Risk Sharing in Joint Venture Projects

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Abstract

Joint ventures are widely used in construction industry as one important cooperation way between the contractors. Risk-sharing is argued an important motivation of construction joint ventures. Risk management and risk-sharing are important topics in construction industry. They are also important topics in construction joint ventures. About risk management in construction joint ventures, the previous literatures focused on providing a list of risks in construction joint ventures. There are no literatures focus on risk-sharing or risk allocations between joint venture partners. The literatures about risk-sharing problem just focus on one risk, there are no literatures about risk-sharing when there are multi-risks. The main purpose of this dissertation is to find when there are multiple risks under which conditions partners will prefer joint ventures to undertaking the whole project themselves. We also try to find which kind of joint venture agreement is relative efficient. When there are multi-risks how the partners can share risks efficiently.

When there are multiple risks, the problem that which kinds of contractors would prefer to set up a joint venture for a project is analyzed. It is found that when there is a background risk partners can improve their certainty equivalent values by setting up a joint venture instead of undertaking the whole project by one contractor. If both partners undertake limited liabilities, setting up joint ventures will make the contractors face another risk here it is called as a partner risk. Then the partners not only have to face all the risks which are related to the project, he also has to face his partner risk. Under this condition the problem that which kinds of contractors will agree to set up a joint venture to undertake a project is analyzed in this thesis. The result of this research showed joint ventures can only be set up successfully between the partners who are different on at least one of the following characteristics: capacities to deal with risks and different degrees of risk-aversion.

The efficiency of joint venture agreements (integrated type joint ventures and separated joint ventures) when there is a risk is analyzed. These two types of joint ventures can be classified into two styles according to their management styles (sponsor style and partner

style). The sponsor style joint venture which is based on the trust between the partners is found to be more efficient than the partner style joint venture in which the partners are equal. The separated type of joint venture is more suitable for the project which can be divided into several independent subprojects.

A model is built to analyze that how to share risks between partners (all of the partners are risk-aversion) in the joint venture when there are multiple risks. If bargaining is permitted, the result of bargaining is always Pareto optimum. In this dissertation, the risks are classified into controllable risks and uncontrollable risks. About the controllable risks, if the partners can share all the costs of dealing with the risks, risks can be shared between the partners without moral hazard problem. About the uncontrollable risks, partners can construct their portfolios by bargaining. Then the Pareto optimal shares of the risks between the partners can be defined.

To my family!

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Acknowledgments

During the period of my doctor course in Graduate School of Engineering Department of Urban Management, Kyoto University, I got so many helps and supports from so many people, without these supports and helps I can not finish this dissertation. Here I acknowledge all of the people with all my heart.

First, I would like to express my sincerest appreciation and profound gratitude to my supervisor, Professor Kiyoshi Kobayashi. First, thank you for your providing me a chance to study in this famous university. At the beginning of my student life in Japan, I can not communicate with others freely either in English or in Japanese. I thought I can not pass the entrance examination of the doctor course and tried to give up. It is Professor Kiyoshi Kobayashi who encouraged me to try my best to pass the examination. During the period of my doctor course, Professor Kiyoshi Kobayashi also encouraged and helped me to deal with the difficulties. So that I can learn so much, not only knowledge but also so many experience which will be helpful to my whole life.

I also wish to express my sincere gratitude to assistant professor, Masamitsu Onishi. From the moment that I came to this lab, I got so many help from him not only about research but also about daily life. Thank you so much for your suggestions and active discussions.

I also wish to express my appreciation to Associated Professor Kakuya Matushima, thank you for your help and support.

I also extend my appreciation to Professor Toshihiko Omoto. Thank you for your kindly discussing with me and your impressive lectures and lessons.

I also wish to express my thanks to Professor Hiroyasu Ohtsu, thank you for your helps and instructive advices about my dissertation. I also want to express my appreciation for your kind recommendation letter.

I also want to express my appreciation to Professor Eiichi Taniguchi, thank you for your helps and instructive advices about my dissertation.

I also want to say thanks to Aya Fujimoto and all my friends in Japan. I think it is you who gave me so many helps and support during my period in Japan. Thank you for your sharing my life in Japan. I will remember the great time with all of you and will always cherish many wonderful memories.

At last I would like to express my appreciation and love to my husband and my parents. Thank you for your love, your support and all the things you did for me.

Chapter 1

Introduction

1.1 Introduction

Over the past two decades there has been an unprecedented change in the nature of global business environment. Joint ventures have emerged as a popular strategy in an environment in which fast access to up-to-dated technology and emerging markets is more critical than ever before (Yoshino et al., 1995[136]). Joint ventures are not only used in manufacturing industry, but also in R & D projects and other industries including construction industry. The increasing magnitudes, complexities, and risks associated with major construction projects have brought together organizations with diverse strengths and weaknesses to form joint ventures to collectively bid for, and to execute projects (Kumaraswamy et al. 2000[74]). Construction organizations have extensively used international joint ventures as a vehicle to enter new construction markets around the world. The number of international construction joint ventures is growing worldwide at an increasing pace, especially in developing countries (Lim et al., 2001[80]). Developing countries see international construction joint ventures as one of the best instruments for meeting the competing interests of national development and the prevention of the domination of the economy by foreign investors (Sornarajah, 1992[119]).

Joint ventures are now a popular way of cooperation between companies. This truth, however does not mean joint ventures are perfect ways for cooperation. Alchian et al. (1987[2]) argued that a joint venture is an efficient organizational device because it avoids the opportunity for expropriation which would result if only one party owned the resource and sold its services to the other. Johnson et al. (2000[64]) argued vertical joint ventures are quasi-market, quasi-hierarchy transaction structures that allow unrelated parts of the firms to a unified structure. Thus, joint ventures can efficiently resolve governance problems that would be too great in arm's-length market transactions, while avoiding the problems associated with combining all of the firms' activities in a hierarchical structure. On the other hand, joint ventures would face some special problems because in the joint ventures partners come from different companies they have different objectives while they share some same objectives. The conflicts of the partners' own objectives can cause many problems, because in the joint venture partners share not only the fruits of their cooperation but also share the control process. During the course of their controlling process the balance of the objectives may become an important problem. The distributions of control rights will affect the importance of each partner's objective and also affect the achievement of each objective. All these conflicts would cause the problem which is called high failure rate of joint ventures (Kogut, 1988[70]) or high instable characteristics of the joint ventures (Beamish, 1985[11]; Gomes-Casseres, 1987[12]).

Even joint ventures are not perfect ways for cooperation, they do resolve some problems while they create some others (Buchel, 1998[23]). Joint ventures are popular in so many fields or industries. Why joint ventures are so widely used? About the motivations of joint ventures there are many arguments. One of the main motivations is risk-sharing, the partners set up joint ventures to share risks, for example, companies always set up a joint venture for the R & D project (market extension and so on) to share the risks. Joint ventures can act as a way to decrease some risks related to transactions, but they also bring some risks related to partner selection, which can be called partner risks. Just as one group of risks called by Li Bing (1999[79]) as internal risks. Here the partner risk is defined as the one which is similar to the one they defined, which are related with the partners, for example, partner's parent company in financial problems, the partner's management competence and resourcefulness and so on.

The risk-sharing problem in joint ventures is focused in this dissertation. First when there are multiple risks, under which conditions partners will choose to set up a joint venture to undertake a project, or which kinds of partners should be chosen when a contractor makes decision to undertake a project in the way of a joint venture is analyzed. This problem is analyzed under two conditions, one is both partners should undertake unlimited liability (full liability), the other is both partners undertake limited liability. Then the efficiency of the joint venture agreement used in construction industry with a risk is analyzed. Finally an efficient way to share risks between partners when there are multiple risks is introduced.

1.2 Definition of Joint Ventures

There are many definitions of joint ventures, each of which describes some features of joint ventures. Some definitions define a broad range of cooperation as joint ventures; while some others define a narrow range of cooperation as joint ventures. The most representative two are the definitions defined by Lynch and Norwood. A joint venture can be defined as a cooperative business activity formed by two or more separate organizations that creates an independent business entity and allocates ownership, operational responsibilities, and financial risks and rewards to each member, while preserving their separate identity/autonomy (Lynch, 1989[83]). Norwood (1999[96]) defined joint ventures as the commercial agreements between two or more companies in order to allow greater ease of work and cooperation towards achieving a common aim, through the manipulation of the appropriate resources. Other definitions are almost same as the two definitions mentioned above. Such as, Johnson et al. (2000[64]) defined joint ventures as the separate entities owned jointly by two or more firms that represent a partial combination of their resources. His definition is almost same as the one defined by Harrigan (1985[49]), joint ventures involve two or more legally distinct organizations, each of which invests in the ventures and actively participates in the decision-making activities of the jointly owned entity.

The definitions can classified into two groups: one group defines joint ventures as a separate entity created by two or more than two partners who bring together their resources and share the control right and profits; the other group defines joint ventures as any cooperation between two or more than two companies. Just as Hennart (1988[53]) summarized joint ventures can be distinguished into equity joint ventures and non-equity joint ventures. Equity joint ventures arise whenever two or more sponsors bring given assets to an independent legal entity and are paid for some or all of their contributions from the profits earned by the entity, or when a firm acquires partial ownership of another firm. The non-equity joint ventures describe a wide array of contractual arrangements, such as licensing, distribution and supply agreements, or technical assistance and management contacts.

An international joint venture is a joint venture in which at least one parent is headquartered outside the venture's country of operation or if the joint venture has a significant level of operation in more than one country (Geringer et al, 1989[41]).

In a narrow sense, a joint venture is defined as: two or more parties (they may be individuals, companies, corporation, or others) combine their resources to create a new company to carry out a special transaction/project according to their agreement. They will share the ownership, operational responsibilities, and the profits and the losses of the new company, and the new company as a separate entity undertakes liability for the debts and the third parties.

1.3 Industries Characteristics and Joint Ventures

Many researchers did researches on the relation between industries and joint ventures, and they tried to find in which industry joint ventures are always chosen as the cooperation ways. Kogut (1988[70]) found a high percentage of joint ventures in the manufacturing industry than the rest; Berg et al. (1977[13]) found joint ventures was predominant in some industries such as mining, petroleum refining and basic chemicals, and low in textiles, paint and agriculture chemicals, and specialty non-electric machinery. Additionally some researchers tried to find the characteristics of the industry in which joint ventures are always used as cooperation means. Pfeffer et al. (1976[103]) found transaction frequency and technology of the venture industry were significantly related to joint venture incidence. They found a high exchange of sales and purchase transactions, and which are technology-intensive, tend to have more joint ventures. There are also researches about whether parent companies of the partners are the same or not. Duncan (1982[36]) found that joint ventures are always used by the parents companies from different industries; while Hennart (1997[54]) found Japanese investors tend to joint venture with U.S. partners which manufacture the same produces. Some other researches tried to find the factors which affect the parent companies' choice of cooperation means. The factors can be summarized from the empirical studies results. The characteristic of the targeted assets is a main factor which affects the choice of the parent companies. Hennart (1988[53]) found if the targeted assets are firm-specific or if the assets are public goods, joint ventures will always be used by the parent companies to achieve the access of the assets. Reuer et al. (2000[110]) found the stock market generally judges favorably those joint ventures formed under conditions of asymmetric information between transacting parties, and respond negatively to joint venture formation when no asymmetric information between the parent companies. Firm's size is also a factor which affects the choice of parent companies (Boyle, 1968[21]).

From the previous literatures, joint ventures are more popular in some industries comparing with others can be found. The characteristics of industries and transactions affect the use of joint ventures by the parent companies.

1.4 Construction and Manufacturing Industries

Most of the researches focus on manufacturing industry joint ventures. Construction industry is different from manufacturing industry. The difference between the manufacturing industry and the construction industry will affect the characteristics of the joint ventures in these industries. To understand the construction joint venture, it is necessary to understand what the difference between the construction joint venture and the manufacturing joint venture is. To understand the difference between the joint ventures in these two industries, at first the difference between the two industries should be clarified. Till now there are no researches focus on the differences between these two industries. It can be clarified by literature reviews.

Certain particular characteristics of the construction industry make it substantially different from manufacturing, principally due to the fact that its final product shows uniqueness, immobility and high variety (Ball, 1988[9]; Gonzalez-Diaz, et al, 2000[45]). Other characteristics such as technologies needed in these two industries, assets specific levels are also different in these two industries. All these differences make the joint ventures different in these two industries.

1.4.1 Output of the Two Industries

The uniqueness of the output is one of the main differences between these two industries. Construction output is the result of a project production system in which the product is adapted to particular buyers, locations and uses. This uniqueness of the output discourages the use of project-specialized assets, unlike manufacturing industries which produce mass products. Almost all the works in the manufacturing are standardized; it can be undertaken on the standard procedure. Because of the uniqueness, the construction projects are different with each other so it is very difficult to standardize the work. Even the procedures can be standardized, however because of the uncertainties related with weather and natural conditions, some measures has to be undertaken to deal with the difference between the standard and the real condition. Construction industry includes a wide variety of final products, from small domestic alterations to huge industrial plant, and each one involves a different mixture of heterogeneous activities. So when a firm starts out on a new product, it has to integrate dissimilar intermediate activities. Thus the activities that construction firms carry out are heterogeneous not only in type but also in geographical location. The uniqueness of the output in construction industry makes management very complex as compared with manufacturing industry. It also makes the related parties face more risks or uncertainties.

1.4.2 Immobility of the Intermediate and Final Product

Immobility of the intermediate product and final product is also different in these two industries. Construction consists of building immobile structure in a certain location and most of the transformations needed take place on site. Productive assets are, therefore, moved to the product and not the other way the products moved around as in manufacturing. Each new project, therefore, demands a new working center. As we all know that in manufacturing industry all the intermediate product move along the product line. In construction industry the intermediate product is immobile, so the plant and workers have to move along the intermediate product. The immobility of the product makes it different in the organizations of the company in two industries. Immobility and uniqueness of the construction output also lead construction firms to establish a dual structure. Construction firms have a central unit, which includes the main activities subject to scale economies, and several working centers located where the different projects are being carried out. It makes management very complex.

1.4.3 Uncertainties

Except for the uncertainties about market which is the same as the manufacturing industry. The site based nature of production makes it highly prone to uncertainties in climate and site conditions, and availability of resources in the local environment where the project is carried out (Usdiken et al, 1988[129]). While in manufacturing industry the uncertainties about climate and site condition almost do not affect the produce process. When the construction project is huge and complex, it is very difficult for only one company to finish the project not only due to problem of financial but also due to technologies needed to manage and construct. So cooperation between the contractors are normal. However, during the course of construction, there is a potential conflict among the parties due to their different interests and objectives. High uncertainties and cooperation between the contractors make the management more complex in construction industry.

1.4.4 Technology Level

The measures which be used to measure the technology level include the degree of product standardization, the extent of substitution of on-site processes by off-site production and the degree of mechanization in the construction process(Usdiken et al, 1988[129]), as well as the degree of the produce process programmed. If the product can be standardized or if there are some substitutions of on-site processes by off-site production or if the degree of mechanization is high or the produce process can be programmed, it means low technology level. According to the measures the conclusion similar to the one mentioned by Ball (1988[9]) can be obtained. Ball argued that the production process in the construction industry is also characterized by the use of relatively low technology and high intensity of labor. With the development of economics more high technology structures are needed. Correspondingly high technology will be needed. From the whole market of construction industry, construction industry is found to be an industry with low technology level . Because of the complexity of the modern structure, it is useful to distinguish two different technological stages in which firms specialize. One focuses on project design and technical management and the other concentrates on project implementation. Each stage requires different capabilities. Design and management are carried out by qualified technical teams having design, supervisory and problem-solving capabilities that enable them to make competitive bids for all kinds of contracts. This kind of firms is high technology level. It is necessary to catch up the innovation of the technology of equipments. Implementation activities, on the other hand, require cost control, operative capabilities and knowledge of local labor markets, i.e., opportunity wages, suitable incentive systems, and precise screening mechanisms. These teams are based on blue-collar workers, mainly craftsman and unskilled laborers, whose purpose is to accurately implement any project. This kind of works can be finished by the one who only has lower technology level. While in manufacturing industry, because of high innovation speed, the technology level will be higher compared with the construction industry.

1.4.5 Customer Satisfaction

A final special feature of the construction industry is the relative value of each unit of product. Each project or contract usually represents an important percentage of the transactors' operations. This happens not only in civil engineering, where all projects are large, but also in residential building. In the latter, projects may be of minor economic importance but firms are also smaller in size, so each project again constitutes a substantial percentage of overall sales. Therefore the conclusion that the demand for construction firms is of quite a discrete nature can be obtained. The quality of each product will affect the reputation of the contractor. In manufacturing industry, it is very easy to change the product with fault without incurring much cost. While in construction industry it is impossible or very costly to change the product with fault. If there is some fault it will take the contractor more to recover in construction industry than in manufacturing industry. Customer satisfaction term is very different from one owner to the other in construction industry; while it is almost the same for all customers in manufacturing industry. This difference will cause more uncertainties related to customer satisfaction in construction industry.

1.4.6 Asset Specific Level

Immobility and uniqueness of the outputs affect the importance of different sources of asset specificity. First, site specificity is not important because construction assets are mobile and relocating them is relatively inexpensive. Second, physical specificity will depend on the type of construction because the productive assets are usually designed for a particular kind of works or products and not for a particular project. Physical specificity will be directly related to the demands in the market, as well as the number of firms that use the assets. In manufacturing industry the asset specific level will be higher than that in construction industry. It is because the machinery is designed for only one type of product and not for some type of work like the one in construction industry.

The differences between manufacturing industry and construction industry can be summarized as table 1.1.

Table 1.1: The Difference Between Maufacturing Industry and Construction Industry

	Content	Manufacturing industry	Construction industry
1	Specific	High asset specific High human specific	Low asset specific Low human specific
2	Uniqueness	Low uniqueness, mass manufacturing	high, for one site for one client
3	Technology	High technology intensive	Low technology intensive
4	Intermediate product	Move along produce line	Material and others move along intermediate produce
5	Uncertainty during the period of product	Low level	High level
6	Period	Long time	Limited time
7	Complexity of the product process	Low level	High level

From the Table 1.1, the results that construction industry is very different from manufacturing industry can be obtained. Construction industry is more complex, riskier, and less specific, and has a longer period and lower technology level compared with manufacturing industry. Such difference between the two industries results in the difference of their joint ventures. The characteristics of construction industry such as more complexity and more risks will make it more difficult and more complex to define responsibilities of the partners, thus make it more difficult to share control right and to make decisions. The characterstic of high uniqueness of the construction will make it very diffcult for the contractor to use their experience gained from this project on that project. Under this condition, the contractor will have to face new problems when they undertake a new project. While lower technology level and lower specific characteristic of construction industry will decrease the hold up problem or moral hazard problem in cooperation.

1.5 Joint Ventures and Efficiency

Joint ventures are not perfect cooperation ways. They also create some problems while they resolve some problems. One of the main problem is inefficiency (Holmstrom, 1982[57]). Because the partners in joint ventures are from different companies, they are always motivated by different objectives to cooperate with each other. Under some conditions they may even compete with each other while they cooperate with each other. Therefore joint ventures are also regarded as inefficient organization structures just because the partners share not only profits and losses, but also control right and ownership. The sharing characteristics of joint ventures make it very difficult to achieve efficiency because the partners can not get enough information about other partners' actions. Under this condition there is a high possibility to cause such problem as moral hazard problems and adverse selection problems. Under some conditions these problems can be resolved according to the previous literatures (Legros, 1993[78]; Holmstrom, 1982[57]). But it is constrained to some special conditions. In this thesis the efficiency of the construction joint venture agreements when there is a risk is analyzed. A way in which partners can share their risks without losing efficiency is also introduced.

Joint ventures are not efficient cooperation ways, though they are used very widely. Why joint ventures are used so widely could be explained from the viewpoint of information asymmetry. The view of information asymmetry argues that the existing of asymmetric information makes the failure of the market transaction, at the same time it also makes acquisition more risky. In the market transaction, asymmetric information will bring more transaction cost, and further higher transaction cost will decrease the market transaction (Williamson, 1979[130]); while in joint ventures partners can access the information which can not be obtained in market transaction. Then the inefficiency of market transactions will be decreased to some degree which is lower than the one in the market transactions. About acquisition, asymmetric information will make it impossible for the transaction partners to agree with each other on the price of the assets, then it will make acquisition fail (Balakrishnan, 1993[8]). When there are risks or uncertainty, bilateral contract will be inefficient, and acquisition will also be inefficient. Under this condition, joint ventures will be used to decrease the inefficiency of the market transactions or acquisitions due to the inaccessability of the information. Construction industry is an industry which is much riskier than other industries. In construction industry, joint ventures are used to access special materials, specialists or technologies to share risks. How to share risks between partners becomes an important problem the partners have to face, especially when both partners undertake only limited liabilities. Limited liabilities will change the behaviors of decision-maker. When both partners have the limited liability, under which conditions they will choose joint ventures as their cooperation way should be clarified.

1.6 Joint Ventures and Limited Liability

Here a joint venture is defined as the new entity created by two or more parties (they may be individuals, companies, corporation, or others) by combining their resources to carry out a special transaction/project according to their agreement. The legal character of the new company depends on the laws of the countries where the joint ventures are set up. The normal structures are: limited liability company and unlimited liability company. Limited liability is used to permit the company to choose some risky investment because limited liability can make sure the owner of the company free from losses more than the amount of his limited liability. Under this condition, the company may act as the one who is less risk-averse or even risk-loving (Golbe, 1988[43]). The partners in the joint ventures undertake joint liability to the client. Limited liability is a very important factor for a company to consider when he makes decisions to choose his potential cooperators in the joint venture for a project.

The liability capacities of the partner will affect his attitude towards risks. The lower the decision-maker's liability capacity is, the more possible for him to choose higher risky project. It is the same in the joint venture, the lower the limited liability of a partner is,

Table 1.2: The Risks Analyzed in Each Chapter

Chapter	Risks
3	A background risk and project risks
4	Partner risks and project risks
5	Project time limit extension
6	Controllable risks and uncontrollable risks

the more risks the other partners will face because of the characteristic of joint liability of joint ventures. Limited-liability makes the decision makers free from high loss and makes the decision-makers take more opportunism action. It is necessary to analyze how to choose limited liability cooperators when there are many risks.

1.7 The Structure of This Thesis

Joint ventures increased very quickly in the past 20 years. Joint ventures are by far one of the most popular forms of cooperation (Buhcel, 1998[23]). There are many researches about joint ventures recently, they spans several disciplines including finance, industrial organization, organization theory, and business policy. They focus on the following topics: the motivations of joint ventures, partner selection, the management of joint ventures and so on. Almost no literatures focus on risk-sharing problem in joint ventures. Construction industry is known as an industry with many risks. The previous literatures about construction joint ventures focus on risk identification in the joint venture, and many classifications are summarized. In this thesis, two kinds of classifications of risks are used here. The first one is background risks, partner risks and project risks; the second one is controllable risks and uncontrollable risks. Risks which are analyzed in each chapter are summarized into the Table 1.2. In this thesis one of the topic of joint ventures: risk sharing is focused on. The problem that when there are risks under which conditions partners (limited liability partners or unlimited liability partners) will choose joint ventures as their cooperation ways is analyzed. The efficiency of construction joint venture agreements is also analyzed. A way to make risk-sharing in the construction joint ventures efficient is introduced. The thesis is organized as:

Literature review is summarized in Chapter 2. In this part, the theories about the motivations of the joint ventures are summarized. According to the previous literature, the motivations of joint ventures are analyzed by using four theories: (1) The transaction cost theory. According to this theory, joint ventures are set up to save some transaction cost. (2) Strategic Behavior theory. In this theory joint ventures are chosen by the parent companies as a strategy which can maximize the profits through improving a firm's competitive position. Organizational Knowledge and Learning theory looks joint ventures as a means by which firms learn or seek to retain their capabilities, especially to learn some tacit knowledge and organizationally embedded knowledge which are very difficult to learn without working together. Joint ventures are real options in terms of the economic opportunities to expand and grow in the future. Besides the motivations of the joint ventures, in this part, the literatures about the motivations of the construction joint ventures are also summarized. The joint ventures and subcontracting which are the two important cooperation means used in construction industry are compared.

In Chapter 3 and Chapter 4, A model is built to analyze the motivations of the construction from the viewpoint of risk sharing. In Chapter 3 partner selection (motivations) of joint ventures which are unlimited liability company are analyzed, and in Chapter 4 partner selection (motivations) of joint ventures which are limited liability companies are analyzed. In the model of chapter 3 the behaviors of the decision-maker who undertakes unlimited liability under the background risk and project risks are analyzed. The conclusion that joint ventures can only be set up by the partners who are different on at least one of the following characteristics: capacities to deal with risks and different degrees of risk-aversion is obtained. When there is a background risk, partner can improve their expected utilities by setting up a joint venture comparing with the one they can get under the condition that one of them undertakes the whole project. In the model of chapter 4, the behaviors of the decision maker who undertakes limited liability under the project risks and partner risk are analyzed. Limited liabilities can change the behaviors of the decision maker. Because both partners undertake limited liabilities, some problem will occur, in this paper, it is called as partner risk. The motivations of joint ventures with the project risks and partner risk are analyzed.

As introduced in chapter 2, in construction industry, joint ventures are classified as integrated type joint ventures and separated type joint ventures. In Chapter 5, the joint venture agreements of the integrated type and the separated type joint ventures when there is a risk–project time extension are analyzed. Different types of the joint venture agreements define different types of risk-sharing between the partners. The effect of the joint venture agreement types on the effort level of the partners is also analyzed. The efficiencies of different type of joint venture agreements are compared. The main results of this research can be summarized as: No matter which type of joint venture, the principle of decision of the project time extension ex post is to minimize the loss of the joint venture. In the separated type of joint venture it is not always easy that the partners can agree with each other about the extension of the project time. Under this condition, in order to achieve agreement about the project time extension the partners have to undertake some cost for negotiation. No matter which type of joint venture, the sponsor style joint venture which is based on the trust between the partners is more efficient than the partner style joint venture in which the partners are equal. The separated type of joint venture is more suitable for the project which can be divided into several independent subprojects. When the project can not be divided into subprojects due to the technology needed, at the same time it is impossible to set up an integrated type joint venture, it is possible that the project can not be executed efficiently. To give an incentive to the partners to execute the project efficiently compensations which are larger than the real losses are needed. Under this condition it is possible for the contractors can not get any profit.

In Chapter 6, a model about how to share risks between partners (all of the partners are risk-aversion) in the joint venture when there are multiple risks is built. In this model, both partners are assumed to be risk-averse, and they define the rules of risk sharing by bargaining. Their shares of risks are not defined as their participation shares or other exogenously given parameters. When bargaining is permitted, the result of bargaining is always Pareto optimum. It means that partners can construct their portfolios by choosing which risks they will undertake. In this chapter, the risks are classified into controllable risks and uncontrollable risks. About the controllable risks, if the partners can share all the costs of dealing with the risks, risks can be shared between the partners without moral hazard problem. About the uncontrollable risks, partners can construct their portfolios by choosing which risks to undertake through negotiation.

In Chapter 7, the conclusions of this thesis are summarized.

Chapter 2

Literature Review

2.1 Review of Motivation Theories of Joint Ventures

Some researchers argued that the emerging of joint ventures is due to the benefits of joint ventures. The major potential benefits of joint ventures can be summarized as: risk reduction, economies of scale and/or rationalization achievement, complementary technologies and patents access, overcoming government-mandated investment or trade barrier and so on. In fact all types of the cooperation can achieve some of these benefits. So it is difficult to consider these benefits as the motivations of joint ventures. Kogut's (1988[70]) classifies three motivations for joint ventures: the transaction cost explanation, the strategic explanation and an organizational knowledge and learning.

2.1.1 Transaction Cost Perspective

Transaction cost explanation is derived from the theory of transaction cost developed by Willamson (1975[131], 1985[131]). Transaction cost theory argued that firms choose how to transact according to the criterion whether the sum of transaction cost and the production cost of the transaction chosen is the minimum among all of the possible choice. It is the cost that defines the boundary activities between firms. Production costs are different among firms due to the scale of operations, to learning or to proprietary knowledge. Transaction costs are defined as the expenses incurred for writing and executing contracts, for haggling over terms and contingent claims, for deviating from optimal kinds of investments in order to increase dependence on a party or to stabilize a relationship, and for administering a transaction.

The transaction cost perspective of joint venture argued that the motivation that a firm chooses joint ventures is due to the considerations of minimizing the cost of production and transaction. Transaction cost explanation of joint venture points out joint ventures can decrease the transaction cost under uncertainties, because joint ventures can create a superior monitoring mechanism and alignment of incentives to reveal information, share technologies, and guarantee performance by joint ownership (and control) rights and the mutual commitment of resources. A joint venture is favorable to acquisition due to the lower costs of divesting or managing unrelated activities or the higher costs of internal development. A firm chooses a joint venture rather than a contract when there are high uncertainties over specifying and monitoring performance, in addition to a high degree of asset specificity. In brief, a joint venture is chosen due to its lower transaction cost relative to a contract and acquisition.

2.1.2 Strategic Behavior Perspective

Strategic behavior perspective explanations the use of joint ventures stems from the strategic theories that strategic behavior would influence the competitive positioning of the firm. Strategic behavior theory points out that a firm makes decisions to some type of transaction by considering the influence of this decision on the firm's competitive positioning and the impact of such positioning on firms' profitability. A firm will choose the strategy which can maximize the profits through improving a firm's competitive position. So firms may choose the vertical integration joint venture that can tie downstream distributors to deprive competitors of raw materials and to stabilize oligopolistic competition. On the other hand many joint ventures are motivated by strategic behavior to deter entry or erode competitor's position.

2.1.3 Organizational Knowledge and Learning Perspective

Organizational knowledge and learning perspective views joint ventures as a means by which firms learn or seek to retain their capabilities. Joint ventures are viewed as an effective vehicle by which tacit knowledge and organizationally embedded knowledge are efficiently transferred. The transfer of this knowledge would be successful only if the organization is itself replicated. Joint ventures provide a firm a way to acquire this knowledge by the partner firms' organization itself replicated. On the other hand, a joint venture is chosen though other forms of cooperation can be executed at lower production and transaction costs because a firm wants to learn the capability of organizing a particular activity to exploit future opportunities.

