualizes the manufacturer and RL provider interplay process as a three-stage game-based framework. The first stage (making green policy) conceptualizes the influence of government intervention via take-back legislation and economic instruments adopted to increase manufacturer responsibility for collecting and recycling their products (Ongondo, Williams, & Cherrett, 2011; Webster & Mitra, 2007). According to Khetriwal, Kraeuchi, and Widmer (2009), the idea of EPR can be implemented via administrative, economic, and informative instruments. At this stage, this work primarily considers regulatory and economic approaches, which are two most popular measures adopted by governments to promote EPR, and are commonly utilized worldwide (Kahhat et al., 2008). Further details about practical cases of government intervention to promote EPR are provided in online Appendix A (A.1). In the second stage, the negotiation process, the manufacturer and RL provider negotiate an agreement on recycled component supply price and quantity under green policies. Upon negotiation completion, the two parties have identified the recycled component supply price and supply quantity. Typically, more than one RL provider may exist in a real situation. A manufacturer may consider factors such as breakdown risks from outside options, and thus, negotiate with all RL providers with the intention of purchasing recycled components from each provider. The third stage, termed product competition in the market, is used to identify the equilibrium solution with respect to manufacturer production under Cournot competition in the product demand market. Fig. 1 shows the proposed framework.

Furthermore, this work addresses two scenarios for contrast analysis. In Scenario 1, an alliance does not exist and RL providers compete. In Scenario 2, an alliance among RL providers exists; these RL providers consider alliances beneficial, as they offer such advantages as a stable and reliable market, and allow RL providers to influence product pricing and quality (Kannan & Tan, 2004). Fig. 2 shows the two scenarios for a dual duopoly competition case.

2.2. Assumptions

This section introduces several assumptions underlying the proposed model.

Assumption 1. Competitive markets in which both producers and RL providers are active are characterized by dual duopoly competition, where two duopolistic manufacturers compete in manufacturing homogeneous green products. Another two duopolistic RL providers collect end-of-life products and then sell the recycled components back to the manufacturers.

Assumption 2. The costs of producing green products, including unit collection and recycling costs, are the same for all manufacturers. Unit recycling cost is the cost of recycling a unit recycled component after collecting and disassembling end-of-life products.

Assumption 3. This work only considers the reverse supply chain case for manufacturing new products, where a unit of product is composed of recycled components and virgin components. Therein, recycled component supply price is determined *via* manufacturer and RL provider negotiations. The virgin component procurement cost is included in manufacturing cost for simplicity.

Assumption 4. Final product price ($P(Q)$) is assumed as a simple Cournot inverse demand (Q) function given by $P = a - bQ$, which follows the downward-sloping linear demand form by Savaskan, Bhattacharya, and Van Wassenhove (2004), where $Q = \sum_{i=1}^{2} q_i$, q_i is the product quantity sold by manufacturer i, and a and b are two positive parameters characterizing the correlation between the price and demand in the end-customer demand market.

Assumption 5. Two competing manufacturers have different bargaining power α_i ($i = 1, 2$) based on their difference in channel power in recycled component supply chains and are dependent upon the resources of their partners (Dwyer & Walker, 1981; Pfeffer & Salancik, 1978). Therein, α_i represents the bargaining power of manufacturer i relative to any given RL provider. For instance, when manufacturer i negotiates with RL provider $j(\forall j)$, the manufacturer's bargaining power is α_i, and that of RL provider $j(\forall j)$ is $1 - \alpha_i$. Differing from an operations research perspective, economic scholars typically utilize simple forms of market competition, *e.g.*, monopoly, duopoly, oligopoly, and perfect competition, to facilitate analyzing market competition of firms. As this work assumes the market competition as dual duopoly competition (Assumption 1), the bargaining power characterized in this work aims at two competing manufacturers relative to two competing RL providers/one RL-alliance.

Assumption 6. The RL providers have the same bargaining power. This work treats these RL providers similarly in all economic respects and, thus, their market influence is similar, particularly when an RL alliance exists. We postulate this assumption to facilitate analysis.

Assumption 7. The government implements green policies to regulate the recycling rate (r_c), environmental pollution fee (f) per unit levied on manufacturers, and unit subsidy (s) provided to RL providers under the goal of social welfare (SW) maximization. Particularly, our rationales for focusing on such economic instruments are rooted in the global trend of EPR from both theoretical and practical perspectives, which are described in detail in online Appendix A (A.2).

3. Model and solutions

To approximate equilibrium solutions for the three-stage game-based problem, this work adopts the backward induction approach (Kreps, 1990). The backward induction approach has been used extensively to search for equilibrium solutions to sequential game problems. In this work, the backward induction process first seeks

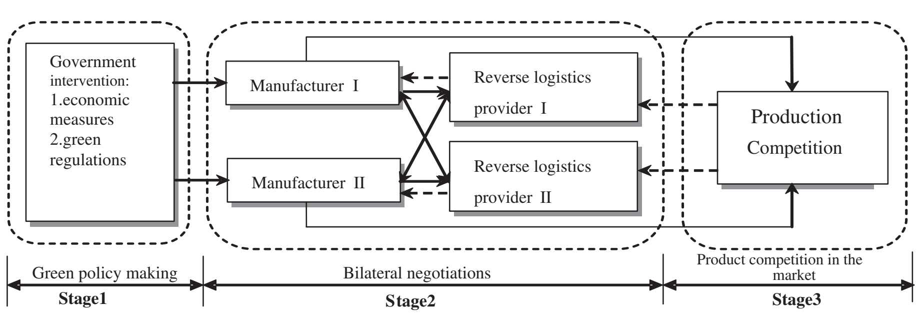

Fig. 1. Model framework which represents the proposed three-stage game-based manufacturer-RL provider negotiation framework in the context of government intervention.

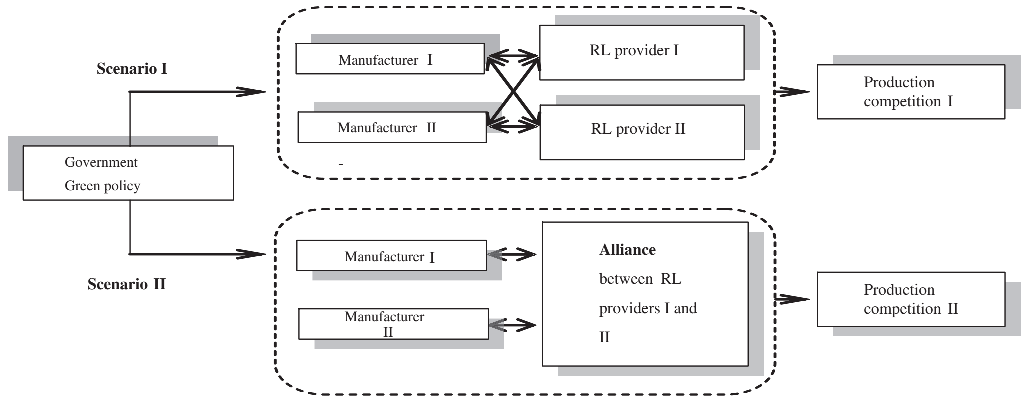

Fig. 2. Framework of scenarios which presents the framework in which manufacturers bargain with RL providers in two scenarios: non-alliance (Scenario I) and RL provider alliance (Scenario II).

tentative equilibrium solutions to the third stage, followed by identifying tentative equilibrium solutions in the second stage using tentative equilibrium solutions from the third stage, and then identifies the equilibrium solutions in the first stage. The tentative equilibrium solutions have not yet been finalized, except for those obtained in the first stage, since the tentative equilibrium solutions obtained at lower levels contain decision variables from higher levels. Therefore, the high-level equilibrium solutions should be inputted forward to lower levels to finalize equilibrium solutions. According to Rasmusen (2007), backward induction ensures perfect subgame equilibrium solutions obtained for sequential games.

Notably, the first and third stages remain unchanged in Scenarios I and II. In the first stage, a government implements green policies, which include an environmental pollution fee (f) levied on a manufacturer for producing per unit product, and a subsidy (s) is provided to an RL provider for recycling per unit recycled component. Another government policy addresses the recycling rate (r_c), which is typically stipulated in take-back laws. In the third stage, the two manufacturers compete for equilibrium output in a Cournot competition game, where both manufacturers have the same market demand curve (by Assumption 4). By contrast, the second stage models the interplay between the manufacturers and RL providers in negotiation using bargaining game theory. The two manufacturers negotiate with the RL providers to identify the recycled component supply price and amounts. The proposed models and applied variables may differ slightly in the two scenarios, which are described in detail in the following subsections.

3.1. Scenario I: No alliance exists between the two RL providers

Consider a dual duopoly competition condition in which two competing manufacturers (denoted by i; $i = 1, 2$) procure recycled components from two competing RL providers (denoted by j; $j = 1, 2$), where recycled component supply prices and amounts are determined through negotiations. One can then identify the relationship between recycled component amounts required and product production associated with manufacturer i by

$$y_{i1} + y_{i2} = q_i k \quad (\forall i) \tag{1}$$

where k is the recycled component amount required by a unit product, and y_{ij} is the recycled component amount required by manufacturer i and supplied by RL provider j. Suppose these two RL providers have the same bargaining power when negotiating with the two manufacturers; thus,

$$y_{i1} = y_{i2} = \frac{q_i k}{2} \quad (\forall i) \tag{2}$$

Under government intervention via green policies, the profit function (π_i) of manufacturer i can then be expressed as

$$\pi_i = (P - c_m - f)q_i - \frac{q_i k}{2}(p_{i1} + p_{i2}) \quad (\forall i) \tag{3}$$

where c_m is the cost of manufacturing a unit product, including input cost of virgin components; p_{ij} and y_{ij} represent recycled component supply price (including take-back cost associated with a unit of a recycled component) and the amount associated with manufacturer i and RL provider j, respectively.

