國立交通大學交通運輸研究所

碩士學位論文

將協商機制導入綠色供應鏈之影響與探討

The impact of negotiating agreement implicating in green supply chain management system

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中文摘要

協商的概念近年已被廣泛使用於研究國際事務及國際貿易之進行，不同的協商機制回直接影響參與者之行為決策並進產衍生出不同的結果。本研究首先將從跨領域的觀點來介紹不同種類的協商理論，並了解促成協商機制順利運作的條件與要素為何。

本研究的核心目的在於建構一個能被實際運用於產業實例中的協商模型，在此所選定的產業案例為綠色供應鏈，而模型的主要概念則是來自於勞動經濟學中的勞資談判理論。我們期待藉由協商機制的導入來活絡供應鏈體系中，上中下游成員間的垂直合作。因此，我們建立了一個三階段的賽局模型，並且融合了綠色供應鏈理論及勞資談判理論，模型中的成員包含了政府、逆向物流供應者及最終商品製造商。藉由模型的推導，我們除可求得綠色供應鏈當中，在政府的最適經濟決策下，綠色原物料的最適價格與供應量，並可觀察到在不同的協商機制中，參與者會有不同的決策行為。

在模型推演結束後，我們發現逆物流供應商的議價能力以及成員所處的經濟結構會顯著影響協商的結果。若是逆物流供應商的議價能力越高，最終產品供製造商越難採行擴張性的生產政策，並且將進一步限制整體綠色供應鏈的總利潤；反之如果逆物流供應商的議價能力越低，最終產品製造商越容易擴大其產出，並且提高整體綠色供應鏈的總利潤。

關鍵字：協商、綠色供應鏈、議價、Stackelberg, Cournot

Abstract

The concept of negotiation has been widely studied and implemented in the fields with international affairs or global trade issues. Different negotiation mechanisms will directly result in different consequences depending on which strategy that participates conduct. This study firstly introduces various of negotiation theories based on the perspective of different science fields, understanding how to facilitate the negotiation process and make it sustainable.

The core spirit of this study aims at constructing an applicable negotiation mechanism which could be implemented in real industry case. The concept of our model is inspired from the study of labor unit bargaining which propose in facilitating the cooperation in a supply chain. Therefore, we constructed a three-stage game which integrated the concept of green supply chain, including government, reversed-logistic suppliers and final-goods manufacturers. By solving the negotiation problem between revered-logistic suppliers and final-goods manufacturers, we can further infer the equilibrium results of price and quantity in terms of recycling raw material as well as government's optimal environmental involvement approach. However, the most essential part of this study is to understand how the participants would perform their strategy in different negotiation scenario.

In the result, we discovered that bargaining power and the type of game that negotiation follows would obviously impact the result of price and quantity. If the reversed-logistic supplier has higher bargaining power, it is more difficult for the manufacturer to conduct expanding strategy which further restricts the total profit of this green supply chain and vice versa when its bargaining power is sufficiently low.

Key words: Negotiation, Green supply chain, Bargaining, Stackelberg, Cournot

誌謝

在北交的兩年轉眼間即將結束，這兩年我學到很多，不只是知識上的成長、生活圈的拓展，更重要的是學習到用嚴謹有條理的思考邏輯處理每一件事情，而這正是論文寫作給我最大的收穫！雖然很多人認為做研究的過程很辛苦，而這也是事實，但從議題探索、文獻回顧、研究分析到最後的結論形成，這一連串的過程卻讓我累積了更多的自信，並學習用科學性的觀點探索這個世界，我認為這個過程是充滿挑戰，也令人畢生難忘的！

這本論文得以如期完成要歸功於一路上支持我的師長與朋友，沒有你們的鼓勵與指導就不會有這本論文。首先我要感謝我的指導教授，許鉅秉老師，感謝許老師在研究的路上導引我走上正確的軌道，給我許多珍貴的建議與指導，而更重要的是老師充分尊重我們的研究興趣，不會限制我們的思考空間，我非常感謝許老師對我的啟發與幫助。

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謹志於交通大學交通運輸研究所

民國九十八年六月

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CHPATER 1 INTRODUCTION

1.1 MOTIVATION AND BACKGROUND INTRODUCTION

In the stage of globalization, the negation mechanism in terms of bilateral and multilateral seems to be more and more important no matter when it comes to the government authority, private sector or even people's behaviors. Nowadays, lots of projects are involved in multinational cooperation and implemented by means of complicated negotiation. Multilateral negotiation was used to be mostly applied in international affairs such as trade negotiation in terms of WTO or G8 summit, imposing a sanction to deal with the nuclear crisis through UN. However, pure multilateral negotiation seems to be inefficient. Therefore, when people are conducting multilateral negotiation problems, they will still proceed with the negotiation by bilateral approach.

Voting mechanism can be viewed as an efficient way to deal with disputes; however, people will do their best to avoid this procedure in a open discussion space since the majority rule often sacrifices the minority's profit. Therefore, establishing a well-functioned negotiation mechanism is very crucial so far. In WTO, when it comes to a new member application, the first thing has to do is bilateral negotiation that each member can require to proceed with a trade negotiation with the new applicant in specific filed such as how to regulate the tariff or decrease the trade obstacles when foreigner products get into the domestic market. Each member can enjoy the applicant's promise resulted from the bilateral negotiation, that is so-called "Most Favored Nation" (MFN). If the application process follows the traditional voting mechanism just like UN does, the applicant would be dominated by some countries that have great power or influence. In order to enter this organization, the applicant has to make some promise to the big country but those promises can't be shared with other members. Therefore, unanimity rule or consensus rule are tend to replace the

traditional voting mechanism regarding to public affairs.

Negotiation can be viewed as a kind of bargaining and participates' chips would not only be money but other resources. However, it used to has a crucial assumption that the target we are bargaining for should be owned by someone, that is ownership, when it comes to bargaining mechanism. Nevertheless, in reality, more and more object's ownership can't be granted to specific parts. The most usual case is the dispute of countries' territory and how to define the usage of public goods. An example here is the dispute of Angling Island between Japan, Taiwan and Mainland China. In this case, each of three countries declared that it has the sovereignty over this land and such declaration causes that no one dare to develop the nature resource in this land. In the past, unit sector spent lots of time on communication but how to trigger the negotiation process is the crucial point.

1.2 PURPOSE OF RESEARCH

Although multilateral negotiation can deal with the inequality problem in terms of majority rule, this mechanism sometimes seems to be inefficient especially when it comes to political disputes or non-ownership problem. Above all, establishing a more efficient bargaining strategy to trigger the negotiation process is very crucial.

Therefore, the purpose of this paper can be divided into the following parts:

1. Briefly examine the current approaches to analysis multilateral interaction.
2. Aims to apply different bargaining strategies in terms of negotiation agendas into a real business case and compare the pro and con in different scenarios.
3. Analyze the coopering relationship between the final good producers and reversed logistic suppliers with respect to the green supply chain management.
4. Understanding the participant's decision-making strategy in different scenarios with different negotiation agenda.

1.3RESEARCH APPROACH

This paper mainly focuses on the game theory application. Based on the game theory assumption, we concretize the conceptual structure as a two-stage game that introduces the relationship between firm's strategies and scenarios: At first , each participant's scale has to be determined which derives the market structure; after determining the market structure, each participant will decide its output that maximizes its profit. We will apply different bargaining targets into different market structure and compare with the final decision outcome that each firm will make.

1.4RESEARCH PROCEDURE

1. Problem definition

   Initializing the problem we are going to discuss through the background introduction. Survey several proper methodologies to proceed with the further research and derives an expecting goal of this research.

2. Literature review

   Reviewing the related papers in multilateral interaction, policy making, game theory and bargaining mechanism to concretize the fundamental framework of this research.

3. Decide the methodology

   Based on the literature review, we use game theory to analysis the process of decision-making in terms of multilateral negotiation and look forward to establishing a more efficient bargaining mechanism to deal with the problem of non-ownership.

4. Propose the conceptual framework

   Combining current bargaining strategies proposed by the literature and multilateral game theory into a new conceptual bargaining mechanism. We then try to induce the participants' decision rule in this new mechanism.

5. Results and analysis

   Based on the mathematical derivation, we can realize what kind of strategy that each participant will make in different scenarios and compare with the efficiency among them.

6. Conclusions and suggestion

   Based on the comparison, we will interpret the decision making rule and evaluate the efficiency of newly-established mechanism, providing some suggestion to the future research.

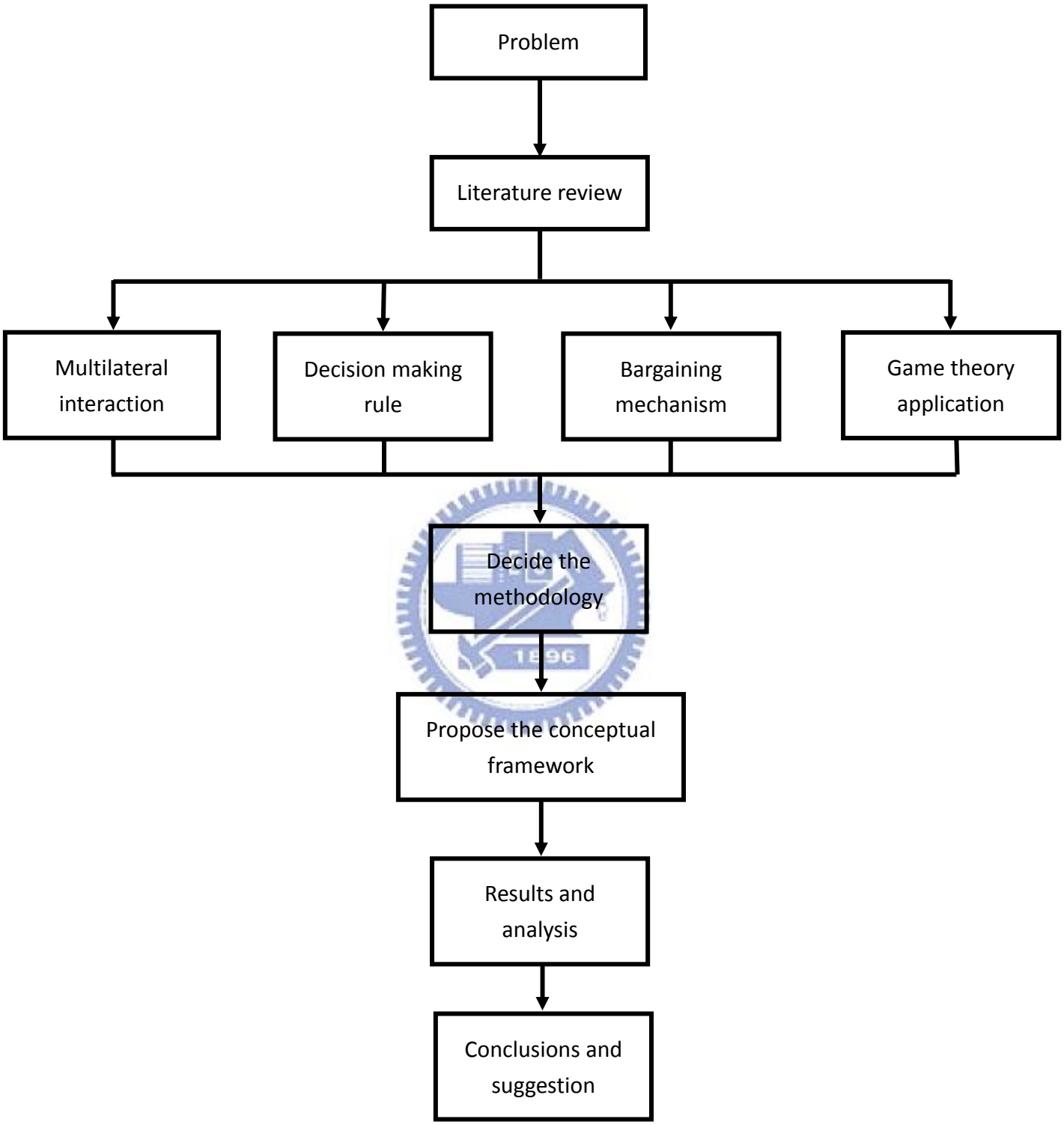

Figure 1. Research procedure

CHAPTER 2 LITERATURE REVIEW

2.1 MULTILATERAL INTERACTION

2.1.1 Definition of multilateral interaction

In this paper, we define multilateral interaction as a dynamic negotiation process that is among more than three participants. In the past research, economists focus on the interaction strategy bilaterally but in the reality, the participants used to be more than two sides which always represent different preference or utility individually. Actually, in many situations, multilateral interaction can be categorized as bilateral only when the participants come to cooperation or coalition. If the cooperation exists, the further interaction strategy would be sampler and could be applied to the traditional game theory model. However, if there is no cooperation or more than one cooperation group in those situations, the following strategy would be complicated and unpredictable. Therefore, literature often aims to come up with some regime or tools to increase the possibility of cooperation, stimulating the efficiency of negotiation. In addition, scholars also use mathematical as well as computer simulation approaches to deal with the issue of dynamic process in terms of the stability and sustainability of bargaining in that the participant's behavior is used to dynamic and the utility function varies with the time period. Jürgen (2000) combined the traditional game theory with mathematical approach to simulate the cooperation between economy and ecology.

2.1.2 Negotiation orientation and negotiation support systems

Information and software researches aim to deal with the complexity of multilateral interaction and to model people's or businesses' optimal strategy. When it comes to negotiation, some elements have to be considered first and scholars regard those elements as negotiation orientation (NO) which is defined as a situationally determined set of attitudes, perceptions and expectations regarding the negotiation

process and outcomes that affects negotiators' objectives, behaviors and levels of satisfaction. Briefly understanding NO is very necessary to establish further negotiation support systems (NSS) which cater toward bargaining, consensus seeking and conflict resolution. NO is negotiators' utility set in different situations while NSS is a tool that assists negotiating parties to increase mutually satisfactory decision based on their NO sets.

NO set comprises the factors that can determine the negotiator's strategy. In the previous researches, scholars paid lots of attention to expand the scope of determining factors and derive the relationships among them. So far, NO sets can be transferred into several patens, including social paten, organization paten, power paten, time preference paten and so on. Social paten is related to environment which contains the culture, constitution system and morality. Organization paten represents the institution system as well as culture in the negotiator parties. Power paten means whether the negotiator has the influence to dominate the market; the negotiation strategy in a competing market and in an oligopoly market must be different. Time preference paten is an index to evaluate negotiator's passion when he is proceeding with negotiation.

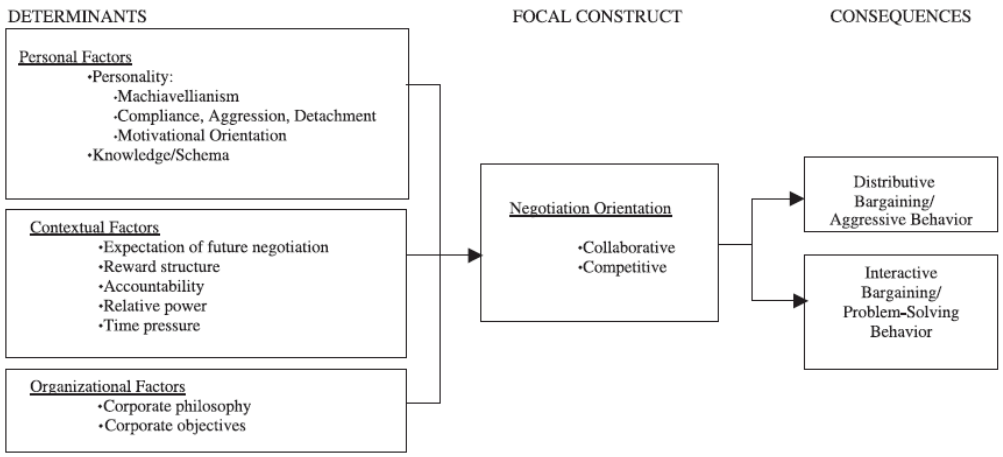

Figure 2. A contextual model of negotiation orientation (Brooks,Bradley W. 2004)

NO sets explain the process of negotiation but that is not enough to make a final

deal. At that time, negotiators rely on a tool to help them reach an optimal negotiation point. However, negotiation process is dynamic that highlights the importance of information flow which makes the negotiator can predict his opponent's strategy.

However, current research and negotiation support systems do not focus on the behavior prediction but aims to coalition formation or slack off the cultural diversity. Information Technology (IT) researcher are really interested in this field by establishing information sharing system or behavior simulation software. As figure 2 implies that a software-based support system still needs to be adjusted by cultural elements and then extends as a coalition formation which will result better negotiation outcomes.

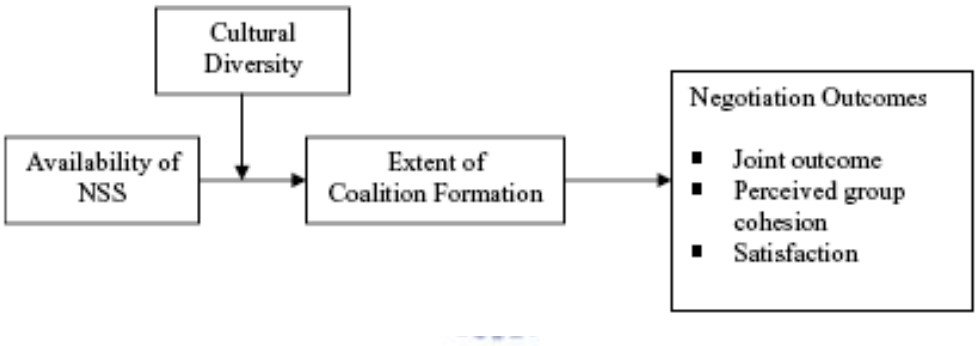

Figure 3. The theoretical framework (Guo,Xiaojia 2007)

2.2 DECISION MAKING RULE

How to making a decision is very critical to a society which comprises several members from different background as well as utility preference. In general, 3 main rules are usually applied between asymmetric multiple negotiation parties. The first one is majority rule, which is the most usual rule when it comes to public decision-making. As this rule stands, the major perspective dominates the final decision. Voting mechanism is a kind of majority rule. The second one is unanimity rule which means only if all participants agree with the proposal, it can be the final decision or it will fail. "Veto Power" or "great power unity" in United Nations

Security Council is a standard example of unanimity rule. Unanimity rule was established to lack off the impacts of majority tyranny but somehow, it excessively highlights minority's influence. Nowadays, more and more policy making rule in government or multinational sectors is charged by consensus rule. WTO's decision rule is characterized as consensus rule which ensures that every agreement is reached at WTO only when no delegation has a fundamental objection on this issue.

Majority rule and consensus rule both partly accelerate the formation of coalition but the latter works better in that in consensus rule mechanism, minor participants have more incentive to cooperate with each other; they don't have to convince all the participants but form as a comparative influential group to object the issue.

2.3 BARGAINING MECHANISM

2.3.1Researvation price

According to Natasha and Gerrit's definition (1996), reservation price is the certain price that sticks in both seller's and buyer's mind which is respectively the maximum or the minimum price they will accept for the subject under negotiation.

As the literature reveals (Raiffa, 1982; Johnston and Benton, 1988; Stroker, 1995), the agreement or trade would be reached only exists when the reservation price of the buyer is equal or higher than the reservation price of the seller. In the meanwhile, the gape between reservation price of the seller and the reservation price of the buyer is named as the bargaining zone. Only when the bargaining zone exists, the very bargaining mechanism can work.

2.3.2 Private value, correlated value and jointed value

The biding action in bargaining is regarded as a way of evaluation. However, the valuation varies as the bargaining mechanisms differs; therefore, when it comes to bargaining, it is very necessary and critical to understand how to conceptualize every participant's valuation or quantify his reservation price. According to the literature,

we can divide participant's value as private value, correlated value and jointed value. Actually, from an exact viewpoint, correlated value in some scenarios has the similar characteristic with jointed value. The difference between them is whether the participants' valuation is independent.