2.1.4 Joint Ventures as Real Options

It was Kogut (1991[71]) who first analyzed joint ventures from the viewpoint of real options. He argued that joint ventures are real options, not in terms of legal assignation of contingent right, but, like many investments, in terms of the economic opportunities to expand and grow in the future. There are two types of options. One is to wait for investing; the other is to expand. The firms will choose to wait before the market for the technology or new product is proven. During this period firms can use its resources in other safer project. Sometimes firms will choose to invest today in order to gain experience with the technology or to establish a brand image with customers, then exercise the valuable option to expand in the future. Joint ventures provide the firms the opportunity to expand in the future. This opportunity is just like a financial call option. In other words, a firm entering into a joint venture with small amount investment in initial, and as long as its initial investment in the joint venture is sunk and the cost of operating the venture is moderate, the firm will continue to pay to wait for the option to expand by acquisition. The option will be exercised when the value of the venture has been proved increased, otherwise, the option to expand is held open. Chi and McGuire (1996[28]) have analyzed the joint ventures by using a strategic option model which integrates the transaction cost and strategic option perspectives on the choice of market entry modes, to find which partner will excise the option and under which conditions joint ventures are used as options to acquisition. The results of their analysis reveal a necessary and sufficient condition for the option to acquire or sell out in a joint venture, which is that the partners anticipate a possible divergence between their ex post valuation of the joint venture. They argued that when there is certain ex ante asymmetry between the partners of a joint venture, the partners will trade in the right to the option. That is to say, the existing of certain ex ante asymmetry between the partners of a joint venture causes the partners to have different valuations of the joint venture. It is the different valuations of the joint venture between the partners' result in the option to acquire or sell out.

2.2 Characteristics of Joint Ventures

The number of alliances increased dramatically during the past two decades (Insead, 2004[109]). Joint ventures are one of the main alliance structures. Just as many researchers argued alliance (joint ventures) failure rate is in the 30-70 percent range (Insead, 2004[109]). Previous literatures explained the reasons of high failure rate as: joint venture encompasses the competitive relationships between the parent companies and the organizational structure of the joint venture (Millington et al, 1997[92]); the ownership structure of the joint ventures (Killing, 1983[68]; Beamish, 1985[11]; Blodgett, 1992[15]) and joint ventures are used as transitional organizational forms (Insead, 1998[59]). It is the characteristics of the joint ventures that cause more problems to manage or to monitor and high failure rate. The main characteristics of joint ventures can be summarized as:

2.2.1 Sharing Rights between the Partners

Joint ventures are defined the new companies created by two or more parties (they may be individuals, companies, or others) who combine their resources to carry out a special transaction/project according to their agreement. They will share the ownership, operational responsibilities, the control right, the profits and the losses of the new company, and the new company as a separate entity undertakes liability for the debts and the third parties (Lynch, 1989[83]; Johnson, 2000[64]; Harrigan, 1985[49]). The characteristic that the partners in the joint venture share not only risks and profits but also control right makes it very difficult to manage and bring many conflicts during the operation of the joint venture. To which degree that each partner can achieve his goals depends on the shares of each partner in the joint venture. The partners define how to share the risks, the profit and control right by negotiating with each other. The result of the negotiation depends on the relative bargaining power of the partners.

2.2.2 Quasi-hierarchies

Economic relationships have been classed under two broad headings, as "market" or "hierarchy". All forms of cooperative arrangement represent a middle ground between the two (Buchel et al.1998[23]). Joint venture structure can be viewed as quasi-hierarchies structure (Osborn et al., 1990[100]). Prior works have suggested that the governance form chosen for these alliances may be particularly important in influencing their success and their ability to meet the objectives of the participating firms (Harrigan, 1988[50]; Rugman, 1981[112]). Hierarchical internal organization will become the preferred operating mode under conditions of substantial uncertainty and complexity (Williamson, 1975[131]). Hierarchical organization is less flexible and it is very difficult to adjust with the change of the market. But it is more efficient to deal with complex conditions and uncertainties, because it can make decisions by authority. When the conditions are complex or with many uncertainties, contractual agreements of selling or providing technology, products, or services (e.g. supply and licensing agreements) are market-dominated. The contractual agreements can not solve the problems which are called moral hazard or adverse selection. Joint ventures, on the other hand, can be seen as quasi-hierarchies. Joint ventures provide joint ownership and control over the use and the fruits of assets. They may be used to bypass market inefficiencies due to uncertainties or complexity. Equity control and both parties' sharing in the profits or losses attained through the venture's performance serve to align the interests of the parent firms, reducing the opportunism that may arise in contractual agreements (Hennart, 1988[52]; Stuckey, 1983[122]). The joint venture form may also allow for a superior monitoring mechanism, since joint venture owners may be legally entitled to independently verify financial information as well as information acquired through direct observation.

2.2.3 Relations between the Partners

Because a joint venture is created by two or more than two companies, these companies cooperate with each other, at the same time they compete with each other. They cooperate with each other to achieve certain goals that neither partner can achieve on their own (Hennart, 1988[52]; Kogut, 1988[71]). On the other hand, the difference of their own goals or their own self-interest will make them to compete with each other (Hamel, 1991[48]). The two kinds of relations between the joint venture partners is also called as 'cooperative dilemma' or 'joint venture dilemma' (Tiessen, 1996[125]). Many researchers have used 'prisoners' dilemma' to model cooperative and competitive behavior in both economics and psychology (Axelrod, 1984[6]; Dawes, 1980[32]; Rapport and Chammah, 1965[107]; Doz and Hamel, 1998[35]). Because the characteristics of the special relations between the partners in the joint venture, it also brings some special problems. Instability or high failure rate (Millington 1997[92]; Gill et al, 2003[42]; Hergertet al, 1988[55]; Pekar, et al, 1994[102]) is one of the most important problems.

2.3 Joint Venture in Construction Industry

2.3.1 Motivation of Joint Ventures

A joint ventures is always used as an important means to cooperate by contractors in construction industry. About the motivations of using joint ventures in construction industry there are many arguments. For example, In Japan, construction joint ventures are used to improve their chance of getting project by small and medium-size companies. In China, construction joint ventures are used by foreign companies to avoid the government policy. Just as in manufacturing industry, joint ventures are also used to avoid the policy of the country, to expand market, to share risks, to decrease cost or access cheaper materials and resources and to transfer technology in construction industry. The motivations of forming construction joint ventures are summarized by Norwood et al as the Table 2.1. The motivations are almost the same as the motivations of joint ventures in other industries. They can also be explained by the theories which are used to explain the motivations of joint ventures as we summarized in Section (2.1).

2.3.2 Types of Joint Venture in Construction Industry

Joint ventures can be classified according to different focuses. The classifications of joint venture which are always used in construction are:

1) The integrated type and non-integrated

According to different forms of sharing or undertaking works, construction joint ventures fall broadly into two categories: integrated and non-integrated (separated type). In

Table 2.1: Motives for Forming Construction Joint Venture (Norwood, 1999[96])

1	To participate in overseas project or to undertake the major project
2	To expand market
3	To spread financial risk
4	To decrease cost by access the cheaper manpower, materials and resources
5	To bring in outside expertise/technology
6	To learn management skills
7	To avoid government policy about foreign investment constraints

the case of non-integrated joint venture, the overall responsibility for the contract usually has to be negotiated by a joint venture board. Separate sections of the work are then subcontracted out, with each of the partners taking over the responsibility for running their own technical and administrative elements of work.

2) The project-based type and traditional type

According to the objective of the joint ventures, construction joint ventures can be classified as project-based joint ventures and traditional type. Project-based joint ventures represent a particularly interesting group of joint ventures, which are different from the traditional joint ventures. The differences are wide-ranging, from the limited life span of the venture, the planning horizons, through the decision making and management style, the space of required information flow to the potential benefits of the two different types of venture. Table (2.2) provides a summary about the specificity of project-based joint ventures. First, project-based joint ventures have a predetermined, limited life span. Their activities are oriented towards well-defined objectives. These joint ventures are terminated upon the completion of the given project. In the construction field, many joint ventures are project-based joint ventures. Traditional joint ventures are also used to maintain the cooperation relations between the partners for long-term.

2.4 Joint Venture and Subcontracting

Subcontracting is a traditional cooperation means in construction industry. With the globalization of the economy, joint ventures occur and become an important cooperation means in many industries including construction industry. Now joint ventures and subcontracting are the two main cooperation means in construction industry. To understand

Table 2.2: Comparison of Project-based and Traditional Joint Ventures (JVs) (Hung et al., 2002[58])

	Contents	Project-based JVs	T raditional JVs
1	Life span	Finite	Indefinite
2	Strategy planning	Short-term orientation	Long-term orientation
3	Nature	Dissolving after project completing	On-going
4	Time to rectify default	Within contract period	On-going process
5	Decision making	Relatively fast	Relatively slow
6	Management style	Task oriented	Business orientation
7	Partner relationship	Short-term orientation	Long-term orientation
8	Information flow requirement	Must be quick	On-going process
9	Product/service improvement	Define by contract	On-going process
10	Control	Hierarchy	Team work
11	Primary objective	Completion of project on time	Business objectives
12	Potential benefits	Possible win-lose situation	Win-win situation

construction joint ventures, we have to know the differences between construction joint ventures and subcontracting.

2.4.1 Subcontracting in Construction Industry

Subcontracting is usually defined as a form of relationship between firms mostly depending upon complete or partial production of goods and services (Taymaz et al., 2002[123]). How should we characterize the nature of subcontracting in construction industry? The answers to this question can be categorized into three thesises: the hybrid thesis, inappropriate thesis and indeterminate thesis. According to Gunnarson et al. (1982[47]) as a representative of hybrid thesis, subcontracting in building construction project can be described as a mixture or hybrid of firm and market. Reven et al. (1984 [111]) who represent the inappropriate thesis describe subcontracting as neither a firm nor a market but a kind of clan relationship between the contractor and consultant. Bon (1989[17], 1991[18]) hold the view that market and hierarchy (firm) are two limits of a continuum of contractual choices. According to Lawrence Wai Chung Lai (2000[76]), subcontracting in the construction industry is a network of individuals (human persons or firms) interacting in a Coasian market, it is indeterminate. Subcontracting relations can be viewed as contractual relations between the partners. All the responsibilities of the partners are defined in the contract. Subcontracting is managed or monitored by laws which are related to the contract. In subcontracting relation, the main contractor does not manage the details of the behaviors or actions of the subcontractors. The main contractor does not monitor the process of the subcontractor's construction. The main contractor just needs to monitor the results of the subcontractor's construction.

General contractors conduct transactions with subcontractors for a number of reasons. Among the reasons unstable market conditions are the overriding reason (Mc Willians et al., 1995[88]; Jones et al., 1997[65]). Buckely et al. (1989[24]) observe that the tendency for main contractors to use subcontractors arises because of the construction industry's product customization (including the effects of wide geographical dispersion, small value orders, complexity and minimal opportunities for production improvements arising out of economies of scale), its structure (including ease of entry) and its sensitivity to cyclical fluctuations. Subcontracting in the construction industry is a response to uncertainty arising from complexity, given bounded rationality of the firm (Williamson, 1975[131]). It is not a response to seasonal variability, as argued by Stinchcombe[121].

2.4.2 Joint Venture in Construction Industry

Badger et al. (1995[7]) looked construction joint ventures as one of the many forms of strategic alliances, set-up to allow companies from all industrial sectors, to compete within the global economy. Here we define that when the two or more companies bring their assets together and set up a new company (entity) as a joint venture, we exclude the non-equity (contractual) joint ventures. Joint venture organizations can be viewed as hierarchical structures. The partners in the joint ventures monitor or manage their relations by hierarchical orders; even they also have agreement between the partners. The agreement between the partners only defines the structure of the joint venture, not details about management. All the details (the process) of the construction are managed or monitored by the hierarchical organization set up by the partners.

Norwood et al (1999[96]) summarized in the construction industry the reasons forming joint venture agreements. The reasons are: (1) an increase in the credibility of a prequalification or bid by two or more companies; (2) reduction of exposure on very large projects to more manageable proportions; (3) combination of general resources; (4) combination of specialist skills; (5) requirements for local participation. About the motivation of forming the joint venture in construction industry they summarized as: (1) to participate in overseas projects; (2) to maintain an overseas presence particularly when the market was low; (3) to spread financial risk; (4) to bring in outside expertise; (5) to make use of existing geographical or regional base; (6) to access greater manpower from local partner. We can find the motivations of construction joint ventures are almost the same as the one in other industries. They are also different from the motivations of subcontracting.

2.4.3 Construction Joint Ventures and Subcontracting

From the summarization above, we can know construction joint ventures and subcontracting are very different with each other, from the motivations to the structures. The differences can be summarized as:

(1) The Difference of Responsibilities

The responsibilities of the partners in subcontracting and joint venture are different. The liabilities of the subcontractors are defined by the subcontracting agreement, and the subcontractors only take the responsibilities to their main (general) contractor, and take no responsibilities to the principal (client). That is to say, whenever the subcontractor fails to undertake his responsibilities he should compensate the loss of the main contractor because of his failure, and then the main contractor will compensate the client for the losses caused by the subcontractor. The client can not ask for the subcontractor compensation directly. When the general contractor failed or defaulted, the client can not be compensated by the subcontractor. From this point, we can find when the general contractor defaulted the client has to incur losses without any compensation.

While the liabilities of the partners in the joint venture are defined by joint venture agreement, and the liabilities of the joint venture are defined in the main contract between the client and the joint venture. All the partners of the joint venture take joint responsibilities (all the responsibilities defined in the main contract) to the principal (client).

When one partner fails to complete his responsibilities to the client, the others should complete them. That is to say the client can ask each partner in the joint venture for the compensation of the losses due to the failure of the other partners. For the partners in the joint venture they will face the risk that the other partners fails to complete their responsibilities. The partners can improve their competition relative to their rivals by setting up a joint venture. For the clients it will be safer to contract their projects to a joint venture than to one main contractor.

(2) Style of Dealing with Risks

Subcontracting is a means by which the general contractor can transfer risks, while in the joint venture partners share risks between them. From the viewpoint of risk management, subcontracting allows the general contractor to transfer some of the risks and financial burdens of a large project onto other numerous subcontractors' organization (Pietroforte et al., 2003[104]; Yau, 1993[135]). That is to say, when you enter into the subcontracting as a general contractor, the risks related to the subproject which is subcontracted will be transferred to the subcontractor. You can get the same profit regardless whether the risks will occur. Under the condition that subcontracting is used to finish some subprojects for the general contractor, the general contractor can transfer the risks relating to this subproject to the subcontractor by using fixed-price contract to make sure that he can get same profit even the risk losses are very large. It is a very important point for the main contractor to pay attention to that he should not transfer too much to the subcontractor, because he has to compensate the client when the subcontractor defaulted or failed to complete his responsibilities. The main contractor can transfer risks to the subcontractors to some degree, but he can not transfer too many risks.

The partners in the joint venture share the ownership, cost, losses and profits of the project. For each of them, according to the risk share defined in the joint venture agreement, the risk losses they undertake maybe be greater or smaller than the same share by subcontracting. Because they have to share the loss of the others' risk while they undertake their own risks according to the share defined in the joint venture agreement.

(3) Control Style

The control styles of the subcontracting and the joint venture are different. If a firm subcontracts an activity, it only needs to monitor the quality of the output, whereas if the firm vertically integrated such an activity it has to know the details of the production process (Gonzalez-Diaz, et al, 2000[45]). While in the joint venture the partners should control the details of the construction process. Subcontracting can decrease the monitor cost of the general cost (Gonzalez-Diaz, et al, 2000[45]) and load of control (Hoe, et al. 2005[56]). At the same time because of the transfer of the control right upon the construction process, it is very difficult for the general contractor to control the quality of the work of the subcontractor (Bresnen et al. 1985[22]). That is to say subcontracting raise the issue of control (Usdiken et.al. 1988[129]). Clarke (1980 [30]) argues that increased subcontracting has reduced the general contractor's control over the construction process, leading to cost and time overruns.

(4) Dispute Resolving Ways

The relationship between the subcontractor and the general contractor is defined by the contract between them. When there are some conflicts or disputes that occur between the general contractor and the subcontractor, it is very difficult to achieve agreement between the two parties, and then the way that the two parties choose to resolve the problem is to resort to the third party such as arbitrators or the court. While in the joint venture as we defined before the partners set up a new company and the company is governed as hierarchy organization. So when disputes or conflicts occur, the partners first try to resolve the disputes or conflicts by authority. The superior of the joint venture organization can resolve the dispute by their control right from the organization. If the disputes can not be resolved in the organization, they will resort to the courts or others ways. It is usual that the joint venture partners will choose one partner to work as the leading member, and authorize this partner the right to make the final decision. This can be found in the guide to the use of FIDIC's (1994[33]) sub-consultancy and joint venture (consortium) agreement, at item 7.6., Which is: in the event of there being disagreement between members of the policy committee on matters not otherwise prescribed in this agreement the chairman shall be entitled to use a casting vote. From the view of efficiency it will be efficient to resolve the problem among the organization than to resort to the third party.

(5) Governance Ways

Just as we defined above, a joint venture is set up when the partners set up a new company. So we can say that the joint venture is monitored by hierarchy structure. Under this condition, the partners can only cooperate with each other as they are only different departments of the same organization. This type of joint venture has all the advantages of hierarchy. Contractual agreements to sell or provide technology, products, or services (e.g. supply and licensing agreements) are market-dominated. Joint ventures, on the other hand, can be seen as quasi-hierarchies. Joint ventures provide joint ownership and control over the use and fruits of assets. They may be used to bypass market inefficiencies due to inaccessible information. Equity control and both parties' sharing in the profits or losses attained through the venture's performance serve to align the interests of the parent firms, reducing the opportunism that may arise in contractual agreements (Hennart, 1988[52]; Stuckey, 1983[122]). The joint venture form may also allow for a superior monitoring mechanism, since joint venture owners may be legally entitled to independently verify financial information as well as to information acquired through direct observation. A joint venture is normally considered more difficult than a contractual agreement to establish, terminate, and fundamentally change (Harrigan, 1988[50]). Joint ventures may offer some potential for protection and control, but at substantial administrative costs.

Subcontracting is monitored according to the contract between the general contractor and the subcontractor. As we all know that contracts in the construction industry are incomplete contract, it is very difficult to define all the conditions and sum of the payment under each condition clearly in the contract. The general contractor will face the problem which is called moral hazard. For example, it is possible that the subcontractor will decrease the quality to decrease his cost, by this way to improve his profit from the project. Under this condition, it is found by the client that the general contractor will have to pay compensation for this low quality to the client. To avoid this problem, in many researches the researchers found that the general contractor always keep stable relations with the same subcontractors for long periods of time (Maisel, 1953[86]; Sansom, 1959[113]; Eccles, 1981[37]). We can summarize the difference between joint ventures and subcontracting as Table 2.3.

Table 2.3: The Difference between JVs and Subcontracting

	Content	Subcontracting	Joint Venture
1	Responsibility	General contractor undertakes all the responsibilities for the client, while the subcontractor undertakes responsibilities for the general contractor	The partners undertake The responsibilities to the client jointly
2	Risk	Transfer the risk to the subcontractor	Share between the partners
3	Control	Control change from process to the result	Share control on the process
4	Conflict resolve	Contract law and court	Hierarchy organization
5	Monitor	Contract	Order or authority

In the terms of Macneil's (1974[85]) three-way classification of contract, classical contracting presumably applies to all standardized transactions (whatever the frequency), relational contracting develops for transactions of a recurring and non-standardized kind, and neoclassical contracting is needed for occasional, non-standardized transactions.

Williamson (1979 [130]) argued that the governance structures of the transaction depend on the following three dimensions: (1) uncertainty, (2) the frequency with which transactons recur, and (3) the degree to which durable transaction-specific investments are incurred. Based on this argument he defined the relationship between governance structure and the characteristic of the transactions as: market governance is the main governance structure for non-specific transactions of both occasional and recurrent contracting. Trilateral governance that is suit for the two types of transactions are occasional transactions of the mixed and highly idiosyncratic kinds, that is the neoclassical contracting. Transaction-specific governance is suitable for the two types of transactions: for which specialized governance structures are common devised are recurring transaction of the mixed and highly idiosyncratic kinds, and that is the relational contracting. According to these arguments, we can say that subcontracting is a kind of neoclassical contracting, or relational contracting relation. So subcontracting is suitable for less risky project, less specific investment project, and suitable for the condition that the main contractor and the subcontractor do not cooperate with each other usually; or they keep close cooperation relationship for long time when the cooperation needs high specific investment, while joint ventures are suitable for the transactions which needs high specific investment, higher risk, and long time or only for one project. Joint ventures are used when there are many risks. One of the main characteristics of joint ventures is that the partners in joint ventures share ownership, share control while they share profits, and when there are many risks, the management will become more complex. So risk management is also an important topic for the success of joint venture project.

2.5 Risk Management and Risk Sharing

Because of the complex nature of construction business activity, process, environment, and organization, the participants are widely exposed to a high degree of risk. Risk management is an important component to make sure the success of the construction project or to make sure the profitability for the contractors. There are many literatures about construction project risk management. The experience of the construction project risk management can also be used to manage risk in construction joint ventures. A joint venture structure is different from the normal firm structure. It will make risk management different with the project risk management in a normal firm.

There are some literatures about risk management in construction joint ventures. Li et al (1999[79]) classified the risks related with construction joint ventures as: (1) Internal risks. The internal risk group represents the risks that are unique in a joint venture because different organizations are involved. (2) The project-specific risks. The project-specific risk group refers to unexpected developments during the construction period that lead to time and cost overruns or in shortfalls in performance parameters of the completed project. (3) External risks. The external risk group represents the risks that emanate from the competitive macro-environment that the joint venture operates in. In their research, they identified the critical risk factors and give some suggestions about how to mitigate the risk factors. The strategies includes: suitable partner selection, clear agreement, subcontracting, fair engineering contract (main contract between the joint venture and the client), high efficiency employment, good relationship with related parties, dominant share in control and others. In their works they only pointed out the strategies about how to mitigate the risk factors. They did not do any analysis about how to share the risks efficiently between the partners when the risks can not be transferred. At same time they did not consider the efficiency of their transfer strategies.

Shen et al. (2001[117]) did some case study about construction joint ventures in China, they established a risk significant index. They classified the risks related construction joint ventures as: financial risks, legal risks, management risks, market risks, policy and political risks and technical risks. In their research they identified all the risk index related to each classification, and then summarized the critical index in each group. Their research provided some reference to the risk manager. In their research they did not do any analysis about how to manage the risks in the joint venture.

Kapila et al. (2001[66]) focus on how to mitigate financial risks. All the literature about risk management in construction joint ventures focused on some aspects of risk management: risk factors identification, mitigation and so on. It is very important to identify risk factors and to mitigate these factors for the success of the project. It is also very important to define how to share or allocate the risks between the partners. All of these literatures did not focus on the other important aspect of risk management—risk allocation or risk share between the partners. Because of the characteristics of joint ventures, risk management in construction joint ventures will be different from the risk management used by construction companies at some aspects. Just as argued by the literatures about alliance, only second-best result can be gotten in the team work (Holmstrom, 1982[57]). It is more efficient to allocate risks to different partners clearly in risk management or to define how to share the risks between the partners clearly.

There are many researches about how to allocate risks among all the related participants and they also gave some principals on how to allocate the risks among the participants. Abrahamson (1973[1]) has suggested that it is proper for a contracting party to bear risk in any one of the following five cases: If the risk loss is due to his/her own willful misconduct or lack of reasonable efficiency or care; If he can cover a risk by insurance and allow for the convenient and practicable for the risk to be dealt with in this way; if the preponderant economic benefit of running the risk accrues to him; if it is in the interests of efficiency to place the risk on him; if, when the risk eventuates, the loss happens to fall on him in the first instance, and there is no reason under any of the above headings to transfer the loss to another, or it is impracticable to do so. The previous managerial literatures on risk allocation (Domberger, 1998[118]; Klein, 1998[91]; Hood and MacGarvey, 2002[62]; European commission, 2003[31]; Guasch, 2004[82]; Medda, 2004[39]; Omoto, 2001[69]) enounce two risk allocation criteria: the risk should be allocated to the party best able to manage it (criterion 1); the risk should be allocated to the least risk-bearing cost partner (criterion 2).

According to the risk allocation principles, risks will be allocated to the more capable partner, under this condition, it will make this partner undertake too many risks. Sometime, it will make this partner default when many risks realize at same time. As a effective risk manager, one can not only consider how to allocate the risks among the participants, under some conditions it is more efficient to share the risks among the partners comparing with allocating risks to some participant. Because portfolio effect can be gotten by sharing different risks and can not be gotten by undertaking a risk totally even the expected losses or expected utilities are same. Risk sharing is also an important mechanism to manage risks.

2.6 Conclusion

In this chapter, we summarized the theory of motivations of joint ventures. The motivations of joint ventures can be explained by the transaction cost theory, strategy theory, organization theory and real option theory. Joint ventures become more and more popular in many fields. It does not mean it is a perfect way of cooperation. Joint ventures do resolve some problems while they also cause some special problems. The characteristics of a joint venture are also summarized, which make it different from the other organization styles. The main characteristics of joint ventures are: the relations between the partners are competition plus cooperation; the second is that the partners should share all things related with joint ventures; the third is that it is an organization style between market and hierarchical organization.

A joint venture is a special organization structure. It can be used in different fields. Joint ventures are also widely used in construction industry. The types of joint ventures and the motivations of the construction joint ventures are also summarized. As we know, subcontracting is a traditional ways of cooperation between the contractors. The problems why now joint ventures become such a popular way of cooperation and the differences of these two cooperation ways should be clarified. In this chapter we also summarized the differences between these two cooperation ways.

Risk management is an important topic in construction industry. It is also an important topic in construction joint ventures. The previous literatures of risk management in construction joint ventures are reviewed. The previous literatures focus on how to allocate the risks between the partners. They did not focus on the topics of how to share one risk or multiple risks between the partners in the joint venture.

Chapter 3

Unlimited Liability Joint Ventures

3.1 Introduction

Many researchers view joint ventures as a panacea for winning work and reducing risk. They argue that the advantages of forming joint ventures are numerous in an overseas context, with improved technology transfer and potential risk reducing being two of the most important aspects to consider (Norwood et al., 1999[96]). Many others also argued that the motivations behind international construction joint ventures formation include: market access, technology transfer, risk sharing, and conforming to host government policies (Reszka et al., 1997[108], Sridharan, 1997[120], Mohamed, 2003[94]). Almost all the literatures about motivations of joint ventures viewed risk-sharing as an important motivation. There are some researchers tried to find whether joint ventures can decrease the risks of each partner. Johnson et al. (2000[64]) tested the motivations of joint ventures by a gross sample of 191 joint ventures, of which 85 (45%) are horizontal ventures and 106 (55%) are vertical ventures, and 345 simple contracts. They found no evidence supporting a risk-sharing motive for joint ventures. They tested this motive by examining the differences in the level of supplier risk (a volatility measure defined as the standard deviation of first differences in operating income for the four years preceding the sample year, scaled by mean assets for that period) and diversification (firms in fewer lines of business are likely less diversified and thus might want to share investment risks with another party) across joint ventures and simple contracts form. They also found horizontal joint ventures elicit wealth gains that are positively correlated across the partners. In vertical joint ventures, only suppliers experience positive excess returns, and buyer's and supplier's wealth changes are uncorrelated.

Karen et al. (2006[34]) test the risk sharing motivation of joint ventures and examined the risk and consequent wealth effects of joint venture activity for U.S. public firms by using a sample of 271 joint ventures events between 1989 and 1997. They found that a statistically significant 96% of the sample does experience a change in risk in response to engaging in joint venture activity and they also found that firms which engaged in joint ventures appear to decreases in systematic risk, and increases private risk. In their research they use the same definition of the system risks and private risks as the one Aharony et al. (1980[3]), and Unal (1989[128]) defined. System risks and private risks are denoted by the variance of returns of securities of the joint venture partners and the variance of the market portfolio.

There is little literature which is theoretical research on the topic whether joint ventures can decrease the partner's risk, or under which conditions partners set up a joint venture to decrease their risks or to share risks. In this chapter, the problem that under which conditions partners will choose joint ventures to undertake a project when there is a background risk and project risks or if a contractor wants to find a cooperator to set up a joint venture for a project, which kinds of companies are suitable to cooperate from the viewpoint of risk sharing is analyzed. It is different from the one Hennart (1997[54]), they only did empirical analysis the choice made by Japanese investors into the United States between full acquisitions of U.S. firms and joint ventures between Japanese and American firms. They did not build any model to analyze the choice problem. In this chapter, the problem if there are project risks and a background risk, under which conditions contractors can set up a joint venture for a project is analyzed.

This chapter is organized as following: Section 3.2 is about definitions and assumptions of risks. Section 3.3 is the model of joint venture style. Section 3.4 is the model of one partner style. In Section 3.5 the two styles are compared, and the conditions that under which partners will choose joint ventures as their cooperation means can be concluded. Section 3.6 is the conclusions of this chapter the future research.

3.2 Risks in Construction Joint Ventures

It is widely accepted that construction activity is particularly subject to more risks than other business activities because of its complexity. A wide range of risks related to construction business have been identified. Shen classified the risks as technical risks, management risks, market risks, legal risks, financial risk and political risks (1997[116]).

In this chapter, a different classification of risks in construction activities is given. The risks are called as: background risks (or system risks) and project risks.

3.2.1 Definition of Background Risk

About background risk, there is no clear definition. Many definitions can be found in previous literatures. For example, background risk is an exogenous risk cannot be insured (Gollier, 2001[44]) and non-tradable (Franke et al., 2006[46]). Background risk which could be associated with labor income or holdings of non-marketable assets is non-insurable (Franke et al., 1998[40]). Arrondel et al. (2002[4]) defined background risk as an uninsurable component of individual income, which is exogenous given. Background risk is therefore the type of risks which can not be controlled by the party who faces it, and can not be insured or hedged.