For a given RL provider j, the total recycled component amount supplied to manufacturers is $\sum_{\forall i} y_{ij}$, and thus, the required amount of collected end-of-life products is $\sum_{\forall i} y_{ij}/r_c$, where r_c is the recycling rate, which can be regulated by green policies, as mentioned. Thus, the profit function (ξ_j) of RLs provider j ($\forall j$) can be expressed as

$$\xi_j = \sum_{\forall i} p_{ij} y_{ij} + \left(s - c_r - \frac{c_{col}}{r_c}\right)\sum_{\forall i} y_{ij} \quad (\forall j) \tag{4}$$

where c_{col} is the cost of collecting one end-of-life product unit, and c_r is the cost for recycling one recycled component unit.

3.1.1. Solution for stage 3

To ensure the existence of equilibrium solutions of q_i ($\forall i$), let the first-order condition of Eq. (3) with respect to q_i ($\forall i$) be $\frac{\partial \pi_i}{\partial q_i} = 0 (\forall i)$. Furthermore, $\frac{\partial^2 \pi_i}{\partial^2 q_i} < 0 (\forall i)$ can be derived to prove that tentative equilibrium solutions exist for manufacturers with respect to production ($q_i^*, i = 1, 2$), and are given by

$$q_1^* = \frac{2(a - c_m - f) + (p_{21} + p_{22} - 2p_{11} - 2p_{12})k}{6b} \tag{5}$$

$$q_2^* = \frac{2(a - c_m - f) + (p_{11} + p_{12} - 2p_{21} - 2p_{22})k}{6b} \tag{6}$$

Observed from Eqs. (5) and (6), the equilibrium solution of a manufacturer i's production ($q_i^*, i = 1, 2$) has positive associations with the recycled component supply prices ($p_{i'j}$) achieved by its competitor ($i' \neq i$) with RL providers ($j = 1, 2$); and however, negative associations with c_m, f, and the supply prices achieved by itself with RL providers ($j = 1, 2$), in conformity with our expectation.

Based on Assumption 4 regarding the linear product demand form, tentative equilibrium solutions of product price (P^*) and total production (Q^*) can be derived by

$$P^* = a - \frac{4(a - c_m - f) - (p_{11} + p_{12} + p_{21} + p_{22})k}{6} \tag{7}$$

$$Q^* = \frac{4(a - c_m - f) - (p_{11} + p_{12} + p_{21} + p_{22})k}{6b} \quad (8)$$

Observed from Eqs. (7) and (8), Q^* has properties similar to $q_i^*(q_i^*, i = 1,2)$; and however, a negative association with P^*.

Notably, although tentative equilibrium solutions, such as $q_i^*(i = 1,2)$, P^*, and Q^*, are derived, the recycled component supply prices p_{ij} ($i = 1, 2; j = 1, 2$) in Eqs. (5)–(8), which are determined in practice through negotiations between manufacturers and RL providers, have not yet been derived. The next step is to input these tentative equilibrium solutions into the second stage (*i.e.*, the negotiation process) to determine tentative equilibrium solutions of p_{ij} ($i = 1, 2; j = 1, 2$).

3.1.2. Solution for stage 2

Stage 2 deals with the negotiation problem between two competing manufacturers and two competing RL providers. Specifically, this work utilizes the asymmetric Nash bargaining game to derive the tentative equilibrium solutions of the recycled component supply prices and amounts (*i.e.*, p_{ij}^* and $y_{ij}^*, \forall i,j$). The basic concept of the asymmetric Nash bargaining game, particularly the components of a generalized form of the asymmetric Nash bargaining objective function, is described in online Appendix B.

Utilizing the asymmetric Nash bargaining game (Muthoo, 1999), this work formulates the pairwise manufacturer and RL provider negotiation problem as an asymmetric Nash bargaining game in which expected profit obtained from cooperation with another partner is considered. The recycled component amount required by a manufacturer can be provided by any one of the two RL providers; thus, remuneration for negotiation breakdown between manufacturer i and RL provider j is the profit from cooperation with another RL provider, provider $j'(j' \neq j)$. Let $\pi_{ij'}$ and $\xi_{i'j}$ be the resulting profits of manufacturer i and RL provider j in the case of negotiation breakdown, where $\pi_{ij'} \equiv (P - c_m - f)\frac{y_{ij'}}{k} - p_{ij'}y_{ij'}(j' \neq j)$ and $\xi_{i'j} \equiv p_{i'j}y_{i'j} + (s - c_r - \frac{c_{col}}{r_c})y_{i'j}(i' \neq i)$. According to Muthoo (1999), the proposed asymmetric Nash bargaining objective function ($\Gamma_{i,j}$) associated with manufacturer i and RL provider j ($\forall i,j$) can then be expressed as

$$\Gamma_{i,j} = Max_{p_{ij}}(\pi_i - \pi_{ij'})^{\alpha_i}(\xi_j - \xi_{i'j})^{1-\alpha_i}, \quad \forall i,j \quad (9)$$

where $i' \neq i; j' \neq j$. The equilibrium solutions of profits (π_i^* and ξ_j^*) gained by manufacturer i and RL provider j ($\forall i,j$) in the asymmetrical Nash bargaining game have the following properties (Eqs. (10) and (11)).

$$\pi_i^* = \pi_{ij'} + \alpha_i \times (\pi_i^* + \xi_j^* - \pi_{ij'} - \xi_{i'j}), \quad \forall i \quad (10)$$

$$\xi_j^* = \xi_{i'j} + (1 - \alpha_i) \times (\pi_i^* + \xi_j^* - \pi_{ij'} - \xi_i'j), \quad \forall j \quad (11)$$

Notably, P^* (Eq. (7)) and Q^* (Eq. (8)) obtained from stage 3 are input into Eqs. (10) and (11). After taking the first-order differential of Eqs. (10) and (11) with respect to p_{ij} ($\forall i,j$), the tentative equilibrium solutions of recycled component supply prices $p_{ij}^*(\forall i,j)$ can be derived as

$$p_{ij}^* = \frac{2\Omega(1-\alpha_i)(8-\alpha_{i'}) - \Lambda k\left(16 + 26\alpha_i + 12\alpha_{i'} - 5\prod_{\forall i}\alpha_i\right)}{\left(32 + 10\sum_{\forall i}\alpha_i - 3\prod_{\forall i}\alpha_i\right)k} \quad (\forall i,j) \quad (12)$$

where $\Omega \equiv a - c_m - f$, and $\Lambda \equiv s - c_r - \frac{c_{col}}{r_c}$ for simplifying the representation of Eq. (12). The tentative equilibrium solutions p_{ij}^* ($\forall i,j$) derived above can be used to solve for stage 3 output; thus,

$$q_i^* = \frac{(2+5\alpha_i)(8-\alpha_{i'})(\Omega + \Lambda k)}{3b\left(32 + 10\sum_{\forall i}\alpha_i - 3\prod_{\forall i}\alpha_i\right)}, \quad \forall i \quad (13)$$

Using Eqs. (2) and (13), the tentative equilibrium solutions of recycled component supply amounts $y_{ij}^*(\forall i,j)$ for output of stage 2 (*i.e.*, the negotiation process) can be derived as

$$y_{ij}^* = \frac{(2+5\alpha_i)(8-\alpha_{i'})(\Omega + \Lambda k)k}{6b\left(32 + 10\sum_{\forall i}\alpha_i - 3\prod_{\forall i}\alpha_i\right)} \quad (\forall i,j) \quad (14)$$

It is worth mentioning that the above tentative equilibrium solutions (*i.e.*, p_{ij}^* and y_{ij}^*) yielded at stage 2 are determined collectively by k, α_i, Ω, and Λ. Specifically, Ω and Λ can be regarded as two profit-oriented constructs containing key factors that influence the profits of manufacturers and RL providers, respectively. Therein, Ω is positively associated with p_{ij}^* and y_{ij}^*, indicating that the increase in Ω facilitates a manufacturer's willingness to pay and intention of procuring more recycled components when bargaining with an RL provider. By contrast, Λ is positively associated with y_{ij}^*; and however, has negative association with p_{ij}^*, indicating that the increase in Λ facilitates an RL provider's willingness of increasing recycled-component supply amount with a lower supply price when negotiating with a manufacturer. The aforementioned effects of Ω and Λ on p_{ij}^* and y_{ij}^*, however, are moderated by bargaining power α_i which remains as a primary factor influencing the dyadic members' decisions in negotiations.