In a private value bargaining mechanism, every participant's valuation is independent which means his reservation value in mind also represents his valuation toward the subject. The participant can not get any information about his valuation by catching other participant's valuation. Even if he gets other's valuation, his valuation won't be changed but his biding strategy. In the contrast, correlated value means every participant's valuation will be influenced by other's valuation.

Jointed value means the value of subject is the same to every participant or can be quantified in the same way. For example, in a jointed value bargaining mechanism such as American Bond market, all participants have the same value (the value of bond is stationary) and forming his own valuation by gathering others' valuation. In this market, the purpose of bargaining is to valuate a subject that has the same value to all the participants while in a private value market, participants just valuate with themselves.

2.3.3 Types of bargaining mechanism

Cassady (1967) introduced several barraging mechanism in his research but we just briefly discussed 4 main mechanisms here.

I. Britain bargaining mechanism (first price open cry)

- Rule

  This mechanism allows each participant to increase his biding as his will and win the bid when no other's bid is higher than his. The highest bid is the total amount that he has to pay for.

- Strategy

A participant's bid comprises 3 ingredients: (1) his value (2) his previous valuation toward other participants (3) a function which accounts for previous bids. The participant switches his new bid by these information sets.

- Payoff

After the bargaining process, the winner's payoff determines his value minus his highest bid; while other loser's payoff is zero.

II. First price sealed bid

- Rule

Every participant proposes a bid and the highest bid wins the subject. The highest bid is the total amount that he has to pay for.

- Strategy

A participant's biding strategy is determined by his subjective valuation toward the subject as well as his conjecture about other's evaluation.

- Payoff

The payoff of winner is the winner's subjective value minus the bid he proposed; while other loser's payoff is zero.

III. Vickrey

- Rule

As the mechanism of first price sealed bid works in general that the highest bid wins the bargaining but he only pay for the second highest price.

- Strategy

Participant's strategy is the function of participant's subjective valuation as well as his conjecture about others' subjective valuation.

- Payoff

The payoff of winner is the winner's subjective value minus the second highest bid; while other loser's payoff is zero.

IV. Holland

- Rule

The seller announces a biding price at first and then lowers down the price progressively until a buyer takes the price.

- Strategy

The buyer's strategy is when to stop the seller's bid which is determined by the function, comprising his value as well as his conjecture about others' value.

- Payoff

The payoff of winner is the winner's subjective value minus the bid he proposed; while other loser's payoff is zero.

2.4 GAME THEORY APPLICATION

2.4.1 Models introduction

Just like bargaining mechanism can be viewed as a way to evaluate a subject's marker value; negotiation is a way of value division. To a participant, the most important thing is to optimize his trading utility while his competitors also have the same goal. However, all participants have a fundamental rule that they can't press others out of the process or the negotiation fails. Therefore, we can contribute negotiation as a relationship between cooperation and competition. Game theory provides several models to explain participant's strategies in negotiation.

I. Standard bargaining problem

This model highlights the most of two critical ingredients in negotiation and bargaining, that are efficiency and bargaining power. Efficiency is an important criterion with which to judge the outcome of a negotiation process that maximizes the participant's joint values. Bargaining power is related to how participants divide the value of the subject. Therefore, the standard bargaining problem is to derive a solution which mathematically represents the efficiency

and proportional division

II. Two-period, alternating-offer game

Alternating-offer game instructs a more realistic model to describe participants' behaviors in negotiation. This model discusses offer-counteroffer and time discount factors which provides the participants more strategies to play. Alternating-offer means a participant can propose to his opponent if his opponent accepts, the game is end. While the opponent rejects, it is turn to the opponent to make a proposal. It goes without saying that both particiapnts are waiting for the best proposal that maximizes their own utilities; however, waiting is a cost that both participants have to consider how to discounts the future payoff. This model assumes that a two-period game that both participants have a chance to make a prosal. If they can not make a deal in this two proposal-periods, both of them get nothing.

III. Infinite-period, alternating-offer game

The basic framework of this model is similar to two-period, alternating-offer game but the time period is infinite. In this model, participants don't have to worry the end of the game until they get their ideal proposal. However, it doesn't mean that participants can propose anything they want while they still have to concern the effects of time cost. Theoretically, both participants will get the same outcomes.

IV. Multilateral bargaining

Sometimes negotiation involves more than two participants. Multilateral bargaining model aims to describe this situation with an endless variety of bargaining protocols. This model assumes the decision rule is unanimity which means if one participant disagree the proposal, the game has to continue with another proposal in the next period. Just like the assumption of previous models,

participants in multilateral bargaining model also have to consider the time discount factor which means every participant's decision strategy is dominated by his discount future payoff. Theoretically, the participant who makes the first proposal is better than the other but as the game continues; all participants will get the same final outcome in the end.

V. Joint decision

When we want to insert an overall summary of negotiating options into a non-cooperative game is to apply joint-decision nodes in the game. A joint decision node is a description of negotiation that comprises several tangible objects between the participants, such as profit-sharing, monetary transfer or a partnership. Namely, a joint decision node represents a place in a game where participants negotiate and make a contract. Wherever there is a joint decision node, it must have another branch as the default decision, which is assumed to go into effect in the even that the participants do not reach an agreement.

2.4.2 Literatures review related to multilateral negotiation

There are several features in terms of negotiation. However, people used to focus on the behavior simulation based on two-player game while in reality, more and more negotiation is multilateral. Therefore, we reviewed several papers related to multilateral negotiation that strengthened our understanding about this topic.

Elaine (1997) in his research inserted the impact of collation and outside option based on Selton's proposal making model (1981) and it reminded the characteristic of the stationarity in multilateral game. In most case, stationarity were a very strong requirement to concretize an extensive form game but it didn't seem unnatural in some context.

Lígia and Glen (2003) applied a multilateral negotiation model in their research to concretize a multidimensional policy making in terms of carbon dioxide trade. They

simulated 7 developed countries' decision strategies based on the multilateral negotiation model which comprised four main scenarios, Trade/similar Trade/un-similar, No trade/similar and No trade/un-similar. Trade means each country can trade carbon dioxide abatement; "similar" means in a scenario that each country is proceeding with carbon dioxide abatement policy. The simulation revealed that if all participants were carbon constrained, the trade regime is unimportant and had similar preference regarding to the abatement policy. On the other hand, if only some participants were carbon construed, preference regarding to abatement policies was very different. In addition, if all participants were carbon constrained, it was quicker to reach an equilibrium agreement while other stimulating mechanism to trigger the negotiation process had no significant effects. However, if only some participants were carbon constrained, it took longer time to reach an agreement and the preference of abatement policies varied that carbon-constrained participants prefer lower and latter abatement while non-abating participants prefer higher and sooner abatements.

Gregory, Gordon and Leo (1996) established an extension framework from traditional multilateral negotiation model to simulate California water policy. This model highlighted the importance of the disagreement policy, which was imposed by default if participants fail to reach agreement as well as participant's reservation utility that described participants' expectation payoff if no agreement was reached and the game continued into next round. According to the simulation results, Gregory, Gordon and Leo found that constitutional structure over which the negotiations take place as well as the preference and internal structure of the participating interest groups were very crucial if we want to conceptualize a multilateral negotiation game.

Guillermo (2007) insert three additional ingredients into a non-cooperative multilateral bargaining model: (1) there is an exogenous deadline; (2) prior to the deadline, participants may sequentially change their demands as they like; (3)

changing one's demand is costly, and this cost increases as the deadline gets closer. This model was suitable to interpret two real-world examples: bankruptcy and Olympic game biding. During bankruptcy proceedings, management may face a court-assigned deadline that they had to reach new agreement with multiple unions. In Olympic game bid, multiple participants also had to make an agreement which was subject to an external deadline. The simulation and mathematic proof suggested that this model had a unique subgame perfect equilibrium prediction that made the agreement was reached immediately and switching costs were avoided. Besides, this model also implied that participants with higher concession costs obtained higher share of the bargaining profit; their bargaining power arouse as the commit to a demand early. This result corresponded to other previous papers.

The most favored nation (MFN) is a very crucial principle in WTO society which releases the trade obstacle. Kamal, Farul and Halis (2007) established an oligopolistic three participants model to simulate whether MFN facilitate multilateral cooperation. Another scenario in this model which was compared to MFN tariff was tariff discrimination. The effect of MNF varied in different countries with different production cost. According to the result of simulation, the participant with high production cost was more willing to cooperate multilaterally under MFN. Meanwhile, they also implied that whether a punishment system was strong would influence the sustainability of MFN and multilateral cooperation.

Young-Han Kim (2004) revealed that different kind of bargaining mechanism such as consensus rule or majority rule was the first obstacle that had to be considered when it came to multilateral negotiation. Secondly, the economic scale or bargaining power that a participant had was very crucial to determine the outcome of multilateral negotiation mechanism. Young-Han Kim established a four-participants model to stimulate a consensus decision rule which was applied in WTO scenario, predicting

each participant's optimal strategy. As the result, Kim suggested that the participant who had a larger market size preferred the non-cooperative trade policy regime while from a relative small participant's perspectives; it would tend to proceed with a multilateral cooperation trade policy regime.

2.5 LITERATURE INTERPRETATION AND COMMENTS

According to the literature review, IT researchers aim to solve the negotiation problems by information gathering, expanding the bargaining set and stimulate the trade process. IT stimulation involves more condition factors such as social factor, mental factor and so on which strengths its model more realistic. However, how to gather such information of specific participants is a very critical problem. Even if we have such information set, it is necessary to establish a mathematical function to derive the logical sense of each factors.

Traditional game theory may not work so precisely such as IT simulation but it provides a basic framework that interprets human's behavior in terms of negotiation, which comprises exact scenarios. In other words, we can regard game theory as an initial approach, conceptualizing an overall strategy sets that reveals different possible direction in different scenarios. Based on game theory model, it will be more direct and precise to arrange the useful information. Therefore, IT approach aims to verify the game theory model and produce a real outcome that can be easily applied into the real world.

As the previous papers imply, whether game theory or IT approach are applied, we all need to consider such following criteria when the multilateral negotiation is working on: (1) the participant's bargaining power (2) the participant's economic scale (3) the decision rule in this negotiation mechanism (4) the structure of market set. In addition, papers also suggest that as the inner factors differ in a market such as the economic scale or production cost, the multilateral negotiation can make more

remarkable effects. Although current researchers in multilateral negotiation pay their attention on government sector or multi-international problems, it is suitable to interpret the strategy of business unit or conceptualize a more realistic bargaining mechanism to stimulate the trade process.

CHAPTER 3 BARGAINING APPLICATION IN GREEN SUPPLY CHAIN MANAGEMENT

In this part, we apply the abovementioned bargaining theory into a constructed scenario and examine the participant's behavior and their strategy consideration. The model scenario we configured here is green supply chain problem (GSCM), which conducts the bargaining problem between reverse logistic suppliers and final goods producer. Through the model induction, we can understand the impact of coalition through the negotiation to the final outcome of the whole green supply chain management (GSCM).

3.1 INTRODUCTION OF GREEN SUPPLY CHAIN MANAGEMENT

As the environment concern grow in the past years, more and more enterprises try to slack off the environmental impacts by modifying their production process in a more environmental friendly way, such as decreasing the usage of hazard ingredients or strengthen the recycling of final products. The purpose that conducts the goods, cash and information flow from the up-stream to down-stream with respect to coordinating the supplier and demander can be viewed as traditional supply chain management. However, traditional supply chain management does not deal with the issue of reversed logistic or any recycling issues. Therefore, we can briefly defined green supply chain management (GSCM) here is the supply chain that integrates traditional logistic and reversed logistic, aiming to highlight the collection, recycling and final disposal of final products. Through the GSCM, some of used-products that used to be regarded as garbage would be add new value and transfer to materials that can be re-used in the traditional supply chain.

The difference between green supply chain management and reversed logistic is the scope of recycling process. GSCM conducts all recycling, collecting and disposal procedure through the whole members while reversed logistic only deals with some

parts of recycling without overall integration among the whole members. Therefore, in green supply chain system, we can clearly observe a product's producing life cycle from the grave to the cradle. Each part of the process can be found a specific member to take responsible.

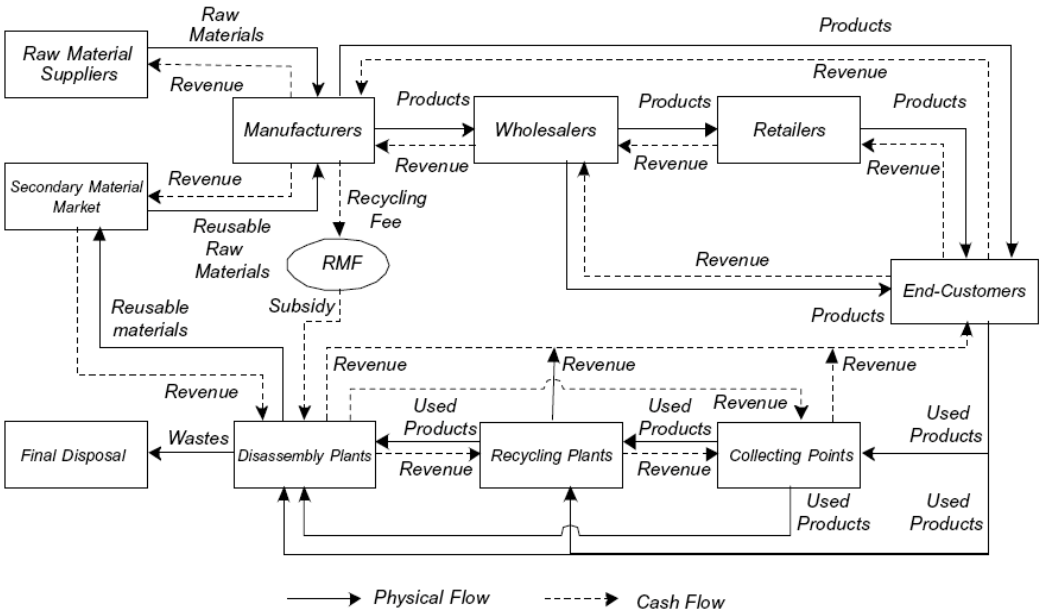

Figure 5. Framework of integrated G-SCM (Sheu, J., Chou, 2005)

3.1.2 THE INVOLVEMENT OF GOVERNMENT IN G-SCM

The involvement of government is very essential when it comes to green supply chain management. There are two main reasons to highlight the necessary of government in this issue.

(1) Responsibility clarification

G-SCM generally requires more new technology input which often burdens enterprises' cost while their final outputs do not obviously increase. Therefore, it decreased enterprise's incentive to proceed with G-SCM in the past. However, the final used-product is a kind of pollution with negative externality with respect to the social welfare. The only way to deal with the externality is to clarify its' ownership or responsibility. Who has to be responsible for this externality? If the enterprises are required to take responsible for slacking off pollution, it may

enhance enterprise's incentive to proceed with G-SCM.

(2) Economic approach implication

Responsibility clarification is not enough to prosper G-SCM. As we have mentioned, a critical obstacle is how to cost-down. For specific enterprise, supply chain integration is a good way to share the cost as well as optimize their profit (Sheu,Jiuh-Biing 2005). In addition, broadening the economic scales of this supply chain is necessary to be considered. Nevertheless, how to trigger those mechanisms sometimes relies on government's policy. The most direct and efficient impact is by economic approaches such as subsidy or tax imposition. Economic approaches are very usual in government's industry policy and it often reflects government's determination to this policy.

Nowadays, governments among EU have imposed such the concept of G-SCM by legislation to their enterprises that some manufactures have to proportionately apply the material that recycled from final goods into their products. This policy prospers the growth of reversed logistic suppliers and provides a more sustainable option to keep the balance between economic growth and environmental protection.

3.2 NEGOTIATION PROCESS

When we conduct the reverse logistic suppliers v.s final goods producer negotiation problem, we have to decide the negotiation rule first. Negotiation rule is the basic framework of such negotiation problem which comprises who make propose first or simultaneously and how to come up with the final result.

After deciding the negotiation rule, we have to define the bargaining scope. The scope varies as the scenario. In our model, the scope we are going to proceed is the cooperation agreement between reverse logistic suppliers and final goods producer. We will establish several cooperation options in this paper and induce an optimal strategy by game theory.

In the third part, we have to decide how many participants would get involved in the negotiation. In most case, the participants would be bilateral (one supplier and one producer) but sometimes there would be more than two participants (more than two suppliers and one producer or one supplier and more than two producers). It goes without saying that as the participants increasing, all participants' bargaining power will be changed.

The abovementioned is the preparation of negotiation. After defining such criteria, the strategy can be proceeded with. Strategy conducts how to maximize participant's utility. In order to do so, participant will evaluate his best approach and proposal. Strategy varies with information follow, bargaining power, and participant's expected outcome.

Only when the participant makes his own best strategy and makes deal with his competitor, the game will be finished and contribute the final outcome. In this model, both sides have to come up with a cooperation formula by negotiation. We will induce an optimal strategy by game theory.

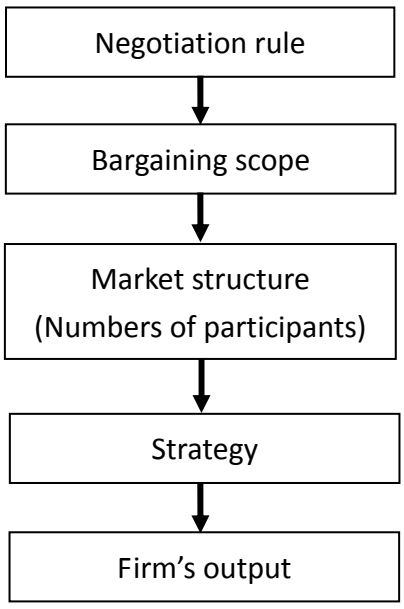

Figure 6. Negotiation process

3.3 BASIC MULTILATERAL BARGAINING MODEL

Sometimes bargaining is multilateral such as the bargaining over the specifications in congress. The process of legislation in congress implies describes (1) how individual members make proposal (2) whether other members are allowed to make other proposals (3) a voting rule that determines the process of legislation, describing how a member responds to other proposal and in which criteria the law could be passed.

Here we are going to apply a basic multilateral bargaining model to examine participant's concerns and behaviors as well as the obstacles of multilateral bargaining.

3.3.1 Model assumption

We assume that there are three legislators in this game and there are infinite periods to proceed with. Each participant can make proposal $X=(X_1, X_2, X_3)$, where X_i denotes the amount offered to participant *i*. Participant 1 make proposal at period 1; participant 2 does so in period 2 and participant 3 in period 3. When the participant in each period make proposal, the other two participants vote for the proposal We assume the voting rule is unanimity. Only when both participants vote in favor, the proposal can be passed and the game ends or it turns to next participant to make proposal. Since this game is infinite period, there is no way to consider the future expected outcome without time discount factors.

3.3.2 Model proceeding

A basic hypothesis here is that the total bargaining value is 1 that means the equilibrium offers of these three participants are described: $X^p + X^n + X^l = 1$

All participants in this game are making decision rationally, evaluating his current and future expected outcome. Therefore, the first participant must offer at least δX^p to the participant who is going to make proposal in next period or this

participant would vote against current proposal. Thus, we can say $X^n \geqq \delta X^p$. Likewise, $X^l \geqq \delta^2 X^p$ and rewrite the equilibrium offer as $X^p + X^n + X^l = X^p + \delta X^p + \delta^2 X^p = 1$, which simplifies to $X^p = 1/1+\delta+\delta^2$; $X^n = \delta/1+\delta+\delta^2$; $X^l = \delta^2/1+\delta+\delta^2$. Based on numerical simulation, we can see that as δ getting increase ($\delta \leqq 1$), three of outcomes will convert to 1/3.

This simple model displays the institution from two-player, infinite-period model. The first proposal get better outcome than the follower. This conclusion triggers an institution, corresponding to Stackelburg competition in our following discussion.