The existing of background risks can change the behaviors of the decision maker. Luciano et al. (2001[81]) showed that if loadings are not too high, positively correlated background risk increases insurance with respect to the case in which no background risk exists. Negatively correlated background risk decreases it, since in this case background risk is itself a hedge, even though the effect depends on the exact relationship between the two risks. It can lead to no insurance at all. The development of portfolio choice theory with incomplete markets has forced researchers to take into account the statistical properties of the uninsurable component of individuals' income risk in explaining the demand for risky assets (Arrondel et al., 2002[4]). The existing of the background risk will change the behaviors of the relevant parties.

The background risk is defined as the type of risks which can not be controlled by the party who faces them, and can not be insured or hedged. In the construction industry, the background risk can be looked as the external risk which is defined by Li et al. (1999[79]). These risks may include risks such as the fluctuations of the price of the materials and the exchange rate of currency, the changes of the country's policy about joint ventures, conflicts due to cultural differences and so on. The risks that should be undertaken by the joint venture are defined in the main contract, which is the contract between the owner and the joint venture. For simplifications, the rules that what risks should be undertaken by the owner and what risks should be undertaken by the joint venture are assumed as some kind of some international rules, such as FIDIC. Under this condition, the background risks are the risks which should be undertaken but can not be controlled or be insured or hedged by the joint venture partners. When one partner of the joint venture undertakes the whole project, the background risks means that the risks should be undertaken by him according to the main contract. All the background risks can not be controlled, be insured or hedged. For the same project the background risk is assumed as the same whether it is undertaken by one contractor or by a joint venture company. For simplification, here the background risk is assumed to be independent with other risks of the project and it affects the whole project.

Project risks are defined as all the risks which are specific to the given project, at the same time they should be undertaken by the partners of the joint venture according to the main contract between the joint venture and the client. Project risks can be viewed as the risks which is defined by Li et al. (1999[79]) as project-specific risks. But here the risks which are related the joint venture partners are excluded, such as the one defined as poor project relationship in Li et al. (1999[79]). The project risks are defined as the risks everyone has to face with as long as he undertakes the project.

3.2.2 Assumptions of the Risks

The problem that when there are two kinds of risks: project risks and a background risk, under which conditions partners prefer to set up a joint venture for a project is analyzed. The two companies set up a joint venture to finish one project and both companies are risk-averse. To focus the effect of the background risk on the choice of cooperation means under different conditions, the project can be divided into two subprojects clearly. Both partners undertake their project risks which belong to their subprojects. This kind of joint ventures are called as separated type joint ventures. This kind of joint ventures can provide efficient incentive to the partners to deal with their risks. Because the partners choose their effort levels by maximizing their certainty equivalent values of the project benefit. Here the partner's certainty equivalent values of the project benefit are defined as the value of the project valued by this partner who is risk-averse. Then they will choose their optimal effort levels to maximize their certainty equivalent values.

(1) Background Risk

There is a background risk which is denoted by a stochastic variable R_0, the loss of the risk can be denoted by a normal distribution ($N[\phi_0, \sigma_0^2]$). It affects the whole project. Here the influence of the background risk on the project is assumed depend on how many percent of the sum of the main contract that each subproject accounts for. In the joint venture, partners have to undertake the same share of the background risk with the share of the subprojects. The distribution of the background risk is assumed to be common knowledge for both partners. The correlation coefficient between the project risk and the background risk is denoted by ρ_{01} and ρ_{02}. For simplification, $\rho_{01} = \rho_{02} = \rho$. That means the background risk affects the whole project.

(2) Project Risk

The whole project can be divided into two subprojects: subproject 1 and subproject 2. $I_1 = \gamma I$ and $I_2 = (1-\gamma)I$ mean the benefits of each subproject, where I denotes the benefit (the sum of the contract when all the conditions realized as normal, that is to say there is no risk occurs) of the whole project, γ is defined by the subproject or their participant share which is exogenously defined. Each company undertakes one subproject, in the joint venture partner A undertakes subproject 1 and partner B undertakes subproject 2. Each subproject has only one project risk, the project risk of subproject 1 is denoted by R_1, and the project risk of subproject 2 is denoted by R_2. The project risks of the two subprojects are independent.

The cost of the subproject risk $R_1 = C_1^A + \epsilon_1$, here $\epsilon_1 \sim N[\phi_1, \sigma_1^2]$ is a normal distribution. C_1^A denotes the cost undertaken by partner A when he undertakes subproject risk R_1. σ_1^2 denotes the variance of the risk loss. Similarly, The cost of the subproject risk $R_2 = C_2^B + \epsilon_2$, here $\epsilon_2 \sim N[\phi_2, \sigma_2^2]$ is a normal distribution. C_2^B denotes the cost undertaken by partner B when he undertakes the subproject risk R_2. σ_2^2 denotes the variance of the risk loss.

3.3 The Model of Joint Venture

3.3.1 The Model of Joint Venture with a Background Risk

In this chapter, both partners undertake unlimited liabilities and they are all risk-averse. Their certainty equivalent values of the subprojects can be defined as a function of the expected values of benefit of their subproject and variances of benefit of their subproject. Here the certainty equivalent value of the subproject of the partner j can be defined as $Q_j = E - k_j\sigma^2$ [1], E is the expected value of the benefits gotten by partner j, σ^2 is the variance of benefits. k_j denotes the degree of risk-aversion of partner j, which satisfies $k_j > 0$. When the partners decided to finish the project by setting up a joint venture, and there exist these two types of risks: project risks and background risks. The certainty equivalent values of the subprojects of the two partners Q_A^{JH} and Q_B^{JH} in the joint venture can be expressed as:

$$Q_A^{JH} = \gamma I - \gamma\phi_0 - C_1^A - \phi_1 - k_A(\sigma_1^2 + \gamma^2\sigma_0^2 + 2\gamma\rho\sigma_1\sigma_0) \tag{3.1}$$

$$\begin{aligned} Q_B^{JH} = {} & (1-\gamma)I - (1-\gamma)\phi_0 - C_2^B - \phi_2 - k_B[\sigma_2^2 \\ & +(1-\gamma)^2\sigma_0^2 + 2(1-\gamma)\rho\sigma_2\sigma_0] \end{aligned} \tag{3.2}$$

3.3.2 The Model of Joint Venture without Background Risk

All the conditions are same with the conditions of joint venture model when there is a background risk. Under the condition that there is no background risk, the certainty equivalent values of the subprojects of the partners Q_A^{JN} and Q_B^{JN} in the joint venture

[1] Here, Mean-Variance preference is used to evaluate the risks. There are many papers discussing the relationship between the Expected Utility and Mean-Variance models. See Tobin(1958[126]; 1965 [127]), Borch (1969[20]), Markowitz (1991[87]), Feldstein (1969[38]), Meyer (1987[89]), Baron (1977[10]), Ormiston et al. (1994[99]). Meyer demonstrated that when the decision maker's choice set consists of random variables differing by location and scale parameters, the main results of Expected Utility analysis are consistent with the Mean-Variance model. Ormiston showed that the Mean-Variance model and Expected Utility yield consistent rankings of random variables when the decision maker's choice set is restricted to random variables differing by mean shifts and monotone mean-preserving spreads. So the results obtained by the Mean-Variance model can also be obtained by using Expected Utility theory.

can be expressed as:

$$Q_A^{JN} = \gamma I - C_1^A - \phi_1 - k_A \sigma_1^2 \tag{3.3}$$

$$Q_B^{JN} = (1-\gamma) I - C_2^B - \phi_2 - k_B \sigma_2^2 \tag{3.4}$$

The effect of the background risk on the certainty equivalent values of the subprojects of partners can be clarified by comparing the two certainty equivalent values of the subprojects under the two conditions. Here Q_{AJV}, Q_{BJV} are used to denote the difference between these two certainty equivalent values.

$$Q_{AJV} = Q_A^{JN} - Q_A^{JH} = \gamma\phi_0 + k_A(\gamma^2\sigma_0^2 + 2\gamma\rho\sigma_1\sigma_0) \tag{3.5a}$$

$$Q_{BJV} = Q_B^{JN} - Q_B^{JH} = (1-\gamma)\phi_0 + k_B[(1-\gamma)^2\sigma_0^2 + 2(1-\gamma)\rho\sigma_2\sigma_0] \tag{3.5b}$$

3.4 One Partner Model

3.4.1 One Partner with a Background Risk

The whole project can be divided into the same two subprojects: subproject 1 and subproject 2. Each subproject has only one project risk, the project risk of subproject 1 is denoted by R_1, and the project risk of subproject 2 is denoted by R_2. The project risks of the two subprojects are independent. $I_1 = \gamma I$ and $I_2 = (1-\gamma)I$ mean the benefits of each subproject respectively, where I denotes the benefit (the sum of the contract when all the conditions realized as normal, that is to say there is no risk occurs) of the whole project, γ is defined by the subproject or the participant share of the partner which is exogenously defined.

The cost of the subproject risk R_1 is denoted by $C_1^j + \epsilon_1$, here $\epsilon_1 \sim N[\phi_1, \sigma_1^2]$ is a normal distribution. C_1^j denotes the cost of dealing with the subproject risk R_1. σ_1^2 denotes the variance of the risk loss for partner j. Similarly, The cost of the subproject risk R_2 is denoted by $C_2^j + \epsilon_2$, here $\epsilon_2 \sim N[\phi_2, \sigma_2^2]$ is a normal distribution. C_2^j denotes the cost of dealing with the subproject risk R_2 for partner j. σ_2^2 denotes the variance of the risk loss. The whole project is undertaken by partners respectively. Under this condition, the certainty equivalent values of the subprojects of partner A and B denoted by Q_A^{wh} and

Q_B^{wh} can be expressed as:

$$Q_A^{wh} = I - \phi_0 - C_1^A - \phi_1 - C_2^A - \phi_2 - k_A(\sigma_0^2 + \sigma_1^2 + \sigma_2^2 + 2\rho\sigma_1\sigma_0 + 2\rho\sigma_2\sigma_0) \quad (3.6)$$

$$Q_B^{wh} = I - \phi_0 - C_1^B - \phi_1 - C_2^B - \phi_2 - k_B(\sigma_0^2 + \sigma_1^2 + \sigma_2^2 + 2\rho\sigma_1\sigma_0 + 2\rho\sigma_2\sigma_0) \quad (3.7)$$

Both partners are assumed can not undertake the whole project when there is a background risk. That is to say when they undertake the whole project their certainty equivalent values would be smaller than their participation values (the participation values are defined as the amount that if the certainty equivalent values of the projects or subprojects valued by the partners is greater than it the partners agree to take part in the joint venture or to undertake the project), $Q_A^{wh} < 0$ and $Q_B^{wh} < 0$. When there is a background risk, partners have to cooperate with others to undertake the project.

3.4.2 One Partner without Background Risks

The certainty equivalent values of the partners' when they undertake the whole project under the condition there is no background risk in the same way can be calculated. When there is no background risks, partners can undertake the project themselves or cooperating with others. $Q_A^{wn} > 0$ and $Q_B^{wn} > 0$ are used to denote their certainty equivalent values.

$$Q_A^{wn} = I - C_1^A - \phi_1 - C_2^A - \phi_2 - k_A(\sigma_1^2 + \sigma_2^2) \quad (3.8)$$

$$Q_B^{wn} = I - C_1^B - \phi_1 - C_2^B - \phi_2 - k_B(\sigma_1^2 + \sigma_2^2) \quad (3.9)$$

3.5 Comparing the Two Styles

3.5.1 When There is a Background Risk

When there is a background risk, under which conditions partners will choose to set up a joint venture. Here partner A is assumed to have the right to make decision whether set up a joint venture or not. Partner A will make the decision to set up a joint venture when his certainty equivalent values of the subproject in the joint venture is greater than his certainty equivalent value of the whole project. That is to say, $Q_A^{JH} > Q_A^{wh}$ and $Q_A^{JH} > 0$. For both partners if their certainty equivalent values of the subprojects are greater than 0 (the participation values of the two partners are assumed to be 0) they will take part in the joint venture. Under the condition $Q_B^{JH} > 0$ partner B will take part in the joint venture. The condition under which both partners will prefer to set up a joint venture to undertake the project rather than to undertake the whole project respectively can be clarified in the following way.

Partner A will prefer to choose to set up a joint venture to undertake the project when his certainty equivalent value of the subproject in the joint venture is greater than his certainty equivalent value of the whole project. And at the same time his certainty equivalent value in the joint venture is greater than his reservation value.

$Q_1^A = \gamma I - C_1^A - \phi_1 - k_A(\sigma_1^2 + \gamma^2\sigma_0^2 + 2\rho\gamma\sigma_0\sigma_1)$ and $Q_2^A = (1-\gamma)I - C_2^A - \phi_2 - k_A[\sigma_2^2 + (1-\gamma)^2\sigma_0^2 + 2\rho(1-\gamma)\sigma_2\sigma_0]$ are used to denote the certainty equivalent value of partner A, when he undertakes subproject 1 and subproject 2 in the joint venture respectively, or the certainty equivalent values of the two partners who have the same degree of risk-aversion and same capacity to deal with the same risk. When the background risk is positive related with the project risks or the two kinds of risks are independent with each other, the sum of the certainty equivalent values of the partners can be found to be greater than the certainty equivalent value that the partner can get when he undertakes the whole project. This is also called risk spread effect. The formula (3.6) can be rewritten as:

$$\begin{aligned} Q_A^{wh} &= Q_1^A + Q_2^A - k_A[2\gamma(1-\gamma)\sigma_0^2 + 2(1-\gamma)\rho\sigma_1\sigma_0 + 2\gamma\rho\sigma_2\sigma_0] \\ &= Q_A^{JH} + Q_2^A - k_A[2\gamma(1-\gamma)\sigma_0^2 + 2(1-\gamma)\rho\sigma_1\sigma_0 + 2\gamma\rho\sigma_2\sigma_0] \qquad (3.10) \end{aligned}$$

Because for each partner in the joint venture, he only needs to undertake part of the background risk. The background risk is shared between the partners. From the formula (3.10) the following conclusion can be obtained: When the background risk is positive related with the project risks or the two kinds of risks are independent with each other, if there are two same partners (have same capacities to deal with the same risks and same degrees of risk-aversion) the sum of the certainty equivalent values of these two partners is greater than the certainty equivalent value of partner A when he undertakes the whole project. When there is a background risk, partners can improve their certainty equivalent values by setting up a joint venture.

Partner A will take part in the joint venture if his certainty equivalent value the subproject in the joint venture is greater than his reservation value. That is to say

$Q_A^{JH} - Q_A^{wh} > 0$.

$$Q_A^{JH} - Q_A^{wh} = (\gamma - 1)I - (\gamma - 1)\phi_0 + C_2^A + \phi_2$$
$$+k_A[(1-\gamma^2)\sigma_0^2 + \sigma_2^2 + 2(1-\gamma)\rho\sigma_0\sigma_1 + 2\rho\sigma_2\sigma_0] \quad (3.11)$$

From the formula (3.11), the following conclusion can be obtained: if partner A can choose whether to set up a joint venture or not, it is more possible for partner A to choose to set up a joint venture when the background risk is positive related to the project risks; When the background risk is negative related with the project risks, partner A may prefer to undertake the whole project. Under this condition if he undertakes the whole project, he can get the risk hedge effect by undertaking the whole project. The negative correlation between the background risk and the project risks acts as a natural hedge against uncertainty, setting up a joint venture will remove or decrease this hedge effect. When the background risk is independent with the project risks, the existing of the background risk will make the difference between the two certainty equivalent values greater. Partner A will choose to set up a joint venture, only when he can get at least the same certainty equivalent value by taking part in the joint venture as the one he can get by undertaking the whole project. At same time he can get at least his reservation value when he takes part in the joint venture.

$$Q_A^{JH} - Q_A^{wh} > 0 \quad (3.12)$$
$$Q_A^{JH} > 0 \quad (3.13)$$

From the formula (3.6) and (3.10)

$$Q_2^A = (1-\gamma)I - (1-\gamma)\phi_0 - C_2^A - \phi_2 - k_A[\sigma_2^2 + (1-\gamma)^2\sigma_0^2$$
$$+ 2(1-\gamma)\rho\sigma_2\sigma_0] < k_A[2\gamma(1-\gamma)\sigma_0^2 + 2(1-\gamma)\rho\sigma_1\sigma_0 - 2\gamma\rho\sigma_2\sigma_0] \quad (3.14)$$

The formula (3.2) can be rewritten as:

$$(1-\gamma)I - (1-\gamma)\phi_0 - \phi_2 = Q_B^{JH} + C_2^B + k_B[\sigma_2^2 + (1-\gamma)^2\sigma_0^2 + 2(1-\gamma)\rho\sigma_0\sigma_2] \quad (3.15)$$

Substituting (3.15) into (3.14)

$$Q_B^{JH} \leq -C_2^B - k_B[\sigma_2^2 + (1-\gamma)^2\sigma_0^2 + 2\rho(1-\gamma)\sigma_0\sigma_2] + C_2^A$$
$$+ k_A[\sigma_2^2 + (1-\gamma^2)\sigma_0^2 + 2\rho(1-\gamma)\sigma_0\sigma_1 + 2\rho\sigma_2\sigma_0(1-2\gamma)] \quad (3.16)$$

The inequality (3.16) means partner B's certainty equivalent value in the joint venture would not be greater than the sum of the two differences, one is the difference of partner A certainty equivalent values in the joint venture and his certainty equivalent value when he undertakes the whole project, the other is the difference between the certainty equivalent values of the two partners for project risk R_2.

From (3.1) and (3.2)

$$Q_A^{JH} = \frac{\gamma}{1-\gamma}\left\{Q_B^{JH} + C_2^B + \phi_2] + k_B[\sigma_2^2 + (1-\gamma)^2\sigma_0^2 + 2\rho(1-\gamma)\sigma_0\sigma_2]\right\} \\ - C_1^A - \phi_1 - k_A[\sigma_1^2 + \gamma^2\sigma_0^2 + 2\rho\gamma\sigma_0\sigma_1] > 0 \quad (3.17)$$

Because of the inequality (3.11)

$$Q_B^{JH} \geq \frac{(1-\gamma)}{\gamma}[C_1^A + \phi_1 + k_A(\sigma_1^2 + \gamma^2\sigma_0^2 + 2\gamma\rho\sigma_0\sigma_1)] \\ - [C_2^B + \phi_2 + k_B[\sigma_2^2 + (1-\gamma)^2\sigma_0^2 + 2\rho(1-\gamma)\sigma_0\sigma_2] \quad (3.18)$$

The part in the first square bracket of the (3.18) means partner A's certainty equivalent value of risk R_1. $\frac{(1-\gamma)}{\gamma}[C_1^A+\phi_1+k_A(\sigma_1^2+\gamma^2\sigma_0^2+2\gamma\rho\sigma_0\sigma_1)]$ means the partner A's certainty equivalent value of risk R_2 expressed by his certainty equivalent value of risk R_1. This means when partner A undertakes the risk R_2 he can get the same level of certainty equivalent value as the one he can get from undertaking subproject 1.

$$\gamma(I - \phi_0) - D_1^A = \gamma Q \quad (3.19)$$

$$(1-\gamma)(I - \phi_0) - D_2^A = (1-\gamma)Q \quad (3.20)$$

The relation between partner A's certainty equivalent values when he undertakes the two risks can be expressed as $D_1^A = \frac{\gamma}{(1-\gamma)}D_2^A$. For partner A, to make sure he can get the same level of certainty equivalent values, his certainty equivalent values for undertaking the risks should satisfied $D_2^A = \frac{(1-\gamma)}{\gamma}D_1^A$.

Partner A's certainty equivalent value of risk R_2 can also be written as $C_2^A+\phi_2+k_A[\sigma_2^2+(1-\gamma)^2\sigma_0^2+2(1-\gamma)\rho\sigma_0\sigma_2]$. That means if partner A makes a decision that he will take part in the joint venture, and he will undertake subproject 2 in the joint venture, his certainty equivalent value of subproject 2 should be at least as great as his certainty equivalent value of risk R_2. The participation values of the two partners are both 0. When partner B's certainty equivalent value of subproject 2 is less than partner A's certainty equivalent value of subproject 2, partner A's participation condition for undertaking subproject 2 can not be satisfied while partner B's participation condition can be satisfied. From the inequalities (3.16) and (3.18) the partner B's certainty equivalent value of risk R_2 is in the intervals as:

$$\begin{aligned} & -C_2^B - k_B[\sigma_2^2 + (1-\gamma)^2\sigma_0^2 + 2\rho(1-\gamma)\sigma_0\sigma_2] + C_2^A \\ & \qquad + k_A[\sigma_2^2 + (1-\gamma^2)\sigma_0^2 + 2\rho(1-\gamma)\sigma_0\sigma_1 + 2\rho\sigma_2\sigma_0(1-2\gamma)] \\ & \qquad \geq Q_B^{JH} \geq C_2^A + k_A[\sigma_2^2 + \sigma_0^2(1-\gamma)^2 + 2(1-\gamma)\rho\sigma_0\sigma_2] \\ & \qquad\qquad - \left\{C_2^B + k_B[\sigma_2^2 + (1-\gamma)^2\sigma_0^2 + 2(1-\gamma)\rho\sigma_0\sigma_2]\right\} \end{aligned} \tag{3.21}$$

If the right side of the inequality (3.21) is greater than 0, partner B's participation condition is satisfied. Partner B will take part in the joint venture. The right side of the inequality (3.21) is greater than 0 means that partner B's certainty equivalent value of risk R_2 should be less than partner A's certainty equivalent value of risk R_2. Otherwise partner B's participation condition can not be satisfied. If partner B's reservation value is not 0, but Q_B^R is greater than 0. If the Q_B^R is greater than the left side of the inequality (the upper-limit of the certainty equivalent value), partner B will never agree to take part in the joint venture.

$$\begin{aligned} & C_2^B + k_B[\sigma_2^2 + (1-\gamma)^2\sigma_0^2 + 2(1-\gamma)\rho\sigma_0\sigma_2] \\ & \qquad \leq C_2^A + k_A[\sigma_2^2 + (1-\gamma)^2\sigma_0^2 + 2(1-\gamma)\rho\sigma_0\sigma_2] \end{aligned} \tag{3.22}$$

If the inequation (3.22) is satisfied, partner B takes part in the joint venture.

3.5.2 Analysis

(1) Partners with Same risk-aversion Degree and Same Capacity of Dealing with Risk

For simplifications, the two partners are same with each other. That is two say, $k_A = k_B = k$. The two partners can deal with the same risk at the same cost, that is to say ($C_2^A = C_2^B$). Under this condition the two sides of the inequality (3.22) are equal. When the partners have the same degree of risk-aversion and same capacities to deal with the same risk, if partner A's participation condition can not be satisfied, partner B's participation condition can be satisfied either. Then they can not set up a joint venture, because none of the partner's participation condition can be satisfied. The conclusion can be found that joint ventures can not be set up by the partners who have the same degree of risk-aversion, same capacity to deal with the same risk and same reservation values. When the reservation values of the two partners are different the partner whose reservation value is higher can find other contractors whose reservation values are relative lower to set up a joint venture. From (3.16) and (3.21), the following inequality can be obtained.

$$C_2^A + \phi_2 + k_A[\sigma_2^2 + \sigma_0^2(1-\gamma)^2] - \left\{C_2^B + \phi_2 + k_B[\sigma_2^2 + (1-\gamma)^2\sigma_0^2]\right\} \leq Q_B^J$$
$$< C_2^A + k_A[\sigma_2^2 + (1-\gamma^2)\sigma_0^2] - C_2^B - k_B[\sigma_2^2 + (1-\gamma)^2\sigma_0^2] \quad (3.23)$$

The inequality (3.21) can be simplified as

$$0 \leq Q_B^{JH} < 2k\gamma(1-\gamma)\sigma_0^2 \quad (3.24)$$

Proposition 1

If a contractor wants to set up a joint venture to undertake a project he should not choose a partner who has the same degree of risk-aversion and same capacity to deal with the same risk when their reservation values are also same with each other. When the reservation values of the two partners are different the partner whose reservation value is higher can find other contractors whose reservation values are relative lower to set up a joint venture.

(2) Partners with Same Risk-aversion Degree and Different Capacity of Dealing with Risk

One of the partners can deal with the risks in a less costly way than the other and both partner have the same degree of risk-aversion ($k_A = k_B = k$). Here partner B is assumed can deal with the project risk of subproject 2 at a lower cost than partner A. Under this condition, if partner B can deal with the risk at lower cost relative to partner A, the participation condition of partner B is satisfied while partner A's participation condition can not be satisfied. Partner B will agree to set up a joint venture with partner A and undertakes subproject 2. A contractor can find the other contractors who can deal with the risks at lower cost to set up a joint venture for a project even they have the same degree of risk-aversion. This result can also be explained as cost-decreasing motivation of joint ventures. It is also same as the risk allocation principle that it is efficient to allocate the risks to the one who can deal with them at lower cost.

Proposition 2

When both partners are risk-averse and they have the same degree of risk-aversion, joint ventures can be set up between the contractors who are technology superior at different tasks or risks.

(3) Partners with Different Risk-aversion Degree and Same Capacity of Dealing with Risk

Here the problem is analyzed under the condition that the risk-aversion degrees of the two partners are different, and their capacities of dealing with risks are same. The inequality (3.22) is then changed to:

$$(k_A - k_B)[\sigma_2^2 + (1-\gamma)^2\sigma_0^2] \geq 0 \tag{3.25}$$

The following conclusion can be obtained: with the risk-aversion degree of partner A increasing or the risk-aversion degree of partner B decreasing, it is easier for the above inequality to be satisfied with. That is to say, if partners B is less risk-averse, it is easier for partner B's participation to be satisfied while partner A's participation condition can not be satisfied. If one partner is less risk-averse than the other, joint ventures can be set up between these two contractors. Because when the contractor whose degree of risk-aversion is relative higher and hi participation condition can not be satisfied the other contractor whose participation condition can be satisfied. A joint venture can be set up by the partner whose degrees of risk-aversion are different, even if they have the same capacities to deal with risks.

Proposition 3

When the partners have different attitudes toward risks, the partner who is more risk-averse can set up a joint venture with other partners whose degree of risk-aversion is relative lower.

(4) Partners with Different Risk-aversion Degree and Different Capacity of Dealing with Risk

Here the problem is analyzed when the risk-aversion degrees of the two partners are different. At same time, they have different capacities to deal with risk. Partner A can set up a joint venture with partner B successfully only when the following inequality is satisfied.

$$C_2^A + k_A[\sigma_2^2 + (1-\gamma)^2\sigma_0^2] \geq C_2^B + k_B[\sigma_2^2 + (1-\gamma)^2\sigma_0^2] \tag{3.26}$$

The following conclusion can be obtained: With the partner B's cost of dealing with risk becoming lower and his risk-aversion being less, the more possible it is for partner B's participation to be satisfied while partner A's participation condition can not be satisfied. At the same time, with the partner A's cost of dealing with the same risk being higher and his risk-aversion being more the more possible it is for partner B's participation condition to be satisfied. In other words when the difference of the cost of dealing with the same risk being more and the difference of the degree of risk-aversion being more, it is more possible for these two partners to set up a joint venture to undertake a project. Because when one partner's participation condition can not be satisfied the other partner's (who is less risk-averse or who can deal with the risk at lower cost) participation condition can be satisfied.

3.5.3 When There is No Background Risk

The participation values of the partners are assumed as 0. When there is no background risk, joint ventures would be set up when the following conditions are satisfied.

$$Q_A^{JN} - Q_A^{wn} > 0 \tag{3.27}$$

$$Q_A^{JN} > 0 \tag{3.28}$$

$$Q_B^{JN} > 0 \tag{3.29}$$

The certainty equivalent value of partner A when he undertakes the whole project himself can be rewritten as:

$$Q_A^{wn} = Q_A^{JN} + [(1-\gamma)I - C_2^A - \phi_2 - k_A\sigma_2^2] \tag{3.30}$$

The part $\{(1-\gamma)I-[C_2^A+\phi_2]-k_B\sigma_2^2\}$ in the formula (3.30) can be seen as the certainty equivalent value of partner A when he undertakes subproject 2 in the joint venture. If the partners have the same degree of risk-aversion and same capacities to deal with the risks, the certainty equivalent value of the partner when he undertakes the whole project can be looked as the sum of the certainty equivalent values of the two same partners in the joint venture, one undertakes subproject 1 and the other undertakes subproject 2. It is different from the relation showed in the formula (3.10). Compared with the sum of the certainty equivalent values of the partners in the joint venture under the condition with a background risk and without a background risk, when there is a background risk the sum of certainty equivalent values is greater than the sum of values without background risk. In the similar way as before, the conditions under which partners will prefer to set up a joint venture to undertake the project can be found.

$$C_2^A + k_A\sigma_2^2 - C_2^B - k_B\sigma_2^2 \geq Q_B^{JH} \geq C_2^A + k_A\sigma_2^2 - (C_2^B + k_B\sigma_2^2) \tag{3.31}$$

The left part of the inequality (3.31) means partner B's certainty equivalent value in the joint venture would not be greater than the sum of the two differences, one is the difference of partner A certainty equivalent values in the joint venture and his certainty equivalent value when he undertakes the whole project, the other is the difference between the certainty equivalent values of the two partners for project risk R_2. The right side of the inequality (3.31) means partner B's certainty equivalent value in the joint venture should be smaller than the difference between their certainty equivalent value of project risk R_2 of the two partners. If partner B's reservation value is greater than the left side of the inequality (3.31), partner B would never agree to take part in the joint venture.

3.5.4 Analysis

When there is no background risk, if the partners are same with each other, they will not set up a joint venture to undertake a project. Because one partner's participation condition can not be satisfied, the other partner's can not be satisfied too. Joint ventures can only be set up by partners who are different with each other.

(1) If $k_A = k_B$ and $C_2^A = C_2^B$, the right part of the inequality (3.31) can be simplified as:

$$Q_B^{JH} \geq C_2^A + k_A\sigma_2^2 - (C_2^B + k_B\sigma_2^2) = 0 \tag{3.32}$$

If partner A's participation condition can not be satisfied, partner B who is same with partner A will not take part in the joint venture. Joint ventures can not be set up by partners who are same with each other. Under this condition if partner B's reservation value is smaller than partner A's, then partner B would agree to take part in the joint venture, because his participation condition is satisfied.

(2) If $k_A = k_B$ the right part of the inequality (3.31) can be simplified as:

$$Q_B^{JH} \geq C_2^A - C_2^B \tag{3.33}$$

Partner B will take part in the joint venture and undertake subproject 2 only when he can deal with the project risk of subproject 2 at lower cost relative to partner A.