3.1.3. Solution for stage 1

Drawing from the theory of environmental economics (Dobbs, 1991; Walls & Palmer, 2001), *SW* specified in this work contains four elements: (1) consumer surplus (*CS*); (2) producer surplus (*PS*); (3) environmental benefits (*EB*) of green products; and (4) environmental pollution cost (*EC*) for manufacturing green products. According to the classical theory of economics, *CS* means consumers can purchase a product for a price that is less than the highest price they would be willing to pay. As we assume the product demand function is a linear demand form sloping downward, one can easily determine that $CS = \frac{1}{2}bQ^2$. Notably, *PS* is defined as the benefit amount for producers from selling products at a market price that is higher than the lowest price at which they would be willing to sell a product. In this work, *PS* is the sum of all profits of chain members (*i.e.*, $PS = \pi_{M1} + \pi_{M2} + \pi_{RS1} + \pi_{RS2}$). According to Dobbs (1991) and Walls and Palmer (2001), external economies mean that the benefit arising from an economic activity does not accrue to the person or firm controlling the activity, including external benefit and external cost. The discussion of external economies dates back to Marshal, who first introduced the term "external economies" in 1890. Marshall's goal was to explain why the paradigm of a perfect market economy is not destroyed through monopolistic concentrations in an industry, even with increasing returns to scale (downward-sloping average cost) (Polack & Heertje, 2000). Therefore, *EB* and *EC* are the total environmental benefits for recycling recycled components and total environmental pollution cost for new-product production. The *SW* function is then derived as $SW = CS + PS + EB - EC$. Accordingly, we assert that the government has the goal of *SW* maximization (*MaxSW*), which is given by

$$Max\,SW = \left[\frac{1}{2}bQ^2\right] + [\pi_{M1} + \pi_{M2} + \pi_{RS1} + \pi_{RS2}] + \left[\delta\frac{Qk}{\gamma_c}\right] - [\gamma Q] \quad (15)$$

where δ represents the environmental benefits by recycling one unit of an end-of-life product; and γ is the environmental pollution cost of manufacturing one green product unit. Based on the value of

$EB - EC$, the term $\frac{\delta k}{r_c} - \gamma$, as in Eq. (15), can be regarded as external profit for recycling each end-of-life product, and must be subject to the condition $\frac{\delta k}{r_c} - \gamma \geqslant 0$ to ensure that manufacturing recycled components for green production benefits environmental protection. Thus, Corollary 3.1 is presented as follows.

Corollary 3.1. *Green production using recycled components has a positive effect on the environment only when* $\frac{\delta k}{r_c} - \gamma \geqslant 0$ *holds.*

Suppose the government does not financially benefit from the take-back law, then the conditions $f = sk$ and $fQ = s\sum_{\forall i}\sum_{\forall j} y_{ij}$ must hold in the proposed model. Using the aforementioned conditions yields $\Omega + \Lambda k = a - c_m - (c_r + c_{col}/r_c)k$, which is input back into the SW objective function (Eq. (15)); thus, $Max\ SW$ becomes

$$Max\ SW = \frac{2\Delta_1(3\theta_1 - \Delta_1)\left[a - c_m - \left(c_r + \frac{c_{col}}{r_c}\right)k\right]^2}{9b\theta_1^2} + \frac{2(3\theta_1 - \Delta_1)\left(\frac{\delta k}{r_c} - \gamma\right)[a - c_m - (c_r + c_{col}/r_c)k]}{3b\theta_1} \quad (16)$$

where $\Delta_1 = 80 + 11\sum_{\forall i}\alpha_i - 4\prod_{\forall i}\alpha_i$; and $\theta_1 = 32 + 10\sum_{\forall i}\alpha_i - 3\prod_{\forall i}\alpha_i$. In Eq. (16), variables f and s no longer exist in the SW function. Thus, we suggest that a government should determine the unit green tax (f) subject to the condition $f = sk$, indicating that f must be imposed after the unit green subsidy (s) is determined.

The next step is to solve for the equilibrium solution for recycling rate (r_c^*) by taking the first-order condition of Eq. (16) as $\frac{\partial SW}{\partial r_c} = 0$. Moreover, the second-order condition $\frac{\partial^2 SW}{\partial^2 r_c} = -\frac{\phi_1[\phi(3\delta\theta_1 - 2c_{col}\Delta_1) + 3\gamma c_{col}\theta_1]^4}{36bk^2\theta_1^2 c_{col}^3(3\delta\theta_1 - c_{col}\Delta_1)} < 0$ can be easily proved, where $\phi_1 = 16 + 19\sum_{\forall i}\alpha_i - 5\prod_{\forall i}\alpha_i (\phi_1 > 0)$ and $\phi = a - c_m - f^* + (s^* - c_r)k$. One can then easily prove that r_c^* exists, and is derived by $r_c^* = \frac{2kc_{col}(3\delta\theta_1 - c_{col}\Delta_1)}{\phi(3\delta\theta_1 - 2c_{col}\Delta_1) + 3\gamma c_{col}\theta_1}$. The equilibrium solution for SW maximization (*i.e.*, SW^*) can then be obtained by inputting r_c^* into Eq. (16).

Once the equilibrium solutions r_c^*, f^*, and s^* are determined in stage 1 for generating green policy, they can be used to derive the equilibrium solutions for recycled components supply prices and amounts (*i.e.*, p_{ij}^* and y_{ij}^*, $\forall i, j$) discussed in stage 2, and production amounts (q_i^*, $\forall i$) derived in stage 3. All equilibrium solutions obtained in Scenario I (*i.e.*, the case without an alliance between the two RL providers) are summarized in online in Appendix C.

3.2. Scenario II: Alliance between RL providers

In contrast with Scenarios I and II considers an RL provider alliance case, where RL providers negotiate as a team when negotiating with manufacturers for recycled component supply prices and amounts. For manufacturer i, the recycled component amount procured from the RL-alliance after negotiation is y_i at price p_i ($\forall i$). The relationship between y_i and product production (q_i) is as follows:

$$y_i = q_i k, \quad \forall i \quad (17)$$

The profit function of manufacturer i (π_i) becomes

$$\pi_i = (P - c_m - f)q_i - p_i y_i, \quad \forall i \quad (18)$$

Relative to the manufacturer profit function specified in Scenario I (Eq. (3)), the manufacturer profit function (Eq. (18)) defined in Scenario II differs mainly in the characterization of the supply amount (y_i) and price (p_i) which are dominated by an RL-alliance in Scenario II.

For the RL-alliance, total recycled component supply amount is $\sum_{\forall i} y_i$; thus, the amount of collected end-of-life products is $\frac{\sum_{\forall i} y_i}{r_c}$, and collection cost is $c_{col} \times \frac{\sum_{\forall i} y_i}{r_c}$. Cost of producing recycled component is $c_r \times \sum_{\forall i} y_i$ with subsidy $s \times \sum_{\forall i} y_i$. The profit function of the RL-alliance, ξ_{all}, can then be expressed as

$$\xi_{all} = \sum_{\forall i} p_i y_i + \left(s - c_r - \frac{c_{col}}{r_c}\right)\sum_{\forall i} y_i \quad (19)$$

Furthermore, α_i ($\forall i$) is defined as the bargaining power of manufacturer i relative to that of the RL-alliance. As a basic assumption, the bargaining power of the RL-alliance is $1 - \alpha_i$, relative to that of manufacturer i.

3.2.1. Solution for stage 3

Based on the first-order differential of π_i with respect to q_i, let the first-order condition $\frac{\partial \pi_i}{\partial q_i} = (a - c_m - f) - 2bq_i - bq_{i'} - p_i k = 0(\forall i)$ hold. Additionally, one can easily derive $\frac{\partial^2 \pi_i}{\partial^2 q_i} < 0(\forall i)$ to prove that the tentative equilibrium solutions of production amounts (q_i^*) associated with these two competing manufacturers exist ($\forall i$), and are given by

$$q_i^* = \frac{(a - c_m - f) + (p_{i'} - 2p_i)k}{3b}, \quad \forall i(i \neq i') \quad (20)$$

Similar to the equilibrium solution of production derived in Scenario I (*i.e.*, Eqs. (5) and (6)), the equilibrium solution of a manufacturer i's production ($q_i^*, i = 1, 2$) is positively associated with the supply prices ($p_{i'}$) achieved by its competitor ($i' \neq i$) with the RL-alliance; however, has negative associations with c_m, f, and the supply price achieved by itself with the RL-alliance. Further, the tentative equilibrium solutions of product price (P^*) and total production (Q^*) can be derived as

$$P^* = \frac{a + 2(c_m + f) + k\sum_{\forall i} p_i}{3} \quad (21)$$

$$Q^* = \frac{2(a - c_m - f) - k\sum_{\forall i} p_i}{3b} \quad (22)$$

Therein, P^* and Q^* derived in Scenario II have the properties the same as those gained in Scenario I by comparing Eqs. (21) and (22) with Eqs. (7) and (8).

Then, the computational results derived above are used as the input to stage 2 to derive the equilibrium solutions for recycled component supply prices and amounts.