3.3.3 Obstacles

Above multilateral negotiation problem only concerns the time discount factor and concludes that the more patient who has, he can get higher payoff in the future. However, this model does not concern the asymmetry of bargaining power. In addition, participants in this model have no way to stop the game only when they make deal but in real world, threatening to get away from the game is also a kind of strategy especially when the participants are some input factor provider such as labor or critical ingredients. In addition, in real business world, bargaining participants seldom have infinite period to proceed with the bargaining. Manufactures often have other options to maintain its regular production instead of reject the proposal and keep waiting. Therefore, if the issue we are discussing is several stages and conducting the final outcome of firms, the scenario of infinite period with respect to traditional multilateral bargaining problems will be not an essential requirement.

3.4 PERSPECTIVE OF LABOR UNIT NEGOTIATION

Negotiation has been widely applied in clarifying the interaction process between labor unit and firms. As far as labor unit is concerned, it not only aims at seeking for more employment but also bargain for higher wage. However, this intuition violates firm's profit principle since higher employment with higher wage is bound to increase

the operation cost. Therefore, the key factor to determine the result of such negotiation is up to participant's bargaining power (Epinosa and Rhee, 1989). However, labor unit and firm can be regarded as an interest community in which no one can survive without the other. In other words, profit sharing may somehow impact the result of negotiation. Interestingly above spirit is much similar with green supply chain.

Nickell and Andrews firstly constructed the labor and firm barging model which only takes place over wages alone (Nickell and Andrew, 1983). Emmanuel further enlarged the bargaining scope from wages to employments (Emmanuel and Minas, 2000) which significantly indicated the possibility of solving multi-interest problem. Emmanuel also proposed a model which simulated labor unit's objective as follow: $U_i(w_i, N_i) = (w_i - w_0)^{\varphi} N_i$,where w_i is the wage that firm i promises to provide; w_0 is the wage that labor unit i seeks for though the outside options and N_i is the employment when labor unit accepts this negotiation agreement. Emmanuel's objective negotiation model clearly clarifies what participants concern when they are making negotiation and simultaneously integrates various bargaining decision factors into signal negotiation process.

Unlike traditional multilateral bargaining problem, labor unit negotiation problem ignores the time discount factors but highlights the bargaining power among participants as well as how to facilitate the mutual agreements.

3.5 Cournot and Stackelberg

Before entering our negotiation model, we have to brief two typical types of oligopoly game models which are widely applied in the issue of game theory.

3.5.1 Cournot duopoly model

Cournot duopoly model is a stage game and the most well-known model that describes two firms proceed with quantity competition simultaneously. To

concretizing, we assume there are two firms (firm 1 and 2) in the market and produce exactly the same good. The products which separately produced by firm 1 and 2 are denoted as q_1 and q_2 so the total output in this market is q_1+q_2. Suppose the price is given by the function $P=1000-q_1-q_2$. We also suppose the production cost of each product is \$100.

To complete the equilibrium strategy, each firm's profit function can be separately expressed as

$\pi_1 = (1000 - q_1 - q_2)q_1 - 100q_1$

$\pi_2 = (1000 - q_1 - q_2)q_2 - 100q_2$.

By first order condition, we can perceive firm 1's optimal best response strategy is $1000 - 2q_1 - q_2 - 100 = 0$ and firm 2's is $1000 - 2q_1 - q_2 - 100 = 0$. Solving for q_1 and q_2, we get $q_1^* = q_2^* = 300$ and $\pi_1 = \pi_2 = 90000$. As we can see, in Cournot Duopoly Model, firm 1 and firm 2 will produce the same quality of goods and get the same payoff which is \$90000.

3.5.2 Stackelberg leader and follower model

Just like the assumption of Cournot model, there are only two firms, making the same product in Stackelberg model. The difference between Stackelberg and Cournot is that the former one is a sequential game which means the follower's strategy is based on perceiving the leader's behavior. In other words, each participant's best response strategy will influence others' strategy.

We assume firm 1 is the leader and firm 2 is the follower. By first order condition of previous example in Cournot duopoly model, firm 2' best response strategy can be expressed as $R_2(q_1)=450-q_2/2$. Since firm 1 is the leader, it determine its output by assuming firm 2's best response strategy, firm 1' payoff function can be rewrote as:

$\pi_1 = (1000 - R_2(q_1) - q_2)q_1 - 100q_1$

By first order condition, we can get $q_1^* = 450$ and $q_2^* = 225$. Therefore, firm 1's payoff

is $101250 while firm 2's payoff is $50625. Obviously, firm 1 enjoys higher revenue than firm 2, and we say that firm 1 enjoys a *Stackelberg leader's rent.*

Comparing with Cournot and Stckelberg, we know that simultaneous or sequential game will impact participant's behavior and result in different payoff. As far as participants are concerned, being a Stackelberg leader is more profitable. This conclusion will play an essential role in our following negotiation model.

3.6 REVERSE LOGISTIC SUPPLIERS AND FINAL GOODS PRODUCER NEGATION MODEL

3.6.1 Model concept

In GSM system, the final goods have to be proportionately produced from reversed ingredients. It means reversed logistic supplier can be regarded as the upper stream of final goods. Therefore, in order to simplify our concept in this model, we assume that the ingredients of final goods all come from reversed logistic suppliers.

In this model, we assume one homogenous product that produced by two firms, having different technology and compete in quantities. There is only one input factor to produce this product and the technologies of both firms remain constant return to scale.

The input factor comes from several reversed logistic suppliers. The final goods producer negotiates with those reversed logistic suppliers to decide the cooperation formula. The bargaining scope is whether to cooperate or not. If they proceed with cooperation, it means vertical integration that the final goods producer could get a lower price of input factor but he has to share the cost with reverse logistic supplier. On the other hand, if the cooperation agreement can't be deal, his replenish cost will be higher but he doesn't have to share reversed logistic supplier's cost.

3.6.2 Model construe

This research is based on an assumption that government gets involved in G-SCM by economic approaches. The most contribution in this research is that we focus on

the interaction between reversed logistic suppliers and final goods producers. In previous research, model was constructed in one by one (one reversed logistic supplier vs one final goods producer). However, our model is constructed in one by more which highlights negotiation and coalition in G-SCM.

In the first stage, reversed logistic suppliers and final goods producer decide their own negotiation target simultaneously. That is both participants have to decide whether to cooperate or not. When both participants mutually agree with the agreement, it moves to the second stage. In this stage, the firm has to conduct the bargaining result in the first stage and carry out the agreement to produce products. If the bargaining result in the first stage is no deal, the final goods producer in the second stage has to make production in a higher replenish cost.

Further more, we are going to conduct numerical analysis with the final outcomes as well as strategy, clarifying the trend of certain variances. Our purpose is to understand whether coalition or cooperation concept is essential in G-SCM. We wish this research could facilitate the application of game theory with respect to bargaining and negation in real business case.

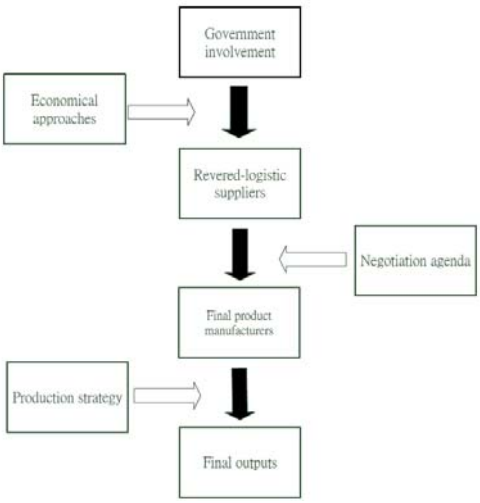

Figure 7. Framework of conceptual model

The following part will briefly introduce the process of GSCM which integrates the negotiation mechanism. At first we assume that government has three economic involvement approaches to drive this GSCM, such as environmental tax, environmental regulations and subsidy. All production in our model has to abide by the environmental regulation which requires a specific proportion of recycling raw material with respect to the final products. This assumption guarantees that all producers have purchase at least amount of recycling raw material. The government then grants an environmental tax to the manufacturers and subsidies the reverse-logistic suppliers.

There are two source of raw material which is from traditional logistic suppliers as well as reverse-logistic suppliers. The manufacturers make production and sell the final products to the end customers by his cooperating retailers. After end customers consume the final products, those unused goods will be collected by the reverse-logistic suppliers and transfer into recycling raw material which can be used by the manufacturers.

Because it is an issue of supply chain in terms of industry integration, it is very necessary to consider the interaction between the key member and followers. In this model, we assume the manufacturers work as the key member while the reverse-logistic suppliers are followers. The key members' purpose is to remain a coopering relationship that is helpful to decrease his procurement cost. Nevertheless as the perspective of followers, they are more willing to have a long-term contract with the key members rather than higher selling in that followers used to have low market power to dominate the selling price.

The cooperating contract between the key member and follower conducts price and guarantee contract. The negotiation mechanism in this model contains two agenda: (1) price agenda (2) guarantee contract agenda. Based on these two agendas, it can be

divided into three scenarios, such as (1) price only (2) price and guarantee contract (3) both of such agenda. Participants in the first scenario can only bargain for price while they have to bargain for both price and guarantee contract. The third scenario here means participants can decide to bargain for only price or both price and guarantee contract. We are not going to discuss the bargaining process very precisely but examine whether the negotiation agenda is sustainable in different situations.

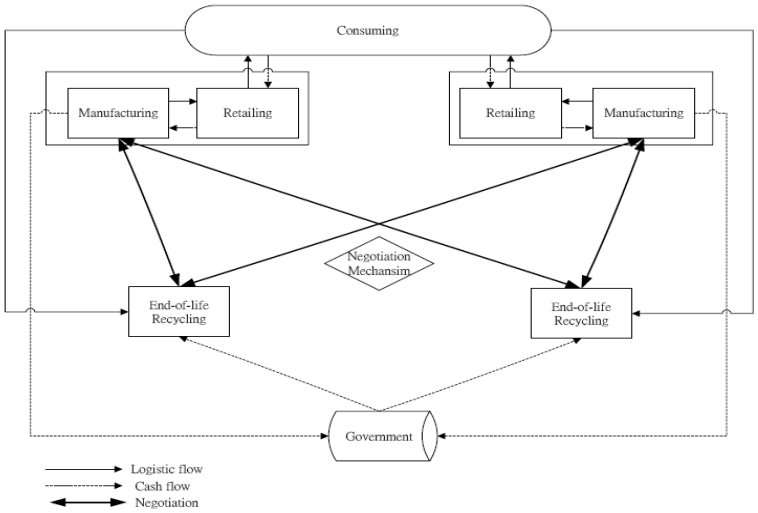

Figure. 8 Model configuration

3.6.3 Model assumption

Assumption 1. *There are two final product manufacturers in the market and proceed with a Cournot oligopoly competition in quantities.* We consider a homogeneous good sector where two manufactures are individually endowed with the same technology in production.

Assumption 2. *Information asymmetry is the only one key factor that determines whether a market leader exists in the final product market.* Thus, if one manufacturer who takes the advantage of information, it tends to dominate the market with ease.

Assumption 3. *The demand of the final product is assumed to have a negative linear relation with the price in final product market.* For simplicity of further induction and

by referring literatures regarding to Counot Model (Joel, 2002), we assume the linear relation between price and quantity remains 1:1, which can be express as

$P(\mathrm{Y}) = a - Y$ [1], where $Y = y_i + y_j$; therefore, it can be rewrote as

$$P = a - y_i - y_j \tag{1}$$

Assumption 4. *For simplicity, we assume the production technology follows constant return to scale and require two material inputs to produce the goods. Since there are two sources of material input and both of them are completely complement, manufacture's production function can be derived by*

$$y_i = \min\left[\frac{R_i}{\sigma^R}, \frac{T_i}{\sigma^T}\right] \tag{2}$$

where y_i is the output; R_i and T_i represent the correspond amount of recycling raw material and traditional raw material by the given specific manufacturer i.

Assumption 5. *Two reversed-logistic suppliers exist in the market of recycling-raw material, forming as a duopoly oligopoly competition where is difficult to carry with Cartel collaboration. Besides, all the manufacturing of recycling raw-material is assumed to be contract-pulled, and dominated by the final product manufacturers.* That is, the production of recycling-raw material is wholly driven by the actual final product demand rather than the order from retailers.

Assumption 6. *Reversed-logistic suppliers are identical endowed with the same bargaining power B and aim to maximize their bargaining utility which contains two parts: (1) profit (2) guaranteed contract; therefore the bargaining objective function can be addressed as*

$$(\pi_i^R)^{\varphi} y_i \tag{3}$$

[1] In order to make further induction clear and highlights the focus on negotiation process, we assume that the output in terms of quantity remains 1:1 relation with price. This kind of assumption is wildly used in economic literatures and text books when aiming at dealing with a complicated problem in a concise way. (Carlton and J. M. Perloff, 2000; Hay and D. J. Morris, 1991; Shepherd, 1990)

Where φ is between 0 to 1 ,representing the reversed-logistic supplier's risk aversion which denoted the elastic substitution between profit and guaranteed purchasing quantity. As far reversed-logistic suppliers' concern in the negotiation process, they firstly aim to acquire good contracts which are profitable. In addition, they also look forward to signing a long-term contract which conducts guaranteed purchasing quantity. It can be obviously observed with regarding to certain real industry fields that in some case of oligopoly competition, especially when the entry barrier is not sufficiently high, firm might protect its market leader position by expanding its market share. Thus, the guaranteed contract in this assumption can be regarded as an approach to expand market share.

This bargaining model is inferred from Emmanuel's labor bargaining model (Emmanuel and Minas, 2000) which regarded labor union's bargaining utility as an integration of wage and employment that firm promises to provide.

Assumption 7. *Government aims to maximize the social welfare (SW) which comprises consumer surplus (CS), producer surplus (PS), environmental benefit (EB), and environmental cost (EC).* Government's objective function can be expressed as follow:

Max $SW = CS + PS - EC + EB$

Assumption 8. *Government's economic involvement approaches is based on budget balance which means government would not have any financial benefit and crowding-out effect in the end.*

Assumption 9. *The proportion of traditional raw material and recycling raw material in a final product has been given by the government's environmental policy.*

According to the concept of green supply chain management, government is leader of this chain by determining and proceeding with the environmental policy as well as involvement approaches. To facilitate the usage of recycling raw material,

government used to regulate a specific proportion of recycling raw material in a unit of final product. In this thesis, we regard the proportion as the government's environmental policy.

CHAPTEE 4 MODELING

In this section, we construct a three-stage game-based model to examine the stability of different negotiation agendas. At first, the government decides how to involve the green supply chain by different approaches. Manufacturer and reversed-logistic supplier mutually decide their own optimal negotiation agenda simultaneously based on government's involvement approaches. If they both agree the other's proposal, the manufacture would make final production. Accordingly, we construct six scenarios: (1) GSCM driven by price agenda based on tax and subsidy (2) GSCM driven by price and guaranteed contract agenda based on tax and subsidy (3) GSCM driven by coexisting contract agenda based on tax and subsidy.

4.1 GSCM DRIVEN BY PRICE AGENDA BASED ON TAX AND SUBSIDY

This scenario aims to evaluate whether it is sustainable to remain a price agenda negotiating process based on the criteria that government charges an environmental tax to the end-of-life product manufacturers. Under the price agenda negotiation process, government decides its optimal economic involvement approach in the first stage. After that, in the second stage, manufacture and reversed-logistic supplier simultaneously bargain over price. In the third stage, the manufacture determines its output strategy and purchasing quantity based on the price from bargaining.

By assumption 1-3, I use backward induction to determine the manufacturer's (m_i) optimal production output which maximizes its profit. Due to our model aims to examine the negotiation process in terms of recycling raw material, we simply assume the price of traditional raw material is the same to all given manufacturers. Therefore, the relation among traditional raw material can be derived as $w_i^T = w_j^T = w^T$ and The profit function can be implied as

$$Max\ \pi = (a - y_i - y_j)y_i - w_i^R \sigma^R y_i - w^T \sigma^T y_i - c_m y_i - f y_i \quad (6)$$

where w_i^R, w^T, c_m separately represent the prices of procuring raw material as well as recycling raw material by manufacturer i and production cost; while f represents the environmental tax that government charges.

The first order condition of Eq.(6) provides the manufacturer i's reaction function, $R_i(y_j) = \frac{a - y_j - w_i^R \sigma^R - w^T \sigma^T - c_m - f}{2}$. Then equilibrium outputs, profits and material purchasing levels are:

$$y_i^*(w_i^R, w_j^R) = \frac{a - 2w_i^R \sigma^R + w_j^R \sigma^R - w^T \sigma^T - c_m - f}{3} \quad (7)^2$$

$$\pi_i^*(w_i^R, w_j^R) = y_i^{*2} \quad (8)$$

The reversed-logistic supplier conducts unused-good collections and material revised. According to spirit of GSCM, in order to enhance the recycling of used-goods, government subsidies the collection parts by quantities. Therefore, the reversed-logistic supplier's profit function can be expressed as

$$\pi_i^R = w_i^R \sigma^R y_i - c\sigma^R y_i - c_l y_i \cdot r + s y_i \cdot r \quad (9)$$

where r is the rate of return.

In the scenario of price negotiation type, the negation agenda only conducts selling price; therefore, we aim to prove that the reversed-logistic supplier has no incentive to switch the current agenda. Given by the assumption 4, the negotiation model can be expressed as

$$\left[\pi_i^{M*}\right]^{(1-B)} \left[(\pi_i^{R\varphi} y_i^*\right]^B \quad (10)$$

The left side of Eq.(10) means the manufacture's optimal profit strategy while he agrees with the current negotiation agenda and the right side means reversed-logistic

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[2] By solving $\frac{d\pi_i}{dy_i} = 0$ and $\frac{d\pi_j}{dy_j} = 0$, we can infer Eq.(7)

suppliers' bargaining utility, where B denotes the bargaining power. To determine the selling price in this negotiation process, we can first rewrite Eq. (10) as

$$(1-B)\ln \pi_i^{M*} + B\varphi \ln \pi_i^R + B\ln y_i^* \qquad (11)$$

Substituting Eq. (8) and Eq. (9) and from the foc of Eq. (11), we can obtain the reaction function of manufacturer/reversed-logistic supplier bargaining unit I,

$$w_i^R(w_j^R) = \frac{B\varphi\sigma^R w_j^R + \left[B\varphi(a - w^T\sigma^T - c_m + f) + (4-2B+2B\varphi)(c\sigma^R + c_l \cdot r - s \cdot r)\right]}{(4-2B+4B\varphi)\sigma^R} \qquad (12)^3$$

Note that $dw_i^R / dw_j^R = B\varphi\sigma^R / (4-2B+4B\varphi)\sigma^R > 0$, the selling prices are strategic complements for manufacturer/reversed-logistic supplier bargaining unit. In addition to Eq.(12), we obtain a stable solution for the negotiated selling price,

$$w_i^{R*} = \frac{\left[B\varphi(a - w^T\sigma^T - c_m - f) + (4-2B+2B\varphi)(c\sigma^R + c_l \cdot r - s \cdot r)\right]}{(4-2B+3B\varphi)\sigma^R} \qquad (13)^4$$

Substitute Eq.(7) with Eq.(13), we can get

$$y_i^* = \frac{(4-2B)(a - w^T\sigma^T - c_m - f) - 3(4-2B+2B\varphi)(c\sigma^R + c_l \cdot r - s \cdot r)}{3(4-2B+3B\varphi)} \qquad (14)$$

Whether our negotiation result is sustainable can be discussed vie a typical Stackelberg game theory. Based on the assumption of Stackelberg game, two firms are conducting sequentially quantity competition. The leader makes production first and the follower observes his action. Therefore, we can view leader's optimal strategy as follower's reaction strategy. Previous literatures imply that moving first maybe more

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[3] Inferred from

$$\frac{dU}{dw_i^R} = \frac{9(-4)\sigma^R(a - 2w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T - f)}{9(a - 2w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T - f)^2} + \frac{(-6)B\sigma^R}{3(a - 2w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T - f)}$$
$$+ \frac{B\varphi\sigma^R(a - 4w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T + 2c\sigma^R + 2c_l \cdot r - 2s \cdot r)}{(w_i^R\sigma^R - c\sigma^R - c_l \cdot r + s \cdot r)(a - 2w_i^R\sigma^R + w_j^R\sigma^R - f)} = 0$$

[4] By solving $\frac{dU}{dw_i^R} = 0$ and $\frac{dU}{dw_j^R} = 0$

profitable when the leader remains a incumbent monopoly in industry since it can expand his quantity and drives out any possible entrants.