(3) If $C_2^A = C_2^B$, the right part of the inequality (3.31) can be simplified as:

$$Q_B^{JH} \geq k_A\sigma_2^2 - k_B\sigma_2^2 \tag{3.34}$$

The conclusion that if the two partners can deal with the risks at same cost, only when partner B's degree of risk-aversion is lower than partner A's partner B will agree to take part in the joint venture to undertake subproject 2 which partner A can not finish can be found.

(4) Partners are different with each other: different degrees of risk-aversion and different capacities to deal with the risk.

$$Q_B^{JH} \geq C_2^A + k_A\sigma_2^2 - (C_2^B + k_B\sigma_2^2) \tag{3.35}$$

With the higher the partner A's cost to deal with the risk is and the higher his degree of risk-aversion is, it is more possible the partner B's participation condition to be satisfied when partner A's participation condition can not be satisfied. With the lower the partner B's cost to deal with the risk is and the lower the degree of risk-aversion of partner B is, it is more possible the partner B's participation condition to be satisfied when partner A's participation condition can not be satisfied.

3.6 Conclusion and Future Research

3.6.1 Conclusion

In relation to the motivations of joint ventures there are many arguments, but there is little theoretical research. According to the previous literatures, risk sharing is one of the main motivations of joint ventures. Some researchers found that partners can not always decrease their risks by setting up a joint venture with others. According to the results of their researches, they found under some conditions setting up a joint venture with others can even increase the risks of the partners.

In this chapter the motivation for partners to set up joint ventures are analyzed from the viewpoint of the risk sharing theoretically. There are many kinds of risks in the construction activities. The existence of these risks can change the behaviors of the relevant partners when they make decisions. In this chapter two kinds of risks, project risks and background risks are focused on. The problem how the existence of these risks affects the decision-makerfs behaviors is analyzed. Under which condition which kinds of companies will be chosen as the cooperators by a company for a project? The conclusions can be summarized as:

If partners can choose whether to set up a joint venture or not, it is more possible for partners to choose to set up a joint venture when the background risk is positive related to the project risks. When the background risk is negative related with the project risks, partners maybe prefer to undertake the whole project. Because when they undertake the whole project, they can get the risk hedge effect by undertaking the whole project. The negative correlation between the background risk and the project risks acts as a natural hedge against uncertainty, setting up a joint venture will remove or decrease this hedge. When the background risk is independent with the background risk, the existing of the background risk will make the difference between the two certainty equivalent values greater compared with the one when there is no background risk.

(1) When partners have the same degree of risk-aversion and they have the same capacities to deal with the same risk, and they also have the same reservation value, if one partner's participation condition is not satisfied the other's can not be satisfied too. Joint ventures can not be set up by the partners who are same with each other. If they have different reservation values even they have the same capacity to deal with the risk and they have the same degree of risk-aversion, a joint venture can be set up between them. If there is a background risk, they can improve their certainty equivalent values by setting up a joint venture.

(2) When both partners undertake unlimited liabilities, if one partner can deal with the risk in a less costly way than the other, they can set up a joint venture successfully.

(3) When the partners have different attitudes toward risks, the partner who is more risk-averse can find a contractor whose degree of risk-aversion is relative lower to set up a joint venture.

From the analysis in this chapter, the conclusion that background risks can affect the behaviors of the decision-maker can be concluded.

The results of this chapter can be used to choose cooperators by a company. When it is not profitable for a company to undertake a project because of too many risks, the company can find another company to cooperate to undertake the project. Under this condition, he can find his cooperators who is less risk-averse or who is better on dealing with the risks than him. The cooperation between the partners who have different special knowledge or have special technologies to cooperate with each other is an efficient way to cooperate. If the risks are changed to tasks, the same conclusion can be obtained. It is optimal for the partners who have different special knowledge or have special technologies to cooperate with each other. This conclusion is same as the conclusion of transaction cost theory. Under this condition the risk sharing motivation of joint ventures can also be looked as cost decreasing motivation. When there is a background risk, risk spread effect can be realized by setting up a joint venture between the partners.

3.6.2 Future Research

In this chapter both partner are assumed to undertake unlimited liabilities. In real world almost all the companies are limited liability companies. It is necessary to find when partners are limited liability companies under which condition they will choose to set up a joint venture for a project. In this chapter, the moral hazard problem is neglected, it is necessary the effect of moral hazard problem when the partners make decision whether to set up a joint venture or undertake the whole project.

Chapter 4

Limited Liability Joint Ventures

4.1 Introduction

There are many researches about joint ventures. Joint ventures are viewed as a way for reducing risks. They argued that there are many advantages of forming joint ventures. Joint ventures can be used as a way to transfer new technology and to reduce the potential risks (Norwood et al., 1999[96]). The motivations behind international construction joint ventures formation are summarized as: market access, technology transfer, risk sharing, and conforming to host government policies (Sridharan, 1997[120]; Mohamed, 2003[94]). Some researches showed setting up a joint venture can not always decrease the risks faced by the partners (Karen et al., 2006[34]).

About the motivations of joint ventures there are some researches. Hennart (1997[54]) conducted an empirical analysis about the choice made by Japanese investors into the United States between full acquisitions of U.S. firms and joint ventures between Japanese and American firms. Pan et al. (2000[101]) argued when a firm makes decision to entry a new market, he should first choose his entry modes (they defined the entry modes as a choice between equity versus non-equity). They used a sample of over 10000 foreign entry activities into China from 1979 to 1998. They showed many country-specific factors impact the mode choice at the equity versus non-equity level. These two researches did not build any model to analyze the choice problem. Buckley et al. (1998[25]) analyzed the entry modes of a firm by comparing the costs of different entry modes. In their research, they did not consider any risks. It is impossible for a firm to make decisions about entering into a new market without considering risks.

When the partner should undertake full liability (unlimited liability) for his project, the partner who is risk-averse will act as a risk-averse decision-maker. When the partner undertakes limited liability for his project, he will act as a less risk-averse decision-maker compared with the condition under which he should undertake full liability. When companies make decision about how to cooperate with other companies they will make different decision under the two conditions that they undertake limited liability and full liability. Limited liability will affect the decisions about partner selection of a company.

When the partners undertake limited liabilities and they have to face partner risks and project risks, under which conditions partners prefer to choose joint ventures as their cooperation ways is a problem the partners have to consider about. When the companies make decision whether to cooperate with other companies by setting up a joint venture, they have to consider all the factors that affecting their decisions including the policy of the country in which the project is, the capacities of the potential cooperators, the risks of the project and so on. From previous literatures (Johnson et al, 2000[64]; Karen et al., 2006[34]) it can be concluded that the partners can not always decrease their risks by setting up a joint venture with other partners. Under some conditions joint ventures can bring some risks to the partners. For example: when the partners undertake limited liability, if one of the partners' project risks realized greater than his limited liability, this partner will declare to be bankruptcy. Then the other partners have to undertake the losses due to the failed partners. Under this condition a new risk which is called partner risk would occur. It is necessary to analyze the motivation of risk decreasing theoretically. It is also necessary to find under which conditions the partners can decrease their risks by setting up joint ventures with other companies.

The remainder of this chapter is organized as follows. Section 4.2 is about the relations between limited liability and risk-taking behavior. The behavior of risk-taking of the partners in the joint venture when they undertake limited liability and unlimited liability is analyzed. The risks in the limited liability joint venture are defined. In Section 4.3 the models of joint venture style and one partner style are built. In Section 4.4 the following problem is analyzed under which condition partners will prefer to set up joint venture by comparing the two style: joint venture style and one partner style when partner A whose limited liability can cover his maximum risk losses has the right to make decision on the cooperation means. The problem is also analyzed under which condition partners will prefer to set up joint venture by comparing the two style: joint venture style and one partner style when partner B whose limited liability can not cover his maximum risk losses has the right to make decision on the cooperation means. In Section 4.5 the following problem is analyzed: under which condition partners will prefer to choose joint ventures as their cooperation means when both partners' limited liabilities can cover their maximum risk losses. Section 4.6 analyzes the choice of the partners when the sum of their limited liabilities is smaller then the sum of the maximum losses of their project risks. Last Section 4.7 is the conclusion of this research and future research.

4.2 Limited Liability and Unlimited Liability

4.2.1 Limited Liability and Risk-taking Behavior

Economists have classified limited liability into two major categories: those that guarantee a certain level of profit (or certainty equivalent value) and those that guarantee a certain level of transfers (or penalty) (Lawarree et al., 1999[75]). Bankruptcy law places an upper limit to an agent's losses therefore guaranteeing him a certain level of (perhaps negative) profit. For a limited liability company, the owners of this company are not responsible for debts that could exceed the amount of their stake. The degree of liability of a decision-maker will affect his decisions.

Another factor which affects the behaviors of the decision-maker is the decision-maker's attitude toward risks. Related to the problem whether a company should be looked as a risk-neutral decision maker or a risk-aversion decision maker, it is more controversial to get the conclusion. About an individual (entrepreneur) almost all of the researchers agree that a individual is risk-averse. If the owner of a firm is perfectly diversified he can be looked as a risk-neutral decision maker. If a decision maker is risk-neutral, he will seek to maximize the expectation of a convex function of the firm's profit. As a result, the decision maker will systematically exhibit a risk-loving behavior and adopt a very risky attitude. As shown by Golbe (1988[43]), a risk-neutral decision maker under limited liability will like any mean-preserving spread of the return of his investment. As shown by Pratt (1964[106]) and Arrow (1965[5]) under unlimited liability, the risk-averse decision maker will choose the optimal scale of the risk as either finite (the expected value of the investment is positive) or infinite. Gollier et al. (1997[44]) showed a risk-averse decision maker will choose larger optimal level of exposure to risk when he should undertake limited liability compared with under the condition that he should undertake unlimited liability. They also showed there is a positive lower bound on the value of the firm below which the firm will invest the largest positive amount in the risky project.

From the above literature, it can be found that the decision-maker will choose his behavior according to his liability degree. If he should undertake full liability he will choose less risky action compared with the one he chooses under the condition that he only undertakes limited liability. The partners in the joint venture choose different behaviors according to their degree of liability when they make decisions. The partners undertake joint liability for the owner of the project. Under this condition one partner's behaviors will affect the profitability of the other partner. When a company makes decisions whether to cooperate with the other company he should consider the limited liability of the other company. If the limited liability of the other company is higher it is safe for him to cooperate with this company. Because higher limited liability means higher capacity to bear risks. If the company has lower limited liability it means it is more possible for him to go bankrupt. Under this condition because the partners undertake joint liability to the owner, the left one has to bear all the losses caused by the bankruptcy partner. On the other hand, with the lower the limited liability of the partner, it is more possible for him to choose to undertake more risky project, and then it is easier for this partner to go bankruptcy. In this chapter the risk that the other declares bankruptcy is called as partner risk.

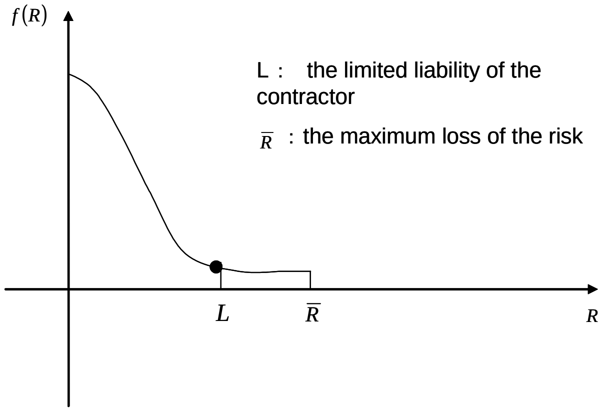
4.2.2 Limited Liability and Unlimited Liability

(1) Unlimited Liability

In this section the decision-making problems are analyzed under two conditions: one is that the decision-maker should undertake limited liability; the other condition is that decision-maker undertakes unlimited liability. The relation between the liability and risk choice of the contractor when the contractor is risk-averse would be clarified.

Here a contractor makes decisions whether to undertake a project with a project

Figure 4.1: Distribution of the Risk Loss



risk. The possible loss of the risk is truncated normal distributed in the intervals $[0, \overline{R}]$, $TN_{(0,\overline{R})}(\mu, \sigma^2)$ showed by Figure 4.1. If the contractor undertakes limited liability, his limited liability is denoted by L. The benefit of the project is denoted by I. I means the benefit that the contractor can get when all the conditions realized as the one which is defined in the contract (between the owner and the contractor).

The certainty equivalent function of the contractor is defined as $Q = E - K\sigma$, where E is the expected value of the benefit he can get by undertaking the project. σ is the variance of the benefit he can get by undertaking the project. K denotes the degree of his risk-aversion. If the contractor undertakes unlimited liability, $\frac{-\mu}{\sigma} = a$ and $\frac{\overline{R}-\mu}{\sigma} = b$. a and b is the normalized amounts of the minimum and maximum loss of the risk. The expected value and the variance of the risk loss can be calculated by:

$$E(\hat{R}) = \mu - \sigma \frac{g(a) - g(b)}{G(a) - G(b)} \tag{4.1}$$

$$V(\hat{R}) = \sigma^2 \left\{ 1 + \frac{ag(a) - bg(b)}{G(b) - G(a)} - \left[\frac{g(a) - g(b)}{G(b) - G(a)} \right]^2 \right\} \tag{4.2}$$

Here $\hat{R}$ means the realized value of the risk loss. $g(a) = \frac{1}{\sqrt{2\pi}} \exp(-\frac{a^2}{2})$, $g(b) = \frac{1}{\sqrt{2\pi}} \exp(-\frac{b^2}{2})$, $G(a) = \int_{-\infty}^{a} \frac{1}{\sqrt{2\pi}} \exp(-\frac{x^2}{2})dx$ and $G(b) = \int_{-\infty}^{b} \frac{1}{\sqrt{2\pi}} \exp(-\frac{x^2}{2})dx$.

Then the certainty equivalent of the contractor Q_f when he undertakes unlimited liability can be calculated by:

$$Q_f = I - \mu + \sigma \frac{g(a) - g(b)}{G(a) - G(b)} - K\sigma^2 \left\{ 1 + \frac{ag(a) - bg(b)}{G(b) - G(a)} - \left[\frac{g(a) - g(b)}{G(b) - G(a)} \right]^2 \right\} \tag{4.3}$$

If the reversation value (if the amount the contractor can get is less than this amount, he will not agree to undertake the project) of the contractor is 0, the maximum value of b can be calculated by solving $Q_f = 0$. Under this condition the contractor will be indifferent between undertaking the project or not undertaking the project. So it can be found that when the contractor should undertake unlimited liability (full liability), there is a upper limit of the risk loss that he will undertake. If the realized maximum loss is assumed to be $I + L$, where L is the same amount as the contractor's limited liability when the contractor undertakes limited liability. In other words, if the maximum loss of the risk realized $I + L$, the certainty equivalent of the project is 0 for this partner, $Q_f(I + L) = 0$. If the possible loss of the risk can realize as a greater amount than $I + L$, the contractor's participant condition can not be satisfied. Then the contractor will not undertake the project.

(2) Limited Liability

If the contractor undertakes limited liability L, the maximum loss realized $\overline{R} > L$, his certainty equivalent value Q_l is:

$$Q_l = I - \mu + \sigma \frac{g(a) - g(c)}{G(a) - G(c)} - K\sigma^2 \left\{ 1 + \frac{ag(a) - cg(c)}{G(c) - G(a)} - \left[\frac{g(a) - g(c)}{G(c) - G(a)} \right]^2 \right\} \tag{4.4}$$

Here $c = \frac{L-\mu}{\sigma}$, $g(a) = \frac{1}{\sqrt{2\pi}} \exp(-\frac{1}{2}a^2)$, $g(c) = \frac{1}{\sqrt{2\pi}} \exp(-\frac{1}{2}c^2)$, $G(a) = \int_{-\infty}^{a} \frac{1}{\sqrt{2\pi}} \exp(-\frac{1}{2}x^2)dx$ and $G(c) = \int_{-\infty}^{c} \frac{1}{\sqrt{2\pi}} \exp(-\frac{1}{2}x^2)dx$.

It is obvious that if all the other conditions are same, a contractor can get higher certainty equivalent when he undertakes limited liability. The proof can be found in Appendix A .

The following assumptions can be made: the reservation value of the contractor is 0, and when the realized benefit of the project is minus or 0 his certainty equivalent value of the project is 0. Then the maximum loss he can undertake equals $I + L$. Because the contractor only undertakes limited liability, when he makes decision whether to undertake the project or not he only considers the expected value of the part of loss he can undertake. It will make him indifferent to undertake the project with possible loss beyond his limited liability. Under this condition, it is possible for him to make the decision to undertake the project. It can be found that even the possible maximum loss of the risk is greater than his limited liability, he would be indifferent between undertaking the project or not.

From the analysis above, it is obvious for the contractors with the same degree of risk-aversion, they will choose to undertake different risky project under the conditions he undertakes limited liability and unlimited liability. The contractor with limited liability will choose the project more risky than the one with unlimited liability. The same conclusion with the previous literature (Golbe, 1988[43]; Pratt, 1964[106]; Arrow, 1965[5]) can be obtained. Limited liability will change the decision behaviors of the decision-maker. It is necessary to analyze the effect of limited liability on the decision-maker when he makes decisions whether to undertake a project by setting up a joint venture or undertakes the project himself.

4.2.3 Risks in Limited Liability Construction Joint Ventures

From the analysis in section 4.2.2, it is obvious that contractors with limited liabilities will be indifferent whether to undertake the project the possible loss greater than their limited liabilities or not. In joint venture activities, partners undertake joint and several liabilities. The limited liabilities of the partners can bring one kind of risk called as partner risk. The partner risk is the kind of risk caused by the other partners in the joint venture, because when the partners undertake limited liability they may undertake some risk with maximum loss greater than their limited liabilities. Under this condition, it is possible this partner to declare default when the risk realized as greater loss than his limited liability. The partners in the joint ventures should undertake joint and several liability to the owner, when one partner default, the left partners have to finish the tasks of this default partner'. It will bring some loss to the partner who left in the joint venture after one partner declared default. This kind of loss is called partner risk. In this chapter, the choice problem is analyzed under the condition that there are two kinds of risks in the construction activities, project risks and partner risks. Project risks are defined as all the risks which are specific to the given project and at the same time they should be undertaken by the partners in the joint venture project according to the main contract between the client and the joint venture.

The partners in the joint venture undertake liabilities to the owner jointly. If one of the partners declares bankruptcy or quitting from the joint venture, it is the responsibility for other partners to finish the whole project. A company makes a decision that setting up a joint venture with other companies means he has to undertake the risks brought by his partners while sharing the project risks. This risk is called as partner risk. The partner risk is the risk of loss caused by the other partners when the other partners fail to finish their subproject and declaring quitting from the joint venture.

4.2.4 Joint Venture Model with Limited Liability

Two companies (or partners) A and B set up a joint venture to undertake a project. Both of these two partners undertake limited liabilities. The whole project can be divided into two subprojects clearly. Each partner undertakes the responsibility to finish one subproject. Each subproject includes one project risk.

(1) Project Risks

In this chapter, the whole project can be divided into two subprojects, subproject 1 and subproject 2, and each partner undertakes one subproject. The project risk of subproject 1 is denoted as the stochastic variable R_1, and the project risk of subproject 2 is denoted as the stochastic variable R_2. The two project risks are independent. In the joint venture partner A undertakes subproject 1, and partner B undertakes subproject 2. The distributions of the risk losses are assumed as truncated normal distributions.

The losses of the risks are defined as the costs when the condition realized as different with the one defined in the contract or different with normal conditions. All the conditions realized as normal conditions means there is no risk occurs, or the risk loss realized as 0. In the joint venture, the risk distribution of project risk R_1 can be denoted by a truncated normal distribution $R_1 = C_1^A + \epsilon$, here $\epsilon \sim TN_{(0,\overline{R})}(0, \sigma^2)$. The cost of dealing with the subprojects risk R_1 is denoted by C_1^A when partner A undertakes this risk. The variance of this project risk R_1 is denoted by σ. The lower limit of the loss of risk R_1 is assumed to be 0, the upper limit of the loss of the risk R_1 is $\overline{R}$. The losses of the risk R_1 is in the interval $[0, \overline{R}]$. Similarly the risk distribution of project risk R_2 can be denoted by a normal distribution $R_2 = C_2^B + \epsilon$, here $\epsilon \sim TN_{(0,\overline{R})}(0, \sigma^2)$. The cost of dealing with the subprojects risk R_2 is denoted by C_2^B when partner B undertakes this risk. The variance of this project risk R_2 is also denoted by σ. The lower limit of the loss of risk R_2 is assumed to be 0, the upper limit of the loss of the risk R_2 is also $\overline{R}$. The losses of the risk R_2 is in the interval $[0, \overline{R}]$.

The limited liability of partner A and B are denoted by L_A and L_B respectively.

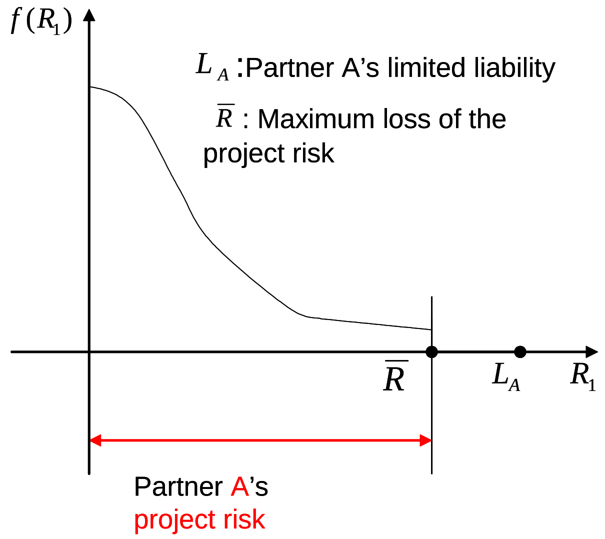


Figure 4.2: Distribution of the Project Risk Loss

$\overline{R} < L_A$, $\overline{R} > L_B$. Partner A can cover all the loss of the projct risk R_1, while partner B can not cover the maximum loss of the project risk R_2. The benefit of each subproject is denoted by I_j $(j = A, B)$, $I_A = \gamma I$ and $I_B = (1-\gamma)I$, where I denotes the sum of the main contract. The project risks of the partners' can be showed as the Figure 4.2 and Figure 4.3.

If the loss realized is greater than partner j's limited liability, he will quit from the joint venture. That is:

$$-\gamma I + C_1^A + \hat{R}_1 \geq L_A \tag{4.5}$$

$$-(1-\gamma)I + C_2^B + \hat{R}_2 \geq L_B \tag{4.6}$$

Where $\hat{R}_1$ and $\hat{R}_2$ are the realized losses of the risks project risk R_1 and R_2 respectively.

Here $\gamma I + L_A - C_1^A = S_A$ and $(1-\gamma)I + L_B - C_2^B = S_B$. In other words, when all the benefit equal 0 or the total loss of the risks equal partner limited liabilities, the realized loss are denoted by S_A and S_B respectively. The partner risk of the partners' can be denoted by the truncated normal distribution (Johnson, 2006[63]; Kortum, 2002[72]) of the project risk distribution at the point where the amount of the loss minus benefit (that this partner can get under the condition that the risk did not occur) equals the limited liability of the partners'. The distribution function and density function of the project

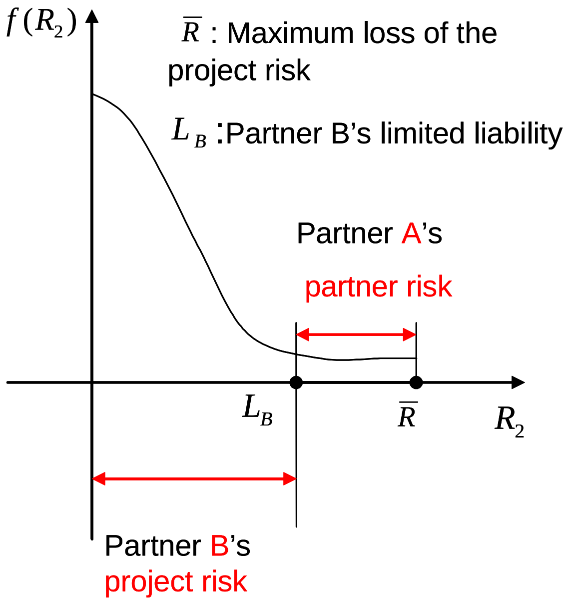


Figure 4.3: Distribution of the Partner Risk Loss

R_1 and R_2 are showed as the following:

$$d(R_1) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(R_1)^2}{2\sigma^2}} \tag{4.7}$$

$$d(R_2) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(R_2)^2}{2\sigma^2}} \tag{4.8}$$

$$D(R_1) = \int_{-\infty}^{R_1} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(R_1)^2}{2\sigma^2}} \cdot dR_1 \tag{4.9}$$

$$D(R_2) = \int_{-\infty}^{R_2} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(R_2)^2}{2\sigma^2}} \cdot dR_2 \tag{4.10}$$

$$r_A = \frac{S_A}{\sigma} \tag{4.11}$$

$$r_B = \frac{S_B}{\sigma} \tag{4.12}$$

r_A and r_B are the normalized values of the loss S_j $(j = A, B)$ which equals $L_A + \gamma I - C_1^A$ for partner A, and $L_B + (1-\gamma)I - C_2^B$ for partner B. To calculate the expected values and the variances of the risks the values of the following formulas at r_A and r_B are needed.

$$g(r_A) = \frac{1}{\sqrt{2\pi}} e^{-\frac{(r_A)^2}{2}} \tag{4.13}$$

$$g(r_B) = \frac{1}{\sqrt{2\pi}} e^{-\frac{(r_B)^2}{2}} \tag{4.14}$$

$$G(r_A) = \int_{-\infty}^{r_A} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} \cdot dx \tag{4.15}$$

$$G(y) = \int_{-\infty}^{r_B} \frac{1}{\sqrt{2\pi}} e^{-\frac{y^2}{2}} \cdot dy \tag{4.16}$$

If the upper limits of the project risk losses and the liabilities of the partners have a relation: $L_A > \overline{R} > L_B$ and $L_A + L_B > \overline{R} + \overline{R}$. The expected values of the project risks for partner A and B which are denoted by $E(R_A^p)$ and $E(R_B^p)$, and the variances of the project risks for partner A and B which are denoted by $V(R_A^p)$ and $V(R_B^p)$, can be expressed as:

$$E(R_A^p) = -\sigma \frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \tag{4.17}$$

$$E(R_B^p) = -\sigma \frac{g(r_B) - g(r^l)}{G(r_B) - G(r^l)} \tag{4.18}$$

$$V(R_A^p) = \sigma^2 \left\{ 1 - \frac{\overline{r} g(\overline{r}) - r^l g(r^l)}{G(\overline{r}) - G(r^l)} - \left[\frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \right]^2 \right\} \tag{4.19}$$

$$V(R_B^p) = \sigma^2 \left\{ 1 - \frac{r_B g(r_B) - r^l g(r^l)}{G(r_B) - G(r^l)} - \left[\frac{g(r_B) - g(r^l)}{G(r_B) - G(r^l)} \right]^2 \right\} \tag{4.20}$$

Here r^l is the normalized amount of minimum loss of the project risk. Here, $\overline{r} = \frac{\overline{R}}{\sigma}$, $r^l = 0$.

(2) Partner Risks

Here $L_B < \overline{R}$, L_B is the limited liability of partner B. If the losses of the joint venture project are greater than their limited liabilities they will quit from the joint venture. Compared with continuing to stay in the joint venture the company prefers to quit from the joint venture. Under this condition, it means the left partner has to finish the whole project without this partner's taking part in. When one partner declares bankruptcy the partner left in the joint venture has to incur the cost overrun. The partners left in the joint ventures can not get any compensation except for the quitting partner's share of the performance bond to the owner when the other partner declares quitting from the joint venture, because according to the order of priority of the bankruptcy law, the order of the left partner who can get compensation will be very low and can not get any compensation.

When the following conditions are satisfied, partner A will face partner risk: $\overline{R} > L_B$ and $L_A > \overline{R}$ and $L_A + L_B > 2\overline{R}$. As the definition of project risks, the partner risk can be defined by a truncated normal distribution in intervals $[r_B, \overline{r}]$ of project risk R_2. Here $\overline{r} = \frac{\overline{R}}{\sigma}$. The partner risk of partner A can be showed as Figure 4.3. Under this condition the expected value and variance of his partner risk can be denoted as:

$$E(R_A^P) = -\sigma \frac{g(\overline{r}) - g(r_B)}{G(\overline{r}) - G(r_B)} \tag{4.21}$$

$$V(R_A^P) = \sigma^2 \left\{ 1 - \frac{\overline{r}g(\overline{r}) - r_B g(r_B)}{G(\overline{r}) - G(r_B)} - \left[\frac{g(\overline{r}) - g(r_B)}{G(\overline{r}) - G(r_B)} \right]^2 \right\} \tag{4.22}$$

4.3 Models of the Two Styles

In this section the choice problem of the partners are analyzed under the condition $(2\overline{R} > L_A > \overline{R} > L_B$ and $L_A + L_B > 2\overline{R}$. The conditions can be explained as: partner A's limited liability can cover the maximum loss of his project risk; while partner B's limited liability can not cover the maximum loss of his project risk; and the sum of the two partners' limited liabilities is greater than the sum of the maximum losses of the project risks.