3.2.2. Solution for stage 2

Similarly, this work utilizes the asymmetric Nash bargaining game to derive the tentative equilibrium solutions of recycled component supply prices ($p_i^*, \forall i$) and amounts ($y_i^*, \forall i$) provided by the RL-alliance to manufacturers. Differing from the non-zero remuneration characterized in Scenario I, in this scenario remuneration after negotiation breakdown is zero for any manufacturer as recycled component amounts required by manufacturer i can only be provided by the RLs-alliance. Conversely, the RL-alliance can retain trading profits when negotiations break down. Thus, in Scenario II the proposed asymmetric Nash bargaining objective function (Γ_i) associated with any given pair of manufacturer i ($\forall i$) and the RL-alliance is given by

$$\Gamma_i = \underset{p_i}{Max}\{\pi_i - 0\}^{\alpha_i}\left\{\xi_j - \left[p_{i'}y_{i'} + \left(s - c_r - \frac{c_{col}}{r_c}\right)y_{i'}\right]\right\}^{1-\alpha_i}, \forall i \quad (23)$$

Inputting product production (Eqs. (20) and (22)) and the product price (Eq. (21)) obtained from stage 3 into Eq. (23) yields

$$\Gamma_i = \underset{p_i}{Max}\left\{\frac{\Omega + k(p_i + p_{i'})}{3} \times \frac{\Omega + k(p_{i'} - 2p_i)}{3b} - \frac{p_i[\Omega + k(p_{i'} - 2p_i)]k}{3b}\right\}^{\alpha_i} \left\{\frac{p_i[\Omega + k(p_{i'} - 2p_i)]k}{3b} + \frac{\Lambda[\Omega + k(p_{i'} - 2p_i)]k}{3b}\right\}^{1-\alpha_i}, \quad \forall i(i \neq i') \quad (24)$$

After taking the first-order differential of Eq. (24) with respect to p_i ($\forall i$), one can derive the tentative equilibrium solutions of recycled component supply prices $p_i^*(\forall i)$ as

$$p_i^* = \frac{\Omega\left(\prod_{\forall i}\alpha_i - 5\sum_{\forall}\alpha_i + 4\alpha_{i'} + 5\right) + 2\Lambda k\left(\prod_{\forall i}\alpha_i - 3\sum_{\forall}\alpha_i + 2\alpha_{i'} - 5\right)}{\left(15 + \sum_{\forall i}\alpha_i - \prod_{\forall i}\alpha_i\right)k},$$
$$\forall i(i \neq i') \quad (25)$$

Observed from Eq. (25), the association of Ω with p_i^* is positive, the same as that revealed in Scenario I, indicating that the increase in Ω facilitates a manufacturer's willingness to pay when bargaining with an RL-alliance. However, the association of Λ with p_i^* is positive, differing from that observed in Scenario I. Therefore, we infer that the increase in the profit-oriented construct (Λ) caused by the RL-alliance stimulates the RL-alliance's intention of raising the supply price when negotiating with a manufacturer.

Using Eq. (20), one can further derive the tentative solutions (q_i^*) for manufacturer production by $q_i^* = \frac{2(1+\alpha_i)(5-\alpha_{i'})(\Omega+\Lambda k)}{3b(15+\sum_{\forall i}\alpha_i - \prod_{\forall i}\alpha_i)}$ ($\forall i; i \neq i'$). As $y_i = q_i k$ (by Eq. (17)), the tentative solutions $y_i^*(\forall i)$ for recycled component amounts procured by manufacturers can then be determined by

$$y_i^* = \frac{2k(1+\alpha_i)(5-\alpha_{i'})(\Omega+\Lambda k)}{3b\left(15 + \sum_{\forall i}\alpha_i - \prod_{\forall i}\alpha_i\right)} \quad ,\forall i(i \neq i') \quad (26)$$

Consistent with that observed in Scenario I, the association of either Ω or Λ with y_i^* is positive, indicating that the increase in either the manufacturer's profit-oriented construct (Ω) or the RL-alliance's profit-oriented construct (Λ) facilitates the achievement of a high level of recycled-component procurement amount in the negotiations between manufacturers and an RL-alliance. Moreover, the aforementioned effects of Ω and Λ on y_{ij}^* are moderated by bargaining power α_i which remains as a primary factor that influences a manufacturer's decisions when negotiating with an RL-alliance.

Before stage 1, one must specify the means for profit sharing between the two RL providers and allocating their recycled components to manufacturers. The assumptions indicate that the two RL providers have the same operating conditions, including unit collection cost, unit cost of recycled component manufacturing, and subsidy from the government. Therefore, this work regards the two RL providers as having the same bargaining power when negotiating their profit share and recycled component supply amounts. Accordingly,

$$\xi_j^* = \xi_{j'}^* = \frac{\xi_{all}^*}{2}, \quad \forall j(j \neq j') \quad (27)$$

$$y_j^* = y_{j'}^* = \frac{\sum_{\forall i} y_i^*}{2}, \quad \forall j(j \neq j') \quad (28)$$

3.2.3. Solution for stage 1

Similar to Scenario I, we posit that the government has the goal of *SW* maximization. Utilizing the generalized form of *SW* objective function (Eq. (15)) and tentative equilibrium solutions derived in previous stages, we can then establish the corresponding objective function (*MaxSW*) as

$$Max\ SW = \frac{2\Delta_2(3\theta_2 - \Delta_2)(\Omega+\Lambda k)^2}{9b\theta_2^2} + \frac{2(3\theta_2 - \Delta_2)\left(\frac{\delta k}{r_c} - \gamma\right)(\Omega+\Lambda k)}{3b\theta_2} \quad (29)$$

where $\Delta_2 = 35 - \sum_{\forall i}\alpha_i - \prod_{\forall}\alpha_i$, and $\theta_2 = 15 + \sum_{\forall i}\alpha_i - \prod_{\forall i}\alpha_i$ for simplicity. Similarly, the government does not benefit financially from this policy and, thus, conditions $f = sk$ and $fQ = s\sum_{\forall i} y_i$ hold in this scenario. Let the first-order condition of Eq. (29) be $\frac{\partial SW}{\partial r_c} = 0$; and the second-order condition of $\frac{\partial^2 SW}{\partial^2 r_c} = -\frac{\phi_2[\phi(3\delta\theta_2 - 2c_{col}\Delta_2) + 3\gamma c_{col}\theta_2]^4}{36bk^2\theta_2^2 c_{col}^3(3\delta\theta_2 - c_{col}\Delta_2)} < 0$ $(3\delta\theta_2 > c_{col}\Delta_2)$ can be proved easily, where $\phi_2 = 10 + 4\sum_{\forall i}\alpha_i - 2\prod_{\forall i}\alpha_i(\phi_2 > 0)$. Thus, the equilibrium solution of $r_c(r_c^*)$ is $r_c^* = \frac{2kc_{col}(3\delta\theta_2 - c_{col}\Delta_2)}{\phi(3\delta\theta_2 - 2c_{col}\Delta_2) + 3\gamma c_{col}\theta_2}$.

Likewise, equilibrium solutions r_c^*, f^*, and s^* are input into stages 2 and 3 to derive equilibrium solutions for recycled component supply prices, amounts (*i.e.*, p_i^* and $y_i^*, \forall i$), and production amounts ($q_i^*, \forall i$), respectively. All equilibrium solutions obtained for Scenario II (*i.e.*, the case with the RL-alliance) are summarized in online Appendix C.

Notably, the proposed model is also applicable when the government does not use financial instruments. The equilibrium solutions for government financial instruments are $f^* = s^*k$ under equilibrium conditions (Tables C1 and C2 in on-line Appendix C). Such equilibrium solutions also apply to the case with financial instruments (*i.e.*, $f^* = s^*k = 0$). That is, let $f = s = 0$, which mimics the case without government financial instruments; model complexity then decreases, and derived equilibrium solutions remain applicable.

4. Analysis and results

Based on the derived equilibrium solutions, qualitative and quantitative analyses are applied to provide additional insights into the effects of bargaining power on the negotiation between manufacturers and RL providers in reverse supply chains. Analytical results are given in the following two subsections.

4.1. Qualitative analysis

This subsection briefly describes analytical results in terms of the effects of bargaining power on reverse supply chain performance based on comparative output in Scenarios I (RL-alliance) and II (no RLs-alliance). In the following example, $x^{(I)}$ and $x^{(II)}$ denote variables/parameters (x) associated with Scenarios I and II, respectively.

Proposition 4.1 (*bargaining power vs. contracted recycled component supply*). *Let* $\delta \geqslant c_{col}$; *condition* $y_i^{*(I)} \geqslant y_i^{*(II)}$ *holds if* $\alpha_i^{(I)} \geqslant \alpha_i^{(II)} \geqslant 0.5$; *moreover, under equilibrium conditions,* $\frac{y_i^{*(II)}}{y_i^{*(I)}} \leqslant \frac{1}{4}(\forall i)$.

In contrast with the case without an RL-alliance, Proposition 4.1 indicates that an RL-alliance may decrease recycled component procurement by manufacturers. We infer that in negotiations with manufacturers, an RL-alliance decreases the bargaining power of manufacturers, even when manufacturers still have relatively more power in reverse supply chains. Therefore, the RL-alliance may raise recycled component supply prices in contracts, which would reduce recycled components procurement by manufacturers.

Proposition 4.2 (*bargaining power vs. manufacturer profits*). *Let* $\delta \geqslant c_{col}$; *condition* $\pi_i^{*(I)} > \pi_i^{*(II)}$ *holds if* $\alpha_i^{(I)} \geqslant \alpha_i^{(II)} \geqslant 0.5$ *under equilibrium conditions; moreover,* $\frac{\pi_i^{*(I)}}{\pi_i^{*(II)}} \leqslant \frac{1}{4}(\forall i)$.