Similarly, we assumed manufacturer i as the game leader whose best strategy is to purchase more material and expand his quantity that would stop manufacturer j coming in; namely, manufacturer i tends to veto current agenda, switching to guaranteed contract agenda while the reversed-logistic suppliers' bargaining power is low. Consequently, leader can take advantage Stackelberg leader's rent.

However, in some extreme situation when reversed-logistic suppliers set maximization of market share as its only priority, that is $\varphi = 0$, the price agenda is never sustainable. It is a normal intuition that when reversed-logistic supplier aims to grab more market share by expanding output, it is much easier for manufacturer i to bargain for a cheap contract regarding to further procurements and both participants have the incentive to veto the price agenda, switching to price/guaranteed contract agenda. Nevertheless, this situation seldom exists in real business case.

Proposition 1：In normal situation that when reversed-logistic suppliers is risk-nature, the price agenda will sustain, if and only if when the bargaining power B is sufficiently high ($B > 0.5$)[5].

Above discussion, leader has the incentive to veto current price agenda while the reversed-logistic supplier's bargaining power is low. Therefore, only when $B > 0.5$, the agenda can be sustainable. Since, the reversed-logistic suppliers have more power to acquire better price when the leader is switching to conduct guaranteed contract. Higher price means more cost and it will eliminate leader' Stackelberg rent. As a result, when $B > 0.5$, the price agenda will sustain.

When it comes to the influence of the government's economic involvement approaches, we can use mathematical approach to discuss the relationship among

[5] Further induction is expressed in Proof 1

environmental tax, subsidy and output level.

Note that,

$$dy_i^* / df = -(4-2B) / 3(4-2B+3B\varphi) < 0 \quad (15a)$$

$$dy_i^* / ds = R > 0 \quad (15b)$$

$$dw_i^* / df = -B\varphi / (4-2B+3B\varphi)\sigma^R < 0 \quad (15c)$$

$$dw_i^* / ds = -(4-2B+2B\varphi) / (4-2B+3B\varphi)\sigma^R < 0 \quad (15d)$$

Eq. (15a) indicates that as environmental tax increases, the manufacturer tends to reduce its output level and negatively impacts the demand of all raw materials (contains traditional and recycling raw material) since the further increment of tax burden. As a result, the decline of recycling raw material drives the selling price to go down, just like Eq. (15c) implies. On the other hand, Eq. (15d) indicates that the increment of subsidy to reversed-logistic supplier diminishes its operation cost which also drives the selling price to go down as well. Consequently, lower selling price then stimulates the demand of recycling raw material and the manufacturer proceed to expand its output level, just like Eq. (15b) implies.

The last step we are going to discuss is government's approaches. By assumption (5), we can further rewrite government's objective function as:

$$Max\ SW = \frac{1}{2}(y_i + y_j)^2 + \sum_{n=i,j} \pi_n^M + \sum_{n=i,j} \pi_n^R - D \times \sum_{n=i,j} y_n + V \times \sum_{n=i,j} y_n \sigma^R \cdot r \quad (16)$$

where D and V respectively represent the incremental environment marginal cost and benefit which is induced by producing a unit product and recycling a unit end-of-life product. In addition, π_n^M and π_n^R respectively represent the total revenue from end-of-life product manufacturers and reversed-logistic suppliers. Based on the assumption 6, we assumed that all economic approaches have to be satisfied with the finance balance; therefore, it can be constructed a constraint function in terms of

government' strategy. The constraint is as follow:

$$f \times \sum_{n=i,j} y_n = s \times \sum_{n=i,j} y_n \cdot r \tag{17}$$

Combining Eq. (15) and Eq. (16), we can formulate government's objective strategy as an incentive-constrained optimization problem:

$$\begin{aligned} &Max \quad SW = \frac{1}{2}(y_i + y_j)^2 + \sum_{n=i,j} \pi_n^M + \sum_{n=i,j} \pi_n^R - D \times \sum_{n=i,j} y_n + V \times \sum_{n=i,j} y_n \cdot r \\ &s.t \ \ f \times \sum_{n=i,j} y_n = s \times \sum_{n=i,j} y_n \cdot r \end{aligned} \tag{18}$$

We use *Lagrangian Function* to solve this problem. Thus, Eq. (17) can be rewrote as:

$$L = \frac{1}{2}(y_i + y_j)^2 + \sum_{n=i,j} \pi_n^M + \sum_{n=i,j} \pi_n^R - D \times \sum_{n=i,j} y_i + V \times \sum_{n=i,j} y_i \sigma^R + \lambda(f \times \sum_{n=i,j} y_n - s \times \sum_{n=i,j} y_n) \tag{19}$$

The focs are:

$$\frac{dL}{df} = 4y_i^* \frac{dy_i^*}{df} + 2\frac{d\pi_i^M}{df} + 2\frac{d\pi_i^R}{df} - 2D\frac{dy_i^*}{df} + 2V \cdot r\frac{dy_i^*}{df} + 2\lambda(y_i^* + f\frac{dy_i^*}{df} - s \cdot r\frac{dy_i^*}{df}) \tag{20}$$

$$\frac{dL}{ds} = 4y_i^* \frac{dy_i^*}{ds} + 2\frac{d\pi_i^M}{ds} + 2\frac{d\pi_i^R}{ds} - 2D\frac{dy_i^*}{ds} + 2V \cdot r\frac{dy_i^*}{ds} + 2\lambda(f\frac{dy_i^*}{ds} - s \cdot r\frac{dy_i^*}{ds} - y_i^* \cdot r) \tag{21}$$

$$\frac{dL}{d\lambda} = (2f - 2s)y_i^* \tag{22}$$

To implement finance balance, we assume $\lambda > 0$ and $\frac{dL}{d\lambda} = 0$ which means government's optimizing strategy follows the bounded budget balance condition. Since $y_i^* > 0$, it can obviously conclude that $f = s > 0$ and $\frac{dL}{df} = \frac{dL}{ds} = 0$.

Therefore, combing with Eq. (20) and Eq. (21) we can infer the relation between subsidy and environmental tax as follow:

$$\begin{aligned} f = {} & s \cdot r + \frac{3(4 - 2B + 3B\varphi)}{6(4 - 2B + 3B\varphi)\lambda + (4 - 2B)}(D - V) \\ & + \frac{(4 - 2B) - (1 - \lambda)(4 - 2B + 3B\varphi)}{6(4 - 2B + 3B\varphi)\lambda + (4 - 2B)} \times (a - w^T\sigma^T - c_m - c\sigma^R - c_l \cdot r) \end{aligned} \tag{23}$$

However, based on assumption 9, government's involvement approach has to satisfy with budget balance; therefore, $\lambda > 0$ and $f = s \cdot r$ when

$$\lambda = \frac{3(4-2B+3B\varphi)(D-V\cdot r)+(4-2B)(4-2B+3B\varphi)(a-w^T\sigma^T-c\sigma^R-c_l\cdot r)}{(4-2B)(4-2B+3B\varphi)(a-w^T\sigma^T-c_m-c\sigma^R-c_l\cdot r)}$$

4.2GSCM DRIVEN BY PRICE AND GUARANTEED CONTRACT AGENDA ON TAX AND SUBSIDY

If the price agenda could not be sustained as the equilibrium whenever the reversed logistic supplier's bargaining power is sufficiently low (B≦0.5), the candidate of equilibrium deal may be located in price and guaranteed contract agenda. In this agenda, manufacturer and reversed-logistic supplier mutually negotiated over the selling price of recycling raw material and guaranteed contract which provides a guaranteed purchasing amount. Nevertheless, if either manufacturer or reversed-logistic supplier is against the inclusion of guaranteed contract, then it has the right to veto the negotiation over guaranteed purchasing amount. Under price and guaranteed contract agenda, manufacturer i and reversed logistic supplier i mutually determine the price and quantity to maximize their own profit. The negotiation model can be expressed as

$$\left[(a-y_i-y_j)y_i-w_i^R\sigma^R y_i-w^T\sigma^T y_i-fy_i\right]^{(1-B)}\left[\left\{y_i(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r\right\}^{\varphi}y_i\right]^B \tag{24}$$

$$\frac{dU}{dy_i}=\frac{(1-B)(a-2y_i-y_j-w_i^R\sigma^R-w^T\sigma^T-f)}{(a-y_i-y_j-w_i^R\sigma^R-w^T\sigma^T-f)y_i}+\frac{B\varphi(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)}{(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)y_i}$$
$$+\frac{B}{y_i}=0 \tag{25a}$$

$$\frac{dU}{dw_i}=\frac{(1-B)(-\sigma^R)y_i}{(a-y_i-y_j-w_i^R\sigma^R-f)y_i}+\frac{B\varphi\cdot\sigma^R\cdot y_i}{(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)y_i}=0 \tag{25b}$$

The results of focs are as follow:

$$(-2+B-B\varphi)y_i+(-1-B\varphi)y_j+(1-B)(a-w_i^R\sigma^R-w^T\sigma^T-f)+ (B\varphi+B)(a-w_i^R\sigma^R-w^T\sigma^T-f) \quad (25c)^6$$

$$(-1+B-B\varphi)w_i^R\sigma^R+B\varphi(a-y_i-y_j-w^T\sigma^T-f)-(-1+B)(c\sigma^R+c_l\cdot r-s\cdot r) \quad (25d)^7$$

By summarizing Eq. (18) and Eq. (19), thus we can get:

$$y_i=\frac{(1+B\varphi)(a-w_i^R\sigma^R-w^T\sigma^T-c_m-f)}{(3-B+2B\varphi)} \quad (26)$$

$$w_i=\frac{B\varphi(a-y_i-y_j-w^T\sigma^T-c_m-f)+(1-B)(c\sigma^R+c_l\cdot r-s\cdot r)}{(1-B+B\varphi)} \quad (27)$$

Note that $dy_i/dy_j=(-1-B\varphi)<0$, it means outputs are strategic substitutes and there is a unique stable solution in outputs space. Besides, since w_i^R depends on y_i, we can substitute Eq. (26) into Eq. (27), deriving

$$w_i^{R*}=\frac{B\varphi\cdot H-K}{G\sigma^R} \quad (28)$$

where $G=[(3-B+2B\varphi)(1-B+B\varphi)-2(1+B)]$

$$H=(1-3B+2B\varphi)(a-w^T\sigma^T-c_m-f)\cdot$$

$$K=(-1+B)(c\sigma^R+c_l\cdot r-s\cdot r)$$

$$y_i^*=\frac{(1+B\varphi)[G\cdot(a-w^T\sigma^T-c_m-f)-(B\varphi\cdot H-K)]}{(3-B+2B\varphi)\cdot G} \quad (29)$$

By substituting Eq. (28) and Eq. (29) into Eq. (6), it can be checked that manufacturer i's profits are $\pi_i^*=(1-B\varphi)y_i^{*2}$.

To check whether price and guaranteed contract negotiation agenda is universal

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[6] By solving $\frac{dU}{dy_i}=0$ and $\frac{dU}{dy_j}=0$

[7] By solving $\frac{dU}{dw_i^R}=0$ and $\frac{dU}{dw_j^R}=0$

sustainable as an equilibrium institution, we assume that pair 2 (manufacturer 2/reversed-logistic supplier 2) conducts price and guaranteed contract negotiation agenda. If this agenda is sustainable, no members in pair 1 have an incentive to veto the inclusion of guaranteed contract. However, by comparing with the profit level of price negotiation agenda, it obviously turns out that manufacturers can proceed higher output level and profit when the agenda excludes the guaranteed contract.

Proposition 2：The price and guaranteed contract agenda is never sustainable as a subgame perfect equilibrium institution.[8]

According to basic spirit of Stackelberg theory, Stackelberg follower will observe its rival's output level to decide its own optimal output strategy. Therefore, it is well-known that firms competing in quantities have no incentive to engage in Stackelberg warfare. Therefore, if the timing of output selection is endogenous, manufacturer 1 's optimal strategy is to wait and determine it output at date 2 by observing its rival's commitment of an output at date 2. Consequently, manufacturer 1 has no incentive to commit its output at date 1.

This philosophy can be similarly applied into our model. If pair 1 conducts s price and guaranteed contract negotiation agenda, manufacturer 1 becomes the Stackelberg leader and expands its output level to gain Stackelberg rent. Manufacturer 2 which engages in pair 2 then becomes the Stackelberg follower while its current optimal strategy is to reduce the procurement of material as well as output, thus pushing the market-cleaning price up. To do this, manufacturer 2 will not only benefit by possessing higher selling price but also save on extra material procurement cost by decreasing the material demand. As a result, manufacturer 2's profit will increase by vetoing the inclusion of guaranteed contract.

Economics literatures also indicate that in Stackelberg competition, if both

[8] Further induction is expressed in Proof 2

participants contest for being leader by expanding their own output level, the market structure will transfer into perfect competition and both participants have no way to grab any extra-profit. This intuition also coheres with our inference.

To sum up, if one of the two manufacturers conducts price and guaranteed contract, the other one will be bound to conduct price negotiation agenda. Therefore, price and guaranteed contract negotiation agenda never universally sustains.

4.3 GSCM DRIVEN BY COEXISTENCE OF PRICE/GUARANTEED CONTRACT AND PRICE AGENDA ON TAX AND SUBSIDY

In this part, we aim to examine that if the bargaining power of reversed-logistic supplier is sufficiently low, one negotiation pair conducts price and guaranteed contract agenda, while the other only conducts price negation agenda. In the pure equilibrium strategy, different manufacturers will determine their output strategy by different negotiation agenda; therefore, the market share and profit of manufacturers and reversed-logistic suppliers will be varied.

We assumed that manufacturer i and reversed-logistic supplier i of negotiation pair 1 choose to negotiate about price and guaranteed contract while manufacturer j and reversed-logistic supplier j of negotiation pair 2 only conduct price agenda. According to Stackelberg theory, manufacturer i works as Stackelberg leader and manufacturer j is follower.

Based on the induction of 4.1, manufacturer tends to achieve Stackelberg rent by conducting guaranteed contract when the bargaining power of reversed-logistic supplier is sufficiently low. Consequently, manufacturer i is more willing to increase its profit by expand its output. The equilibrium scope of negotiation pair 1 chooses w_i^R and y_i to maximize

$$\left[(a - y_i - R_j(y_i) - w_i^R\sigma^R - w^T\sigma^T - f)y_i\right]^{(1-B)}\left[y_i(w_i^R\sigma^R - c\sigma^R - c_l \cdot r + s \cdot r)^{\varphi} y_i\right]^B \quad (30)$$

Taking as given the negotiated wage w_j^R, and manufacturer j's optimal response to its output strategy decision in the subsequent stage. Meanwhile, manufacturer j's reaction function can be expressed as $R_j(y_i) = (a - y_i - w_j^R\sigma^R - w^T\sigma^T - f)/2$ which can be derived by first order condition from manufacturer j's profit subjective function. Substituting $R_j(y_i)$ into Eq. (24), proceeding the focs by w_i^R and y_i, we can get:

$$\frac{dU}{dy_i} = \frac{(1-B)(a-2y_i - R_j(y_i) - y_i\frac{dR_j(y_i)}{dy_i} - w_i^R\sigma^R - w^T\sigma^T - f)}{(a - y_i - R_j(y_i) - w_i^R\sigma^R - w^T\sigma^T - f)y_i} \quad (31a)$$
$$+\frac{B\varphi(w_i^R\sigma^R - c\sigma^R - c_l\cdot r + s\cdot r)}{(w_i^R\sigma^R - c\sigma^R - c_l\cdot r + s\cdot r)y_i} + \frac{B}{y_i} = 0$$

$$\frac{dU}{dw_i} = \frac{(1-B)(-\sigma^R)y_i}{(a - y_i - R_j(y_i) - w_i^R\sigma^R - f)y_i} + \frac{B\varphi\cdot\sigma^R\cdot y_i}{(w_i^R\sigma^R - c\sigma^R - c_l\cdot r + s\cdot r)y_i} = 0 \quad (32b)$$

By solving Eq.(31a) and (32b), we can infer:

$$(2 - B + B\varphi)y_i + 2(1 + B\varphi)w_i^R\sigma^R = (1 + B\varphi)(a + w_j^R\sigma^R - w^T\sigma^T - f)$$
$$B\varphi\cdot y_i + 2(1 - B + B\varphi)w_i^R\sigma^R = (-2)(1-B)(-c\sigma^R - c_l\cdot r + s\cdot r) \quad (31c)\ (31d)$$
$$+ B\varphi(a + w_j^R\sigma^R - w^T\sigma^T - f)$$

By arranging Eq. (25a) and (25b), we can solve w_i^R and y_i,

$$y_i = \frac{(1+B\varphi)(1-B)(a + w_j^R\sigma^R - w^T\sigma^T - f - 2c\sigma^R - 2c_l\cdot r + 2s\cdot r)}{I} \quad (32a)$$

$$w_i^R = \frac{(1-B)[(a + w_j^R\sigma^R - w^T\sigma^T - f) + (-4 + 2B - 2B\varphi)(c\sigma^R + c_l\cdot r - s\cdot r)]}{2I\sigma^R} \quad (32b)$$

Where $I = (1 - B + B\varphi)(2 - B + B\varphi) - B\varphi(1 + B\varphi)$

Due to $dw_i^R/dw_i^R > 0$, w_j^R is a strategic complement to w_i^R. Therefore an increase in selling price of recycling raw material of negotiation pair 2 will make manufacturer i more profitable as the decrease in sell price of w_i^R. In addition to $dy_i/dw_j^R > 0$, an

increase of w_i^R will also enhance manufacturer i profit as the increase of it profit.

As previous description, manufacturer j and reversed-logistic supplier j in pair 2 only negotiate about selling price. Therefore, member in negotiation pair 2 chooses w_j^R to maximize

$$\begin{aligned}&\left[(a-y_i-R_j(y_i)-w_j^R\sigma^R-w^T\sigma^T-f)R_j(y_i)\right]^{(1-B)}\times\\&\left[(w_j^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)R_j(y_i)^{\varphi}R_j(y_i)\right]^{B}\end{aligned}\tag{33}$$

Taking as given w_i^R, y_i as well as manufacturer j's optimal interaction in the subsequence production stage $R_j(y_i)$ and solve w_j^R by foc. We can get

$$w_j^R=\frac{[(-2+B)(-c\sigma^R-c_l\cdot r+s\cdot r)+B\varphi(a-y_i-w^T\sigma^T-c_m+c\sigma^R+c_l\cdot r-s\cdot r+f)]}{(2-B+B\varphi)\sigma^R}\tag{34}$$[9]

Since $dw_j^R/y_i<0$, it turns out that as manufacturer i increases its output level, member in pair 2 tends to lower its selling price w_i^R to preserve its competitiveness.