4.3.1 Model of Joint Ventures

When the partners undertake limited liabilities, under which conditions partners prefer to choose to set up a joint venture to undertake a project. Under the following condition: $2\overline{R} > L_A > \overline{R} > L_B$ and $L_A + L_B > 2\overline{R}$, partner A faces partner risk. The certainty equivalent values of the two partners are:

$$\begin{aligned} Q_A^J = {} & \gamma I - C_1^A + \sigma \frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \\ & + \sigma \frac{g(\overline{r}) - g(r_B)}{G(\overline{r}) - G(r_B)} - k_A \sigma^2 \left\{ \left\{ 1 - \frac{\overline{r}g(\overline{r}) - r^l g(r^l)}{G(\overline{r}) - G(r^l)} - \left[\frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \right]^2 \right\} \right. \\ & \left. + \left\{ 1 - \frac{\overline{r}g(\overline{r}) - r_B g(r_B)}{G(\overline{r}) - G(r_B)} - \left[\frac{g(\overline{r}) - g(r_B)}{G(\overline{r}) - G(r_B)} \right]^2 \right\} \right\} \end{aligned} \tag{4.23}$$

$$Q_B^J = (1-\gamma)I - C_2^B + \sigma\frac{g(r_B) - g(r^l)}{G(r_B) - G(r^l)} - k_B\sigma^2\left\{1 - \frac{r_B g(r_B) - r^l g(r^l)}{G(r_B) - G(r^l)} - \left[\frac{g(r_B) - g(r^l)}{G(r_B) - G(r^l)}\right]^2\right\} \quad (4.24)$$

4.3.2 Model of One Partner Style

For simplification, the whole project is divided into two subprojects as before. All the parameters are also same as those used in the former section. Here the whole project is assumed to be undertaken by partners respectively. The relation between the maximum risk losses and partner A's limited liability satisfies with $2\overline{R} > L_A > \overline{R}$.

The maximum losses of the whole project risks is $2\overline{R}$, and the minimum losses of the whole project risks is 0. $r_w^l = 0$ means the normalized minimum losses of the project risks is 0. $r_A^w = \frac{I+L_A-C_1^A-C_2^A}{\sqrt{2}\sigma}$ is the normalized loss of the project risks of the whole project which equals the limited liability of the partner A. The expected value and variance of project risk R_1 are same as before which are expressed as:

$$E(R_A^w) = -\sqrt{2}\sigma\frac{g(r_A^w) - g(r_w^l)}{G(r_A) - G(r_w^l)} \quad (4.25)$$

$$V(R_A^w) = 2\sigma^2\left\{1 - \frac{r_A^w g(r_A^w) - r_w^l g(r_w^l)}{G(r_A) - G(r_w^l)} - \left[\frac{g(r_A^w) - g(r_w^l)}{G(r_A^w) - G(r_w^l)}\right]^2\right\} \quad (4.26)$$

Partner A can deal with the risk R_1 and R_2 at the cost C_1^A and C_2^A. Under this condition, the certainty equivalent value of partner A denoted by Q_A^w can be expressed as:

$$Q_A^w = I - C_1^A + \sqrt{2}\sigma\frac{g(r_A^w) - g(r_w^l)}{G(r_A^w) - G(r_w^l)} - C_2^A - 2k_A\sigma^2\left\{1 - \frac{r_A^w g(r_A^w) - r_w^l g(r_w^l)}{G(r_A^w) - G(r_w^l)} - \left[\frac{g(r_A^w) - g(r_w^l)}{G(r_A^w) - G(r_w^l)}\right]^2\right\} \quad (4.27)$$

4.4 Comparing the Two Styles

4.4.1 Partner A Has the Right to Choose Cooperation Style

The risk losses and partners' limited liabilities satisfies: $2\overline{R} > L_A > \overline{R} > L_B$ and $L_A + L_B > 2\overline{R}$. Here the problem how partner A makes decision whether to set up a joint venture for the project or to undertake the whole project himself is analyzed.

Here the certainty equivalent value of partner A when he undertakes subproject 2 in the joint venture can be calculated. Q_2^A is used to denote partner A's certainty equivalent value under this condition.

$$\begin{aligned} Q_2^A = (1-\gamma)I + \sigma\frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} - C_2^A \\ -k_A\sigma^2\left\{1 - \frac{\overline{r}g(\overline{r}) - r^l g(r^l)}{G(\overline{r}) - G(r^l)} - \left[\frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)}\right]^2\right\} \end{aligned} \tag{4.28}$$

Partner A will choose to set up a joint venture when the following conditions are satisfied:

$$Q_A^J - Q_A^w \geq 0 \tag{4.29}$$

$$Q_A^J \geq Q_A^R = 0 \tag{4.30}$$

Q_A^R denotes the reservation value of partner A, here $Q_A^R = 0$.

$$\begin{aligned} Q_A^J - Q_A^w = (\gamma - 1)I + \sigma\frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \\ + \sigma\frac{g(\overline{r}) - g(r_B)}{G(\overline{r}) - G(r_B)} - k_A\sigma^2\Bigg\{\left\{1 - \frac{\overline{r}g(\overline{r}) - r^l g(r^l)}{G(\overline{r}) - G(r^l)} - \left[\frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)}\right]^2\right\} \\ + \left\{1 - \frac{\overline{r}g(\overline{r}) - r_B g(r_B)}{G(\overline{r}) - G(r_B)} - \left[\frac{g(\overline{r}) - g(r_B)}{G(\overline{r}) - G(r_B)}\right]^2\right\}\Bigg\} - \sqrt{2}\sigma\frac{g(r_A^w) - g(r_w^l)}{G(r_A^w) - G(r_w^l)} \\ + C_2^A + 2k_A\sigma^2\left\{1 - \frac{r_A^w g(r_A^w) - r_w^l g(r_w^l)}{G(r_A^w) - G(r_w^l)} - \left[\frac{g(r_A^w) - g(r_w^l)}{G(r_A^w) - G(r_w^l)}\right]^2\right\} \geq 0 \end{aligned} \tag{4.31}$$

From the inequality (4.31) it is obvious that partner A will prefer to take part in joint ventures only when his certainty equivalent value of subproject 1 even he should undertake partner risk is greater than his certainty equivalent value of subproject 2.

$$Q_B^J = (1-\gamma)I - C_2^B + \sigma\frac{g(r_B) - g(r^l)}{G(r_B) - G(r^l)} \tag{4.32}$$

$$-k_B\sigma^2\left\{1 - \frac{r_B g(r_B) - r^l g(r^l)}{G(r_B) - G(r^l)} - \left[\frac{g(r_B) - g(r^l)}{G(r_B) - G(r^l)}\right]^2\right\} \geq Q_B^R = 0 \tag{4.33}$$

The formulas (4.29) and (4.30) can be expressed as:

$$\sigma\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}+\sigma\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)}-k_A\sigma^2\left\{\left\{1-\frac{\overline{r}g(\overline{r})-r^lg(r^l)}{G(\overline{r})-G(r^l)}-\left[\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\right]^2\right\}\right.$$
$$\left.+\left\{1-\frac{\overline{r}g(\overline{r})-r_Bg(r_B)}{G(\overline{r})-G(r_B)}-\left[\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)}\right]^2\right\}\right\}+\sqrt{2}\sigma\frac{g(r_A^w)-g(r_w^l)}{G(r_A^w)-G(r_w^l)}$$
$$+\sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}+2k_A\sigma^2\left\{1-\frac{r_A^wg(r_A^w)-r_w^lg(r_w^l)}{G(r_A^w)-G(r_w^l)}-\left[\frac{g(r_A^w)-g(r_w^l)}{G(r_A^w)-G(r_w^l)}\right]^2\right\}$$
$$+C_2^A-C_2^B-k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\}\geq Q_B^J \quad (4.34)$$

Form the inequality (4.34) it is not difficult to find that the certainty equivalent value of partner B when he takes part in the joint venture can not be greater than the left side of the inequality (4.34). The left side of the inequality (4.34)means partner B's certainty equivalent value in the joint venture would not be greater than the sum of the two differences, one is the difference of partner A certainty equivalent values in the joint venture and his certainty equivalent value when he undertakes the whole project, the other is the difference between the certainty equivalent values of the two partners for project risk R_2. If the reservation value of partner B is greater than the left side of the inequality (4.34) partner B will not agree to set up a joint venture with partner A.

The certainty equivalent values of the partners can be rewritten as:

$$Q_A^J=\gamma I-D_1^A=\frac{\gamma}{1-\gamma}(Q_B^J+D_2^B)-D_1^A\geq 0 \quad (4.35)$$
$$Q_2^A=(1-\gamma)I-D_2^A \quad (4.36)$$
$$Q_B^J=(1-\gamma)I-D_2^B \quad (4.37)$$

Partner B's certainty equivalent value can be expressed by the certainty equivalent value of partner A.

$$Q_B^J\geq\frac{1-\gamma}{\gamma}D_1^A-D_2^B=D_2^A-D_2^B \quad (4.38)$$

The relation between partner A's certainty equivalent values of risk R_1 and R_2 satisfied with $D_1^A=\frac{\gamma}{(1-\gamma)}D_2^A$. For partner A, to make sure he can get the same level of certainty equivalent value when he undertakes the two risks, his certainty equivalent values of risk R_2 and R_1 should satisfied $D_2^A=\frac{(1-\gamma)}{\gamma}D_1^A$. For partner A his certainty equivalent value of risk R_2 can also be written as: $\sigma\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}-C_2^A-k_A\sigma^2\left\{1-\frac{\overline{r}g(\overline{r})-r^lg(r^l)}{G(\overline{r})-G(r^l)}-[\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}]^2\right\}$.

If partner B agrees to take part in the joint venture, the right side of inequality (4.38) should be greater than partner B's reservation value, here partner B's reservation value is assumed to be 0. That is to say the following inequality should be satisfied.

$$\begin{aligned}&\sigma\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}+C_2^A+k_A\sigma^2\left\{1-\frac{\overline{r}g(\overline{r})-r^lg(r^l)}{G(\overline{r})-G(r^l)}-\left[\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\right]^2\right\}\\&\geq C_2^B+\sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}+k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\}\end{aligned}\tag{4.39}$$

4.4.2 Analysis

(1) If $k_A = k_B = k$, the inequality (4.34) is changed to:

$$\begin{aligned}C_2^A-C_2^B\geq\ &\sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}-\sigma\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\\&+k\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\}\\&-k\sigma^2\left\{1-\frac{\overline{r}g(\overline{r})-r^lg(r^l)}{G(\overline{r})-G(r^l)}-\left[\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\right]^2\right\}\end{aligned}\tag{4.40}$$

From the inequality (4.40), it is obvious that if the cost for partner B to deal with subproject risk R_2 is lower than partner A to the degree that the inequality (4.40) is satisfied, partner B will take part in the joint venture.

(2) When their costs of dealing with the subproject risk 2 are same, $C_2^A = C_2^B$, and they have different degree of risk-aversion. The inequality (4.34) is changed to:

$$\begin{aligned}&\sigma\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}+k_A\sigma^2\left\{1-\frac{\overline{r}g(\overline{r})-r^lg(r^l)}{G(\overline{r})-G(r^l)}-\left[\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\right]^2\right\}\\&\geq\sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}+k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\}\end{aligned}\tag{4.41}$$

With the lower the degree of risk-aversion of partner B is, it is easier for the inequality (4.41) to be satisfied. With the higher the degree of risk-aversion of partner A is, it is easier for the inequality (4.41) to be satisfied.

(3) When $k_A = k_B = k$ and the costs of dealing with the subproject risk 2 are same, $C_2^A = C_2^B$, for partner B, only when his limited liability is lower than partner A's limited liability his participation condition can be satisfied. Here partner B's participation condition can not be satisfied. When the two partners have different reservation values,

and partner B's is smaller than partner A's, a joint venture can also be set up between them.

(4) If the cost of dealing with the risks and the degree of risk-aversion of the partners are different, the higher the partner A's cost of dealing with the risk is and the higher his risk-aversion is, the easier partner B's participation condition to be satisfied. The lower the partner B's cost of dealing with the risk is and the lower his risk-aversion is, the easier partner B's participation condition to be satisfied.

4.4.3 Partner B Has the Right to Choose Cooperation Style

(1) The Model of Partner B Style

For simplification, the whole project is divided into two subprojects as before. All the parameters are same as before. The relation between the maximum losses of the risks and the partners' limited liabilities are: $2\overline{R} > L_A > \overline{R} > L_B$ and $L_A + L_B > 2\overline{R}$. Here the whole project is undertaken by partner B.

For partner B, the expected value and variance of whole project can be expressed as:

$$E(R_B^p) = -\sqrt{2}\sigma \frac{g(r_B^w) - g(r_w^l)}{G(r_B^w) - G(r_w^l)} \tag{4.42}$$

$$V(R_B^p) = 2\sigma^2 \left\{ 1 - \frac{r_B^w g(r_B^w) - r_w^l g(r_w^l)}{G(r_B^w) - G(r_w^l)} - \left[\frac{g(r_B^w) - g(r_w^l)}{G(r_B^w) - G(r_w^l)} \right]^2 \right\} \tag{4.43}$$

Here $r_w^l = 0$ means the normalized minimum losses of the project risks is 0. $r_B^w = \frac{I + L_B - C_1^B - C_2^B}{\sqrt{2}\sigma}$ is the normalized loss of the project risks of the whole project which equals the limited liability of the partner B. Under this condition, the certainty equivalent values of partner B denoted by Q_B^w can be expressed as:

$$\begin{aligned} Q_B^w = I - C_1^B + \sqrt{2}\sigma \frac{g(r_B^w) - g(r_w^l)}{G(r_B^w) - G(r_w^l)} - C_2^B \\ - 2k_B\sigma^2 \left\{ 1 - \frac{r_B^w g(r_B^w) - r_w^l g(r_w^l)}{G(r_B^w) - G(r_w^l)} - \left[\frac{g(r_B^w) - g(r_w^l)}{G(r_B^w) - G(r_w^l)} \right]^2 \right\} \end{aligned} \tag{4.44}$$

(2) Comparing the Two Styles

Under the same condition, $2\overline{R} > L_A > \overline{R} > L_B$ and $L_A + L_B > 2\overline{R}$, if partner B has the right to choose whether to set up a joint venture with partner A.

Partner B will choose to set up a joint venture when his certainty equivalent value of taking part in the joint venture is greater than his certainty equivalent value of whole project, and his certainty equivalent value of taking part in the joint venture is greater than his reservation value. That is to say partner B will choose to set up a joint venture when the following formulas are satisfied.

$$Q_B^J - Q_B^w \geq 0 \tag{4.45}$$

$$Q_B^J \geq 0 \tag{4.46}$$

Then

$$\begin{aligned}Q_B^J - Q_B^w = {} & -\gamma I + \sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)} + C_1^B - \sqrt{2}\sigma\frac{g(r_B^w)-g(r_w^l)}{G(r_B^w)-G(r_w^l)} \\ & -k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\} \\ & +2k_B\sigma^2\left\{1-\frac{r_B^wg(r_B^w)-r_w^lg(r_w^l)}{G(r_B^w)-G(r_w^l)}-\left[\frac{g(r_B^w)-g(r_w^l)}{G(r_B^w)-G(r_w^l)}\right]^2\right\} \geq 0\end{aligned} \tag{4.47}$$

From the (4.45), the following inequality can be obtained.

$$Q_B^1 \leq 2Q_1 - Q_w \tag{4.48}$$

Here, Q_B^1 means the certainty equivalent value of subproject 1 for partner B. Q_1 mean the certainty equivalent value of one project risk, and Q_w means the certainty equivalent value of the risks when the partner undertakes the whole project. That is to say, partner B will prefer to set up a joint venture with others only when his certainty equivalent value of subproject 1 satisfies with (reftiaojian).

$$\begin{aligned}Q_B^1 = {} & \gamma I + \sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)} - C_1^B \\ & -k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\}\end{aligned} \tag{4.49}$$

$$\begin{aligned}Q_1 = {} & \sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)} \\ & -k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\}\end{aligned} \tag{4.50}$$

$$\begin{aligned}Q_w = {} & \sqrt{2}\sigma\frac{g(r_B^w)-g(r_w^l)}{G(r_B^w)-G(r_w^l)} \\ & -2k_B\sigma^2\left\{1-\frac{r_B^wg(r_B^w)-r_w^lg(r_w^l)}{G(r_B^w)-G(r_w^l)}-\left[\frac{g(r_B^w)-g(r_w^l)}{G(r_B^w)-G(r_w^l)}\right]^2\right\}\end{aligned} \tag{4.51}$$

From the (4.45), the certainty equivalent of partner A when he takes part in the joint venture has an upper limit showed by the following inequality.

$$\begin{aligned}\sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}+C_1^B-C_1^A-k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\}\\+2k_B\sigma^2\left\{1-\frac{r_B^wg(r_B^w)-r_w^lg(r_w^l)}{G(r_B^w)-G(r_w^l)}-\left[\frac{g(r_B^w)-g(r_w^l)}{G(r_B^w)-G(r_w^l)}\right]^2\right\}+\sigma\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\\+\sigma\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)}-k_A\sigma^2\left\{\left\{1-\frac{\overline{r}g(\overline{r})-r^lg(r^l)}{G(\overline{r})-G(r^l)}-\left[\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\right]^2\right\}\right.\\\left.-\sqrt{2}\sigma\frac{g(r_B^w)-g(r_w^l)}{G(r_B^w)-G(r_w^l)}+\left\{1-\frac{\overline{r}g(\overline{r})-r_Bg(r_B)}{G(\overline{r})-G(r_B)}-\left[\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)}\right]^2\right\}\right\}\geq Q_A^J\end{aligned}\tag{4.52}$$

If Q_A^R is greater than the left side of the inequality (4.52), partner A's participation condition can not be satisfied. The left side of the inequality (4.52)means partner A's certainty equivalent value in the joint venture would not be greater than the sum of the two differences, one is the difference of partner B certainty equivalent values in the joint venture and his certainty equivalent value when he undertakes the whole project the difference, the other is the difference between the certainty equivalent values of the two partners for project risk R_1. Partner A will take part in the joint venture only when his certainty equivalent value of taking part in the joint venture is greater than his reservation value.

$$Q_A^J\geq Q_A^R=0\tag{4.53}$$

Q_A^R denotes the reservation value of partner A, here $Q_A^R=0$. The certainty equivalent value of partner A can be rewritten as:

$$Q_B^J=\frac{\gamma}{1-\gamma}[Q_A^J-D_1^A]+D_2^B\geq 0\tag{4.54}$$

Here,

$$\begin{aligned}D_1^A=-C_1^A+\sigma\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}+\sigma\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)}\\-k_A\sigma^2\left\{\left\{1-\frac{\overline{r}g(\overline{r})-r^lg(r^l)}{G(\overline{r})-G(r^l)}-\left[\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\right]^2\right\}\right.\\\left.+\left\{1-\frac{\overline{r}g(\overline{r})-r_Bg(r_B)}{G(\overline{r})-G(r_B)}-\left[\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)}\right]^2\right\}\right\}\end{aligned}\tag{4.55}$$

$$D_2^B = -C_2^B + \sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)} - k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\} \quad (4.56)$$

The following condition can be obtained:

$$Q_A^J \geq -\frac{\gamma}{1-\gamma}D_2^B + D_1^A = -D_1^B + D_1^A \quad (4.57)$$

Here, $\frac{\gamma}{1-\gamma}D_2^B$ denote partner B's certainty equivalent value of risk R_1, at this certainty equivalent value level when partner B undertakes R_1, he can get the same level of certainty equivalent value as he undertakes risk R_2 in the joint venture. $D_1^B = -C_1^B + \sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)} - k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}]^2\right\}$ can also be used to denote partner B's certainty equivalent value of risk R_1.

Partner A will take part in the joint venture when he can get at least his reservation value. Here the reservation value of partner A is 0. That is to say, the right side of the inequality (4.57) should be greater than 0.

$$\begin{aligned} &C_1^B - \sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)} + k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\} \\ &\quad\geq C_1^A - \sigma\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)} + k_A\sigma^2\left\{\left\{1-\frac{\overline{r}g(\overline{r})-r^lg(r^l)}{G(\overline{r})-G(r^l)}-\left[\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\right]^2\right\}\right. \\ &\qquad\left.-\sigma\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)} + \left\{1-\frac{\overline{r}g(\overline{r})-r_Bg(r_B)}{G(\overline{r})-G(r_B)}-\left[\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)}\right]^2\right\}\right\} \end{aligned} \quad (4.58)$$

4.4.4 Analysis

(1) From above formula, if $k_A = k_B = k$, the inequality (4.58) can be expressed as:

$$\begin{aligned} C_1^B - C_1^A \geq\ &\sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)} + k\sigma^2\left\{\left\{1-\frac{\overline{r}g(\overline{r})-r^lg(r^l)}{G(\overline{r})-G(r^l)}-\left[\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\right]^2\right\}\right. \\ &\left.-\sigma\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)} + \left\{1-\frac{\overline{r}g(\overline{r})-r_Bg(r_B)}{G(\overline{r})-G(r_B)}-\left[\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)}\right]^2\right\}\right\} \\ &-\sigma\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)} - k\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\} \end{aligned} \quad (4.59)$$

Then partner A will take part in the joint venture only when he can deal with the project risk R_1 at lower cost relative to partner B.

(2) If $C_1^B = C_1^A$, the inequality (4.58) is changed to:

$$-\sigma\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}+k_B\sigma^2\left\{1-\frac{r_Bg(r_B)-r^lg(r^l)}{G(r_B)-G(r^l)}-\left[\frac{g(r_B)-g(r^l)}{G(r_B)-G(r^l)}\right]^2\right\}$$
$$\geq -\sigma\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}+k_A\sigma^2\left\{\left\{1-\frac{\overline{r}g(\overline{r})-r^lg(r^l)}{G(\overline{r})-G(r^l)}-\left[\frac{g(\overline{r})-g(r^l)}{G(\overline{r})-G(r^l)}\right]^2\right\}\right.$$
$$\left.-\sigma\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)}+\left\{1-\frac{\overline{r}g(\overline{r})-r_Bg(r_B)}{G(\overline{r})-G(r_B)}-\left[\frac{g(\overline{r})-g(r_B)}{G(\overline{r})-G(r_B)}\right]^2\right\}\right\} \quad (4.60)$$

The higher the degree of risk-aversion of partner B is, and the lower the degree of risk-aversion of partner A is, it is more possible for partner A to take part in the joint venture.

(3) If $C_1^B = C_1^A$ and $k_A = k_B = k$, it is impossible for these two partners to set up a joint venture. Because partner A's participation condition can not be satisfied. When they have different reservation values, and partner B's reservation value is smaller than partner A' a joint venture can also be set up by them.

(4) If both the costs of deal with the same risk and the degrees of risk-aversion of the two partners are different, the following result can be found: The lower the cost of deal with the risk for partner A is, the lower his degree of risk-aversion is, it is more possible for him to take part in the joint venture.

4.5 Partners with Similar Liabilities

In this section the choice problem is analyzed under the condition $2\overline{R} > L_A = L_B > \overline{R}$. $L_A = L_B = L > \overline{R}$ means the limited liability of the partners. $r_a = \frac{I+L-C_1^A-C_2^A}{\sqrt{2}\sigma}$, $r_b = \frac{I+L-C_1^B-C_2^B}{\sqrt{2}\sigma}$ are the normalized losses of the whole project that the partners can undertaken. $\overline{r} = \frac{\overline{R}}{\sigma}$ means the normalized maximum loss of the risk. $r^l = 0$ is the normalized minimum loss of the subproject risk. $r_w^l = 0$ is the normalized minimum loss of the project risks of the whole project. In other words, both partners can cover the maximum loss of his project risks. Under this condition there is no partner risk. All the other assumptions are same with former sections. The certainty equivalent values of the partners when they set up a joint venture are:

$$
\begin{aligned}
Q_A^J &= \gamma I - C_1^A + \sigma \frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \\
&-k_A \sigma^2 \left\{ 1 - \frac{\overline{r} g(\overline{r}) - r^l g(r^l)}{G(\overline{r}) - G(r^l)} - \left[\frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \right]^2 \right\} \qquad (4.61)\\
Q_B^J &= (1-\gamma) I - C_2^B + \sigma \frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \\
&-k_B \sigma^2 \left\{ 1 - \frac{\overline{r} g(\overline{r}) - r^l g(r^l)}{G(\overline{r}) - G(r^l)} - \left[\frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \right]^2 \right\} \qquad (4.62)
\end{aligned}
$$

The certainty equivalent values of the partners when they undertake the whole project can be expressed as:

$$
\begin{aligned}
Q_A^w &= I - C_1^A + \sqrt{2}\sigma \frac{g(r_a) - g(r_w^l)}{G(r_a) - G(r_w^l)} - C_2^A \\
&-2k_A \sigma^2 \left\{ 1 - \frac{r_a g(r_a) - r_w^l g(r_w^l)}{G(r) - G(r_w^l)} - \left[\frac{g(r_a) - g(r_w^l)}{G(r_a) - G(r_w^l)} \right]^2 \right\} \qquad (4.63)\\
Q_B^w &= I - C_1^B + \sqrt{2}\sigma \frac{g(r_b) - g(r_w^l)}{G(r_b) - G(r_w^l)} - C_2^B \\
&-2k_B \sigma^2 \left\{ 1 - \frac{r_b g(r_b) - r_w^l g(r_w^l)}{G(r_b) - G(r_w^l)} - \left[\frac{g(r_b) - g(r_w^l)}{G(r_b) - G(r_w^l)} \right]^2 \right\} \qquad (4.64)
\end{aligned}
$$

The problem that under which conditions partner A will choose to set up a joint venture by substituting the certainty equivalent values into formulas (4.45) and (4.53) can be analyzed:

$$
\begin{aligned}
&C_2^A + k_A \sigma^2 \left\{ 1 - \frac{\overline{r} g(\overline{r}) - r^l g(r^l)}{G(\overline{r}) - G(r^l)} - \left[\frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \right]^2 \right\} \\
&\qquad \geq C_2^B + k_B \sigma^2 \left\{ 1 - \frac{\overline{r} g(\overline{r}) - r^l g(r^l)}{G(\overline{r}) - G(r^l)} - \left[\frac{g(\overline{r}) - g(r^l)}{G(\overline{r}) - G(r^l)} \right]^2 \right\} \qquad (4.65)
\end{aligned}
$$

If $k_A = k_B$, only when partner B can deal with subproject risk R_2 at lower cost than his cost, partner A will choose to set up a joint venture with partner B.

If the partners deal with the same project risks at same cost $C_2^A = C_2^B$, only when the degree of risk-aversion of partner A is higher than partner B, $k_A > k_B$, partner A will choose to set up a joint venture with partner B. Similarly, under this condition if partner B has the right to choose whether to set up a joint venture with partner A, he will not choose to set up a joint venture with partners whose degree of risk-aversion is higher than his own.

Proposition:

If both partners have the same limited liability, they will choose to set up a joint venture under the following conditions:

(1) If the degrees of risk-aversion of the two partners are same, only when each partner can deal with one project risk at lower cost than the other they will choose to set up a joint venture.

(2) If they deal with the same risk at same cost, only when they have different degree of risk-aversion, they prefer to set up a joint venture.

4.6 The Limited Liabilities Can Not Cover the Losses

In this section, the following problem is analyzed: how partners make decisions whether to set up a joint venture or not under the following conditions: one partner's limited liability is greater than the maximum loss of his project, while the other partner's limited liability is smaller than the maximum loss of his project risk, at same time, the sum of the limited liabilities is smaller than the sum of the maximum losses of the risks. The details can be found in Appendix B. The conclusion can be summarized as:

(1) When risks realized as small loss for subproject 1 and great loss for subproject 2, under the condition that the sum of these two losses is greater than the limited liability of each partner but smaller than the sum of their limited liabilities; or when subproject risk R_1 realized as great loss and subproject risk R_2 realized as small loss and the sum of these two losses is smaller than the limited liability of partner A, partner A will choose to set up a joint venture with partner B under the condition that the project risk R_1 realized as small loss and at same time he should face partner risk, his certainty equivalent value of undertaking risk R_1 is still greater than his certainty equivalent value of risk R_2. Under this condition partner B will not choose to set up a joint venture with partner A. Under these conditions joint ventures can not be set up by partner A and partner B.

(2) When risk R_1 realized as small loss, risk R_2 realized as great loss and the sum of these two losses is smaller than the limited liability of partner A, partner A will choose to set up a joint venture with partner B, when his certainty equivalent value of subproject 1 is greater than his certainty equivalent value of undertaking subproject 2 under the condition that the risk of subproject 2 occurs as small loss and the risk of subproject 1

occurs as great loss. Partner B will choose to set up a joint venture when his certainty equivalent value of undertaking subproject 2 is greater than his certainty equivalent value of undertaking subproject 1 when both risks realized as small losses.

Joint ventures can only be set up between the partners who are technology superior on different subproject or different project risks management.

4.7 Conclusion and Future Research

4.7.1 Conclusion

In realities most companies are limited liability companies. In this chapter the choice problem that under which conditions partners with limited liabilities will choose to set up a joint venture to undertake a project is analyzed. The two conditions that partners have different limited liability and they have same limited liabilities are analyzed. The conclusions are summarized as:

Under the condition that the relation between the losses of risks and limited liabilities are: $2\overline{R} > L_A > \overline{R} > L_B$ and $L_A + L_B > 2\overline{R}$, how the partners choose their cooperation means. The conditions can be explained as: one of the partners can cover the maximum loss of his project, while the other partner can not cover his maximum loss, and the sum of their limited liabilities is greater than the sum of maximum losses of the project risks.

Under this condition, partner A will prefer to set up a joint venture with the partner (whose limited liability can not cover his maximum loss of his project risk) only when his certainty equivalent value of partner risk is greater than his certainty equivalent value of subproject 2. Partner B will take part in the joint venture under the following conditions:

(1) If partner B can deal with the project risk R_2 at relative lower cost to some degree, he will take part in the joint venture.

(2) If their costs of dealing with project risk R_2 are same, it is more possible for partner B to take part in the joint venture when his degree of risk-aversion is relative lower compared with partner A's.

(3) If the degrees of risk-aversion of them are same and their costs of dealing with the subproject risk R_2 are same, and at the same time they have the same reservation values, for partner B, only when his limited liability is lower than partner A's limited liability he

will take part in the joint venture with partner A. Otherwise, partner B's participation condition can not be satisfied. It is contrary to the assumption of the relations between the maximum losses and the limited liabilities of the partners. When the partners are same with each other they will not set up a joint venture for a project. If they have different reservation value and the reservation value of partner B is smaller than parnter A's, a joint venture can also be set up between them even they have the same capacity to deal with the risk and the same degree of risk-aversion.

(4) When the cost of dealing with the risks and the degree of risk-aversion of the partners are different, the higher the partner A's cost of dealing with the risk is and the higher his risk-aversion is, the easier partner B's participation condition to be satisfied. The lower the partner B's cost of dealing with the risk is and the lower his risk-aversion is, the easier partner B's participation condition to be satisfied. Under these two conditions the more possible the joint venture to be set up by these two partners.