Combining propositions 4.1 and 4.2 indicates that even when a manufacturer has relatively more bargaining power than an RL provider after an RL-alliance is formed, the resulting manufacturer profits decrease when compared with those in the case of no RL-alliance. This analytical result is likely when recycled component supply prices increase and the recycled component supply decreases. A further inference is that an RL-alliance may weaken manufacturer bargaining power and further decrease profit sharing in a cooperative supply chain. The proofs of propositions 4.1 and 4.2 are provided in on-line Appendix D.

Corollary 4.1. *According to* Proposition 4.2, *the profit for a given manufacturer i may decrease by up to 25%* ($\pi_i^{*(\mathrm{II})}/\pi_i^{*(\mathrm{I})} \cong 1/4$) *under a symmetric power condition (i.e.,* $\alpha_i^{(\mathrm{II})} = 1 - \alpha_i^{(\mathrm{II})} = 0.5, \forall i$).

Corollary 4.1 approximates manufacturer profit. Suppose a manufacturer has the same bargaining power as an RL provider in an RL-alliance. In this specific condition, the resulting profits of a manufacturer decrease to approximately 75% that in the case without an RL-alliance.

Corollary 4.2 (*high asymmetric bargaining power—powerful manufacturers*). *If* $\alpha_i^{*(\mathrm{I})} = \alpha_i^{*(\mathrm{II})} = 1.0(\forall i)$, *then* $\pi_i^{*(\mathrm{I})} = \frac{[49(\delta\phi-\gamma c_{col})]^2}{4b(3\delta\theta_1 - c_{col}\Delta_1)^2}$ *and* $\pi_i^{*(\mathrm{II})} = \frac{[4(\delta\phi-\gamma c_{col})]^2}{b(3\delta\theta_2 - c_{col}\Delta_2)^2}$ *while* $\xi_j^{*(\mathrm{I})} = \xi_j^{*(\mathrm{II})} = 0$.

This corollary presents the case of extreme asymmetric bargaining power in which a manufacturer has markedly more bargaining power (*i.e.*, $\alpha_i^{*(\mathrm{I})} = \alpha_i^{*(\mathrm{II})} = 1.0, \forall i$) in negotiations than either RL provider or the RL-alliance. In this case, the manufacturer monopolizes the resulting chain-based profits, including profits of its chain partners. Thus, an RL provider may not profit when dealing with such an powerful manufacturer.

Theorem 4.1 (*Vender-dominated market—extremely powerful RL providers/alliance*). *If* $\alpha_i^{*(\mathrm{I})} = \alpha_i^{*(\mathrm{II})} = 0(\forall i)$, *then (a)* $\pi_i^{*(\mathrm{I})} > \pi_i^{*(\mathrm{II})} > 0$ *and* $\xi_j^{*(\mathrm{I})} > 2\xi_j^{*(\mathrm{II})}(\forall i,j)$; *and (b)* $\xi_j^{*(\mathrm{I})} = 3\pi_i^{*(\mathrm{I})}$ *and* $\xi_j^{*(\mathrm{II})} = \frac{3}{2}\pi_i^{*(\mathrm{II})}(\forall i,j)$.

This theorem provides several managerial insights into the performance of reverse supply chain members in a recycled component market dominated by RL providers. First, an RL-alliance does not enhance profits of RL providers in a recycled component market dominated by RL providers. As Theorem 4.1(a) indicates, induced RL provider profits may decrease by more than 50% (*i.e.*, $\xi_j^{*(\mathrm{II})} < 1/2\xi_j^{*(\mathrm{I})}$) when an RL-alliance forms to negotiate with manufacturers. The resulting inference is that RL providers do not need to form an RL-alliance to negotiate with manufacturers in a recycled component vender-dominated market. Specifically, according to Theorem 4.1(b), RL provider profits ($\xi_j^{*(\mathrm{I})}$) are three times higher than manufacturer profits in Scenario I (*i.e.*, no RL-alliance) ($\pi_i^{*(\mathrm{I})}$) but only 1.5 times higher in Scenario II (an RL-alliance exists) ($\xi_j^{*(\mathrm{II})} = \frac{3}{2}\pi_i^{*(\mathrm{II})}$). From the manufacturer's perspective, the resulting manufacturer profits may decrease when negotiating with a powerful RL-alliance. However, a manufacturer will still benefit from a cooperative reverse supply chain agreement, even when the recycled component market is dominated by RL providers. Since Theorem 4.1 is easily proven using equilibrium solutions by setting $\alpha_i^{*(\mathrm{I})} = \alpha_i^{*(\mathrm{II})} = 0$, the corresponding proof is not given.

Theorem 4.2. *Let* $\delta = c_{col}$; $\pi_i^{*(\mathrm{I})} > \pi_i^{*(\mathrm{II})}(\forall i)$ *then holds unconditionally; however, the relationship between* $\xi_j^{*(\mathrm{I})}$ *and* $\xi_j^{*(\mathrm{II})}$ *varies* ($\forall j$).

Theorem 4.2 indicates that manufacturer profit when an RL-alliance (Scenario II) exists is unconditionally lower than that without an RL-alliance (Scenario I). This generalization indicates that the coalition of RL providers, which may increase the bargaining power of an RL provider in negotiations with manufacturers, is never favorable for manufacturer profits in the reverse supply chain negotiation framework. For example, let $\alpha_i^{(\mathrm{II})} = \varepsilon\alpha_i^{(\mathrm{I})}(0 \leqslant \varepsilon \leqslant 1)$; inputting this relational function into the manufacturer profit functions $\pi_i^{*(\mathrm{I})}$ and $\pi_i^{*(\mathrm{II})}$ for comparison shows that $\pi_i^{*(\mathrm{I})} > \pi_i^{*(\mathrm{II})}((\forall i))$. Conversely, bargaining power has a variable effect on RL provider profits when RL providers bargain as a coalition. From the perspective of RL providers, an interesting issue exists under the condition in which the RL-alliance obtains a profit increase (*i.e.*, $\xi_j^{*(\mathrm{I})} < \xi_j^{*(\mathrm{II})}$). To identify the conditions favorable for an

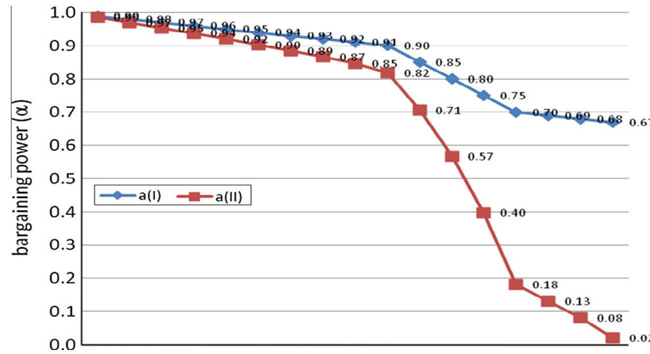

Fig. 3. Changes in bargaining power of a manufacturer when bargaining with RL providers without and with RL-alliance (subject to $\xi_j^{*(\mathrm{I})} < \xi_j^{*(\mathrm{II})}$) represented by α(I) and α(II), respectively.

RL-alliance, the values of $\alpha_i^{(\mathrm{I})}, \alpha_i^{(\mathrm{II})}$, and $\alpha_i^{(\mathrm{I})} - \alpha_i^{(\mathrm{II})}$ are determined subject to constraint $\xi_j^{*(\mathrm{I})} < \xi_j^{*(\mathrm{II})}$. Fig. 3 presents analytical results, which generate three important remarks.

Remark 1. *An RL-alliance positively affects RL provider profits when* $0.67 \leqslant \alpha_i^{(\mathrm{I})} < 1$. In the proposed reverse supply chain negotiation framework, an RL-alliance increases RL provider profits (*i.e.*, $\xi_j^{*(\mathrm{II})} > \xi_j^{*(\mathrm{I})}, \forall j$) only when the initial condition for manufacturer bargaining power, $0.67 \leqslant \alpha_i^{(\mathrm{I})} < 1$, holds. For instance, the RL-alliance contributes to a significant decrease in manufacturer bargaining power (from 0.67 to 0.02), which increases RL provider profits.

Remark 2. *The RL-alliance is profitable to an RL provider, particularly when negotiating with manufacturers that have extremely high bargaining power* For instance, given $\alpha_i^{(\mathrm{I})} = 0.98$, a slight decrease in manufacturer bargaining power (from 0.98 to 0.97) caused by an RL-alliance increases RL provider profits (*i.e.*, $\xi_j^{*(\mathrm{II})} > \xi_j^{*(\mathrm{I})}$).

Remark 3. *The effect of an RL-alliance on bargaining power correlates negatively with manufacturer bargaining power* For example, given $\alpha_i^{(\mathrm{I})} = 0.67$, the RL-alliance significantly decreases manufacturer bargaining power ($\alpha_i^{(\mathrm{I})} - \alpha_i^{(\mathrm{II})} = 0.62$), and this decrease is much greater than that in the case of $\alpha_i^{(\mathrm{I})} = 0.99$.

According to analytical results, the RL-alliance will likely increase the bargaining power of an RL provider when negotiating with a manufacturer for a profitable recycled component supply contract; however, this typically decreases manufacturer profit. Particularly in the case of a recycled component vender-dominated market, an RL-alliance may not be a win–win strategy as RL providers may become overly powerful when negotiating with manufacturers. The resulting counter-profit effect then hurts all players in the reverse supply chain negotiation framework, including RL providers, and decreases aggregate profit in reverse supply chains.