Furthermore, we can solve the linear equations among w_i^R, y_i and w_j^R by substituting Eq.(32a), (32b) and (34). Then we can obtain a stable solution as follow:

$$w_i^{R*}=\frac{\begin{array}{l}(1-B)\{(2-B+B\varphi)(a-w^T\sigma^T-c_m-f)\\+[(1+B\varphi)(4-2B+2B\varphi)-1](c\sigma^R+c_lr-sr)\}\end{array}}{2(1+B\varphi)I\sigma^R}\tag{35a}$$

[9] Inferred from

$$\frac{dU}{dw_j^R}=\frac{(1-B)\left[(a-w^T\sigma^T-c_m-f)\frac{dR_j(y_i)}{dw_j^R}-2R_j(y_i)\frac{dR_j(y_i)}{dw_j^R}-(\sigma^RR_j(y_i)+w_j^R\sigma^R\frac{dR_j(y_i)}{dw_j^R})\right]}{(a-y_i-R_j(y_i)-w_j^R\sigma^R-w^T\sigma^T-f)R_j(y_i)}$$
$$+\frac{B\varphi\left[\sigma^RR_j(y_i)+w_j^R\frac{dR_j(y_i)}{dw_j^R}-c\sigma^R-c_l\cdot r+s\cdot r\right]}{(w_j^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)R_j(y_i)}+\frac{B\frac{R_j(y_i)}{dw_j^R}}{R_j(y_i)}=0$$

$$w_j^{R*} = \frac{[(1-B+B\varphi)\cdot a - B(w^T\sigma^T + c_m + f) + (1+2B\varphi)(c\sigma^R + c_l \cdot r - s \cdot r)]}{(1+B\varphi)\sigma^R}$$

(35b)

$$y_i^* = \frac{(-1+B)[(-2+B-2B\varphi)\cdot a - B(w^T\sigma^T + c_m + f) - (1+2B\varphi)(c\sigma^R + c_l \cdot r - s \cdot r)]}{I}$$

(35c)

Besides, since $y_j^* = R_j(y_i) = (a - y_i - w_j^R\sigma^R - w^T\sigma^T - f)/2$, we can derive

$$y_j^* = \frac{[BI-(1-B)(-2+B-2B\varphi)]\cdot a - [(1-B)B + I(2+B+2B\varphi)](w^T\sigma^T + c_m + f) - [(1-B)(1+2B\varphi)+I](c\sigma^R + c_l \cdot r - s \cdot r)}{2(1+B\varphi)I}$$

(35d)

Based on such results, it can also be checked that $\pi_i^* = \frac{(1-B\varphi)}{2} y_i^{*2}$ and $\pi_j^* = y_j^{*2}$.

As the negotiation pair 1 conducts price and guaranteed contract agenda, while pair 2 conducts only price agenda, manufacturer j who get involved in pair 2 becomes the Stackelberg follower. Being the Stackelberg leader in the final product market, manufacturer i achieves higher joint rent than if manufacturer i conduct Cournor competition while manufacturer j also conducts price and guaranteed contract agenda simultaneously. So far, as long as manufacturer i enjoys significantly high joint rent, it has incentive to stay in the price and guaranteed contract since it can grab more revenue than manufacturer j by expanding output in advance.

Besides, based on previous introduction, when manufacturer i conducts price and guaranteed agenda, manufacturer j has no incentive to include the guaranteed contract in its negotiation agenda. If manufacturer j decides to get involved the negotiation about guaranteed contract, it will enhances the competition in terms of quantity in final product market which will pull the price of final product down and hurts both manufacturers. Therefore, a wise strategy of manufacturer j is to veto the inclusion of guaranteed contract.

Proposition 3：If the revered logistic suppliers' bargaining power is sufficiently low (B≦0.5), price/guaranteed contract negotiation agenda and price negotiation agenda coexist. Members i and j will chose different negotiation agenda as the subgame perfect equilibrium.

Just like the part of 4.1, we can use mathematical approaches to examine how the environmental tax and subsidy influence manufacturers' output level.

Note that

$$\frac{dy_i^*}{df} = \frac{-(1-B)B}{I} < 0 \quad (36a)$$

$$\frac{dy_j^*}{df} = \frac{-[(1-B)+I(2+B+2B\varphi)]}{2(1+B\varphi)I} < 0 \quad (36b)$$

$$\frac{dy_i^*}{ds} = \frac{(1+2B\varphi)}{I} > 0 \quad (36c)$$

$$\frac{dy_j^*}{ds} = \frac{[(1-B)(1+2B\varphi)+I]}{2(1+B\varphi)I} > 0 \quad (36d)$$

$$\frac{dw_i^*}{df} = \frac{-(1-B)(2-B+2B\varphi)}{I} < 0 \quad (36e)$$

$$\frac{dw_j^*}{df} = \frac{-B}{(1+B\varphi)\sigma^R} < 0 \quad (36f)$$

$$\frac{dw_i^*}{ds} = \frac{-[(1+B\varphi)(4-2B+2B\varphi)-1]}{2(1+B\varphi)I\sigma^R} < 0 \quad (36g)$$

$$\frac{dw_j^*}{ds} = \frac{-(1+2B\varphi)}{(1+B\varphi)\sigma^R} < 0 \quad (36h)$$

Eq. (36a) and (36b) show that the increment of environmental tax makes a negative impact to both manufacturers' output level because of the further tax burden. Therefore, the tax burden shift the demand curve of recycling raw material to left and drives the selling price to go down, just as Eq. (36e) and (36f) tell. On the contrary, if the government increases the subsidy to the revered-logistic suppliers, it will diminish their operation costs and drive the selling price to go down, just like Eq. (36g) and (36h) tell. The lower selling price will shift the demand curve of recycling raw material to right and stimulates manufacturer's intensive to make more production

eventually. Therefore, as the subsidy increases, the manufacturers' output level will increase as well.

The next step is to drive the government's optimal decision regarding to the environmental tax and subsidy. The government's objective function is the same with Eq. (18) which is bounded by budget balance assumption; therefore, *Lagrangian Function* is applied to derive final equilibrium in terms of tax and subsidy. The focs are as follow:

$$\frac{dSW}{df}=\frac{1}{2}\left[2y_i^*\frac{dy_i^*}{df}+2(y_j^*\frac{dy_i^*}{df}+y_i^*\frac{dy_j^*}{df})+2y_j^*\frac{dy_j^*}{df}\right]+(a-y_i^*-y_j^*-w^T\sigma^T-c_m-c\sigma^R)$$
$$\times(\frac{dy_i^*}{df}+\frac{dy_j^*}{df})-[D-V\cdot r](\frac{dy_i^*}{df}+\frac{dy_j^*}{df})+\lambda\left[(y_i^*+y_j^*)+f(\frac{dy_i^*}{df}+\frac{dy_j^*}{df})-s\cdot r(\frac{dy_i^*}{df}+\frac{dy_j^*}{df})\right]$$
$$=0 \qquad (37a)$$

$$\frac{dSW}{ds}=\frac{1}{2}\left[2y_i^*\frac{dy_i^*}{ds}+2(y_j^*\frac{dy_i^*}{ds}+y_i^*\frac{dy_j^*}{ds})+2y_j^*\frac{dy_j^*}{ds}\right]+(a-y_i^*-y_j^*-w^T\sigma^T-c_m-c\sigma^R)$$
$$\times(\frac{dy_i^*}{ds}+\frac{dy_j^*}{ds})-[D-V\cdot r](\frac{dy_i^*}{ds}+\frac{dy_j^*}{ds})+\lambda\left[f(\frac{dy_i^*}{ds}+\frac{dy_j^*}{ds})-s\cdot r(\frac{dy_i^*}{df}+\frac{dy_j^*}{df})-r(y_i^*+y_j^*)\right]$$
$$=0 \qquad (37b)$$

$$\frac{dSW}{d\lambda}=f(y_i^*+y_j^*)-s\cdot r(y_i^*+y_j^*)=0 \qquad (37c)$$

To implement finance balance, we assume $\lambda>0$ and $\frac{d\mathrm{SW}}{d\lambda}=0$ which means government's optimizing strategy follows the bounded budget balance condition. Since $y_i^*>0$, it can obviously conclude that $f=s>0$ and $\frac{dSW}{df}=\frac{dSW}{ds}=0$.

Therefore, combing with Eq. (37a) ,Eq. (37b) and substitute the equilibrium output level which are expressed in Eq. (35c) and Eq. (35b) we can infer the relation between subsidy and environmental tax as follow:

$$f = s \cdot r + \frac{2(1+B)I}{[(1-B)(1+B+B^2)+I(2+B+2B\varphi)]}\left[D - V \cdot r\right]$$
$$+\left[\frac{(1-B)(1+B+B^2)-I(B-2B\varphi-2\lambda-2B\lambda)}{(1-B)(1+B+B^2)+I(2+B+2B\varphi+4\lambda+4B\lambda)}\right](a - w^T\sigma^T - c_m - c\sigma^R - c_l \cdot r) \quad (38)$$

Due to the assumption of budget balance that any of the government's involvement approaches has to follows, we can infer that $f = s \cdot r$ and this equilibrium relation sustains only when

$$\lambda = \frac{2(1+B)I}{(1+B)(a - w^T\sigma^T - c_m - c\sigma^R - c_l \cdot r)I}\left[D - V \cdot r\right]$$
$$-\left[I(B-2B\varphi)-(1-B)(1+B+B^2)\right]$$

Proposition 4.Environmental tax and subsidy remain a proportion relation when government keeps budget balance.

To satisfy the budget balance assumption, government's economic involvement approaches have to be constrained by the budget condition that is all environmental tax can finance the subsidy. Thus, we can further derive that if the environmental tax has been given by regulation, how much subsidy the reversed-logistic supplier has is up to the recycling rate. Table 1. briefly indicates the equilibrium solutions in different negotiation agendas. We can perceive whether negotiation agendas are conducted, government's optimal strategy based on budget balance is to remain in $f = s \cdot r$.

Table 1. Equilibrium solutions of different negotiation agendas

Scenario 1: GSCM driven by universal price agenda	
y_i^*	$\frac{(4-2B)(a-w^T\sigma^T-c_m-f)-3(4-2B+2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)}{3(4-2B+3B\varphi)}$
w_i^{R*}	$\frac{\left[B\varphi(a-w^T\sigma^T-c_m-f)+(4-2B+2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)\right]}{(4-2B+3B\varphi)\sigma^R}$
π_i^{M*}	$\left[\frac{(4-2B)(a-w^T\sigma^T-c_m-f)-3(4-2B+2B\varphi)(c\sigma^R+c\cdot r-s\cdot r)}{3(4-2B+3B\varphi)}\right]^2$
π_i^{R*}	$\left[\frac{B\varphi(a-w^T\sigma^T-c_m-f-c\sigma^R-c\cdot r+s\cdot r)}{(4-2B+3B\varphi)}\right]$ $\times\left[\frac{(4-2B)(a-w^T\sigma^T-c_m-f)-3(4-2B+2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)}{3(4-2B+3B\varphi)}\right]$
f, s	$f=s\cdot r$
SW	$2y_i^{*2}+2\pi_i^{M*}+2\pi_i^{R*}+2(V\cdot r-D)\cdot y_i^*$
Scenario 2: GSCM driven by universal price and guaranteed contract agenda	
y_i^*	$\frac{(1+B\varphi)[G\cdot(a-w^T\sigma^T-c_m-f)-(B\varphi\cdot H-K)]}{(3-B+2B\varphi)\cdot G}$ where $G=[(3-B+2B\varphi)(1-B+B\varphi)-2(1+B)]$ $H=(1-3B+2B\varphi)(a-w^T\sigma^T-c_m-f)\cdot$ $K=(-1+B)(c\sigma^R+c_l\cdot r-s\cdot r)$
w_i^*	$\frac{B\varphi\cdot H-K}{G\sigma^R}$ where $G=[(3-B+2B\varphi)(1-B+B\varphi)-2(1+B)]$ $H=(1-3B+2B\varphi)(a-w^T\sigma^T-c_m-f)\cdot$ $K=(-1+B)(c\sigma^R+c_l\cdot r-s\cdot r)$

π_i^{M*}	$(1-B\varphi)\left\{\frac{(1+B\varphi)\left[G\cdot(a-w^T\sigma^T-c_m-f)-(B\varphi\cdot H-K)\right]}{(3-B+2B\varphi)\cdot G}\right\}^2$
π_i^{R*}	$\left\{\frac{B\varphi(1-3B+2B\varphi)9a-w^T\sigma^T-c_m-f)-\left[(3-B+2B\varphi)(1-B+B\varphi)-4B\right]}{\times(c\sigma^R+c_l\cdot r-s\cdot r)}{G}\right\}$ $\times\left[\frac{(1+B\varphi)\cdot G\cdot(a-w^T\sigma^T-c_m-f)-(B\varphi\cdot H-K)}{(3-B+2B\varphi)\cdot G}\right]$
Scenario 3: GSCM driven by coexistence of price and price/guaranteed contract agenda	
y_i^*	$\frac{(-1+B)[(-2+B-2B\varphi)\cdot a-B(w^T\sigma^T+c_m+f)-(1+2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)]}{I}$ Where $I=(1-B+B\varphi)(2-B+B\varphi)-B\varphi(1+B\varphi)$
y_j^*	$\frac{[BI-(1-B)(-2+B-2B\varphi)]\cdot a-[(1-B)B+I(2+B+2B\varphi)](w^T\sigma^T+c_m+f)}{-[(1-B)(1+2B\varphi)+I](c\sigma^R+c_l\cdot r-s\cdot r)}{2(1+B\varphi)I}$ Where $I=(1-B+B\varphi)(2-B+B\varphi)-B\varphi(1+B\varphi)$
w_i^*	$\frac{(1-B)\{(2-B+B\varphi)(a-w^T\sigma^T-c_m-f)+[(1+B\varphi)(4-2B+2B\varphi)-1](c\sigma^R+c_lr-sr)\}}{2(1+B\varphi)I\sigma^R}$
w_j^*	$\frac{[(1-B+B\varphi)\cdot a-B(w^T\sigma^T+c_m+f)+(1+2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)]}{(1+B\varphi)\sigma^R}$
π_i^{M*}	$\frac{(1-B\varphi)}{2}\left\{\frac{(1-B)[(2-B+2B\varphi)\cdot a-B(w^T\sigma^T+c_m+f)-(1+2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)]}{I}\right\}^2$

π_j^{M*}	$\left\{\frac{\begin{[BI-(1-B)(2-B+2B\varphi)]\cdot a- \\ [(1-B)B+I(2+B+2B\varphi)](w^T\sigma^T+c_m+f) \\ -[(1-B)(1+2B\varphi)+I](c\sigma^R+c_l\cdot r-s\cdot r)}{2(1+B\varphi)I}\right\}^2$
π_i^{R*}	$\left\{\frac{\begin{(1-B)\{(2-B+B\varphi)(a-w^T\sigma^T-c_m-f) \\ +\{[(1+B\varphi)(4-2B+2B\varphi)-1]-(1+B\varphi)I\}(c\sigma^R+c_l\cdot r-s\cdot r)}{2(1+B\varphi)I}\right\}$ $\times\left\{\frac{(1-B)[(-2+B-B\varphi)\cdot a-B(w^T\sigma^T+c_m+f)-(1+2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)}{I}\right\}$
π_j^{R*}	$\left\{\frac{(1-B+B\varphi)\cdot a-B(w^T\sigma^T+c_m+f)+B\varphi)I\}(c\sigma^R+c_l\cdot r-s\cdot r)}{2(1+B\varphi)I}\right\}$ $\times\left\{\frac{\begin{[BI-(1-B)(-2+B-B\varphi)]\cdot a- \\ [(1-B)+(2+B+2B\varphi)](w^T\sigma^T+c_m+f)-(1+2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)}{2(1+B\varphi)I}\right\}$
f, s	$f=s\cdot r$
SW	$\frac{1}{2}(y_i^*+y_j^*)^2+\pi_i^{M*}+\pi_j^{M*}+\pi_i^{R*}+\pi_j^{R*}+2(V\cdot r-D)\cdot(y_i^*+y_j^*)$

4.4 PROPOSITIONS SUMMARY

After demonstrating the induction of above three scenarios, we then come up with five propositions as follow:

Proposition 1： In normal situation that when reversed-logistic suppliers is risk-nature, the price agenda will sustain, if and only if when the revered-logistic supplier's bargaining power B is sufficiently high (B >0.5) Because of much difficulty

in barging for cheaper procurement price when reversed-logistic supplier has great barraging power, manufacturer can not earn joint rent by conducting price and guaranteed contract agenda. Thus, no one has incentive to get involved in negotiating about guaranteed contract.

Proposition 2： Universal price and guaranteed contract agenda is never sustainable as a subgame perfect equilibrium institution. Universal price and guaranteed contract agenda obviously enforces the degree of market rivalry that poses serious harm to all participants. Therefore, a participant has incentive to veto the inclusion of guaranteed contract negotiation when its rival has conduct price and guaranteed contract negotiation agenda. The Stackelberg leader can obtain joint rent by conducting price and guaranteed contract agenda without increasing much procurement cost since revered-logistic supplier is not strong enough to bargain. Besides, to avoid being hurt by price-cutting in final product market, the follower is bound to stay in price negotiation agenda.

Proposition 3：If the revered- logistic suppliers' bargaining power is sufficiently low (B≦0.5), price/guaranteed contract negotiation agenda and price negotiation agenda coexist. Members i and j will chose different negotiation agenda as the subgame perfect equilibrium. By summarizing proposition 1 and 2, it certainly infer that when the reversed-logistic supplier's bargaining power is low enough, there will coexist with two negotiation agenda.

Proposition 4：Environmental tax and subsidy remain a constant proportional relation regarding to return rate when government keeps budget balance and both of such involvement approaches certainly make effects to final product output level and price

associated with recycling raw material.

1. When government increases the environmental tax which is imposed to the manufacturers, it will reduce the output level regarding to final product and further depreciates the price of recycling raw material.
2. When government increases the subsidy to the reversed-logistic suppliers, it will firstly makes the price of recycling raw material cheaper and thus drives the output level regarding to final product down.

Proposition 5：A green supply chain which is dominated by single key member may overwhelmingly earn higher profit than a green supply dominated by dual key members. Referring to literatures associated with Stackelberg and Cournot completion and observing participants' behavior separately in Scenario 1 and 3, we possibly infer that if the key member's barging power is not strong enough to dominate the rest of members, the production may progress inefficiently. In our case, if reversed-logistic supplier's barging power gets increased, manufacturer finds it more difficult to expand its output and barging for cheap procurement. In this situation, we can regard the supply chain is actually dominated by two key members.

Proposition 6：Enhancing reversed-logistic suppliers' bargaining power will pose a negative impact to output level regarding to final product and may further cause a negative influence to social welfare when the proportion of recycling raw material in a unit of final product has been given. If the reversed-logistic suppliers are endowed with strong bargaining power, they will barging for a high selling price regarding to recycling raw material. However, due to the given proportion of recycling raw material that government required, manufacturer has no way to substitute other relative cheap material. Consequently, the rising price in terms of recycling part will

directly drive the final product more expensive and thus restrict the output level as well. Although reversed-logistic suppliers' profit may be enhanced by their strong bargaining power, the drawbacks regarding to the loss of consumers' surplus and producers' surplus may be overweight overwhelmingly.

CHAPTER 5 NUMERICAL ANALTSIS

Based on previous inference in Chapter 4, we construct a specific scenario in which some variables have been given to proceed with numerical analysis. The purpose of this chapter aims to understand how a variable while others have been given influences the manufacturer's final output level as well as its profit. Through the analysis, it is more easily to observe the relationship regarding to bargaining power, risk aversion and profit. The analysis is conducted based on Matlab 7.0 and Microsoft Excel 2007.

5.1 SET UP THE VARIABLES

The scenario we constructed is based on the recycled tire market in Taiwan.

1. Industry structure.

   We assumed there are two manufacturers in this market and two recycling providers as well. For simplicity, those two manufacturers and two recycling providers are endowed with the same technology. Therefore, we can infer that both of manufacturers make the same production.

2. Government's policy

   (1) The proportion of traditional and recycling raw material $\left(\sigma^T : \sigma^R\right)$

   Referring to European environmental regulation, we assume when it comes to make one unit of final products, it needs 72% of recycling raw material and 28% of traditional raw material.

   (2) The recycling rate $\left(r\right)$

   We assume the yield of rate in terms of recycling raw material is 90% and it requires 72% of recycling raw material to make one unit product; therefore, the recycling rate is 80%.

   (3) Environmental tax and subsidy

   Based on the result of chapter 4, we know that the optimal relationship between

tax and subsidy is $f = r \cdot s$; therefore, we assumed the environmental tax is 8 and the subsidy is 10.