Under the same condition, if partner B has the right to make decisions whether to set up a joint venture with partner A, he will always choose to set up a joint venture with partner A when the cost decreased of project risk of subproject 1 is higher than the certainty equivalent value of project risk over his limited liability. If they can deal with project risk of subproject risk 1 at same cost he will not choose to set up a joint venture with partner A.

Under the condition: $2\overline{R} > L_A > \overline{R} > L_B$ and $L_A + L_B > 2\overline{R}$, If both partners have the same limited liability, they will choose to set up a joint venture under the following conditions:

(1) If the degrees of risk-aversion of the partners are same, partner A will take part in the joint venture only when he can deal with the project risk R_1 at lower cost relative to partner B.

(2) If the costs of dealing with the risk are same for the two partners, the higher the degree of risk-aversion of partner B is, and the lower the degree of risk-aversion of partner A is, it is more possible for partner A to set up a joint venture with partner B.

(3) If the partners are same with each other, here it means that the partners have the same cost of dealing with the risk, same degree of risk-aversion and same reservation value, it is impossible for these two partners to set up a joint venture. Under this condition, partners will not set up a joint venture to undertake the project. If they have different

reservation value and partner A's reservation value is smaller than partner B's even they have the same cost of dealing with the risk and the same degree of risk-aversion a joint venture can also be set up between them.

(4) If both the costs of dealing with the same risk and the degrees of risk-aversion of the two partners are different, the following result can be found: The lower the cost of deal with the risk for partner A is, the lower his degree of risk-aversion is, it is more possible for him to take part in the joint venture.

Under the condition: one partner's limited liability is greater than the maximum loss of his project, while the other partner's limited liability is smaller than the maximum loss of his project risk, at same time, the sum of the limited liabilities is smaller than the sum of the maximum losses of the risks, joint ventures can only be set up between the partners who are technology superior on different projects or risk management.

From the analysis in this chapter, joint ventures will not be set up by the partners who have the same degree of risk-aversion, at same time they can deal with the risk at same cost. Joint ventures can be set up between the partners at least they are different on one aspect, either cost or degree of risk-aversion. From this viewpoint, the same conclusion with the transaction cost theory, joint ventures are set up to decrease cost, is obtained.

4.7.2 Future Research

In this chapter, the problem that how the partners make the decision whether to set up a joint venture or undertakes the whole project is analyzed. As we all knew that subcontracting is also an important way used widely in construction industry. It is necessary to make it clear which factors affect the choice between a joint venture and subcontracting. It is also necessary to make it clear how the partners make the choice between the subcontracting and a joint venture.

Chapter 5

Joint Venture Agreements Efficiency Analysis

5.1 Introduction

In construction industry it is not rare that several contractors cooperate with each other in the form of joint ventures. The advantages of joint ventures include, risk share, improvement of capability of financing, strengthening of technology, attaining experience and so on. On one side, because of the low rate of expansions of construction industry, the small and medium-sized enterprises set up joint ventures to increase the chance of wining a bid. As a result, the enterprises can go on without having to lay-off any personnel.

As we all know construction involves many risks. In the joint venture agreement the partners define how to share the risks and costs during the duration of the project, and at the same time they define the procedure of decision when an uncertainty occurs. One of the functions of the joint venture agreement is to encourage the partners to make their effort to decrease the risk losses by defining a suitable risk sharing rule among the partners beforehand. If there is no clear definition of the risk sharing in the agreement, when the risks occur, no measures of dealing with the risks can be adopted in time, then the project time will have to be extended and as a result extra cost should be incurred. The profit of this project will be decreased. It is necessary to do some theoretical analysis about different kinds of risk sharing schemes in the joint venture agreements.

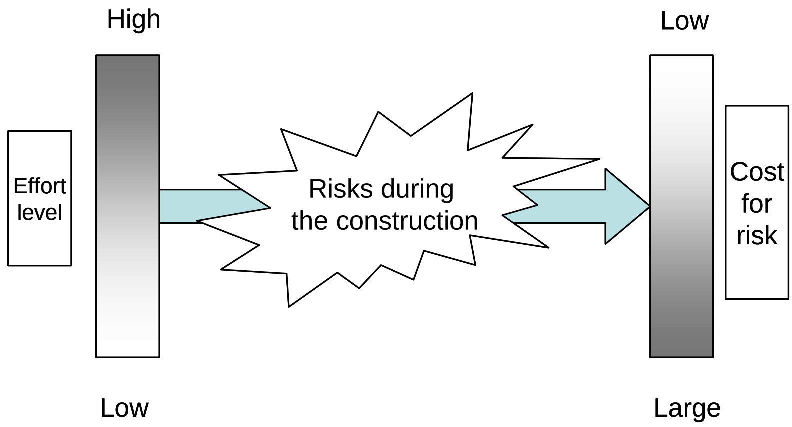
In this paper, separated type and integrated type joint ventures are analyzed. The effects of governance structure upon the effort inducing are also analyzed. The Section 5.2 deals with methodology of this chapter. In Section 5.3 and 5.4 the effects of the governance structures of integrated type joint venture and seperated type joint venture on the partners' efforts are analyzed respectively. In Section 5.5 the efficiency of the two types of joint venture agreement schemes is compared. Based on analysis and comparison, the effect of the compensation rule which is used to make sure the efficiency of the joint venture is also analyzed. Section 5.6 is the conclusion of this research and future research.

5.2 The Methodology

5.2.1 Types of Joint Venture Agreement

In general, joint ventures are means of cooperation between two or more companies for some project. In Japan, there are many types of joint ventures. According to the governance structure of the joint venture agreements, all joint venture agreements can be classified into two types, integrated type and separated type (1996[67]). In the integrated type of joint venture, the partners shared costs and profits according to their participation share defined in the joint venture agreement. In this type of joint venture the partners assign their own managers and workers, at the same time they contribute material and plant needed for the project. All the plant, material and labor contributed by each partner belong to the joint venture during the duration of the project. There are two kinds of the governance schemes of the integrated type joint ventures which are: 1) one of the partners is chosen as the sponsor (lead partner) to monitor all the works of all partners and communicate with the client. This kind of governance scheme is called as sponsor style governance scheme; 2) all the partners in the joint venture are regarded as equals and they work as partnership. This kind of governance scheme is called as partner style governance scheme. In the separated type joint ventures, the partners divide the project into subprojects, and each partner undertakes one subproject; at the same time they undertake the responsibilities of their own subproject. In this type of joint ventures the partners also choose one partner as the sponsor to communicate with the client. According to the governance schemes used by the separated type joint ventures, the separated type joint ventures can also be divided into two governance styles: the sponsor style and the

Figure 5.1: The Relation between the Effort and Cost



partner style. In the separated type joint ventures the partners use one account to manage their expenses, and they share the profits according to their subprojects. In Japan almost all the construction joint ventures are sponsor style joint ventures.

5.2.2 Joint Venture Type, Partners' Efforts and Efficiency

In construction, it is impossible to define all the conditions which will occur in the future beforehand. Usually after the conditions realized the measures will be decided. The costs for the uncertainties in the future will change according to the efforts beforehand which can be denoted as in Figure (5.1). For example, almost all the works in the construction can not be done by using some standard methods. Even the same type of work, in different projects the procedure will change according to the real conditions at the site, and if the same work is done by different people the cost will be different. Because under these conditions the cost changes according to the measures executed, the measures being decided by the people who undertake the work. The person assigned to the joint venture can be looked as the representative of efforts of the partner. It is because when some person was send to this project, it is impossible to assign the same people to other projects. It can also be called opportunity cost of this person. When the parent companies decide who should be sent to which project, they compare the profits with opportunity costs.

The efforts of the partners are interrelated in the integrated type joint ventures. That is to say, if one partner did more effort, the profit brought by the effort of this partner will be shared among the partners according to the shares defined in the joint venture agreement. This phenomenon is also called externality. On the other hand, in the separated type joint venture the profits brought by each partner belong to each subproject, the other partners can not share the fruits of this partner's effort.@That is to say there is no dependence between the efforts of the partners. The characteristics of the two types of joint venture can be summarized as the Table 5.1.

Table 5.1: Types of Joint Venture Agreement and Characteristics

	Integrated Joint Ventures	Separated Joint Ventures
Captial	Share of captial	Subproject
Profit share	Share of captial	Share of captial
Responsibility	All the partners	Subproject
Dependence between the efforts of all partners	Yes	No

5.2.3 Risk-Sharing in Joint Ventures

In construction, there is a variety of risks (Omoto, 2001[98]). In this paper, a very important one—delay will be analyzed. If the project is delayed, the usage of the constructed structure will also be delayed, because of the delay the client (the society) has to undertake losses. During the duration of the construction, the delay may be caused by the client, or the partners in the joint venture, or both of them. In this research, only the delay due to the partners in the joint venture is considered.

Usually, if the client delayed the project he will undertake the responsibility. For example, according to the Central Construction Industry Counsil of Japan: The Standard Form of Agreement and General Conditions of Government Contract for Works of Builiding and Civil Engineering Construction (GCW[124]), clause 45, when the project cannot be executed according to the schedule because of the client, the contractor can ask for compensation. That is to say, during the course of construction whichever party can not meet the responsibilities defined in the contract will have to compensate the other partners for the losses. This is called compensation agreement (Miceli, 1997[90]). When the project is undertaken by only one contractor, he/she will compensate the client for the losses due to the delay. When the project is undertaken by joint venture, then joint venture will compensate the client. How to share this compensation between the partners is worth to study.

In the integrated type of joint ventures, the compensation will be undertaken by all the partners, and the amount each partner should undertake is decided by their participation share. In the separated type joint ventures, the compensation will be undertaken by the partner who undertakes the delayed subproject. When it is clear that the delay is caused by which partner, that partner should undertake the compensation. When the delay is caused by several partners, how to share the compensation among the partners is difficult to decide. Under this condition, the shares of compensation will also affect the partners' profits, and then affect the efforts of the partners, so it is possible that the moral hazard problem arises.

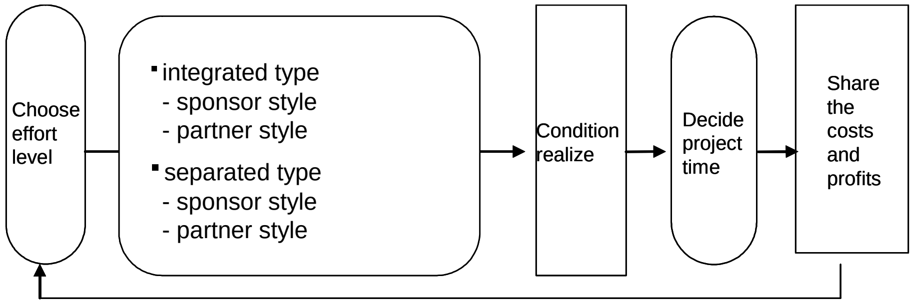
5.2.4 Incompleteness of Joint Venture Agreements

Along with the execution of the project, the real conditions realize (Winch, 2002[132]). The conditions realized are different with those defined in the joint venture agreement. Under this condition it is impossible to finish the project on schedule. It is impossible to define all the conditions that will occur during the course of the project and under which conditions the time of project should be extended ex ante because of the complexity of construction. It is necessary to define the rules of how to change the time limit and how to share the compensations after the conditions realized as different from the one defined in the agreement. So joint venture agreements are also called incomplete contracts (Hart, 1995[51]; Yanagawa, 2000[134]).

In the joint venture, a steering committee is set up to deal with the problems which occur during the period of construction. When an issue arises the committee will decide whether it is necessary to change the time limit of the project and how to share the losses. Usually, in the steering committee the sponsor will be appointed as the chairperson to monitor the project. It is very difficult to prevent the sponsor from making a self-interest decision.

In this paper, a model is used to analyze the project time change due to risks and also to analyze the incompleteness of the joint venture agreement. The necessary extension

Figure 5.2: Model of This Research



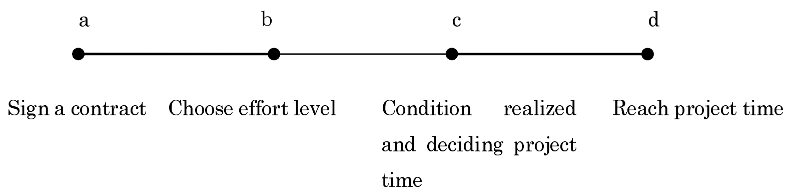
depends not only on the degree to which the conditions changed, but also depend on the effort level of each partner and the compensation needed. When the compensation to the client is shared between the partners it will affect the effort level of each partner. A model is used to analyze the effects of the joint venture structure on the effort levels chosen ex ante. The procedure of this model is shown in Figure (5.2).

5.2.5 Literature Review

Economics of contract is used in almost all the researches concerning joint ventures (Bolton, 2005[16]). The integrated type joint venture is similar to the partnership called in economics of contract. Partnership is one kind of organization in which all the partners share the profits gained by the organization (Itoh, 2003[61]). Alchian et al. (1972[17]) used team production to analyze the inefficiency of the partnership. In the partnership, there is externality of the action of each partner, and at the same time it is very difficult (or impossible) to decompose the profits of each partner to valuate the contribution of each partner. Holmström (1982[57]) argued that the simple structure of partnership will bring out the low level effort of the partners, thus create a moral hazard. In this paper, the effects of the two types of joint venture structures on the effort level of each partner will be analyzed.

The theory of incomplete contracts are used to analyze the joint venture agreement (Bolton, 2005[16]). According to the theory of incomplete contracts, because it is impossible to define all the conditions in the contract, it will make the partners under-invest in the specific-materials. It is necessary to define the measures to deal with the problem when the unforeseeable condition occurs. Kobayashi et al. (2001[69]) argued that con-

Figure 5.3: The Procedure of the Model



struction contracts are typical incomplete contracts, and they also proved the Japanese style construction contracts are efficient. In this chapter the inefficiency of construction joint venture agreements as incomplete contracts is analyzed.

There are many researches about agreement compensations in law economics (Miceli, 1997[90]). Chung (1992[29]) verified that the agreement compensations can bring out the efficient action of the contractor. The researchers represented by Chung used one client and one contractor in their model. While in the joint venture instead of only one contractor there are several partners and all the partners should undertake the compensation to the client jointly. In this paper, the problem how the agreement compensation affects the effort levels chosen by the partners is analyzed.

5.3 Model of Integrated Type Joint Ventures

5.3.1 Assumption

There are two partners: partner A and partner B who set up a joint venture, and bid for a project. All the partners are risk neutral. The partners will execute the project according to the procedure showed by Figure (5.3). At point a, partner A and partner B sign a joint venture agreement. In this agreement the participants' shares are defined. α denotes the share of partner A, and the share of partner B is denoted by $(1-\alpha)$. At point a, the joint venture and the client sign the main contract. In this contract the project time q_0 and sum of the contract p_0 are defined. The project time defined in the contract is decided according to the standard technology and the conditions defined by the client. Sum of contract is decided by competitive bidding. The project q_0 and the sum of contract p_0 are exogenous parameters.

If and only if the project can be finished in the project time defined in the contract, the client can get the benefit v. If the project is delayed, the benefit of the client will be decreased. Let t denote the loss of the client per unit delay. When the project time is changed to $q = q_0 + \Delta q$, the benefit of the client is reduced to $V(q) = v - t\Delta q$. Under the condition that the project is delayed because of the partners of the joint venture, according to the contract, the joint venture should compensate the losses of the client, and the compensation per unit delay is denoted as t. Then the client can always get the benefit v no matter the delay occurs or not. When the project is delayed by Δq, the joint venture should pay for the delay, $t\Delta q$. At point b, the partners of the joint venture choose their effort levels. Let i_A and i_B, denote the effort levels of partner A and partner B respectively. It is impossible for a third party to verify the effort level chosen by the partners because of lack of evidence. This is also called unverifiablity. During the course of the construction at point c the real conditions of the project realize, it can be denoted by $d \in \{g, b\}$. Where g is the real condition realized as the condition which is same with the one defined in the contract. Let $d = b$ denote the condition which is more sever than the one defined in the contract. Under condition $d = b$, it is impossible to finish the project in the project's scheduled time. The additional cost needed when the project is delayed is the function of the effort levels of the partner chose ex ante and the extension needed.

$$c(i_A, i_B, \Delta q) = c_f \Delta q + c_v(i_A, i_B, \Delta q) \tag{5.1}$$

c_f is a constant which denote the fix cost needed for unit time delay. $c_v(i_A, i_B, \Delta q)$ is a variable cost which depends on the effort level chosen ex ante and project time extension needed. The variable cost function is the same as with Kobayashi et al. (Kobayashi et al. 2001[69]).

$$\frac{\partial c_v(i_A, i_B, \Delta q)}{\partial i_A} < 0 \tag{5.2a}$$

$$\frac{\partial^2 c_v(i_A, i_B, \Delta q)}{\partial {i_A}^2} > 0 \tag{5.2b}$$

$$\frac{\partial c_v(i_A, i_B, \Delta q)}{\partial i_B} < 0 \tag{5.2c}$$

$$\frac{\partial^2 c_v(i_A, i_B, \Delta q)}{\partial {i_B}^2} < 0 \tag{5.2d}$$

$$\frac{\partial^2 c_v(i_A, i_B, \Delta q)}{\partial i_A \partial i_B} > 0 \tag{5.2e}$$

The variable cost function is a strictly convex and decreasing function and two times differentiable in the effort levels of the partners. It is assumed that as the project time extension becomes longer, the variable cost becomes smaller.

$$\frac{\partial c_v(i_A, i_B, \Delta q)}{\partial \Delta q} \leq 0 \tag{5.3a}$$

$$\frac{\partial^2 c_v(i_A, i_B, \Delta q)}{\partial \Delta q^2} > 0 \tag{5.3b}$$

$$\frac{\partial^2 c_v(i_A, i_B, \Delta q)}{\partial i_A \partial \Delta q} > 0 \tag{5.3c}$$

$$\frac{\partial^2 c_v(i_A, i_B, \Delta q)}{\partial i_A \partial \Delta q} > 0 \tag{5.3d}$$

That is to say, with the shortening the extension the variable cost increases, and with the effort level increasing the marginal cost decreases. To make sure that the interior point solution in $(0, +\infty)$ can be obtained, the following assumptions are made:

$$\lim_{\Delta q \to +0} \frac{\partial c_v(i_A, i_B, \Delta q)}{\partial \Delta q} = -\infty \tag{5.4}$$

$$\lim_{\Delta q \to +\infty} \frac{\partial c_v(i_A, i_B, \Delta q)}{\partial \Delta q} = 0 \tag{5.5}$$

The equation (5.4) is to say the in that interval $(0, +\infty)$ the variable cost function is a decreasing function on Δq. The equation (5.5) is to say when the extended project time becomes infinite the absolute value of the marginal variable cost will get close to zero. The partners will negotiate about the project time extension and then decide, Δq, when the real condition is more sever than the one defined in the contract.

5.3.2 The Sponsor Style Joint Ventures

In Japan, when the partners choose integrated type of joint ventures as their cooperation means, they always appoint one of the partners as the sponsor (lead member). Here this type of joint venture governance structure is analyzed. In this type of joint ventures, the sponsor works as the monitor and allocates the resources and risks to maximize the profit of the joint venture. Here partner A is appointed as the sponsor here. At point b the conditions defined in the contract have been defined and the two partners choose their effort levels. When at point c the real condition d is g, there is no need to change the project time. When the real condition d is b, it is impossible to finish the project in the project time defined in the contract. Then the project time limit has to be changed. The optimal extension (Δq^*) is the one which can minimize the losses of the joint venture. That can be expressed by the following.

$$W(\Delta q, \hat{i}_A, \hat{i}_B | d = b) = (t + c_f)\Delta q + c_v(\hat{i}_A, \hat{i}_B, \Delta q) + \hat{i}_A + \hat{j}_B \tag{5.6}$$

From the first order condition the optimal extension (Δq^*) can be obtained.

$$\frac{\partial c_v(\Delta q^*, \hat{i}_A, \hat{i}_B)}{\partial \Delta q} = -(t + c_f) \tag{5.7}$$

From the assumption (5.4), the interior point solution can be calculated. For simplicity, $\Delta q^* = \Delta q^*(\hat{i}_A, \hat{i}_B)$. At point b, when partner A and partner B choose their effort levels they want to minimize their expected loss.

$$\min_{i_A, i_B} \pi\{(t + c_f)\Delta q^*(i_A, i_B) + c_v(i_A, i_B, \Delta q^*(i_A, i_B))\} + i_A + i_B \tag{5.8}$$

The first order of this problem can be expressed as:

$$-\pi\Big\{(t + c_f)\frac{\partial \Delta q^*}{\partial i_A} + \frac{\partial c_v^*}{\partial \Delta q^*}\frac{\partial \Delta q^*}{\partial i_A} + \frac{\partial c_v^*}{\partial i_A}\Big\} = 1 \tag{5.9a}$$

$$-\pi\Big\{(t + c_f)\frac{\partial \Delta q^*}{\partial i_B} + \frac{\partial c_v^*}{\partial \Delta q^*}\frac{\partial \Delta q^*}{\partial i_B} + \frac{\partial c_v^*}{\partial i_B}\Big\} = 1 \tag{5.9b}$$

Where $c_v^* = c(i_A, i_B, \Delta q^*(i_A, i_B))$. Substiting (5.7) into the formulas (5.9a) and (5.9b). The optimal effort level i_A^*, i_B^* can be expressed as

$$-\pi\frac{\partial c_v^*(\Delta q^*(i_A, i_B), i_A, i_B)}{\partial i_A} = 1 \tag{5.10a}$$

$$-\pi\frac{\partial c_v^*(\Delta q^*(i_A, i_B), i_A, i_B)}{\partial i_B} = 1 \tag{5.10b}$$

Here, the variable cost function c_v is:

$$c_v(i_A, i_B, \Delta q) = \Delta q^{-1} {i_A}^{-a} {i_B}^{-b} \tag{5.11}$$

Where $a > 0$, $b > 0$. It can be verified that the variable cost function satisfied with the assumption (5.3a)-(5.3d), (5.4) and (5.5). By substituting the effort levels $\hat{i}_A, \hat{i}_B$ same as the one used in the formula (5.7) into (5.11), the optimal project time can be expressed as:

$$\Delta q^* = \Big\{(t + c_f)\hat{i_A}^a \hat{i_B}^b\Big\}^{-\frac{1}{2}} \tag{5.12}$$

From (5.10a) and (5.10b)

$$\pi a(\Delta q^*)^{-1} {i_A}^{-a-1} {i_B}^{-b} = 1 \tag{5.13a}$$

$$\pi b(\Delta q^*)^{-1} {i_A}^{-a} {i_B}^{-b-1} = 1 \tag{5.13b}$$

Solving this function, the optimal effort levels i_A^* and i_B^* can be obtained as:

$$i_A^* = \left\{\pi a^{1+\frac{b}{2}} b^{-\frac{b}{2}} (t+c_f)^{\frac{1}{2}}\right\}^{\frac{2}{a+b+2}} \tag{5.14a}$$

$$i_B^* = \left\{\pi a^{-\frac{a}{2}} b^{1+\frac{a}{2}} (t+c_f)^{\frac{1}{2}}\right\}^{\frac{2}{a+b+2}} \left(= \frac{b}{a} i_A^*\right) \tag{5.14b}$$

5.3.3 The Partner Style Joint Ventures

In this section, all the partners of the joint venture are equal and they make decisions by negotiation. This kind of joint ventures are also called partnership. It is different from the sponsor style. All the partners maximize their own profit when they choose their effort level. The profit of the joint venture will be allocated between the partners according to their participant share. The expected profit $U_{jointventure}(i_A, i_B, \Delta q)$ which joint venture can get from the contract between the joint venture and the client can be expressed by the following formula.

$$U_{jointventure}(i_A, i_B, \Delta q) = p_0 - \pi\{(t+c_f)\Delta q + c_v(\Delta q, i_A, i_B)\} \tag{5.15}$$

At point c the partners chose their own effort level $\hat{i}_A$, $\hat{i}_B$, and if the real condition realized as $d = b$, there is no need to change the project time. The optimal extension of project time can be calculated by minimizing the loss of the joint venture.

$$\min_{\Delta q}(t+c_f)\Delta q + c_v(\hat{i}_A, \hat{i}_B, \Delta q) \tag{5.16}$$

The optimal condition of this problem is same with (5.7), that is to say, the optimal extension problem is same with the sponsor style. The expected profits of partner A and partner B can be expressed as:

$$U_A(i_A, i_B, \Delta q^*(i_A, i_B)) = \alpha U_{jointventure}(i_A, i_B, \Delta q^*(i_A, i_B)) - i_A \tag{5.17a}$$

$$U_B(i_A, i_B, \Delta q^*(i_A, i_B)) = (1-\alpha) U_{jointventure}(i_A, i_B, \Delta q^*(i_A, i_B)) - i_B \tag{5.17b}$$

Each partner choose his effort level by maximizing his expected profit.

$$-\alpha\pi\frac{\partial c(i_A, i_B, \Delta q^*(i_A, i_B))}{\partial i_A} = 1 \tag{5.18a}$$

$$-(1-\alpha)\pi\frac{\partial c(i_A, i_B, \Delta q^*(i_A, i_B))}{\partial i_B} = 1 \tag{5.18b}$$

The optimal effort level of the partners is a Nash equilibrium solution which is satisfied with the formulas (5.18a) and (5.18b). The same variable cost function as (5.11) can be used, then the formula (5.18a)and (5.18b) can be expressed as:

$$\alpha\pi a(\Delta q^*)^{-1}{i_A}^{-a-1}{i_B}^{-b} = 1 \tag{5.19a}$$

$$(1-\alpha)\pi b(\Delta q^*)^{-1}{i_A}^{-a}{i_B}^{-b-1} = 1 \tag{5.19b}$$

Δq^* is same with (5.12). The optimal effort level i_A°, i_B° can be obtained from this formula.

$$i_A^\circ = \left\{\alpha^{1+\frac{b}{2}}(1-\alpha)^{-\frac{b}{2}}\pi a^{1+\frac{b}{2}}b^{-\frac{b}{2}}(t+c_f)^{\frac{1}{2}}\right\}^{\frac{2}{a+b+2}} \tag{5.20a}$$

$$i_B^\circ = \left\{\alpha^{-\frac{a}{2}}(1-\alpha)^{1+\frac{a}{2}}\pi a^{-\frac{a}{2}}b^{1+\frac{a}{2}}(t+c_f)^{\frac{1}{2}}\right\}^{\frac{2}{a+b+2}} \left(=\frac{(1-\alpha)b}{\alpha a}i_A^\circ\right) \tag{5.20b}$$

Here, the problem that the participant share is decided endogenously is analyzed. The second part of the formula (5.15) on α can be minimized to calculate the optimal share. The part in { } can be changed into:

$$2\pi(t+c_f)^{\frac{1}{2}}{i_A^\circ}^{-\frac{a}{2}}{i_B^\circ}^{-\frac{b}{2}} \tag{5.21}$$

Pay attention to this part ${i_A^\circ}^{-\frac{a}{2}}{i_B^\circ}^{-\frac{b}{2}}$, and use (5.20a) and (5.20b), it can be changed into:

$${i_A^\circ}^{-\frac{a}{2}}{i_B^\circ}^{-\frac{b}{2}} = \Omega\left\{\alpha^{-\frac{a}{a+b}}(1-\alpha)^{-\frac{b}{a+b}}\right\}^{-\frac{a+b}{a+b+2}} \tag{5.22}$$

Whereas

$$\Omega = \left(a^{\frac{a}{a+b}}b^{\frac{b}{a+b}}(t+c_f)^{\frac{1}{2}}\right)^{-\frac{a+b}{a+b+2}} \tag{5.23}$$

Maximizing the profit of the joint venture in share α.

$$\min_{\alpha} \alpha^{-\frac{a}{a+b}}(1-\alpha)^{-\frac{b}{a+b}} \tag{5.24}$$

The optimal share α^* which guarantees the maximization of the profit of the joint venture can be expressed as

$$\alpha^* = \frac{a}{a+b} \tag{5.25}$$

The optimal effort level of a partner with optimal share α^* can be calculated by the following problem.

$$i_A^\circ = \left\{ \left(\frac{a}{a+b} \right) \left(\frac{a}{b} \right)^{\frac{b}{2}} \right\}^{\frac{2}{a+b+2}} i_A^* \tag{5.26a}$$

$$i_B^\circ = \left\{ \left(\frac{b}{a+b} \right) \left(\frac{b}{a} \right)^{\frac{a}{2}} \right\}^{\frac{2}{a+b+2}} i_B^* \tag{5.26b}$$

From the above the following proposition can be proposed:

When partner style joint ventures are compared with the sponsor style joint ventures the following conclusion can be found: there exists $s^\circ(> 1)$, when $a > s^\circ b$ partner A will make excessive effort, while partner B make insufficient effort; when $b/s^\circ < a < s^\circ b$ both the partners make insufficient effort; when $b > s^\circ a$, partner A make insufficient effort while partner B make excessive effort. Proof can be found in the Appendix C .

In the proposition, the value of parameter a depends on the inter-dependence between the technologies of the partner. If partner A depends on partner B for technology, parameter a will be very large. When the joint venture use sponsor style of governance structure, partner A will work as sponsor. According to the Proposition, when the joint venture use the partner style governance structure, partner A which is superior in technology will make excessive effort. The larger the difference between the partners in technology capacity, the more possible the inferior partner will execute moral hazard. Formula (5.25) indicates if partner A is more superior his participation share will be larger. If the joint venture uses the sponsor style governance structure, the object that maximizes the profit of the joint venture can be achieved. From the viewpoint of the efficiency, the sponsor style is more efficient than the partner style. The conclusion that in the integrated type of joint venture the sponsor style is more efficient than the partner style can be obtained. To make the sponsor style work well it is necessary that the partners trust with each other and they believe that the sponsor will make the decisions that maximize the profit of the joint venture. Otherwise it is impossible that the sponsor style achieve efficiency.

5.4 Model of Separated Type Joint Ventures

5.4.1 Assumption

In the separated type of joint ventures, the partners divide the project into subprojects, and each partner undertake one subproject and undertake the responsibility of this subproject. For example, when the project is a hydro electric power plant, the project can be divided into dam, and electric generation (1996[67]). The division of the project depends on the technology. Here it is assumed to be exogenous.