4.2. Numerical analysis

The subsequent quantitative analysis was conducted by adopting the example of China's notebook computer (NC) manufacturing industry. Lenovo, HP, Dell, ASUS and Acer are first-tier manufacturers in China's NC market. According to a survey by China Computer World (CCW) Research (2008), the top 5 NC manufacturers in terms of annual sales are Lenovo, HP, Dell, ASUS and Acer. Lenovo (including the Thinkpad) is ranked No. 1 with a market share of 29.1%, followed by HP (16.8%), Dell (11.5%), ASUS (10.9%) and Acer (7.0%). China's NC market is dominated by these five NC firms as they account for over 80% of China's NC market. In the symmetric

Table 1
Preset values of parameters used for quantitative analysis, where the values of cost-related parameters are determined using data obtained from semi-structured interviews; the values of government-related parameters are determined through reviewing several real cases implemented around the world.

1. Government-related parameters		3. Manufacturer-related parameters	
Unit green tax f^*	30	Unit manufacturing cost *Cm*	100
Unit green subsidy S^*	5	Recycled component amount for unit product production *k*	6
Unit green benefit δ	19	4. RL-provider related parameters	
Unit green cost γ	37	Unit cost for recycling one recycled component unit *Cr*	7
2. Number of competitors		Unit cost for end-of-life product collection *Ccol*	20
Number of competitive manufacturers	2	5. Product demand market $P = a - bQ$	
Number of competitive RL-providers	2	$a = 600$	$b = 1$

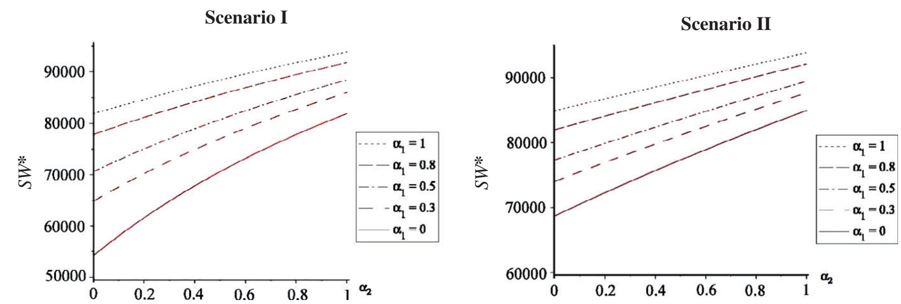

Fig. 4. Numerical results with respect to the correlations between bargaining power and social welfare (SW^*) obtained in Scenarios I (non-alliance) and II (RL-alliance), where α_1 and α_2 represent the bargaining powers of manufacturers 1 and 2 relative to RL-providers, respectively.

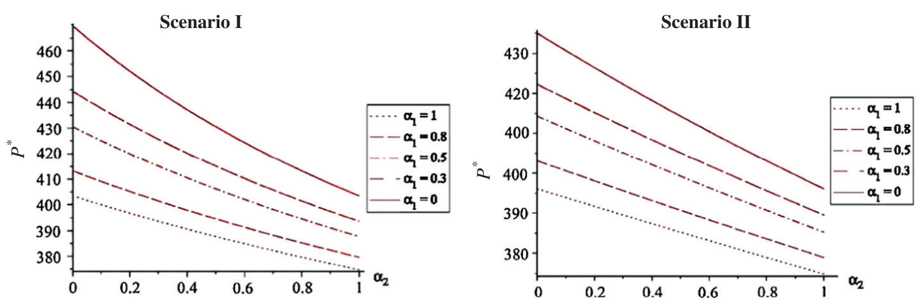

Fig. 5. Numerical results with respect to the correlations between bargaining ower and product price (P^*) obtained in Scenarios I (non-alliance) and II (RL-alliance), where α_1 and α_2 represent the bargaining powers of manufacturers 1 and 2 relative to RL-providers, respectively.

oligopoly market, the competing behaviors of these five companies are characterized by mutual dependence and mutual constraint. In the same economic environment, NC prices of these five manufacturers are similar because they have similar operational scales and cost structures. Competition among these firms is fierce, particularly in terms of output competition for market share. Such competitive situations are characterized by features of symmetric Cournot oligopoly/duopoly competition, and conform to the assumptions of this work.

Via preliminary analysis, cost-related parameters for the proposed model were then preset using data obtained from semi-structured interviews of 12 managers in the global logistics sectors of NC producers and recyclers in China. These cost-related parameters are unit manufacturing cost, c_m, unit green cost, γ, benefit, δ, recycled component amount per unit product production, k, unit cost for recycling one recycled component unit, c_r, and unit cost for end-of-life product collection, c_{col}. Particularly, the necessary condition (*i.e.*, $\frac{\delta k}{r_c} - \gamma \geqslant 0$) revealed in Corollary 3.1 is utilized to set the values of γ and δ to ensure that the use of recycled components for green production benefits the environment. Furthermore, we collected information with respect to green taxes and subsidies applied in real cases. In reality, several examples of advanced recycling fees and similar programs have been applied in the US, California, Canada, Japan, and Taiwan (Gable & Shireman, 2001; Hicks, Dietmar, & Eugster, 2005; Hong & Ke, 2011; Lee, Chang, Wang, & Wen, 2000; Nixon & Saphores, 2007). For example, an advanced recycling fee ranging from $6 to $10 on all electronic products is adopted in California (Nixon & Saphores, 2007). In Hong and Ke (2011), the unit green subsidy of US$9 is suggested for collecting and recycling per unit end-of-life product in the case of Taiwan. As the case illustrated in this work is China, we thus adopt $5 as the unit green subsidy used for recycling per unit recycled component in the numerical example for simplicity. Table 1 summarizes the key preset parameters in this case study; cost parameters are in US dollars.

In the following numerical analysis, five levels of manufacturer bargaining power (α_i, $i = 1, 2$) relative to that of RL providers in the reverse supply chain negotiation framework are on a scale of 0–1, where $\alpha_i = 1$ and $\alpha_i = 0$ represent two extreme power asymmetric cases, *i.e.*, absolute bargaining power of manufacturers and RL providers, respectively. Figs. 4–8 present analytical results.

Fig. 4 shows the variation in equilibrium *SW* (SW^*). In both scenarios, SW^* increases as the bargaining power (α_2) of manufacturer 2 increases. If the bargaining power (α_1) of manufacturer 1 also

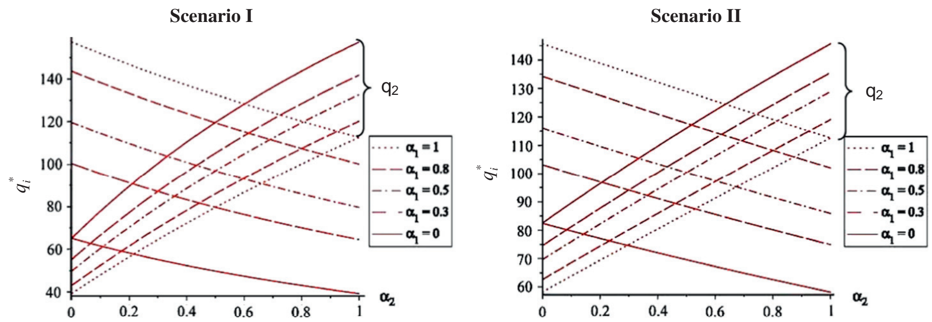

Fig. 6. Numerical results with respect to the correlations between bargaining power and manufacturer production (q_i^*) obtained in Scenarios I (non-alliance) and II (RL-alliance), where α_1 and α_2 represent the bargaining powers of manufacturers 1 and 2 relative to RL-providers, respectively; negatively-sloped curves for q_1^*; and positively-sloped curves for q_2^*.

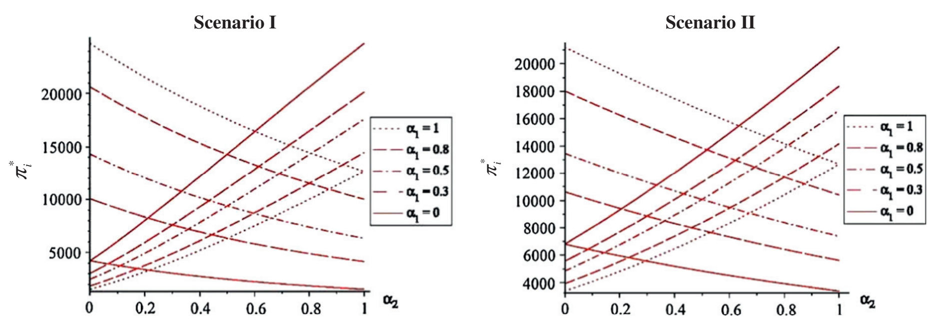

Fig. 7. Numerical results with respect to the correlations between bargaining power and manufacturer profit (π_i^*) obtained in Scenarios I (non-alliance) and II (RL-alliance), where α_1 and α_2 represent the bargaining powers of manufacturers 1 and 2 relative to RL-providers, respectively; negatively-sloped curves for π_1^*; and positively-sloped curves for π_2^*.