3. Other variables

Other variables are given as follows:

(1) The demand function of final product is $P=a-y_i-y_j$, where a=1000

(2) Marginal cost of final product $c_m=5$

(3) One unit recycling raw material production cost c=4

(4) Marginal collection cost $c_l=3$

(5) One unit of traditional raw material $w^T=20$

Table2 . Present parameters for sensitivity analysis

Parameter	Numbers of manufacturers	Input proportion of recycling raw material (σ^R)	Input proportion of traditional raw material (σ^T)	Rate of return (r)
Present value	2	72%	28%	80%
Parameter	Final product demand function $(y = a - y_i - y_j)$	Marginal final product production cost (c_m)	One unit recycling raw material production cost (c)	Marginal collection cost (c_l)
Present value	a=1000	5	4	3
Parameter	Environmental tax (f)	Subsidy (s)	Incremental environmental marginal cost	Incremental environmental marginal

			(D)	benefit (V)
Present value	8	10	39	20

5.2 SENSITIVITY ANALYSIS

The analysis in this part is divided into two parts. First part is associated with the negotiation results which are impacted by reversed logistic suppliers' bargaining power. Second part is related to government's regulation. According to previous literatures, it has obviously indicated the relationship among environmental cost, environmental benefit and social welfare. Thus, in this part, we are curious about the impact of recycling rate to manufacturer's profit. All analyses in this section are finished by Matlab 7.0 and Microsoft Excel 2007.

1. Bargaining power

The relationship among barraging power, risk aversion and final output of products is expressed as figure 6.

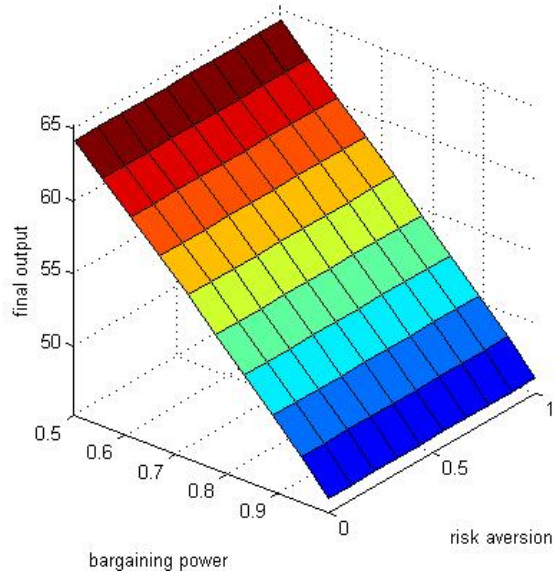

Figure 9. The variation between risk aversion, barging power and final output

Figure 9. previously indicates as the reversed-logistic supplier's barraging power increases, the final output declines as well. This result is satisfied with normal intuition that as the seller's barging power gets stronger; it is more difficult to barging

for a cheap price. Thus the final output decreases as well. Comparing with barraging power, risk aversion's impact is very minor.

We then go into further analysis regarding to the relationship between barraging power and manufacturer's profit while reversed-logistic supplier is risk nature. Figure 10. is coherent with our previous inference that as reversed-logistic supplier's barraging power increases, manufacturer's profit gets down.

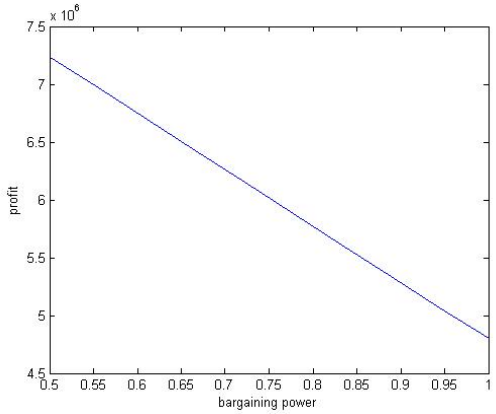

Figure 10. Barging power's impact to profit

Furthermore, figure 11a and figure 11b separately imply the social welfare and the profit of green supply chain, varying with the barraging power in different negotiation agenda. The former one is based on universal price agenda; the latter one is based on coexistence of price and price/guaranteed contract agenda. Whether the negotiation agenda we conducted, both results indicate that reversed-logistic supplier's bargaining power has a negative impact toward social welfare and green supply chain's profit. When the reversed-logistic supplier's bargaining power is strong, it is more easily to bargain for high price which will cause further cost burden to the manufacturer.

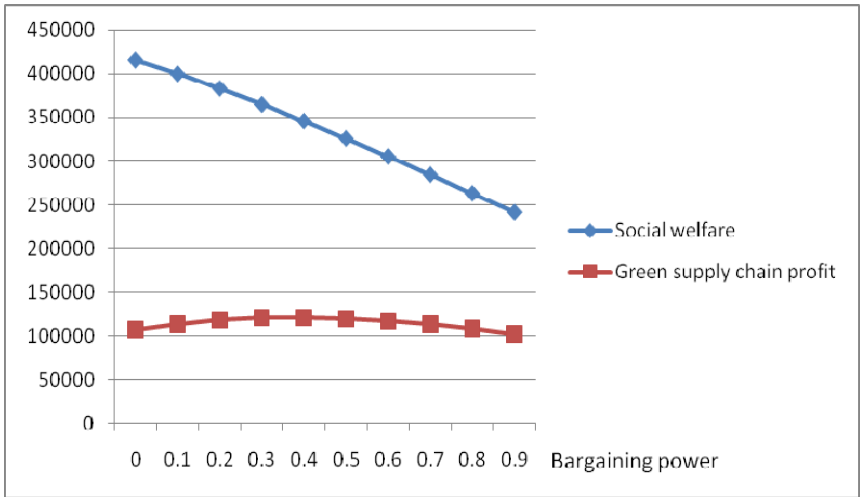

Figure 11a. Baring power's impact to social welfare and GSCM in Scernario 1

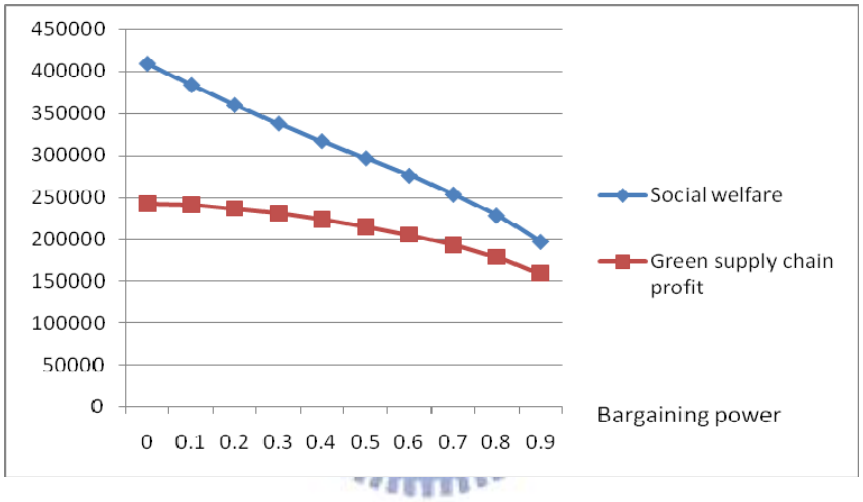

Figure 11b. Baring power's impact to social welfare and GSCM in Scernario 3

After understanding the overal bargining power's impact toward social welfare, we then further devide social welfare into four elements and deeply clasify how bagrining power affects each parts as well. Through studying with Figure 12.a and 12.b, it certainly indicate that reversed logistic suppliers are able to bargin for higher selling price regading to recyling raw materail because of stronger bargining power and thus makes final product more expensive as well. Consequently, consumer's surplus is dramatically worsened off which majoly dominates the trend with totall

socail welfare[10].

In addition, by summarizing above figures, we can also conclue that bargining power casues more significant impact to social welfare in scenario 1 than in scenario 3 in that the effects of price bargining is reinforced by only conduct price negotiaiton in scenario 1.

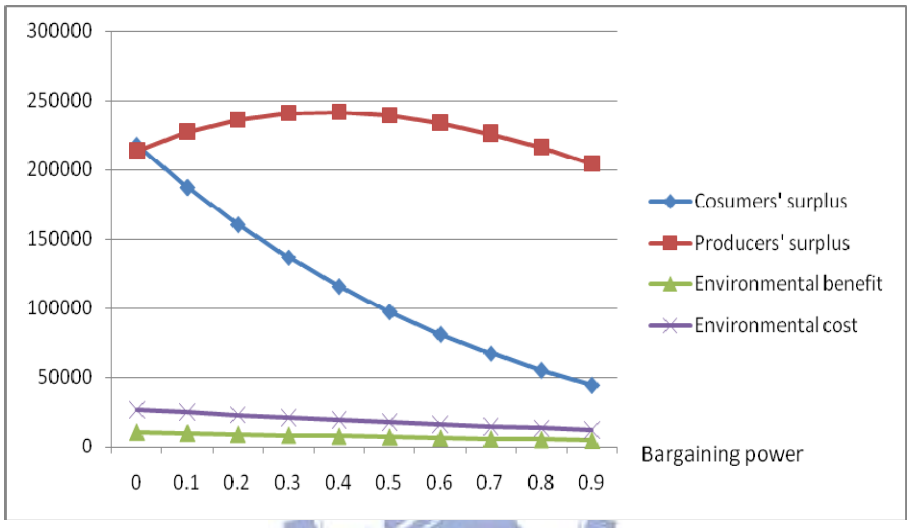

Figure 12a. Baring power's impact to social welfare in Scernario 1

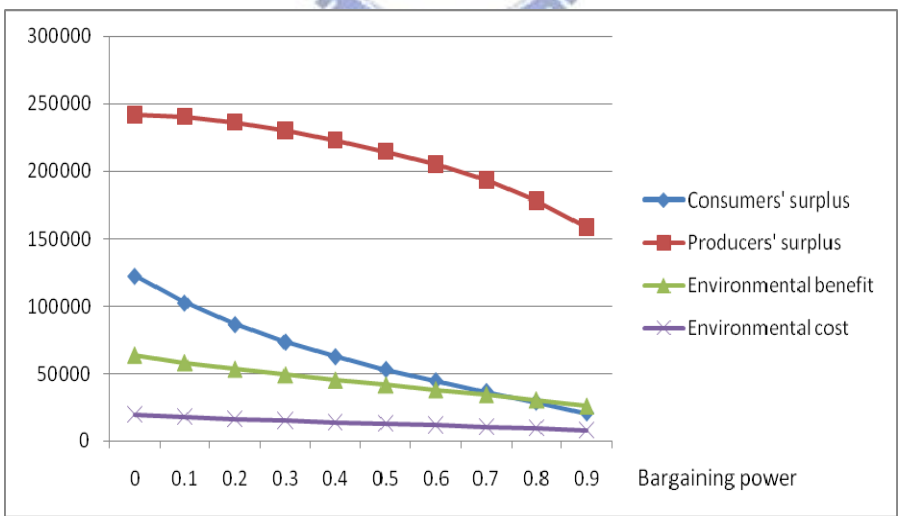

Figure 12b. Figure 12a. Baring power's impact to social welfare in Scernario 3.

[10] When reversed-logistics' barging power get increased, price of recycling raw material will certainly be enhanced and thus restricts output level regarding to final product. According to our assumptions, final product's supply function can be expresses as $P = a - Y$ which implies that the decrement of final product leads increasing selling price as well. Consequently, higher price but lower quantity associated with final product will eventually cause lower consumers' surplus.

2. Risk aversion

In normal case based on universal price agenda, risk aversion does not have obvious impact to the profit of manufacturer and reversed-logistic supplier. However, only in an extreme case where φ=0, the reversed-logistic supplier's profit will be minus while manufacturer's profit will be maximized. Figure 13a indicates that as risk aversion increases, manufacturer's profit will decline but reversed-logistic supplier's increases as well.

The result in coexistence of price and price/guaranteed contract agenda is a little different. Reversed-logistic suppliers have the highest profit while manufacturers have the lowest profit whereφ=0. However, the trend of further results whenφ>0 is similar to what it is based on universal price agenda.

Whenφ=0, it means that revered-logistic supplier aims to grab further market shares, pushing its rivals out of current market by maximizing its own output quantity. According the numerical result in figure 13a, we can obviously perceive that there may not be any profit when reversed-logistic supplier chose this strategy in universal price agenda since manufacturer can easily bargain for much lower price than usual. Nevertheless, such intuition no longer stands in the coexistence of price and price/guaranteed contract agenda in that price/guaranteed contract agenda that first mover conducts has to provide certain price and quantity simultaneously which automatically protects reversed-logistic supplier's negotiation position. In addition, since coexistence of price and price/guaranteed contract agenda is a Stackelberg sequential game, we can infer that the leading revered-logistic supplier can potentially and easily grab the whole markets share if it set market share maximization as its priority. Consequently, revered-logistic suppliers' profits in figure 13b whenφ=0 might be only determined by the first mover.

Whenφ＞0, it means revered-logistic supplier set profit as one of its decision

concern which prevents the leader from grabbing the whole market and favors the follower to stay in the market. Thus, the reversed-logistic suppliers' profits are accounted by both leader and follower whose trend follows the normal rule in figure 13b.

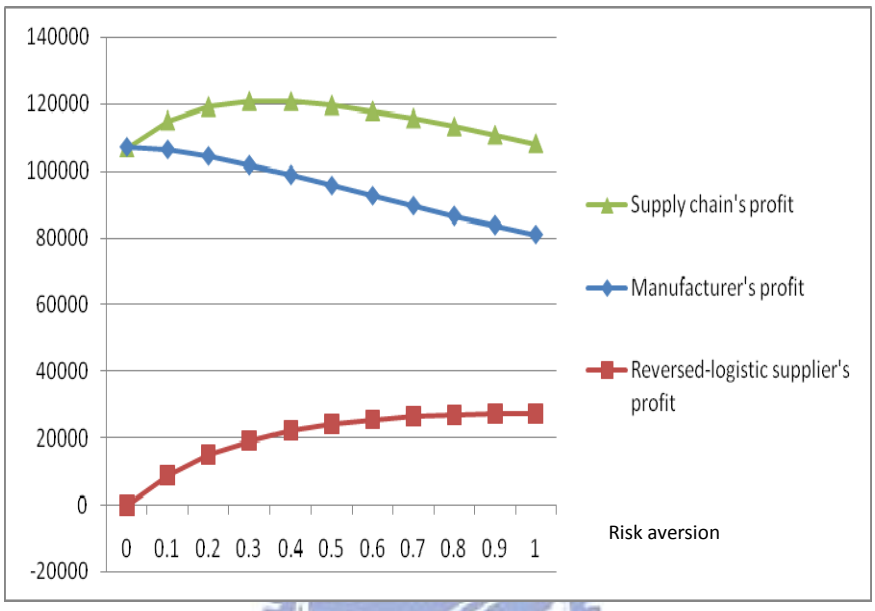

Figure 13a. Risk aversion's impact to members in GSCM (scenario 1)

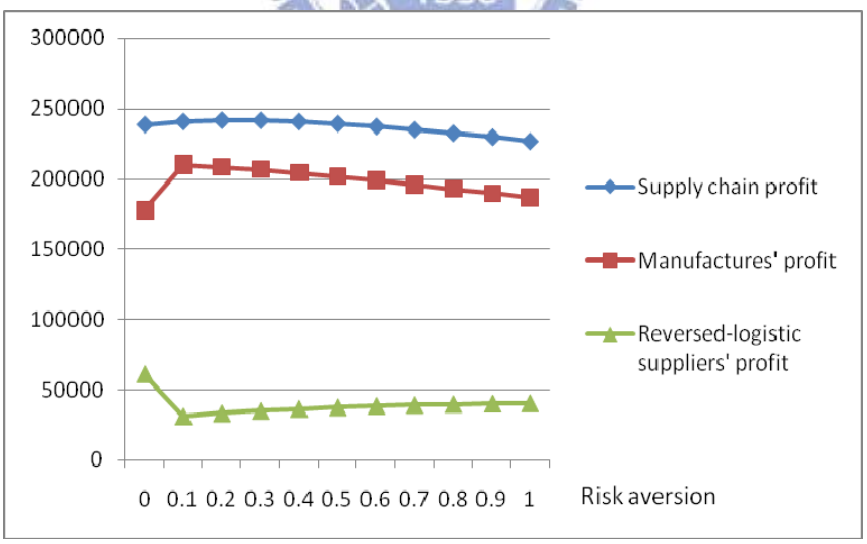

Figure 13b. Risk aversion's impact to members in GSCM (scenario 3)

3. Rate of return

In addition to environmental tax, subsidy and regulation regarding to the proportion of raw material, rate of return is also a key factor which may influence the

social welfare. As far as government's concerned, tax and subsidy are taken to facilitate the recycling rate and promote the social welfare in the end. Our sensitivity analysis whether it is based on universal price agenda or coexistence of price and price/guaranteed contract agenda which separately showed in Figure 14a. and Figure 14b. both support this intuition that recycling rate has a positive relation with social welfare and green supply chain's profit.

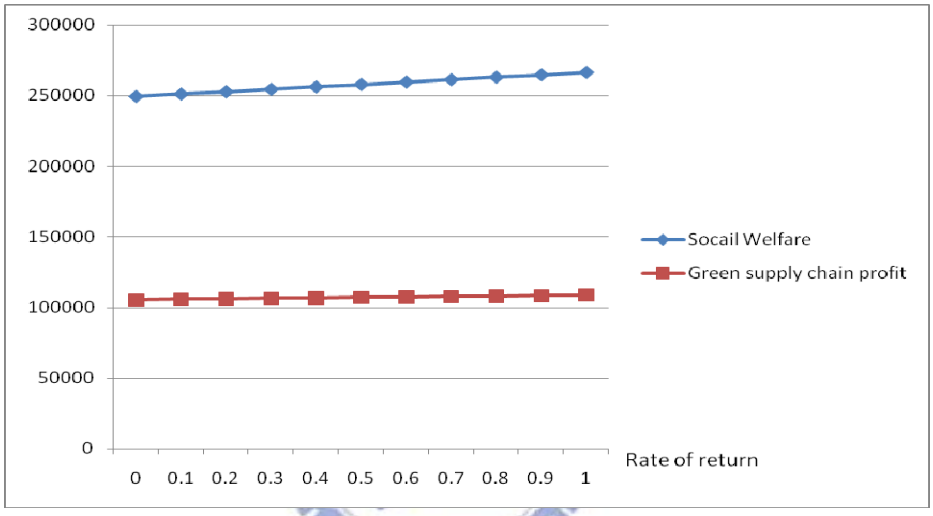

Figure 14a. Rate of retun's impact to socail welfare and GSCM in scenario 1

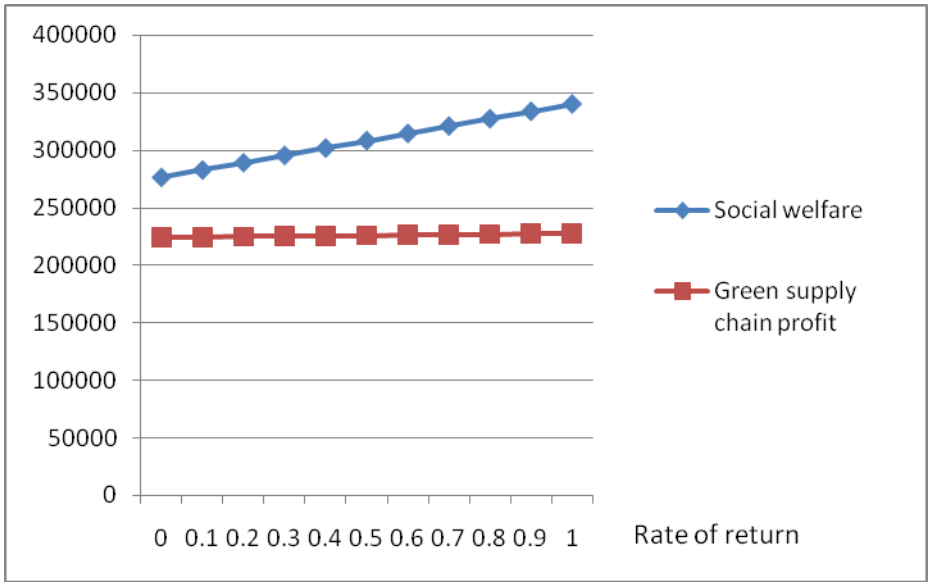

Figure 14b. Rate of retun's impact to socail welfare and GSCM in scenario 3

4. Proportion of recycling raw material

The proportion of recycling raw material which has to be used in one unit final product has to abide by the environmental regulation which is also associated with government's environmental policy. The variation of proportion in between recycling raw material and traditional raw material will impact the social welfare and green supply chain's profit. Figure 15a.(scenario 1) and 15b.(scenario 3) separately indicate that as government increase the proportion requirement of recycling raw material, whether in scenario 1 or scenario 3, both social welfare and green supply chain's profit will be enhanced even though the impact seem to be relatively minor.