In the separated type joint ventures the variable cost of each subproject is undertaken by the given partner. The procedure of this model is same with the Figure 5.3. At point c both real conditions of both partners' subprojects realized. At point b the partners choose their own effort level i_A, i_B. The effort levels of the partners are assumed to be independent, that is to say, there is no substitution or complementation between the effort levels of the partners. If at point c, the real conditions are $d = (d_A, d_B)$. Let $d_A, d_B \in \{g, b\}$ denote the real conditions of the subprojects of each partner. The probability of each set of conditions of both partners are: $\text{Prob}[d = (b, g)] = \pi_1$, $\text{Prob}[d = (g, b)] = \pi_2$, $\text{Prob}[d = (b, b)] = \pi_3$, $\text{Prob}[d = (g, g)] = \pi_4$, the probabilities are exogenous, and $\sum_i \pi_i = 1$. Let $C^A(i_A, \Delta q, d_A)$ and $C^B(i_B, \Delta q, d_B)$ denote the variable cost function of partner A and B. The variable costs of the partners can be defined as:

$$C^A(i_A, \Delta q, d_A) = \begin{cases} c_0^A & \text{if } d_A = g \\ c_0^A + c^A(i_A, \Delta q) & \text{if } d_A = b \end{cases} \tag{5.27}$$

$$C^B(i_B, \Delta q, d_B) = \begin{cases} c_0^B & \text{if } d_B = g \\ c_0^B + c^B(i_B, \Delta q) & \text{if } d_B = b \end{cases} \tag{5.28}$$

When the project is delayed partner A and partner B need additional cost to finish their subprojects. $c^A(\Delta q, i_A)$ and $c^B(\Delta q, i_B)$ can be calculated by

$$c^j(i_j, \Delta q) = {c_f}^j \Delta q + {c_v}^j(i_j, \Delta q) \tag{5.29}$$

$$\text{for } j = A, B$$

The additional variable cost function is also assumed as (5.11). That is

$$\frac{\partial {c_v}^j(i_j, \Delta q)}{\partial i_j} < 0, \ \frac{\partial {c_v}^j(i_j, \Delta q)}{\partial \Delta q} < 0 \tag{5.30}$$

$$\frac{\partial^2 {c_v}^j(i_j, \Delta q)}{\partial i_j \Delta q} < 0 \ \text{ for } j = A, B \tag{5.31}$$

When the project is delayed, the joint venture should pay the client compensation t per unit time delay. The compensation to the client should be shared among the partners. Here the subproject delayed can be defined clearly. Under this condition, the share of the agreement compensation is defined as: 1) If only one subproject is delayed, the compensation to the client should be paid by the partner who undertakes the subproject; at the same time this partner has to pay compensation to the other partner for the fixed cost incurred during the period of delay. How long should the project time is extended is decided by the delay partner. 2) If both the subprojects are delayed, the project time extension and shares of the compensation to the client will be decided by negotiation. The assumption 2) comes from the incomplete contract theory. Because it is impossible to define all the conditions which cause delay in the agreement ex ante, it is impossible to define how to share the compensations when both subprojects are delayed in the contract or in the agreement. So it is necessary to make a decision about how long the project time will be extended and how to share the compensations between the partners by negotiation between the partners.

5.4.2 The Sponsor Style Joint Ventures

To compare the efficiency of the two styles, the sponsor style will be viewed as a benchmark. In the sponsor style, the sponsor will decide the material and risks shares to maximize the profits of the joint venture. Here partner A will act as the sponsor. Partner A will decide the effort levels of both partners to maximize the profit of the joint venture. At point c, when the real condition is realized, the optimal project time extension should satisfy the following conditions. The effort levels chosen at point b is denoted by $\hat{i}_A$, $\hat{i}_B$.

The optimal project time extension depends on the realized real conditions.

$$\frac{\partial {c_v}^A(\hat{i}_A, \Delta q_1^*)}{\partial \Delta q} = -L \quad \text{if } d = (b, g) \tag{5.32a}$$

$$\frac{\partial {c_v}^B(\hat{i}_B, \Delta q_2^*)}{\partial \Delta q} = -L \quad \text{if } d = (g, b) \tag{5.32b}$$

$$\frac{\partial [{c_v}^A(\hat{i}_A, \Delta q_3^*) + {c_v}^B(\hat{i}_B, \Delta q_3^*)]}{\partial \Delta q} = -L \quad \text{if } d = (b, b) \tag{5.32c}$$

Where, $L = t + {c_f}^A + {c_f}^B$ the optimal effort levels can be calculated by the following problem.

$$\begin{aligned}\min_{i_A, i_B} {c_0}^A + {c_0}^B &+ \pi_1[L\Delta q_1^*(i_A) + {c_v}^A(\Delta q_1^*(i_A), i_A)] + \pi_2[L\Delta q_2^*(i_B) + {c_v}^B(\Delta q_2^*(i_B), i_B)] \\ &+ \pi_3[L\Delta q_3^*(i_A, i_B) + {c_v}^A(\Delta q_3^*(i_A, i_B), i_A) + {c_v}^B(\Delta q_3^*(i_A, i_B), i_A)]\end{aligned} \tag{5.33}$$

The optimal effort levels can be calculated by substituting the optimal conditions (5.32a)-(5.32c) into the first order condition of the above formula.

$$-\pi_1 \frac{\partial {c_v}^A(\Delta q_1^*(i_A), i_A)}{\partial i_A} - \pi_3 \frac{{c_v}^A(\Delta q_3^*(i_A, i_B), i_A)}{\partial i_A} = 1 \tag{5.34a}$$

$$-\pi_2 \frac{\partial {c_v}^B(\Delta q_2^*(i_B), i_B)}{\partial i_B} - \pi_3 \frac{{c_v}^B(\Delta q_3^*(i_A, i_B), i_B)}{\partial i_B} = 1 \tag{5.34b}$$

For simplicity, the variable cost function ${c_v}^A(\cdot)$ and ${c_v}^B(\cdot)$ are defined as the following.

$${c_v}^A(i_A, \Delta q) = \Delta q^{-1} {i_A}^{-a} \tag{5.35a}$$

$${c_v}^B(i_B, \Delta q) = \Delta q^{-1} {i_B}^{-b} \tag{5.35b}$$

Whereas $a,\ b > 0$. Here the defined variable cost functions can be verified to satisfy the assumptions (5.30) and (5.31). From (5.32a)-(5.32c) the following formulas can be obtained.

$$\Delta {q_1}^* = \left(L\hat{i_A}^a\right)^{-\frac{1}{2}} \tag{5.36a}$$

$$\Delta {q_2}^* = \left(L\hat{i_B}^b\right)^{-\frac{1}{2}} \tag{5.36b}$$

$$\Delta {q_3}^* = \left\{\frac{L}{(\hat{i_A}^{-a} + \hat{i_B}^{-b})}\right\}^{-\frac{1}{2}} \tag{5.36c}$$

Whereas, $\pi_1 = \pi_2 = \Pi$ and $a = b = \rho$. From (5.34a) and (5.34b)

$$\{\Pi\rho(\Delta q_1^*)^{-1} + \pi_3\rho(\Delta q_3^*)^{-1}\}{i_A}^{-\rho-1} = 1 \tag{5.37a}$$

$$\{\Pi\rho(\Delta q_2^*)^{-1} + \pi_3\rho(\Delta q_3^*)^{-1}\}{i_B}^{-\rho-1} = 1 \tag{5.37b}$$

Substituting (5.36a)-(5.36c) into the above, then:

$$i_A^* = i_B^* = \left\{\left(\Pi + \frac{\pi_3}{\sqrt{2}}\right) L^{\frac{1}{2}}\rho\right\}^{\frac{2}{\rho+2}} \tag{5.38}$$

5.4.3 The Partner Style Joint Ventures

In this section, the partner style joint ventures in which each partner undertakes separated subproject is discussed. At point c the real conditions realize. How to decide the project time extension is analyzed. At first, the real conditions are $d = (g, b),\ (b, g)$, only the project time of the subproject which realized condition is b should be changed. The compensation for the delay will be undertaken by the partner whose subproject is delayed. The project time extension at point c satisfies the optimal condition for extension (5.32a) and (5.32b). When the real conditions are $d = (b, b)$, the project time extension will be negotiated between the partners. If the partners can not agree with each other, they have to pay large penalties P_A and P_B. As the result of the negotiation, the project time extension which satisfies with (5.32c) will be adopted. The project time extension Δq_3^* is deciding by minimizing the cost. The changed project time adopted by the partners satisfies with (5.32a)-(5.32c).

From the above, only when the conditions are $d = (b, b)$, the project time change will be decided by negotiation between the partners. The status quo of the negotiation is the profits of the partners $(-P_A, -P_B)$ when the partner fail to achieve agreement. The reduced loss of the joint venture $\Delta W(\Delta q_3^*)$ due to the change of the project time can be expressed as:

$$\{P_A - c_v^A(\Delta q_3^*, i_A)\} + \{P_B - c_v^B(\Delta q_3^*, i_B)\} - L\Delta q_3^* \tag{5.39}$$

Here the discount rates of both partners are assumed to be the same. Negotiation solution (Nash, 1950[95]) of partner A and B are

$$\left(-P_A + \frac{1}{2}\Delta W(\Delta q_3^*), -P_B + \frac{1}{2}\Delta W(\Delta q_3^*)\right)$$

So, at point b the expected profits of partner A and B can be expressed as:

$$\begin{aligned}U_A(\Delta q_3^*(i_A,i_B),i_A,i_B)) &= -\pi_1\{t\Delta q_1^*(i_A)+c_A(\Delta q_1^*(i_A),i_A)\}\\ &-\pi_3\{P_A-\frac{1}{2}\Delta W(\Delta q_3^*(i_A,i_B),i_A,i_B)\}-i_A\\ U_B(\Delta q_3^*(i_A,i_B),i_A,i_B)) &= -\pi_2\{t\Delta q_2^*(i_B)+c_B(\Delta q_2^*(i_B),i_Bj)\}\\ &-\pi_3\{P_B-\frac{1}{2}\Delta W(\Delta q_3^*(i_A,i_B),i_A,i_B)\}-i_B\end{aligned}$$

Substituting (5.32a) and (5.32c) into the above, the effort levels of the partners i_A, i_B as a Nash negotiation solution can be obtained.

$$-\pi_1\frac{\partial c_v^A(\Delta q_1^*(i_A),i_A)}{\partial i_A}-\frac{\pi_3}{2}\left\{\frac{\partial c_v^A(\Delta q_3^*(i_A,i_B),i_A)}{\partial i_A}\right\}=1 \tag{5.40a}$$

$$-\pi_2\frac{\partial c_v^B(\Delta q_2^*(i_B),i_B)}{\partial i_B}-\frac{\pi_3}{2}\left\{\frac{\partial c_v^B(\Delta q_3^*(c,i_B),i_B)}{\partial i_B}\right\}=1 \tag{5.40b}$$

The same variable cost function with the previous sections (5.35a) and (5.35b) is used here. And $\pi_1=\pi_2=\Pi$ and $a=b=\rho$. The formula (5.40a) and (5.40a) can be changed into.

$$\{\Pi\rho(\Delta q_1^*)^{-1}+\frac{\pi_3}{2}\rho(\Delta q_3^*)^{-1}\}{i_A}^{-\rho-1}=1 \tag{5.41a}$$

$$\{\Pi\rho(\Delta q_2^*)^{-1}+\frac{\pi_3}{2}\rho(\Delta q_3^*)^{-1}\}{i_B}^{-\rho-1}=1 \tag{5.41b}$$

Substituting (5.36a)-(5.36c) into the above and resolving the problem

$$i_A^\circ=i_B^\circ=\left\{\left(\Pi+\frac{\pi_3}{2\sqrt{2}}\right)L^{\frac{1}{2}}\rho\right\}^{\frac{2}{\rho+2}} \tag{5.42}$$

Comparing the formula (5.42) with (5.38), $i_A^\circ=i_B^\circ<i_A^*=i_B^*$ is clarified. In the separated type of joint venture, both partners of the partner style make insufficient effort.

5.5 Joint Venture Type and Efficiency

5.5.1 Comparison the Efficiency of the Joint Ventures

The results derived from above are summarized in Table (5.2). First, the partners choose the project time extension when risk occurs that minimizes the loss of the joint venture no matter in which type of joint ventures. The mechanism of how to decide the project time extension is essentially different in the two types of joint ventures. The joint venture agreement is an incomplete contract. If it is verified that the risk occurs, the project time change should be decided by negotiation. It is possible to make the decision that maximizes the profit of the joint venture, because in the integrated type joint ventures how to share the risks between the partners is defined clearly in the contract. When the risks occur it is easy for the partners to agree on the project time extension by negotiation. The incompletement of the joint venture agreement is not a problem for the integrated type joint venture. In the separated type joint ventures if both partners delayed their subprojects, they have to negotiate to decide the extension. This is different with the integrated joint venture, because there are some conflicts between the interests of the partners. If the sponsor can not coordinate the partners to reach as agreement, more cost will arise.

Table 5.2: Comparing the Efficiency of Joint Ventures

Type of Joint Venture		EOT	Effort Level
Integrated Type	Sponsor style	Efficienct	Efficienct
	Partner style	Efficient	Inferior
Separated Type	Sponsor style	Efficienct	Efficienct
	Partner style	Efficient	Inferior

Next, by comparing the effect of the structure of the joint venture agreement on the effort level of the partners, the following result can be obtained. The partner style joint venture agreements is always less efficient than the sponsor style whether it is the integrated type or the separated type joint ventures. In the integrated type joint ventures there is a mechanism which causes the low level of effort, called partnership by Holmström. That is to say in the partner style joint ventures of the integrated type, losses are shared between the partners. Only part of the marginal benefit of the effort the partner does can be gotten by him/her. Thus the partner will only choose a low level of effort. It is necessary to choose the governance structure with one sponsor to decide effort levels of each partner. The joint venture type which is used in Japan with one partner acting as the sponsor will induce the efficient effort level of the partners. Then why the sponsor style is always used in reality can be understood.

In the separated type joint venture if only one partner delayed his subproject, the losses will be undertaken by this partner. The losses can be internalized in the joint venture. When both subprojects are delayed the project time extension would be decided by negotiation between the partners. If both subprojects are delayed it will be the same as with the integrated type joint ventures. That is to say, low effort level will be induced. It is the same result as the partner style in the integrated type joint venture. In the separated type joint venture, the sponsor style joint ventures are also more efficient than the partner style joint ventures. The separated type joint venture is suitable for a project in which the risks can be divided clearly according to the subprojects. When it is difficult to use the separated type joint venture because of technology it is preferred to use the integrated type joint venture. If it is impossible to set up a sponsor style joint venture which is based on the trust between the partners, the partners may face the moral hazard problem.

5.5.2 The Effect of the Agreement Compensation

First, in the integrated type of joint ventures the inefficiency is not caused by the incompletion of the joint venture agreement but by the problem called moral hazard by Holmström. Holmström proved that even though their is no risks between the result and partners' action there exists a moral hazard. By forcing the partners in the partnership to pay the penalty the moral hazard problem can be resolved. In the model of the integrated type of joint ventures in 5.3, the compensations are assumed to be the same as with the loss of the client t. The condition that the compensation can be larger than the losses of the client is considered. The compensation of partner A and B can be assumed to be different. Under this condition, to make sure that both partners will choose optimal social effort levels, the compensation l_A^*, l_B^* which satisfy with the following formula are optimal.

$$\frac{t + c_f}{l_A^* + c_f} = \left(\frac{a}{a+b}\right)^2 \left(\frac{a}{b}\right)^b \tag{5.43a}$$

$$\frac{t + c_f}{l_B^* + c_f} = \left(\frac{b}{a+b}\right)^2 \left(\frac{b}{a}\right)^a \tag{5.43b}$$

It is impossible for the third party to define the optimal compensation ex ante. It is impossible to define different compensations, here the compensation can be assumed to be larger than the loss. Such the assumption $\alpha = 1/2$ is made.

$$(t + c_f)^{\frac{1}{2}} = \frac{1}{2}(l^* + c_f)^{\frac{1}{2}} \Leftrightarrow l^* = 4t + 3c_f \tag{5.44}$$

When the compensation is chosen as l^* which satisfies with the above formula. From (5.14a), (5.14b) and (5.20a), (5.20b), the efficient effort levels of the partners can be induced. By defining larger compensations in the separated type of joint ventures efficient effort levels can also be deduced. From (5.44) to get efficient effort levels it is possible that the amount of the compensation l^* to be unreasonably high. When the compensation is defined very high, it is possible no one will take part in the bid for the project.

5.6 Conclusion

In this chapter, the integrated type and the separated type joint venture agreements are analyzed. Different types of the joint venture agreements define different types of risks share between the partners. The effect of the joint venture type on the effort levels of the partners is also analyzed. The efficiencies of different type of joint venture agreements are compared. The main results of this research can be summarized as:

In both types of joint venture agreements, the principle of decision of the project time extension ex post is to minimize the loss of the joint venture. In the separated type of joint venture it is not always that the partners can agree with each other about the project time extension, the partners have to undertake some cost to negotiate on the project time extension. In both types of joint ventures, the sponsor style joint venture which is based on the trust between the partners is more efficient than the partner style joint venture in which the partners are equal. The separated type of joint venture is more suitable for the project which can be divided into several independent subprojects. When the project can not be divided into subprojects because of the technology needed, and it is impossible to set up a separated type joint venture, it is possible that the project will be executed inefficiently. To give an incentive to the partners to execute the project efficiently compensations which are larger than the real losses are needed. Under this condition it is possible that the contractors can not get any profit.

In this chapter, the mechanisms of risk-sharing in the two types of joint ventures are analyzed by using very simple model. It is very clear that these two types of joint ventures are different with each other. In realities, there are many risks in the joint venture, it is very necessary to find how these risks are shared between the partners in the joint venture. In realities there are many rules which are widely accepted in construction industry are not written in the joint venture agreement. Some of these rules are related with the risk-sharing between the partners in the joint venture. It is necessary to identify these rules and to make it clear if they can provide an efficient mechanism to share risks between the partners.

Chapter 6

Risk Sharing in Joint Ventures: When There Are Multi-risks

6.1 Introduction

The complex nature of the construction business activity, process, environment and organization makes the participants widely exposed to a high degree of risk. Risk management is an important aspect which affects the success of the joint venture or the profitability of the project for the contractors. The first step of risk management is to identify all risks. After all the risks factors are identified it is important to define who will be responsible for which risk, in other words, defining risk allocation or risk sharing. Because of the complexity of construction activities contractors set up joint ventures to undertake a project to share risks. There are many researches about how to allocate risks among all the related participants and they also gave some principals on how to allocate the risks among the participants. Abrahamson (1973[1]) has suggested that it is proper for a contracting party to bear risk in any one of the following five cases: If the risk is of loss due to his/her own willful misconduct or lack of reasonable efficiency or care; If he can cover a risk by insurance and allow for the convenient and practicable for the risk to be dealt with in this way; if the preponderant economic benefit of running the risk accrues to him; If it is in the interests of efficiency to place the risk on him; If, when the risk eventuates, the loss happens to fall on him in the first instance, and there is no reason under any of the above headings to transfer the loss to another, or it is impracticable to do so. The previous managerial literature on risk allocation (Domberger, 1998[118]; Klein, 1998[91]; Hood et al., 2002[62]; European commission, 2003[31]; Guasch, 2004[82]; Medda, 2004[39]; Omoto et al., 2001[69]) enounces two risk allocation criteria: the risk should be allocated to the party best able to manage it (criterion 1); the risk should be allocated to the least risk-bearing cost partner (criterion 2).

According to the risk allocation principles risks will be allocated to the more capable partner, under this condition, it will make this partner undertake too many risks. Sometime, it will make this partner default when many risks realize at the same time. As an effective risk manager, one can not only consider how to allocate the risks among the participants, he should also know under some conditions it is more efficient to share the risks among the partners compared with allocating a whole risk to some party.

About risk sharing there are many researches, some of them use expected utility theory; some of them use un-expected utility theory. There is no research about risk sharing when there are multiple risks. Borch (1962[19]) condition is a famous Pareto efficient risk allocation condition, the condition says that if a risk allocation is Pareto efficient, it must be that the marginal rates of substitution between consumption in state s and consumption in state t are the same of all individuals in the population. Olsen (2005[97]), Shavell(1979[115]) used principal and agent model to analyze the risk sharing problem. Itoh (1991[60]) used the principal-multiagent model to analyze the effects of coalitional behavior, and found under some conditions coalition can improve the principal's welfare. The efficient risk-sharing is analyzed by Machina (1995[84]) in a non-expected utility framework, in his research, he showed all important results derived with expected utility carry over to frechet-differentiable preference functional, which generalized expected utility by replacing the independence axiom with a much weaker differentiability assumption; Schmidt (1999[114]) used the other kind of non-expected utility called dual theory to analyze efficient risk-sharing problem, he found all efficient risk-sharing arrangement in the case of dual expected utility (DEU) theory assigns the whole risk to the least risk-averse individual while all other individuals receive a constant payment. Chateauneuf et al. (2000[27]) characterized Pareto optimal risk-sharing when the agents are not Von Neumann-Morgenstern (vNM) expected utility case, but are Choquet-expected utility case, and found when the agents have capacities that are the convex transform of some probability distribution, Pareto-optima can be realized in the two-state case if the intersection of the core of agent's capacities is non-empty. All the literatures about risk sharing are about how to share a risk between or among the related parties.

In the former chapter, the efficiency of risk sharing mechanisms in different types of joint venture agreements when there is only one risk (time limit extension) is analyzed. Efficiency can be realized when the responsibilities of the partners can be divided clearly. In this chapter a risk sharing model is built when there are two independent project risks in the separated type of joint ventures. The partners can improve their certainty equivalent values by using option to choose their preferable share of the project risks. In this model partners can make co-insurance by undertaking some loss of their cooperators and transferring their loss to their cooperators when the losses beyond some amount. If the partners can share all the costs that they used to deal with the risks, there is no moral hazard problem. At the same time, partners can share their risks.

6.1.1 Bargaining Powers of the Partners

When the partners make the decision to set up a joint venture, they define all the things by bargaining with each other. The results of their bargaining depend on their relative bargaining powers. About the factors which affect the relative bargaining powers of the partners in the joint venture, there are many researches. Yan et al. (1994[133]) identified the components of bargaining power. They classified the factors into two context-based and seven resource-based. The two context-based bargaining power components are: alternatives available and strategic importance. The seven resource-based components are: technology, management expertise, global service support, local knowledge, product distribution, material procurement and equity.

Before the joint venture is set up, the bargain is operated by the parent companies of the two partners. About the factors which affect the relative bargaining powers of the parent of the partners, there are also some researches. Blodgett (1991[14]) identified five factors influencing the bargaining power of joint venture parents. And in his paper, he also got the relationship between bargaining power and resource contribution by ranking each of the resources according to the criteria of tacitness and appropriability. The factors ordered as government suasion, technology, local knowledge/marketing skills, control of intra-system transfer and financial capital provided for the venture. Mjoen et al. (1997[93]) found that the following factors affect the bargaining power of the partners of the joint ventures: a parent's relative resource contribution, the parent's equity share, the parent's specific control, the parent's overall control.

According to the previous literature, the relative bargaining power of international joint venture partners arises from the interplay of several factors including: the perceived strategic importance of (Yan et al., 1994[133]) and the resource linkage between the international joint venture and the parent firm (Lecraw, 1984[77]; Kumar et al., 1998[73]); the amount and availability of alternatives facing the parent firm (Yan et al., 1994[133]); the strategic resources that the respective partners will contribute to the venture (Poynter, 1986[105]; Blodgett, 1991[14]; Mjoen et al., 1997[93]); and host government restrictions (Benjamin, 1990[12]).

In this research, the relative bargaining powers of the partners are exogenously given. When the parent companies choose their cooperators, they should pay attention to the factors which affect their relative bargaining powers. Or when they bargain on the details of the joint ventures they should know the merits and demerits of their own and their cooperators'. If a partner can make good use of his merits, and avoiding his demerits, he can make the results of the bargain more beneficial to him.

6.1.2 Portfolio Theory

Portfolio analysis is widely used by financial investors to create robust portfolios that produce efficient outcomes under various economic conditions. Efficient portfolios are defined by the following properties: they maximize the expected return for any given level of risk, while minimizing risk for every given level of expected return. Properly designed portfolios yield a portfolio effect—risk reduction attained through diversification.

According to the theory of joint ventures or partnerships many researchers argued that because in this kinds of organizations, partners share the fruits of their joint work, it is easy to cause the problem which is called as free-ride or moral hazard. So they argued that efficiency can be improved by dividing the tasks of each partner clearly. But it will cause another problem because it will decrease the portfolio effect. When they divide the whole project into two subprojects, they also divide all project risks into two groups, and then portfolio effect is lost.

This chapter is organized as: In Section 6.2, a model is built to analyze how to share controllable risks between two risk-averse partners. In Section 6.3 a model is build to analyze how to share uncontrollable risks between two risk-averse partners. In the last Section 6.4, the conclusion of this chapter is summarized.

6.2 Risk Sharing Bargaining Model

In this section a bargaining model of risk sharing between the partners in the joint venture is introduced. In this model the partners are permitted to bargain on their shares of each risk to construct their portfolios.

6.2.1 Assumption of the Model

There is a project, which can be divided into two subprojects clearly, subproject 1 and subproject 2. There are two project risks which belong to each subproject denoted by R_1 and R_2 respectively. These two project risks are independent. The losses from the project risks are assumed to be normally distributed. As we know that the losses of the risks can be decreased to some degree by the efforts of the contractor, but can not be decreased to 0. The part of losses that can be decreased is called controllable loss; the part that can not be decreased is called uncontrollable loss. In the joint venture, partner A will undertake subproject 1, partner B undertakes subproject 2.

e_1^A and e_2^B are used to denote the effort levels chosen by partner A and partner B to deal with their project risks (partner A undertakes project risk R_1, partner B undertakes project risk R_2). The effort levels chosen by the partners are assumed that can not be verified. The distribution function of the project risks can be defined as $R_1 = c_A(e_1^A) + \epsilon_1$, $\epsilon_1 \sim N(\phi_1, \sigma_1^2)$; $R_2 = c_B(e_2^B) + \epsilon_2$, $\epsilon_2 \sim N(\phi_2, \sigma_2^2)$. $c_A(e_1^A)$ denotes the part of risk loss that can be controlled by partner A which decreases with the increasing of the effort level e_1^A; $c_B(e_2^B)$ denotes the part of risk loss that can be controlled by partner B which decreases with the increasing of the effort level e_2^B. ϵ_1 denotes the part of risk loss that can not be controlled by partner A; ϵ_2 denotes the part of risk loss that can not be controlled by partner B. $f_A(e_1^A)$ denotes the cost of partner A's effort to deal with project risk R_1 which increases with the increasing of effort level e_1^A; $f_B(e_2^B)$ denotes the cost of partner

B's effort to deal with project risk R_2 which increases with the increasing of effort level e_2^B. The distribution functions of the risks are assumed known by both partners. The effort cost functions are also common knowledge.

All the costs of dealing with the project risk which includes their effort costs and losses of risk can be verified. So partners can define the cost in their agreement. $I_A = \gamma I$ and $I_B = (1-\gamma)I$, where I denotes the benefit of the whole project, γ is defined by the subprojects or their participant shares which is exogenously defined.

6.2.2 Model

Both partners undertake unlimited liabilities and they are all risk-averse. Their certainty equivalent values can be defined as a function of the expected values of risks and variances of risks. Here the certainty equivalent value of the partner j is defined as $Q_j = E - k_j\sigma^2$,

To decrease their risks, partners can construct their portfolios. Here partners choose their shares of different risks by options. When the loss of the subproject 1 is greater than P_1, partner B will undertake the loss by share α which is $\alpha[\hat{R}_1 + c_A(e_1^A) + f_A(e_1^A)]$. When the cost of subproject 2 is greater than P_2 partner A will compensate the cost by share β which is $\beta[\hat{R}_2 + c_B(e_2^B) + f_B(e_2^B)]$. Here $\hat{R}_i$ means the part of the loss of risk i that can not be controlled by partners. This assumption is suitable in the real world, because the partners set up a new company to undertake the project. In this new company, they share the same accounting system, so that all the cost used by one partner can be known by the other partner. So it is realistic to make such an assumption. By using option defined as these, the partners can share their risks without bringing the moral hazard problem.

When the partners decided to undertake the project by setting up a joint venture, and there are two project risks, the realized benefits (the sum of the share of contract minus cost minus loss of risk realized) of the two partners B_A and B_B can be expressed as:

$$\begin{aligned} B_A = \gamma I - [c_A(e_1^A) + \hat{R}_1] + \alpha \max\{\hat{R}_1 + f_A(e_1^A) + c_A(e_1^A) - P_1, 0\} \\ -f_A(e_1^A) - \beta \max\{\hat{R}_2 + f_B(e_2^B) + c_B(e_2^B) - P_2, 0\} \end{aligned} \tag{6.1}$$

$$\begin{aligned} B_B = (1-\gamma) I - [c_B(e_2^B) + \hat{R}_2] + \beta \max\{\hat{R}_2 + c_B(e_2^B) + f_B(e_2^B) - P_2, 0\} \\ -f_B(e_2^B) - \alpha \max\{\hat{R}_1 + f_A(e_1^A) + c_A(e_1^A) - P_1, 0\} \end{aligned} \tag{6.2}$$

e_i^{j*} is used to denote the optimal effort level of the partner j to deal with his project risk which satisfied with $c'_j(e_i^{j*}) = f'_j(e_i^{j*})$. In the other words, the optimal effort level executed by the partner j which means at this effort level the marginal cost decreased equals the marginal effort cost. From above formula, partners are found to try their best to deal with risks. That is to say at point b, partners will choose their effort levels by maximizing their certainty equivalent values. Partners will choose optimal effort levels to maximize their certainty equivalent values. That is to say, in the options, $\max\{\hat{R}_1 + f_A(e_1^A) + c_A(e_1^A) - P_1, 0\}$ and $\max\{\hat{R}_2 + c_B(e_2^B) + f_B(e_2^B) - P_2, 0\}$, $e_1^A = e_1^{A*}$ and $e_2^B = e_2^{B*}$. In other words, by defining options properly they can share risks without moral hazard problem.