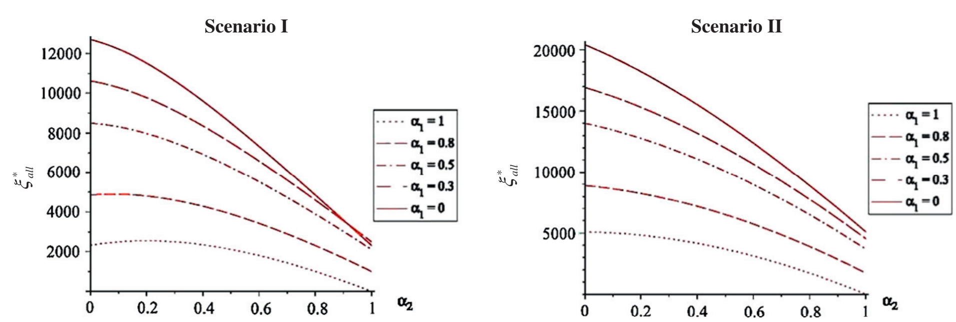

Fig. 8. Numerical results with respect to the correlations between bargaining power and aggregate profit of RL providers (ξ_{all}^*) obtained in Scenarios I (non-alliance) and II (RL-alliance), where α_1 and α_2 represent the bargaining powers of manufacturers 1 and 2 relative to RL-providers, respectively.

increases, SW^* increases; however, the rate of increase in SW^* declines. Therefore, we infer that SW^* correlates negatively with manufacturer bargaining power.

Fig. 5 shows the variation in equilibrium product price (P^*). Given the bargaining power (α_1) of manufacturer 1, P^* declines as the bargaining power (α_2) of manufacturer 2 increases; however, the rate of decline in P^* correlates negatively with α_2 (Fig. 5). A further inference is that since a manufacturer with high bargaining power often negotiates a low recycled component supply price from RL providers, it can reduce the prices of its products. This variation in P^* is extremely important when the bargaining power of competitive manufacturers is highly asymmetric.

Specifically, Fig. 6 indicates that a trade-off exists between variations in equilibrium solutions for disaggregate production amounts (*i.e.*, q_1^* and q_2^*) associated with these two competitive manufacturers. The negatively and positively sloped curves represent production of manufacturer 1 (q_1^*) and manufacturer 2 (q_2^*), respectively. When the bargaining power of manufacturer 2 (α_2) increases subject to condition $\alpha_2 \geqslant \alpha_1$, both q_2^* and Q^* increase because the increase in q_2^* exceeds the rate of decline in q_1^*. When $\alpha_2 < \alpha_1$, the rate of increase in q_2^* caused by the increase in α_2 becomes smaller than the rate of decline in, leading to a decline in total production (Q^*). Fig. 7 shows the trade-offs for varying manufacturer profits (π_i^*) under equilibrium conditions. The curve with the negative slope is the profit curve (π_1^*) for manufacturer 1, and the curve with the positive slope is the profit curve (π_2^*) for manufacturer 2. Thus, as the bargaining power of manufacturer 2 increases, π_2^* increases and π_1^* decreases. Specifically, when the bargaining power of manufacturer 2 (α_2) increases subject to condition $\alpha_2 \geqslant \alpha_1$, the incremental increase in profit of manufacturer II exceeds the decrease in profit of manufacturer 1 (*i.e.*, $|\Delta\pi_2^*| > |\Delta\pi_1^*|$). Conversely, when $\alpha_2 < \alpha_1$, the incremental increase in profit for manufacturer 2 associated with the increase in α_2 is smaller than the decrease in profit of manufacturer 1 (*i.e.*, $|\Delta\pi_2^*| < |\Delta\pi_1^*|$).

Fig. 8 shows the varying aggregate RL-provider profits ($\sum_{\forall j}\xi_j^*$) in Scenarios I and II. This work does not differentiate between the bargaining power of RL providers, inferring that both RL providers acquire the same profit in all cases. Thus, Fig. 8 merely shows the varying aggregate profits of RL providers. In Scenario I, when manufacturer 1 has absolute bargaining power ($\alpha_1 = 1$), the bargaining power (α_2) of manufacturer 2 may initially increase and then decrease aggregate profit (ξ_{all}^*) of RL providers. We infer that when manufacturer 1 has absolute bargaining power, RL providers may prefer negotiating with manufacturer 2, which has less bargaining power than manufacturer 1; however, when the bargaining power of manufacturer 2 increases, the profits of RL providers from transactions with manufacturer 2 gradually decrease; thus, the aggregate profit of RL providers begins declining. As the bargaining power of manufacturer 1 decreases, the aggregate profit curve of RL providers declines dramatically as the bargaining power of manufacturer 2 increases; manufacturer 2 has become a powerful competitor because of its increased bargaining power. In Scenario II, although aggregate profit (ξ_{all}^*) of RL providers decreases as the bargaining power of manufacturer 2 increases, the resulting profit variation does not change as significantly as in Scenario I. This is likely due to the formation of an RL-alliance that hamstrings RL providers and renders free competition impossible in the recycled component supply market.

5. Conclusions and recommendations

Briefly, reverse supply chain members must consider compliance with green laws when negotiating cooperative agreements. Instead of the typical coalition of RL providers, this work suggests that cooperation between reverse supply chain members (*e.g.*, manufacturers and RL providers) provides complementary synergism. By cooperating, reverse supply chain members can collectively enhance their performance. Additionally, a cooperative reverse supply chain can increase the competitiveness of all chain members, create new profit sources, and provide reciprocal mechanisms for sharing resources, profits, and environmental responsibility. Cooperation between manufacturers and RL providers improves waste recycling and resource-sharing activities, such as refurbishment, restructuring, and recycling, which are needed to achieve the goals of saving resources, protecting the environment, and enhancing competitiveness.

Bargaining power reflects the influence of individual negotiators. Therefore, bargaining power is a factor key to the profit of participants in an reverse supply chain negotiation framework. Notably, increased bargaining power in negotiations ensures increased profits. The ratio of unit collection cost to unit environment benefit (*i.e.*, $\frac{c_{col}}{\delta}$) must also be considered. Therein, the value of $\frac{c_{col}}{\delta}$ smaller than and equal to 1 is favorable for achieving equilibrium conditions in the reverse supply chain negotiation framework; Otherwise, the equilibrium solutions for recycled component supply price and supply may no longer be available, even though a manufacturer has high bargaining power relative to that of an RL provider.

As a regulator of market activities, governments are obligated to protect the environment to achieve sustainable and rapid economic development. Governments must also regulate market behavior of enterprises by implementing take-back laws and regulations as guidelines for RL and by providing preferential economic policies, such that enterprises can participate in environmental protection. Although government-mandated recycling rates can increase *SW*, the bargaining power structure among reverse supply chain members should also be considered.

Numerical analysis demonstrates that bargaining power affects profits of manufacturers and RL providers. A manufacturer with absolute bargaining power limits the profit of RL providers. However, an RL-alliance can increase the bargaining power and profits of RL providers by competing against manufacturers. One exceptional case is that of a recycled component market dominated by RL providers, in which an RL-alliance negotiating with manufacturers will likely have a counter-profit effect on RL providers. Furthermore, bargaining power (α_i) is a key consideration of the government when determining the equilibrium recycling rate (r_c^*). This is demonstrated by analytical results, indicating that r_c^* is a function of α_i in the cases of no RL-alliance and when an RL-alliance exists. Furthermore, the government can play a key role in guiding reverse supply chain members in sharing extended enterprise responsibility. This can be inferred from Corollary 3.1, as the term external profit (*i.e.*, $\frac{\delta k}{r_c} - \gamma$) for recycling per end-of-life product unit has proven to be a primary factor influencing green supply chain performance, particularly in terms of the environment. Therefore, governments should develop timely green policies to encourage manufacturers and RL providers to form sustainable green supply chains. Additionally, we agree that the factor of bargaining power in the case of either RL non-alliance or alliance is regarded as an exogenous variable in this work. Additional analyses (*e.g.*, empirical studies and quantitative models) are needed if bargaining power is treated as an endogenous variable as it is determined by numerous factors, including the size of alliance, alliance structure and mechanisms, and alternative partners to manufacturers.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ejor.2013.09.021.

References

Aksen, D., Aras, N., & Karaarslan, A. G. (2009). Design and analysis of government subsidized collection systems for incentive-dependent returns. *International Journal of Production Economics, 119*, 308–327.

Anderson, S. P., Goeree, J. K., & Holt, C. A. (1998). A theoretical analysis of altruism and decision error in public goods games. *Journal of Public Economics, 70*, 297–323.

Andreoni, J. (1988). Why free ride? Strategies and learning in public goods experiments. *Journal of Public Economics, 37*, 291–304.

Argyres, N. S., & Liebeskind, J. P. (1999). Contractual commitments, bargaining power, and governance inseparability: Incorporating history into transaction cost theory. *Academy of Management Review, 24*(1), 49–63.

Bloom, P. N., & Perry, V. G. (2001). Retailer power and supplier welfare: The case of Wal-Mart. *Journal of Retailing, 77*, 379–396.

Cachon, G. P., & Lariviere, M. A. (2005). Supply chain coordination with revenue-sharing contracts: strengths and limitations. *Management Science, 51*(1), 30–44.

Chen, Y.-M., & Sheu, J.-B. (2009). Environmental-regulation pricing strategies for green supply chain management. *Transportation Research Part E, 45*, 667–677.

Chen, Y.-M., Sheu, J.-B., & Lirn, T.-C. (2012). Fault tolerance modeling for an e-waste recycling supply chain. *Transportation Research Part E, 48*(5), 897–906.