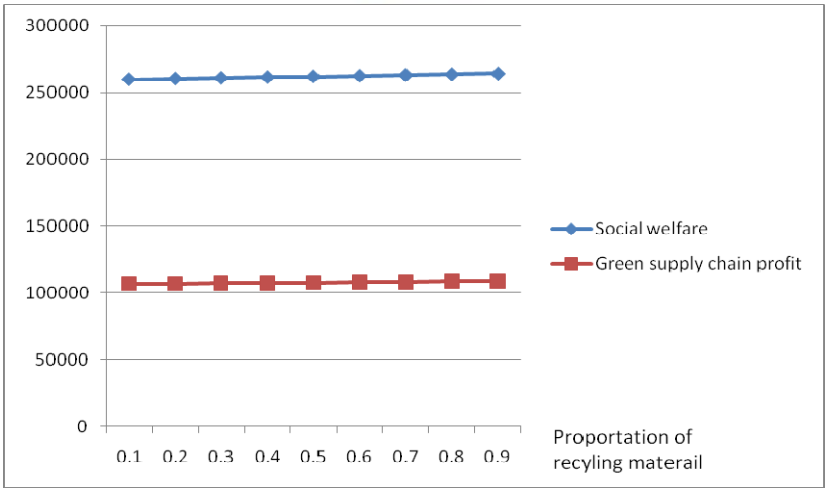

Figure 15a. Impact to social welfare and GSCM regading to prorption of recycling mateail (scenario 1)

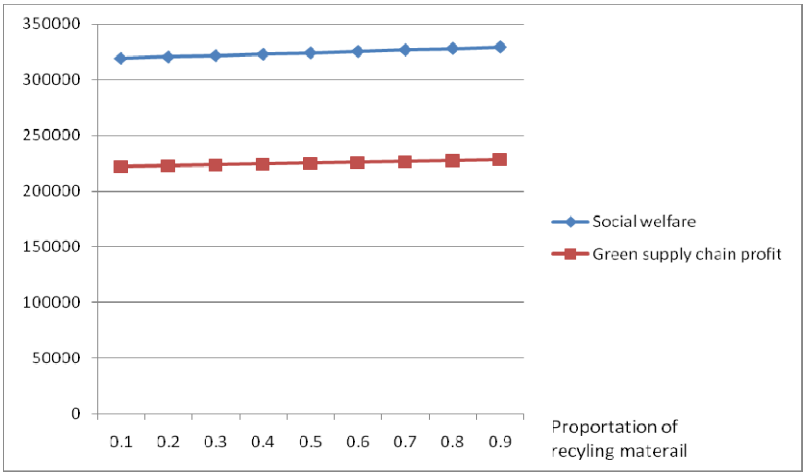

Figure 15b. Impact to social welfare and GSCM regading to prorption of recycling mateail (scenario 3)

CHAPTER 6 CONCLUSIONS AND SUGGESTIONS

6.1 CONCLUDING REMARKS

This paper has constructed two negotiation agenda in three scenarios where are driven by government's economic involvement approaches. The market structure in terms of final product or recycling raw material is determined by imperfectly competition. The first scenario is a three stage game and conducting Cournot competition. The inference indicates two possible results depending on which type the reversed-logistic supplier is. In normal situation, revered-logistic supplier is risk-nature which does not have remarkable preference toward guaranteed contract. Therefore, the reversed-logistic supplier is also profit-oriented. In this situation, it is more difficult for manufacturer to bargain for a cheaper long-term contract than it does when revered-logistic supplier is quantity-oriented. Our inference indicts that only when the bargaining power is greater than 0.5, the universal price agenda is sustainable. Scenario 1 is based on the assumption that both manufacturers do not have enough information to predict their rival's strategy. Therefore, they both assume their rival's output is constant which is fitted with the hypothesis of Cournot competition.

Scenario 2 is a two stage game that manufacturer determines its output and purchasing price through the negotiation mechanism. As long as manufacturer wants to being a Stackelberg leader, it has incentive to conduct price/guaranteed contract agenda which also ensures revered-logistic supplier with long-term profit. However, if both manufacturers seek for being leader by competing in quantity, they will get into a prisoner dilemma where they are both suffered. As a result, when one manufacturer has conducted the price/guaranteed contract agenda, the other one has incentive to deviate. In scenario 2, we assume both manufacturers can take charge of information flow, and aim to be the market leader.

Coexistence of price agenda and price/guaranteed agenda is well-facilitated when the baring power of revered-logistic supplier is low enough. In scenario 3, information asymmetric makes one manufacturer who has better information flow being the market leader while the other is the follower. This scenario is a typical Stackelberg competition which is sustainable when the bargaining power is low enough.

Government is the leader over the whole system, making the involvement approaches and maximizes social welfare. Whether in scenario 1 or 3, government's involvement approaches contribute the same impact to the price of recycling raw material and final output level. However, the social welfare varies with the output amount of final products. According to economic literature, total production in Stackelberg industry is more than in Cournot industry. Thus, if the final product is highly contaminating, it is wise to increase environmental tax and avoid the formation of Scenario 3.

In addition, through the numerical analysis, it obviously indicates that any variation of certain parameter may contribute larger impact in scenario 3 than what it is in scenario 1. This insight can simply infer from the results that economics had found in comparing with the Stackelberg competition and Cournot competition, which reveals that the former may contribute to larger output level than the latter. Consequently, government's involvement approaches can easily impact the social welfare more significant.

The most significant contribution of this study is that we succeed in demonstrating certain factor leading to various sustainably negotiation mechanisms. Although the effect from government is comparatively minor due assumptions which are endowed to fit with mathematical induction as well as basic economical logic, this study still provides a crucial insight in favor of policy construction associated with

eco-system regulation. Though out this study, it appeals to readers that output level in scenario 3 will exceed output level in scenario 1. Therefore, our conclusion will infer an inspirable issue discussing how to assist participants in conducting a negotiation agenda which leads to eco-friendly by executing other policy.

6.2 SUGGESTIONS

This research integrates the concept of negotiation theory and green supply chain management, aiming to modify a real negotiation process which can be applied in a real business case. However, this research still also has several obstacles which need to be solved in the future. We believe these following suggestions can favor and inspire future research.

(1) In most recycling market, it is more possible to observe a loose oligopoly[11] competition rather than a duopoly oligopoly competition. However, it is very difficult to modify a market structure where coexists with different scale of firms. If we can succeed in modifying a scale asymmetric market, we can more easily modify a real business situation.

(2) In this research, government proposes tax and subsidy to facilitate the recycling rate. However, there are still other potential approaches that were not discussed in our model, such as trade of emission and tax refund. Further research about such approaches is favorable to comprehensively evaluate the government's environmental policy.

(3) All negotiation scenarios in this research are bilateral; however, in real business case, bargaining process usually takes place in a multilateral mechanism. It is

[11] CR_4 (four-firm concentration rate) is widely used to evaluate the market structure. CR_4 aims to evaluate the market share of the 4 largest firms in this market. If CR_4 is between 40%~60%, we regard this market as a loose oligopoly market where it is difficult to proceed with Cartel collaboration.

necessary to construct a multilateral bargaining mechanism especially when it comes to a more complicated market.

(4) We ignore the technology asymmetric in this model, regarding all manufacturers are endowed with the same technology. This philosophy highlights the sense of perfect duopoly competition which assumes both competitors are well-matched in strength. This assumption is well-applied into a matured market but too simple to modify an emerging market. Thus, considering the technology asymmetric factor is necessary in future research.

(5) Our model briefly implies that risk aversion will makes effect only in some extreme situation but it does mean that risk aversion should be ignored in further research. On the contrary, we think the integration of risk aversion and technology substitution should be involved in further research. This sense can facilitate the understanding of manufacturer's behavior in terms of risk evaluation.

(6) Our negotiation model is bilateral-based and ignores the time element which means our equilibrium is a short-term solution. According to previous literature review in chapter 3, it obviously implies that "time discount factor" is an essential decision point with regarding to multilateral negotiation. This philosophy is also coherent with the long-term analysis. Thus, future research can expand current negotiation scope as well as participants by means of considering time discount factor which is helpful to infer the view of participant's long term behaviors.

APPENDIX

A.1 PROOF OF PROPOSITION 1

When we want to proof that the universal price agenda is sustainable, we have to indict in which condition that no participants in the negotiation pair have incentive to switch to the universal price/guaranteed contract agenda. We supposedly assume manufacturer i unilaterally deviate the price agenda by conducting guaranteed contract negotiation; therefore, manufacturer i becomes the Stackelberg leader as well. Given that the negotiated selling price of pair2 is w_j^{R*} which can be derived from Eq. (12)., while manufacturer j's (which is the Stackelberg follower) optima response function is $R_j(y_i) = (a - y_i - w_j^{R*}\sigma^R - w^T\sigma^T - c_m - f)/2$, and negotiation pair 1 maximize their negotiation utility by choosing (y_i, w_i)

$$\begin{aligned}&\left[(a - y_i - R_j(y_i) - w_i^R\sigma^R - w^T\sigma^T - c_m - f)y_i\right]^{(1-B)} \\ &\times\left[(w_i^R\sigma^R - c\sigma^R - c_l\cdot r + s\cdot r)^{\varphi} y_i\right]^{B}\end{aligned} \tag{A1}$$

$$\begin{aligned}\frac{dU}{dy_i} &= \frac{(1-B)(a - 2y_i + w_j^R(w_i^R)\sigma^R - 2w_i^R\sigma^R - w^T\sigma^T - c_m - f)}{(a - y_i - w_j^R(w_i^R)\sigma^R - 2w_i^R\sigma^R - w^T\sigma^T - c_m - f)} \\ &+ \frac{(w_i^R\sigma^R - c\sigma^R - c_l\cdot r + s\cdot r)}{(w_i^R\sigma^R - c\sigma^R - c_l\cdot r + s\cdot r)y_i} + \frac{B}{y_i} = 0\end{aligned}$$

$$\begin{aligned}\frac{dU}{dw_i^R} &= \frac{2(1-B)(\frac{dw_j^R(w_i^R)}{dw_i^R}\sigma^R y_i - 2\sigma^R y_I)}{(a - y_i + w_j^R(w_i^R) - 2w_i^R\sigma^R - w^T\sigma^T - c_m - f)y_i} \\ &+ \frac{B\varphi\sigma^R y_i}{(w_i^R\sigma^R - c\sigma^R - c_l\cdot r + s\cdot r)} = 0\end{aligned}$$

By the focs, substituting w_j from Eq. (12), and solving the equations, we can get：

$$y_i = \frac{(4-2B)(a - w^T\sigma^T - c_m - f) - 3(4 - 2B + 2B\varphi)(c\sigma^R + c_l\cdot r - s\cdot r)}{(4 - 2B + 3B\varphi)(2 - B\varphi)} \tag{A2}$$

$$w_i^{R*} = \frac{\left[B\varphi(a - w^T\sigma^T - c_m - f) + (4 - 2B + 2B\varphi)(c\sigma^R + c_l \cdot r - s \cdot r)\right]}{(4 - 2B + 3B\varphi)\sigma^{\mathrm{R}}} \qquad \text{(A3)}$$

Thus, we can compare manufacturer i's final profit separately deriving from the universal price agenda and price/guaranteed contract agenda by π_i / π_i^*, where π_i^* has been figured out through Eq.(12) and (13). Only when $\pi_i > \pi_i^*$, manufacturer i has incentive to deviate the price agenda. Since $\pi_i / \pi_i^* = 9(1 - B\varphi) / 2(2 - B\varphi)^2$, the result can be divided into two scenarios. As long as revered-logistic supplier is risk nature (φ=1) which is normally exist in real business, manufacturer i enjoys higher profit when B＜0.5. However, if the reversed-logistic supplier sets market share as first priority; namely it does not care the profit (φ=0), it tends to seek for more quantity of sales. Thus, the price agenda fails since $\pi_i > \pi_i^*$ (9>8), which is always sustained.

A 2. PROOF OF PROPOSITION 2

To implement the proposition 2, we only have to proof that manufacturer j (negotiation pair 2) enjoys higher profits by conducting the price agenda. Given that negotiation pair 1 chooses , and manufacturer j responds to (y_i^{1*}, w_i^{R1*}) (given in Eq.(28)) in the next stage. Negotiation pair 2 bargain about w_j^{R2} by means of responding to y_i^{1*} while manufacturer j's reaction function can be expressed as follow:

$R_j(y_i^{1*}) = (a - y_i^{1*} - w_j^{R2}\sigma^R - w^T\sigma^T - c_m - f) / 2$, thus the negotiation object of pair 2 is

$$\left[(a - y_i^{1*} - R_j(y_i^{1*}) - w_j^{R2}\sigma^R - w^T\sigma^T - c_m - f)R_j(y_i^{1*})\right]^{(1-B)} \times$$
$$\left[(w_j^{R2}\sigma^R - c\sigma^R - c_l \cdot r + s \cdot r)R_j(y_i^1)^{\varphi} R_j(y_i^{1*})\right]^B$$

(A3)

$$\frac{dU}{dw_j^{R2}} = \frac{(1-B)\begin{bmatrix}(a-w^T\sigma^T-c_m-f)\dfrac{dR_j(y_i^{1*})}{dw_j^{R2}}-2R_j(y_i^{1*})\dfrac{dR_j(y_i^{1*})}{dw_j^{R2}}\\ -(\sigma^R R_j(y_i^{1*})+w_j^{R2}\sigma^R\dfrac{dR_j(y_i^{1*})}{dw_j^{R2}})\end{bmatrix}}{(a-y_i^{1*}-R_j(y_i^{1*})-w_j^{R2}\sigma^R-w^T\sigma^T-f)R_j(y_i^{1*})}$$
$$+\frac{B\varphi\left[\sigma^R R_j(y_i^{1*})+w_j^{R2}\dfrac{dR_j(y_i^{1*})}{dw_j^{R2}}-c\sigma^R-c_l\cdot r+s\cdot r\right]}{(w_j^{R2}\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)R_j(y_i^{1*})}+\frac{B\dfrac{R_j(y_i^{1*})}{dw_j^{R2}}}{R_j(y_i^{1*})}=0$$

By the foc and substituting y_i^{1*} from Eq. (29), we get

$$w_j^{R2}=\frac{B\varphi\cdot H-K}{G\sigma^R} \tag{A4}$$

where $G=[(3-B+2B\varphi)(1-B+B\varphi)-2(1+B)]$

$$H=(1-3B+2B\varphi)(a-w^T\sigma^T-c_m-f)\cdot$$

$$K=(-1+B)(c\sigma^R+c_l\cdot r-s\cdot r)$$

From manufacturer j's reaction function, we can infer

$$y_i^*=\frac{(2-B\varphi)(1+B\varphi)[G\cdot(a-w^T\sigma^T-c_m-f)-(B\varphi\cdot H-K)]}{2(3-B+2B\varphi)\cdot G} \tag{A5}$$

Then we have to compare manufacturer j's final profit from the price agenda (π_j) and price/guaranteed contract agenda (π_j^*, which is given by Eq. (28) and (29)). Since $\pi_j \big/ \pi_j^1 = (2-B\varphi)^2 \big/ 4(1-B)$ is always greater than 1, manufacturer j has incentive to veto the inclusion of guaranteed contract.

A 3.1. INDUCTION OF UNIVERSAL PRICE AGENDA

Equilibrium negotiation results are all implemented in backward induction in this our research. We firstly optimize manufacturers' output levels which have been modified as Eq (6) by first order condition. Thus, we can infer that

$$\frac{d\pi_i}{dy_i} = a - 2y_i - y_j - w_i^R\sigma^R - w^T\sigma^T - c_m - f$$

$$\frac{d\pi_j}{dy_j} = a - 2y_j - y_i - w_j^R\sigma^R - w^T\sigma^T - c_m - f$$

By solving such simultaneous equation, we can get

$$y_i^*(w_i^R, w_j^R) = \frac{a - 2w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T - c_m - f}{3}$$

Then, we are proceeding in determining the negotiation price by solving the negotiation model which has been modified in Eq (10).

$$\left[\left(a - y_i - y_j - w_i^R\sigma^R - w^T\sigma^T - c_m - f\right)y_i^*\right]^{(1-B)} \times \left[(w_i^R\sigma^R - c\sigma^R - c_l \cdot r + s \cdot r)y_i^{*\varphi}y_i^*\right]^B$$

$$(1-B)\ln\left(\frac{a - 2w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T - c_m - f}{3}\right)^2$$
$$+B\ln\left[\left(\frac{a - 2w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T - c_m - f}{3}\right)\left(w_i^R\sigma^R - c\sigma^R - c_l \cdot r + s \cdot r\right)\right]$$
$$+B\ln\left(\frac{a - 2w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T - c_m - f}{3}\right)$$

$$\frac{dU}{dw_i^R} = \frac{9(-4)\sigma^R(a - 2w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T - f)}{9(a - 2w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T - f)^2} + \frac{(-6)B\sigma^R}{3(a - 2w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T - f)}$$
$$+\frac{B\varphi\sigma^R(a - 4w_i^R\sigma^R + w_j^R\sigma^R - w^T\sigma^T + 2c\sigma^R + 2c_l \cdot r - 2s \cdot r)}{(w_i^R\sigma^R - c\sigma^R - c_l \cdot r + s \cdot r)(a - 2w_i^R\sigma^R + w_j^R\sigma^R - f)} = 0$$

$$\frac{dU}{dw_j^R} = \frac{9(-4)\sigma^R(a - 2w_j^R\sigma^R + w_i^R\sigma^R - w^T\sigma^T - f)}{9(a - 2w_j^R\sigma^R + w_i^R\sigma^R - w^T\sigma^T - f)^2} + \frac{(-6)B\sigma^R}{3(a - 2w_j^R\sigma^R + w_i^R\sigma^R - w^T\sigma^T - f)}$$
$$+\frac{B\varphi\sigma^R(a - 4w_j^R\sigma^R + w_i^R\sigma^R - w^T\sigma^T + 2c\sigma^R + 2c_l \cdot r - 2s \cdot r)}{(w_j^R\sigma^R - c\sigma^R - c_l \cdot r + s \cdot r)(a - 2w_j^R\sigma^R + w_i^R\sigma^R - f)} = 0$$

$$(4 - 2B + 4B\varphi)w_i^R\sigma^R - B\varphi w_j^R\sigma^R$$
$$= B\varphi(a - w^T\sigma^T - c_m - f) + (4 - 2B + 2B\varphi)(c\sigma^R + c_l \cdot r - s \cdot r)$$

$$(4-2B+4B\varphi)w_j^R\sigma^R - B\varphi w_i^R\sigma^R$$
$$= B\varphi(a - w^T\sigma^T - c_m - f) + (4-2B+2B\varphi)(c\sigma^R + c_l \cdot r - s \cdot r)$$

By solving such simultaneous equations, we can get

$$w_i^{R*} = \frac{\left[B\varphi(a - w^T\sigma^T - c_m - f) + (4-2B+2B\varphi)(c\sigma^R + c_l \cdot r - s \cdot r)\right]}{(4-2B+3B\varphi)\sigma^R}$$

Substitute w_i^{R*} into Eq(7), we can get

$$y_i^* = \frac{(4-2B)(a - w^T\sigma^T - c_m - f) - 3(4-2B+2B\varphi)(c\sigma^R + c_l \cdot r - s \cdot r)}{3(4-2B+3B\varphi)}$$

After determining the equilibrium price and output level, we then solve the equilibrium subsidy and tax in the last stage.

By the first order condition of Eq(8), we can get the *Kuhn-Tucker conditions*

$$\frac{dSW}{df} = 4y_i\frac{dy_i}{df} + 2\left(a - 2y_i - w^T\sigma^T - c\sigma^R - c_l \cdot r\right)\frac{dy_i}{df} - 2\left(D - V \cdot r\right)\frac{dy_i}{df}$$
$$+\lambda\left(2y_i + 2f\frac{dy_i}{df} - 2s \cdot r\frac{dy_i}{df}\right) = 0$$

$$\frac{dSW}{df} = 4y_i\frac{dy_i}{ds} + 2\left(a - 2y_i - w^T\sigma^T - c\sigma^R - c_l \cdot r\right)\frac{dy_i}{ds} - 2\left(D - V \cdot r\right)\frac{dy_i}{ds}$$
$$+\lambda\left(2f\frac{dy_i}{ds} - 2s \cdot r\frac{dy_i}{ds} - 2Ry_i\right) = 0$$

By arranging above equations, we can get

$$\left(a - 2y_i - w^T\sigma^T - c\sigma^R - c_l \cdot r\right)\frac{dy_i}{df} - \left(D - V \cdot r\right)\frac{dy_i}{df} + \lambda\left(y_i + f\frac{dy_i}{df} - s \cdot r\frac{dy_i}{df}\right) = 0$$

$$\left(a - 2y_i - w^T\sigma^T - c\sigma^R - c_l \cdot r\right) - \left(D - V \cdot r\right) + \lambda\left(y_i + f\frac{1}{\frac{dy_i}{df}} - s \cdot r\right) = 0$$

$$\left[1-\frac{(4-2B)}{3(4-2B+3B\phi)}-\lambda\right]\left(a-w^T\sigma^T-c\sigma^R-c_l\cdot r\right)-\left(D-V\cdot r\right)$$
$$+\frac{(4-2B)}{3(4-2B+3B\varphi)}\left(f-s\cdot r\right)+2\lambda\left(f-s\cdot r\right)=0$$

$$f=s\cdot r+\frac{3\left(4-2B+3B\varphi\right)}{6\left(4-2B+3B\varphi\right)\lambda+\left(4-2B\right)}\left(D-V\cdot r\right)$$
$$+\left[\frac{\left(4-2B\right)-\left(1-\lambda\right)\left(4-2B+3B\varphi\right)}{6\left(4-2B+3B\varphi\right)\lambda+\left(4-2B\right)}\right]\left(a-w^T\sigma^T-c\sigma^R-c_l\cdot r\right)$$

A 3.2 Induction of universal price/guaranteed contract agenda

Manufacturer i negotiate about the price and quantity in universal price guaranteed contract agenda. In other words, the induction of this agenda is solved straightforward by the first order conditions of the following model.

$$\left[(a-y_i-y_j)y_i-w_i^R\sigma^R y_i-w^T\sigma^T y_i-fy_i\right]^{(1-B)}\left[\left\{y_i(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r\right\}^{\varphi}y_i\right]^B$$

At first, we have to rewrite the above equation as

$$\left(1-B\right)\ln\left[\left(a-y_i-y_j-w_i^R\sigma^R-w^T\sigma^T-c_m-f\right)y_i\right]+B\varphi\ln\left[\left(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r\right)y_i\right]$$
$$+B\ln y_i$$

By focs, we can get

$$\frac{dU}{dy_i}=\frac{(1-B)(a-2y_i-y_j-w_i^R\sigma^R-w^T\sigma^T-f)}{(a-y_i-y_j-w_i^R\sigma^R-w^T\sigma^T-f)y_i}+\frac{B\varphi(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)}{(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)y_i}+\frac{B}{y_i}=0$$

$$\frac{dU}{dy_j}=\frac{(1-B)(a-2y_j-y_i-w_j^R\sigma^R-w^T\sigma^T-f)}{(a-y_i-y_j-w_j^R\sigma^R-w^T\sigma^T-f)y_j}+\frac{B\varphi(w_j^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)}{(w_j^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)y_j}+\frac{B}{y_j}=0$$

$$\left(-2+B-B\varphi\right)y_i+\left(-1-B\varphi\right)y_j$$
$$+\left[\left(1-B\right)\left(a-w_i^R\sigma^R-w^T\sigma^T-c_m-f\right)+\left(B\varphi+B\right)\left(a-w_i^R\sigma^R-w^T\sigma^T-f\right)\right]=0$$

$$(-2+B-B\varphi)\,y_j+(-1-B\varphi)\,y_i$$
$$+\left[(1-B)\left(a-w_j^R\sigma^R-w^T\sigma^T-c_m-f\right)+(B\varphi+B)\left(a-w_j^R\sigma^R-w^T\sigma^T-f\right)\right]=0$$

By solving above simultaneous equations, we can get

$$y_i=\frac{(1+B\varphi)(a-w_i^R\sigma^R-w^T\sigma^T-c_m-f)}{(3-B+2B\varphi)} \tag{A6}$$

$$y_j=\frac{(1+B\varphi)(a-w_j^R\sigma^R-w^T\sigma^T-c_m-f)}{(3-B+2B\varphi)} \tag{A7}$$

After determining y_i, we then solve the price by focs and get

$$\frac{dU}{dw_i}=\frac{(1-B)(-\sigma^R)y_i}{(a-y_i-y_j-w_i^R\sigma^R-f)y_i}+\frac{B\varphi\cdot\sigma^R\cdot y_i}{(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)y_i}=0$$

$$(-1+B-B\varphi)\,w_i^R\sigma^R+B\varphi\left(a-y_i-y_j-w^T\sigma^T-c_m-f\right)-(-1+B)\left(c\sigma^R+c_l\cdot r-s\cdot r\right)=0$$

$$w_i^R=w_j^R=\frac{B\varphi(a-y_i-y_j-w^T\sigma^T-c_m-f)+(1-B)(c\sigma^R+c_l\cdot r-s\cdot r)}{(1-B+B\varphi)} \tag{A8}$$

Since $w_i^R=w_j^R$, we can infer that $y_i=y_j$. Thus Eq.(A8) can be rewrote as

$$w_i^R=\frac{B\varphi(a-2y_i-w^T\sigma^T-c_m-f)+(1-B)(c\sigma^R+c_l\cdot r-s\cdot r)}{(1-B+B\varphi)} \tag{A9}$$

By solving the simultaneous equations of Eq.(A6) and Eq.(A9), we can get

$$2B\varphi\cdot y_i+(1-B+B\varphi)w_i^R=B\varphi\left(a-w^T\sigma^T-c_m-f\right)+(1-B)\left(c\sigma^R+c_l\cdot r-s\cdot r\right)$$

$$(3-B+2B\varphi)\,y_i+(1+B\varphi)\,w_i^R=(1+B\varphi)\left(a-w^T\sigma^T-c_m-f\right)$$

The equilibrium of w_i^{R*} and y_i^* are as follow

$$w_i^{R*} = \frac{B\varphi \cdot H - K}{G\sigma^R}$$

where $G = [(3 - B + 2B\varphi)(1 - B + B\varphi) - 2(1 + B)]$

$$H = (1 - 3B + 2B\varphi)(a - w^T\sigma^T - c_m - f) \cdot$$

$$K = (-1 + B)(c\sigma^R + c_l \cdot r - s \cdot r)$$

$$y_i^* = \frac{(1 + B\varphi)[G \cdot (a - w^T\sigma^T - c_m - f) - (B\varphi \cdot H - K)]}{(3 - B + 2B\varphi) \cdot G}$$

A 3.3 INDUCTION OF COEXISTENCE OF PRICE AND PRICE/GUARANTEED CONTRACT AGENDA

Coexistence of price and price/guaranteed contract agenda is a Stckelberg leader and follower competition game. We assumed that manufacturer i works as the leader which conducts price and output levels in negotiation agenda. Thus, manufacturer i determines its negotiation strategy by considering its rival's reaction which has been driven by the first order condition of Eq (6), that is

$$R_j(y_i) = (a - y_i - w_j^R\sigma^R - w^T\sigma^T - f)/2$$

Hence, the negotiation model can be expressed as

$$\left[(a - y_i - R_j(y_i) - w_i^R\sigma^R - w^T\sigma^T - f)y_i\right]^{(1-B)}\left[y_i(w_i^R\sigma^R - c\sigma^R - c_l \cdot r + s \cdot r)^{\varphi} y_i\right]^B$$

The above equation can be rewrote as

$$(1 - B)\ln\left\{\left[a - y_i - R_j(y_i) - w_i^R\sigma^R - w^T\sigma^T - c_m - f\right]y_i\right\} + B\varphi\ln\left[\left(w_i^R\sigma^R - c\sigma^R - c_l + s\right)y_i\right] + B\ln y_i$$

By focs, we can get

$$\frac{dU}{dy_i}=\frac{(1-B)(a-2y_i-R_j(y_i)-y_i\dfrac{dR_j(y_i)}{dy_i}-w_i^R\sigma^R-w^T\sigma^T-f)}{(a-y_i-R_j(y_i)-w_i^R\sigma^R-w^T\sigma^T-f)y_i}$$
$$+\frac{B\varphi(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)}{(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)y_i}+\frac{B}{y_i}=0$$

$$\frac{dU}{dw_i}=\frac{(1-B)(-\sigma^R)y_i}{(a-y_i-R_j(y_i)-w_i^R\sigma^R-f)y_i}+\frac{B\varphi\cdot\sigma^R\cdot y_i}{(w_i^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)y_i}=0$$

$$\frac{2(1-B)\left(-\sigma^R\right)\left(a-y_i^{1*}-w_j^R\sigma^R-w^T\sigma^T-c_m-f\right)}{(a-y_i^{1*}-w_j^R\sigma^R-w^T\sigma^T-c_m-f)}$$
$$+\frac{2B\varphi\sigma^R\left(\dfrac{a-y_i^{1*}-2w_j^R\sigma^R-w^T\sigma^T-c\sigma^R+c_l\cdot r-s\cdot r-c_m-f}{2}\right)}{(w_j^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)(a-y_i^{1*}-w_j^R\sigma^R-w^T\sigma^T-c_m-f)}$$
$$+\frac{-B\sigma^R}{(a-y_i^{1*}-w_j^R\sigma^R-c_m-f)}=0$$

$$\frac{(1-B)(-2\sigma^R y_i^{1*})}{(a-y_i^{1*}-w_j^R\sigma^R-w^T\sigma^T-c_m-f)y_i^{1*}}+\frac{B\varphi y_i^{1*}\sigma^R}{(w_j^R\sigma^R-c_l\cdot r+s\cdot r)y_i^{1*}}=0$$

$$(2-B+B\varphi)y_i+2(1+B\varphi)w_i^R\sigma^R=(1+B\varphi)(a+w_j^R\sigma^R-w^T\sigma^T-f)$$
$$B\varphi\cdot y_i+2(1-B+B\varphi)w_i^R\sigma^R=(-2)(1-B)(-c\sigma^R-c_l\cdot r+s\cdot r)$$
$$+B\varphi(a+w_j^R\sigma^R-w^T\sigma^T-f)$$

By solving above simultaneous equations, we can get

$$y_i=\frac{(1+B\varphi)(1-B)(a+w_j^R\sigma^R-w^T\sigma^T-f-2c\sigma^R-2c_l\cdot r+2s\cdot r)}{I}$$

$$w_i^R=\frac{(1-B)[(a+w_j^R\sigma^R-w^T\sigma^T-f)+(-4+2B-2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)]}{2I\sigma^R}$$

Where $I=(1-B+B\varphi)(2-B+B\varphi)-B\varphi(1+B\varphi)$

On the other hand, negotiation pair 2 chooses w_j^{R*} to maximize its negation object which can be expressed as

$$\left[(a-y_i-R_j(y_i)-w_j^R\sigma^R-w^T\sigma^T-f)R_j(y_i)\right]^{(1-B)}$$
$$\times\left[(w_j^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)R_j(y_i)^{\varphi}R_j(y_i)\right]^{B}$$

The above equation can be rewrote as

$$(1-B)\ln\left\{\left[a-y_i-R_j(y_i)-w_i^R\sigma^R-w^T\sigma^T-c_m-f\right]R_j(y_i)\right\}$$
$$+B\varphi\ln\left[\left(w_i^R\sigma^R-c\sigma^R-c_l+s\right)R_j(y_i)\right]+B\ln R_j(y_i)$$

Negotiation pair 2 conducts price agenda; therefore, we only have to solve the equilibrium price at this stage. Consequently, by foc, we got

$$\frac{dU}{dw_j^R}=\frac{(1-B)\left[(a-w^T\sigma^T-c_m-f)\frac{dR_j(y_i)}{dw_j^R}-2R_j(y_i)\frac{dR_j(y_i)}{dw_j^R}-(\sigma^R R_j(y_i)+w_j^R\sigma^R\frac{dR_j(y_i)}{dw_j^R})\right]}{(a-y_i-R_j(y_i)-w_j^R\sigma^R-w^T\sigma^T-f)R_j(y_i)}$$
$$+\frac{B\varphi\left[\sigma^R R_j(y_i)+w_j^R\frac{dR_j(y_i)}{dw_j^R}-c\sigma^R-c_l\cdot r+s\cdot r\right]}{(w_j^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)R_j(y_i)}+\frac{B\frac{R_j(y_i)}{dw_j^R}}{R_j(y_i)}=0$$

$$\frac{(1-B)\left[(a-w^T\sigma^T-c_m-f)-2R_j(y_i)-\frac{\sigma^R R_j(y_i)}{\frac{dR_j(y_i)}{dw_j^R}}+w_j^R\sigma^R\right]}{(a-y_i-R_j(y_i)-w_j^R\sigma^R-w^T\sigma^T-f)}+\frac{B\varphi\left[\frac{\sigma^R R_j(y_i)}{\frac{dR_j(y_i)}{dw_j^R}}+w_j^R-\frac{(c\sigma^R+c_l\cdot r-s\cdot r)}{\frac{dR_j(y_i)}{dw_j^R}}\right]}{(w_j^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)}$$
$$+B=0$$

$$\frac{(1-B)\left[(a-w^T\sigma^T-c_m-f)-R_j(y_i)+w_j^R\sigma^R\right]}{(a-y_i-R_j(y_i)-w_j^R\sigma^R-w^T\sigma^T-f)}+\frac{B\varphi\left[R_j(y_i)+w_j^R+\frac{(c\sigma^R+c_l\cdot r-s\cdot r)}{2}\right]}{(w_j^R\sigma^R-c\sigma^R-c_l\cdot r+s\cdot r)}+B=0$$

$$w_j^R=\frac{[(-2+B)(-c\sigma^R-c_l\cdot r+s\cdot r)+B\varphi(a-y_i-w^T\sigma^T-c_m+c\sigma^R+c_l\cdot r-s\cdot r+f]}{(2-B+B\varphi)\sigma^R}$$

By substituting y_i and w_i^{R*} which we have previously solved from negotiation pair 1 and then we can obtain a stable solution as follow:

$$w_i^{R*} = \frac{(1-B)\{(2-B+B\varphi)(a-w^T\sigma^T-c_m-f) + [(1+B\varphi)(4-2B+2B\varphi)-1](c\sigma^R+c_l r-sr)\}}{2(1+B\varphi)I\sigma^R}$$

$$w_j^{R*} = \frac{[(1-B+B\varphi)\cdot a - B(w^T\sigma^T+c_m+f)+(1+2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)]}{(1+B\varphi)\sigma^R}$$

$$y_i^* = \frac{(-1+B)[(-2+B-2B\varphi)\cdot a - B(w^T\sigma^T+c_m+f)-(1+2B\varphi)(c\sigma^R+c_l\cdot r-s\cdot r)]}{I}$$

Since $R_j(y_i) = (a-y_i-w_j^R\sigma^R-w^T\sigma^T-f)/2$, we can infer that

$$y_j^* = \frac{[BI-(1-B)(-2+B-2B\varphi)]\cdot a - [(1-B)B+I(2+B+2B\varphi)](w^T\sigma^T+c_m+f) - [(1-B)(1+2B\varphi)+I](c\sigma^R+c_l\cdot r-s\cdot r)}{2(1+B\varphi)I}$$

After determining the equilibrium price and output level, we then solve the equilibrium subsidy and tax in the last stage. The induction process is the same with what we have done in universal price agenda. By the first order condition of Eq(8), we can get the *Kuhn-Tucker conditions:*

$$\frac{dSW}{df} = \frac{1}{2}\left[2y_i^*\frac{dy_i^*}{df}+2(y_j^*\frac{dy_i^*}{df}+y_i^*\frac{dy_j^*}{df})+2y_j^*\frac{dy_j^*}{df}\right]+(a-y_i^*-y_j^*-w^T\sigma^T-c_m-c\sigma^R)$$
$$\times(\frac{dy_i^*}{df}+\frac{dy_j^*}{df})-[D-V\cdot r](\frac{dy_i^*}{df}+\frac{dy_j^*}{df})+\lambda\left[(y_i^*+y_j^*)+f(\frac{dy_i^*}{df}+\frac{dy_j^*}{df})-s\cdot r(\frac{dy_i^*}{df}+\frac{dy_j^*}{df})\right]$$
$$=0$$

$$\frac{dSW}{ds} = \frac{1}{2}\left[2y_i^*\frac{dy_i^*}{ds}+2(y_j^*\frac{dy_i^*}{ds}+y_i^*\frac{dy_j^*}{ds})+2y_j^*\frac{dy_j^*}{ds}\right]+(a-y_i^*-y_j^*-w^T\sigma^T-c_m-c\sigma^R)$$
$$\times(\frac{dy_i^*}{ds}+\frac{dy_j^*}{ds})-[D-V\cdot r](\frac{dy_i^*}{ds}+\frac{dy_j^*}{ds})+\lambda\left[f(\frac{dy_i^*}{ds}+\frac{dy_j^*}{ds})-s\cdot r(\frac{dy_i^*}{df}+\frac{dy_j^*}{df})-r(y_i^*+y_j^*)\right]$$
$$=0$$

By arranging the above equations,

$$\left(a - w^T\sigma^T - c_m - c\sigma^R - c_l \cdot r\right)\cdot\left(\frac{dy_i^*}{df} + \frac{dy_j^*}{df}\right) - \left(D - V \cdot r\right)\cdot\left(\frac{dy_i^*}{df} + \frac{dy_j^*}{df}\right)$$
$$+\lambda\left[\left(y_i^* + y_j^*\right) + f \cdot \left(\frac{dy_i^*}{df} + \frac{dy_j^*}{df}\right) - s \cdot r \cdot \left(\frac{dy_i^*}{df} + \frac{dy_j^*}{df}\right)\right] = 0$$

$$\left(a - w^T\sigma^T - c_m - c\sigma^R - c_l \cdot r\right) - \left(D - V \cdot r\right) + \lambda\left[\left(y_i^* + y_j^*\right)\cdot\left(\frac{1}{\frac{dy_i^*}{df} + \frac{dy_j^*}{df}}\right) + f - s \cdot r\right] = 0$$

$$\left[1 - \frac{(1-B)(1+B+B^2) + I(2+B+2B\varphi)}{2(1+B)\cdot I} - \lambda\right]\left(a - w^T\sigma^T - c_m - c\sigma^R - c_l \cdot r\right) - \left(D - V \cdot r\right)$$
$$+\frac{(1+B)(1+B+B^2) + I(B - 2B\varphi - 2\lambda - 2B\lambda)}{2(1+B)\cdot I}\left(f - s \cdot r\right) + \lambda\left(f - s \cdot r\right) = 0$$

$$f = s \cdot r + \frac{2(1+B)I}{\left[(1-B)(1+B+B^2) + I(2+B+2B\varphi)\right]}\left[D - V \cdot r\right]$$
$$+\left[\frac{(1-B)(1+B+B^2) - I(B - 2B\varphi - 2\lambda - 2B\lambda)}{(1-B)(1+B+B^2) + I(2+B+2B\varphi+4\lambda+4B\lambda)}\right](a - w^T\sigma^T - c_m - c\sigma^R - c_l \cdot r)$$

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