China Computer World Research (2008). China laptop market research report 2007–2008. <http://www.ccwresearch.com.cn/store/report_contentn.asp?columnId=1515&view>.

Clean Production Action (2003). Establishing effective extended producer responsibility legislation: a checklist for decision-makers, zero waste advocates and waste managers. <http://www.cleanproduction.org/library/EPR_dvd/CHECKLISTrevised.pdf>.

Crook, T. R., & Combs, J. G. (2007). Source and consequence of bargaining power in supply chain management. *Journal of Operations Management, 25*(2), 546–555.

DiMatteo, L. A., Prentice, R. A., Morant, B. D., & Barnhizer, D. D. (2007). *Vision of contract theory: Rationality, bargaining, and interpretation*. North Carolina: Carolina Academic Press.

Dobbs, I. M. (1991). Litter and waste management: Deposal taxes versus user charges. *Canadian Journal of Economics, 24*(1), 221–227.

Du, F., & Evans, G. W. (2008). A bi-objective reverse logistics network analysis for post-sale service. *Computers & Operations Research, 34*, 1442–1462.

Dwyer, F. R., & Walker, O. C. Jr., (1981). Bargaining in an asymmetrical power structure. *Journal of Marketing, 45*(Winter), 104–115.

Gable, C., & Shireman, B. (2001). Computer and electronics product stewardship: Policy options. *Interfaces, 33*(6), 3–6.

Greenpeace International (2010). Guide to greener electronics version 16, October, 2010. <http://www.greenpeace.org/>.
Guide, V. D. R., Jayaraman, V., Srivastava, R., & Benton, W. C. (2000). Supply-chain management for recoverable manufacturing systems. *Interfaces, 30*(3), 125–142.
Hauert, C., De Monte, S., Hofbauer, J., & Sigmund, K. (2002). Volunteering as red queen mechanism for cooperation in public goods game. *Science, 296*(5570), 1129–1132.
Helbing, D., Szolnoki, A., Perc, M., & Szabo, G. (2010). Punish, but not too hard: How costly punishment spreads in the spatial public goods game. *New Journal of Physics, 12*. http://dx.doi.org/10.1088/1367-2630/12/8/083005.
Hicks, C., Dietmar, R., & Eugster, M. (2005). The recycling and disposal of electrical and electronic waste in China-legislative and market responses. *Environmental Impact Assessment Review, 25*, 459–471.
Hong, I.-S., & Ke, J.-S. (2011). Determining advanced recycling fees and subsidies in "E-scrap" reverse supply chains. *Journal of Environmental Management, 92*, 1495–1502.
Hu, T.-L., Sheu, J.-B., & Huang, K.-H. (2002). A reverse logistics cost minimization model for the treatment of hazardous wastes. *Transportation Research Part E, 38*, 457–473.
Inderst, R. (2002). Contract design and bargaining power. *Economics Letters, 74*, 171–176.
Kahhat, R., Kim, J., Xu, M., Allenby, B., Willams, E., & Zhang, P. (2008). Exploring e-waste management systems in the United States. *Resources, Conservation and Recycling, 52*(7), 955–964.
Kang, H.-Y., & Schoenung, J. M. (2005). Electronic waste recycling: A review of US infrastructure and technology options. *Resources, Conservation and Recycling, 45*(4), 368–400.
Kannan, V. R., & Tan, K. C. (2004). Supplier alliances: differences in attitudes to supplier and quality management of adopters and non-adopters. *Supply Chain Management: An International Journal, 9*(4), 279–286.
Kara, S., Rugrungruang, F., & Kaebernick, H. (2007). Simulation modeling of reverse logistics networks. *International Journal of Production Economics, 106*, 61–69.
Khetriwal, D. S., Kraeuchi, P., & Widmer, R. (2009). Producer responsibility for e-waste management: Key issues for consideration-Learning from the Swiss experience. *Journal of Environmental Management, 90*, 153–165.
Kim, K., Song, I., Kim, J., & Jeong, B. (2006). Supply planning model for remanufacturing system in reverse logistics environment. *Computers & Industrial Engineering, 51*(2), 279–287.
Koulamas, C. (2006). A newsvendor problem with revenue sharing and channel coordination. *Decision Science, 37*(1), 91–100.
Kreps, D. M. (1990). *Game theory and economic modeling*. Oxford: Clarendon Press.
Kreps, D. M., & Sheinkman, J. (1983). Quantity precommitment and Bertrand competition yields Coutnot outcomes. *Bell Journal of Economics, 14*, 326–337.
Krumwiedea, D. W., & Sheu, C. (2002). A model for reverse logistics entry by third-party providers. *Omega, 30*, 325–333.
Lee, C.-H., Chang, S.-L., Wang, K.-M., & Wen, L.-C. (2000). Management of scrap computer recycling in Taiwan. *Journal of Hazardous Materials, 73*(3), 209–220.
Liu, Q., & Zhang, C.-Y. (2008). Reverse logistics alliance and its consolidation algorithm. In *Proceedings of 7th World Congress on Intelligent Control and Automation (WCICA)* (pp. 3511–3516). Chongqing, China; June 25–27, 2008.
Macy, M. W., & Flache, A. (2002). Learning dynamics in social dilemmas. *Proceedings of the National Academy of Sciences of the United States of America, 99*(3), 7229–7236.
Min, H., & Ko, H. J. (2008). The dynamic design of a reverse logistics network from the perspective of third-party logistics service providers. *International Journal of Production Economics, 113*(1), 176–192.
Ministry of Environmental Protection, P.R.C. (2011). Environmental regulations and standards putting into effect as of January 1, 2011. Standards and Reports, Ministry of Environmental Protection, People's Republic of China.
Mitra, S., & Webster, S. (2008). Competition in remanufacturing and the effects of government subsidies. *International Journal of Production Economics, 111*(2), 287–298.
Muthoo, A. (1999). *Bargaining theory with applications*. Cambridge: Cambridge University Press.
Nagarajan, M., & Bassok, Y. (2008). A bargaining framework in supply chains: The assembly problem. *Management Science, 54*(8), 1482–1496.
Nixon, H., & Saphores, J. D. (2007). Financing electronic waste recycling Californian households' willingness to pay advanced recycling fees. *Journal of Environmental Management, 84*, 547–559.
Ongondo, F. O., Williams, I. D., & Cherrett, T. J. (2011). How are WEEE doing? A global review of the management of electrical and electronic wastes. *Waste Management, 31*(4), 714–730.
Pasternack, B. (1985). Optimal pricing and returns policies for perishable commodities. *Marketing Science, 4*, 166–176.
Perc, M. (2012). Sustainable institutionalized punishment requires elimination of second-order free-riders. *Scientific Reports, 2*, 334. http://dx.doi.org/10.1038/srep00344.
Perc, M., & Szolnoki, A. (2012). Self-organization of punishment in structured populations. *New Journal of Physics, 14*(043013). http://dx.doi.org/10.1088/1367-2630/14/4/043013.
Pfeffer, J., & Salancik, G. R. (1978). *The external control of organizations–A resource dependency perspective*. New York: Harper and Row.
Polack, J. B., & Heertje, A. (2000). *Analytical transport economics: An international perspective*. Chaltenham: Edward Elgar Publishing Limited.
Rasmusen, E. (2007). *Games and information–An introduction to game theory*. Massachusetts: Blackwell Publishing Ltd., MA, USA.
Savaskan, R. C., Bhattacharya, S., & Van Wassenhove, L. N. (2004). Closed-loop supply chain models with product remanufacturing. *Management Science, 50*(2), 239–252.
Schemalensee, R. (1976). A model of promotional competition in oligopoly. *Review of Economic Studies, 43*(3), 493–507.
Semmann, D., Krambeck, H.-J., & Milinski, M. (2003). Volunteering leads to rockpaper-scissors dynamics in a public goods game. *Nature, 425*, 390–393.
Sheu, J.-B. (2007). A coordinated reverse logistics system for regional management of multi-source hazardous wastes. *Computers & Operations Research, 34*, 1442–1462.
Sheu, J.-B. (2011). Bargaining framework for competitive green supply chains under governmental financial intervention. *Transportation Research Part E, 47*(5), 573–592.
Stevels, A., & Huisman, J. (2005). An industry vision on the implementation of WEEE and RoHS. WEEE-forum, European Association of Electrical and Electronic Waste Take Back Systems. <http://www.weee-forum.org/>.
Szolnoki, A., & Perc, M. (2010). Reward and cooperation in the spatial public goods game.. *EPL-A Letters Journal Exploring the Frontiers of Physics, 92*(38003). http://dx.doi.org/10.1209/0295-5075/92/38003.
Tuğba, E., Semih, Ö., & Elif, K. (2008). A holistic approach for selecting a third-party reverse logistics provider in the presence of vagueness. *Computer & Industrial Engineering, 54*(2), 269–287.
Ulrich, D., & Barney, J. B. (1984). Perspectives in organizations: resource dependence, efficiency, and population. *Academy of Management Review, 9*(3), 471–481.
Walls, M., & Palmer, K. (2001). Upstream pollution, downstream waste disposal, and the design of comprehensive environmental policies. *Journal of Environmental Economics and Management, 41*(1), 94–108.
Webster, S., & Mitra, S. (2007). Competitive strategy in remanufacturing and the impact of take-back laws. *Journal of Operations Management, 25*(6), 1123–1140.