In fact, the excised price can affect the shares that partners prefer to choose in their portfolios. The partners can bargain over the amount beyond which they will share the loss, they also can bargain over the shares of the loss. In this research the amounts are assumed to be given exogenously, the partners bargain over the shares. Here $P_i = c_j(e_i^{j*}) + f_j(e_i^{j*}) + \phi_i$ is assumed to be the excised price of the option. The moral hazard problem can be resolved. The options chosen by partners can be expressed as:

$$\max\{\hat{R}_1 - \phi_1, 0\} \tag{6.3}$$

$$\max\{\hat{R}_2 - \phi_2, 0\} \tag{6.4}$$

$\max\{\hat{R}_1 - \phi_1, 0\}$ can be expressed as the right side of a truncated normal distribution of risk R_1 truncated at point ϕ_1. Similarly, $\max\{\hat{R}_2 - \phi_2, 0\}$ can be expressed as the right side of a truncated normal distribution of risk R_2 truncated at point ϕ_2. The expected values and the variances of these options can be expressed as:

$$E_A^o = \phi_1 + \sigma_1 \lambda(p_1) \tag{6.5}$$

$$E_B^o = \phi_2 + \sigma_2 \lambda(p_2) \tag{6.6}$$

$$V_A^o = \sigma_1^2 \Big[1 + p_1 \lambda(p_1) - \lambda(p_1)^2\Big] \tag{6.7}$$

$$V_B^o = \sigma_2^2 \Big[1 + p_2 \lambda(p_2) - \lambda(p_2)^2\Big] \tag{6.8}$$

Here E_j^o means the expected value of partner j's option. V_j^o means the variance of partner j's option. $\lambda(p_i) = \frac{\phi(p_i)}{1-\Phi(p_i)}$. P_i is the excised price of the option of partner j. $p_1 = \frac{\phi_1 - \phi_1}{\sigma_1} = 0$, $p_2 = \frac{\phi_2 - \phi_2}{\sigma_2} = 0$, $\lambda(p_1) = \frac{g(p_1)}{1-G(p_1)}$ and $\lambda(p_2) = \frac{g(p_2)}{1-G(p_2)}$. The formula of

$g(p_1)$, $g(p_2)$, $G(p_1)$ and $G(p_2)$ are:

$$g(p_1) = \frac{1}{\sqrt{2\pi}} e^{-\frac{p_1^2}{2}} = 0.399 \tag{6.9}$$

$$g(p_2) = \frac{1}{\sqrt{2\pi}} e^{-\frac{p_2^2}{2}} = 0.399 \tag{6.10}$$

$$G(p_1) = \int_{-\infty}^{p_1} \frac{1}{\sqrt{2\pi}} e^{-\frac{{p_1}^2}{2}} \cdot dp_1 = 0.5 \tag{6.11}$$

$$G(p_2) = \int_{-\infty}^{p_2} \frac{1}{\sqrt{2\pi}} e^{-\frac{{p_2}^2}{2}} \cdot dp_2 = 0.5 \tag{6.12}$$

Then

$$\lambda(p_i) = \frac{g(p_i)}{1 - G(p_i)} = 0.798 \tag{6.13}$$

$$E_A^o = \phi_1 + \sigma_1 \lambda(p_1) = \phi_1 + 0.798\sigma_1 \tag{6.14}$$

$$E_B^o = \phi_2 + \sigma_2 \lambda(p_2) = \phi_2 + 0.798\sigma_2 \tag{6.15}$$

$$V_A^o = \sigma_1^2 \Big[1 + p_1\lambda(p_1) - \lambda(p_1)^2\Big] = 0.363\sigma_1^2 \tag{6.16}$$

$$V_B^o = \sigma_2^2 \Big[1 + p_2\lambda(p_2) - \lambda(p_2)^2\Big] = 0.363\sigma_2^2 \tag{6.17}$$

The expected values of partners' bebefits and the variances of the partners' benefits can be calculated as:

$$\begin{aligned} E(B_A) = {} & \gamma I - [c_A(e_1^A) + \phi_1] + \alpha[\phi_1 + 0.798\sigma_1] - f_A(e_1^A) \\ & -\beta[\phi_2 + 0.798\sigma_2] \end{aligned} \tag{6.18}$$

$$\begin{aligned} E(B_B) = {} & (1-\gamma)I - [c_B(e_2^B) + \phi_2] + \beta[\phi_2 + 0.798\sigma_2] \\ & -f_B(e_2^B) - \alpha[\phi_1 + 0.798\sigma_1] \end{aligned} \tag{6.19}$$

$$V(B_A) = \sigma_1^2 - \alpha^2 0.363\sigma_1^2 + \beta^2 0.363\sigma_2^2 = (1 - 0.363\alpha^2)\sigma_1^2 + 0.363\beta^2\sigma_2^2 \tag{6.20}$$

$$V(B_B) = \sigma_2^2 + \alpha^2 0.363\sigma_1^2 - \beta^2 0.363\sigma_2^2 = (1 - 0.363\beta^2)\sigma_2^2 + 0.363\alpha^2\sigma_1^2 \tag{6.21}$$

The certainty equivalent values of the partners in the joint venture can be expressed as:

$$\begin{aligned} Q_A = {} & E(B_A) - k_A V(B_A) = \gamma I - [c_A(e_1^A) + \phi_1] + \alpha[\phi_1 + 0.798\sigma_1] - f_A(e_1^A) \\ & -\beta[\phi_2 + 0.798\sigma_2] - k_A\{(1 - 0.363\alpha^2)\sigma_1^2 + 0.363\beta^2\sigma_2^2\} \end{aligned} \tag{6.22}$$

$$\begin{aligned} Q_B = {} & E(B_B) - k_B V(B_B) = (1-\gamma)I - [c_B(e_2^B) + \phi_2] + \beta[\phi_2 + 0.798\sigma_2] \\ & -f_B(e_2^B) - \alpha[\phi_1 + 0.798\sigma_1] - k_B\{(1 - 0.363\beta^2)\sigma_2^2 + 0.363\alpha^2\sigma_1^2\} \end{aligned} \tag{6.23}$$

Partners will choose their effort levels by maximizing their certainty equivalent values. The first order conditions on their effort levels of the formulas (6.22) and (6.23) are:

$$\frac{dc_A(e_1^A)}{de_1^A} = \frac{df_A(e_1^A)}{de_1^A} \tag{6.24}$$

$$\frac{dc_B(e_2^B)}{de_2^B} = \frac{f_B(e_2^B)}{de_2^B} \tag{6.25}$$

To maximize their certainty equivalent values they will try their best to deal with the risks. In other words, they will choose their effort levels as optimal effort levels. The partners can share their risks without moral hazard problems.

The partners' reservation values are assumed to be 0. The partners' participation constrictions should be satisfied when they agree to set up a joint venture. In other words, $Q_A > 0$ and $Q_B > 0$ when $\alpha \in [0,1]$ and $\beta \in [0,1]$. Then it is possible that $Q_A^{\delta} Q_B^{1-\delta} > 0$ in the area $\alpha \in [0,1]$ and $\beta \in [0,1]$. The partners bargain over the shares of their project risk α, β to maximize their certainty equivalent values. The bargaining powers of partner A and partner B are δ and $(1-\delta)$ respectively, $\delta \in [0,1]$. Here the bargaining powers of the partners are assumed to be exogenously given. The share of background risk γ is exogenously defined. That is to say, α and β can be calculated by maximizing the objective function:

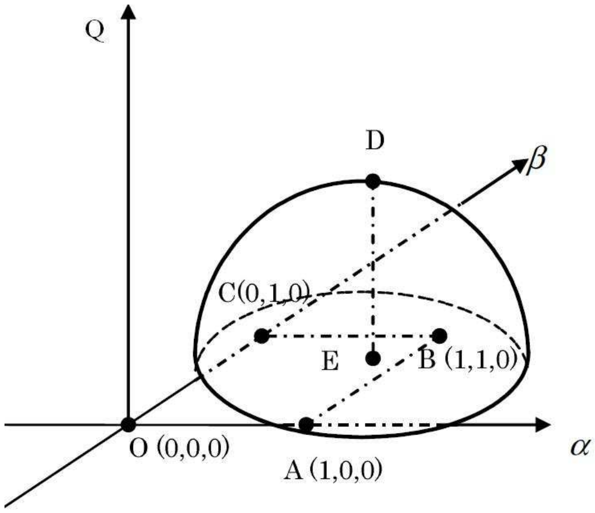
$$\max_{\alpha,\beta} Q = \max_{\alpha,\beta} Q_A^{\delta} Q_B^{1-\delta} \tag{6.26}$$

It can be proved that Q is a concave function of the shares α and β, the details see Appendix D. If one of the partners has full bargaining power relative the other partner, the model will change to the principal-agent model. In the joint ventures it is almost not realistic to make the assumption that one partner has full bargaining power. The objective function can be showed as the Figure 6.1. In this figure, point D is used to denote the maximum value of the objective function. It also defines the optimal shares α^* and β^*. From the Figure 6.1, the optimal shares are defined uniquely when the other conditions are given. The changes of the other conditions only changes the position of the function, they will not change the shape of the figure. The optimal shares can be calculated the first order-condition of the function (6.26):

$$\frac{\partial Q}{\partial \alpha} = Q_B^{-\delta} Q_A^{\delta-1} [\frac{\partial Q_A}{\partial \alpha} \delta Q_B + \frac{\partial Q_B}{\partial \alpha} Q_A (1-\delta)] = 0 \tag{6.27}$$

$$\frac{\partial Q}{\partial \beta} = Q_B^{-\delta} Q_A^{\delta-1} [\frac{\partial Q_A}{\partial \beta} \delta Q_B + \frac{\partial Q_B}{\partial \beta} Q_A (1-\delta)] = 0 \tag{6.28}$$

Figure 6.1: Optimal Shares



The optimal shares can be calculated by solving the functions (6.27) and (6.28). If the optimal shares obtained from the formulas satisfied with $\alpha \in [0,1]$ and $\beta \in [0,1]$. Then the optimal shares is denoted by $\alpha = \alpha^*$ and $\beta = \beta^*$. It is possible that $\alpha \in [0,1]$ and $\beta \in [0,1]$ can not be satisfied. In realities, it is impossible that one can get payment more than his lost. α and β should be constrained to satisfy with $\alpha \in [0,1]$ and $\beta \in [0,1]$.

α and β are constrained institutionally not to exceed one and no less than zero. Substitute $\alpha = 1$, $\alpha = 0$, $\beta = 0$ and $\beta = 1$ into the formulas (6.27) and (6.28) then the following formulas can be obtained:

$$\frac{\partial Q}{\partial \alpha}|_{\alpha=0} = Q_B^{-\delta} Q_A^{\delta-1}[\frac{\partial Q_A}{\partial \alpha}\delta Q_B + \frac{\partial Q_B}{\partial \alpha}Q_A(1-\delta)] = D_1 \tag{6.29}$$

$$\frac{\partial Q}{\partial \beta}|_{\beta=0} = Q_B^{-\delta} Q_A^{\delta-1}[\frac{\partial Q_A}{\partial \beta}\delta Q_B + \frac{\partial Q_B}{\partial \beta}Q_A(1-\delta)] = D_2 \tag{6.30}$$

$$\frac{\partial Q}{\partial \alpha}|_{\alpha=1} = Q_B^{-\delta} Q_A^{\delta-1}[\frac{\partial Q_A}{\partial \alpha}\delta Q_B + \frac{\partial Q_B}{\partial \alpha}Q_A(1-\delta)] = D_3 \tag{6.31}$$

$$\frac{\partial Q}{\partial \beta}|_{\beta=1} = Q_B^{-\delta} Q_A^{\delta-1}[\frac{\partial Q_A}{\partial \beta}\delta Q_B + \frac{\partial Q_B}{\partial \beta}Q_A(1-\delta)] = D_4 \tag{6.32}$$

$$\frac{\partial Q}{\partial \alpha}|_{0\leq\alpha\leq1} = Q_B^{-\delta} Q_A^{\delta-1}[\frac{\partial Q_A}{\partial \alpha}\delta Q_B + \frac{\partial Q_B}{\partial \alpha}Q_A(1-\delta)] = D_5 \tag{6.33}$$

$$\frac{\partial Q}{\partial \beta}|_{0\leq\beta\leq1} = Q_B^{-\delta} Q_A^{\delta-1}[\frac{\partial Q_A}{\partial \beta}\delta Q_B + \frac{\partial Q_B}{\partial \beta}Q_A(1-\delta)] = D_6 \tag{6.34}$$

Because the function Q is a concave function of α and β, there should exist some optimal shares to maximize the objective function Q. In the Figure (6.1) point D is used to denote the maximum value can be realized. From the Figure (6.1) it is obvious that the optimal shares change according to the position of E, which is the projection of point D in the plane $\alpha - \beta$. When E is in the area $OABC$, the optimal shares are $\alpha^* \in [0, 1]$, and $\beta^* \in [0, 1]$. When point E is not in the area $OABC$, the optimal shares can be classified into the following conditions:

(1) When the conditions $D_1 \leq 0$ and $D_2 \leq 0$ realized, the optimal shares are $\alpha^* = 0$ and $\beta^* = 0$. These conditions mean that it is an optimal choice for partner A to maximize his certainty equivalent value by undertaking their project risk respectively.

(2) When the conditions $D_1 \leq 0$ and $D_4 \geq 0$ realized, the optimal shares are $\alpha^* = 0$ and $\beta^* = 1$. These conditions mean that it is an optimal choice for partner A to maximize his certainty equivalent value by undertaking both the project risks R_1 and R_2. While partner B does not need to undertake any project risk.

(3) When the conditions $D_3 \geq 0$ and $D_2 \leq 0$ realized, the optimal shares are $\alpha^* = 1$ and $\beta^* = 0$. These conditions mean that it is an optimal choice for partners B to maximize his certainty equivalent values by undertaking both the project risks R_1 and R_2; While partner A does not need to undertake any project risk.

(4) When the conditions $D_3 \geq 0$ and $D_4 \geq 0$ realized, the optimal shares are $\alpha^* = 1$ and $\beta^* = 1$. These conditions mean that it is optimal choices for partner A and B to maximize their certainty equivalent values by exchanging their project risks.

(5) When the conditions $D_5 = 0$ and $D_6 = 0$ realized, the optimal shares are $\alpha^* \in [0, 1]$ and $\beta^* \in [0, 1]$. These conditions mean that it is optimal choice for partners A and B to maximizing his certainty equivalent values by constructing their portfolios.

(6) When the conditions $D_2 \leq 0$ and $D_6 = 0$ are satisfied, the optimal shares are $\alpha^* = 0$ and $\beta^* \in [0, 1]$. These conditions mean that it is an optimal choice for partner A to maximize his certainty equivalent value by undertaking his own project risk and part of partner B's project risk. While for partner B it is optimal for him to undertake part of his own risk.

(7) When the conditions $D_5 = 0$ and $D_1 \leq 0$ are satisfied, the optimal shares are $\alpha^* \in [0, 1]$ and $\beta^* = 0$. These conditions mean that it is an optimal choice for the partner A to maximize his certainty equivalent value by undertaking part of his own project risk. While for partner B it is optimal for him to set up his portfolio by choosing part of partner A's project risk at the same time undertaking his own risk.

(8) When the conditions $D_3 \geq 0$ and $D_6 = 0$ are satisfied, the optimal shares are

$\alpha^* = 1$ and $\beta^* \in [0, 1]$. These conditions mean that it is an optimal choice for partner A to maximize his certainty equivalent value by undertaking part of partner B's project risk. While for partner B it is optimal for him to set up his portfolio by choosing part of his own project risk at the same time undertaking partner A's project risk.

(9) When the conditions $D_5 = 0$ and $D_4 \geq 0$ are satisfied, the optimal shares are $\alpha^* \in [0, 1]$ and $\beta^* = 1$. These conditions mean that it is an optimal choice for the partner A to maximize his certainty equivalent value by constructing his portfolio by undertaking partner B's project risk and part of his project risk. While for partner B it is optimal for him to undertake part of partner A's project risk.

The shares defined by bargaining between the partners are Pareto optimum shares. Under this condition, both partners can maximize their certainty equivalent values by construct their portfolios.

The certainty equivalent values can be calculated by substituting the optimal shares into the certainty equivalent values of the partners.

$$\begin{aligned} Q_A = {} & \gamma I - c_A(e_1^A) - \phi_1 + \alpha^*(\phi_1 + 0.798\sigma_1) - f_A(e_1^A) \\ & -\beta^*(\phi_2 + 0.798\sigma_2) - k_A\{[1 - 0.363(\alpha^*)^2]\sigma_1^2 + 0.363(\beta^*)^2\sigma_2^2\} \end{aligned} \tag{6.35}$$

$$\begin{aligned} Q_B = {} & (1-\gamma)I - c_B(e_2^B) - \phi_2 + \beta^*(\phi_2 + 0.798\sigma_2) - f_B(e_2^B) \\ & -\alpha^*(\phi_1 + 0.798\sigma_1) - k_B\{[1 - 0.363(\beta^*)^2]\sigma_2^2 + 0.363(\alpha^*)^2\sigma_1^2\} \end{aligned} \tag{6.36}$$

6.3 Risk Sharing Model with Uncontrollable Risks

In the paper of Cb Chapman et al. (1994[26]) they classified the risks into three kinds: contractor controllable risks, client controllable risks and uncontrolled risks. In their paper they argued the uncontrollable risks should be shared because sharing uncontrollable risks will be mutually beneficial to both contractor and the client, and it is suitable to allocate the risks which can be controlled by the clients to the client and allocate the risks which can be controlled by the contractors to the contractors. In realities, the clients have the right to design the main contract, if the clients are also risk-averse or maybe for other reasons, the clients always allocate more risks to the contractors including the risks which can not be controlled by the contractors. How to share the uncontrollable risks between the related parties?

In this section the problem would be analyzed under the condition that there are n risks totally. All of the risks can not be controlled by both partners. The distribution of the risks R_i is denoted by $R_i \sim N(\phi_i, \sigma_i^2)$ $(i = 1, 2, \cdots, n)$. All the risks have the normal distribution and they are independent with each other. The two partners, partner A and partner B, set up a joint venture to undertake a project which has n risks. In the agreement of the joint venture, the partners define their share of the benefit of the main contract as γ (partner A) and $(1-\gamma)$ (partner B). The benefit of the main contract is denoted by I, which is the benefit when all the conditions realize as the one defined in the main contract. The share of the benefit is also exogenously given (or partners divide the whole project into two subprojects, these two subprojects only define the share of the benefit of the project among the partners, γ and $(1-\gamma)$).

The certainty equivalent value functions of the partners are also defined as $Q_j = E - k_j\sigma^2$, $j = A$ or B. Here E is the expected value of the benefit. σ means the variance of the risks. k_j denotes the degree of risk-aversion of partner j. The bargaining powers of the partners are also denoted by δ (partner A) and $(1-\delta)$ (partner B). They are also exogenously given. Here such an assumption would be made that the two partners undertake the whole project without dividing the whole project into two subprojects. During the period of the construction, there will be n risks which are independent with each other.

In this section the following problem is analyzed: how to share the risks between the partners when there are multiple risks in the project or there are multiple risks allocated to the joint ventures according to the main contract. All the risks are assumed that can not be controlled by both partners.

Partner A is assumed to prefer to undertake each risk by the share α_i, $\alpha_i \in [0, 1]$, while partner B undertakes each risk with a share $(1-\alpha_i)$, they decide the value of the α_i by bargaining with each other.

The partners choose their shares of each risk by bargaining. The certainty equivalent values of the partners are:

$$Q_A = \gamma I - \sum_{i=1}^{n} \alpha_i\phi_i - k_A \sum_{i=1}^{n} \alpha_i^2\sigma_i^2 \tag{6.37}$$

$$Q_B = (1-\gamma)I - \sum_{i=1}^{n}(1-\alpha_i)\phi_i - k_B \sum_{i=1}^{n}(1-\alpha_i)^2\sigma_i^2 \tag{6.38}$$

The first order functions are:

$$\frac{\partial Q_A}{\partial \alpha_i} = -\phi_i - 2k_A\alpha_i\sigma_i^2 \quad (6.39)$$

$$\frac{\partial Q_B}{\partial \alpha_i} = \phi_i + 2k_B(1-\alpha_i)\sigma_i^2 \quad (6.40)$$

$$\frac{\partial^2 Q_B}{\partial \alpha_i^2} = -2k_B\sigma_i^2 \quad (6.41)$$

$$\frac{\partial^2 Q_A}{\partial \alpha_i^2} = -2k_A\sigma_i^2 \quad (6.42)$$

Q_A and Q_B can be verified to be concave functions of α_i. Here the partners decide the shares by bargaining. The bargaining model can be expressed as:

$$\max_{\alpha_i} Q = \max_{\alpha_i} Q_A^{\delta} Q_B^{1-\delta} \quad (6.43)$$

The first-order condition:

$$\frac{\partial Q}{\partial \alpha_i} = Q_B^{-\delta} Q_A^{\delta-1}[\frac{\partial Q_A}{\partial \alpha_i}\delta Q_B + \frac{\partial Q_B}{\partial \alpha_i} Q_A(1-\delta)] = 0 \quad (6.44)$$

It is not difficult to prove that Q is the concave function of α_i. The optimal shares are denoted by α_i^{**} which can be calculated by the formula (6.44). α_i^* is used to denote the optimal share which is realistic, because $\alpha_i \in [0,1]$, the optimal shares can be calculated in the following way.

If $\alpha_i^{**} \in [0,1]$, then $\alpha_i^{**} = \alpha_i^*$.

If $\alpha_i^{**} > 1$, and $\frac{\partial Q}{\partial \alpha_i}|_{\alpha_i=1} > 0$ are satisfied, the optimal share is $\alpha_i^* = 1$. The condition $\frac{\partial Q}{\partial \alpha_i}|_{\alpha_i=1} > 0$ means that the certainty equivalent value increases with the increasing of α_i at point $\alpha_i = 1$. So it is an optimal choice to choose $\alpha_i = 1$ in all the range of α, then the realistic optimal share can be obtained as $\alpha_i^* = 1$.

If $\alpha_i^{**} < 0$, and $\frac{\partial Q}{\partial \alpha_i}|_{\alpha_i=0} < 0$ are satisfied, the optimal share is $\alpha_i^* = 0$. This condition $\frac{\partial Q}{\partial \alpha_i}|_{\alpha_i=0} < 0$ means that the certainty equivalent value decreases with the increasing of α_i at point $\alpha_i = 0$. So it is the optimal choice to choose $\alpha_i = 0$ in all the range of α, then the realistic optimal share can be obtained as $\alpha_i^* = 0$.

By this means the partners can choose different risks to construct their portfolios. How to construct the portfolio in this research is different from the one used in finance market by constraining the share of each risk in the interval $[0,1]$. On the other hand because the share of each partner for each risk is defined by bargaining between the partners, so the results of risk sharing is Pareto efficient.

6.4 Conclusion and Future Research

About the risk-sharing problem there are many researches, some of them use vNM utility theory, some of them use others non-expected utility. All of them dealt with how to share one risk between or among the related parties.

In this chapter, models are built to analyze how to share two or more risks between the partners who are both risk averse. The risks are classified into two groups: controllable risks and uncontrollable risks. In this chapter, a model is built by using portfolio theory which permits partners to choose which risks they prefer to undertake to construct their portfolios. The following conclusion can be found that if all the costs related to controllable risks can be shared between the partners, by using portfolio theory efficient risk-sharing can be realized. In other words, the partners can share risks without moral hazard problems. About the uncontrollable risks, it is easier to derive Pareto efficient risk-sharing results. One more point should be paid to attention to is here a constraint condition is used to make sure the loss of each risk can be shared completely. Because there are only two partners in the joint venture, the shares of each partner of each risk in the intervals $[0, 1]$ can be obtained to make it consistent with the real world. In the models the partners are permitted to define their shares of each risk by bargaining. Then the Pareto efficient risk-sharing results can be obtained.

In this chapter the bargaining powers are assumed to be exogenously given, before a contractor bargains with the other contractor it is very important for a contractor to know his strong points and weak points compared with the other. It is necessary to find which factors affect the relative bargaining power of a contractor. In this chapter bargaining cost is assumed to be zero, bargaining cost would affect the process and the results of the bargaining. When the partners should undertake bargaining cost how the optimal shares would be changed. In this chapter one way which can provide an efficient way to share risks between two partners is proposed. In realities in the joint venture there maybe more than two partners in the joint venture. It is an important topic how to share risks among three or more than three partners in the joint venture.

Chapter 7

Conclusion

7.1 Conclusion

Over the past two decades there has been an unprecedented change in the nature of global business environment. Joint ventures have emerged as a popular strategy in an environment which fast access to up-to-dated technology and emerging markets is more critical than ever before. In construction industry, the number of joint ventures also increased. Joint ventures are special structures which are different with the normal firm or company structures. The special characteristics make management of joint ventures different from the normal firm management. These characteristics also make higher failure rate of the joint ventures compared with the other organization structures.

Joint ventures are so widely used in different industries. The number of joint ventures continues to increase. Joint ventures attract the attentions from different fields: economic, law, engineering and so on. Why are joint ventures so widely used? There are many arguments which use different theories to explain this phenomenon. Joint ventures are always used to deal with some kind of uncertainties. For example, R & D companies always use joint ventures; when the companies entry into new market or new field they always use joint ventures. Construction projects are very complex and full of risks. To decrease risks or to share risks, contractors always set up joint ventures to undertake huge and complex projects. In this thesis, one of the main motivations of joint ventures—risk sharing is focused on.

In the joint venture, partners from different companies share the control right, the losses and the profits. In this thesis, the first problem which is focused on is that when there are many kinds of risks which kinds of companies would prefer to set up a joint venture for a project. The second problem is the efficiency analysis of the joint venture agreements which are used in the real world when there is a risk. The third problem is how the partners can share risks efficiently. The main results of this thesis are summarized as:

In Chapter 1, though the motivations of joint ventures are almost same with each other in the manufacturing industry and construction industry, the joint ventures themselves are different with each other in these two industries at many aspects. This phenomenon occurs just because of the different characteristics of these two industries. The two industries are different with each other from the following aspects: (1) The degree of specific of technology and others. Expect for very special structures, in construction industry, almost very little specific construction technologies are needed compared with manufacturing industry in which high speed technology innovations are needed. (2) Uniqueness. The uniqueness is one of the main characteristics of the construction industry. The uniqueness can be denoted by several phenomena, such as the uniqueness of the cites of each project, uniqueness of the clients of each project, uniqueness of the designs of each project and so on, it is the characteristic of uniqueness of the construction industry that makes all the things very different from the ones in manufacturing industry. (3) Degree of complexities and uncertainties. Construction industry is an industry with higher complexities and high uncertainties compared with manufacturing industry. Just as argued in organization design theory, construction industry which is high complexities and high uncertainties need hierarchical organization structure. Joint venture structures are semi-hierarchical structures. They can decrease the problem due to contract relations to some degree. All these differences between these two industries make joint ventures in these two industries very different. The research results about joint ventures in manufacturing industry can not be directly used into construction joint ventures.

In chapter 2, from literatures review, the motivations of joint ventures are found almost same with each other in the manufacturing industry and construction industry. In the previous literatures, the motivations of joint ventures are analyzed by using four theories: the transaction cost theory, strategic behavior theory, organizational knowledge and learning theory, and real options theory. In this chapter, the characteristics of the joint ventures are summarized as: (1) Sharing between the partners. The partners in the joint ventures share not only the profits and losses; they also share the control right, ownership and so on. (2) Quasi-hierarchies. Comparing with the normal firm structure, joint ventures have flexibility compared with traditional hierarchical structure. It is because joint venture structures are the intermediate conditions between the market and the hierarchical organization structures. (3) The relations between the partners. The relations between the partners are competition and cooperation.

Subcontracting is a traditional cooperation means in construction industry. With the globalization of the economy, joint ventures occur and become an important cooperation means in many industries including construction industry. To understand construction joint ventures, the differences between construction joint ventures and subcontracting should be clarified. By comparing the joint ventures and subcontracting, it can be found that these two cooperation ways are different from the following aspects: (1) Responsibilities to the client, in joint ventures partners undertake joint liabilities to the client; while in subcontracting, only main contractor undertakes responsibility to the client. (2) Risk management style, in joint ventures partners share all the losses of the risks, while in the subcontracting, the main contractor transfers some risks to the subcontractor. (3) Control style, in joint ventures all the partners share the control right on each process; while in subcontracting, the main contractor only needs to control the results of the subcontractor' work, not the process of the subcontractor's work. (4) Conflict resolving style and monitor style, in joint ventures the conflicts can be resolved according to the hierarchical orders and others like the one used in firm organization; while in subcontracting conflicts should be resolved according to the laws and contracts.

In Chapter 3 and Chapter 4, models are built to analyze the motivations of the construction joint ventures from the viewpoint of risk sharing. In Chapter 3 the joint venture in which the partners are unlimited liability companies is analyzed, and in Chapter 4 the joint venture the partners in which are limited liability companies is analyzed. In the model of chapter 3 the behaviors of the decision maker who undertakes unlimited liability when there is a background risk and project risks are analyzed. The following conclusion is obtained that joint ventures can only be set up by the partners who are different on at least one of the following characteristics: capacities to deal with risks and different degrees of risk-aversion. When there is a background risk partners can improve their certainty equivalent values by setting up a joint venture compared with the condition that one of them undertakes the whole project. In the model of chapter 4, the behaviors of the decision maker who undertakes limited liability when there are project risks are analyzed. Limited liabilities can change the behavior of the decision-maker. Because both undertake limited liabilities, there is a problem which is caused by limited liabilities. In this paper, it is called as partner risks. The motivations of joint ventures when there are project risks and partner risk are analyzed. If the limited liabilities are different with each other, for the partner whose limited liability can cover the maximum loss of his project risk, he will take part in the joint venture only when his certainty equivalent value of partner risk is smaller than his certainty equivalent value the other project risk. The same conclusion as the one obtained from chapter 3 can be concluded: joint ventures can only be set up by the partners who are different on at least one of the following characteristics: capacities to deal with risks and different degrees of risk-aversion.

As introduced in chapter 2, in construction industry, joint ventures are classified as integrated type joint ventures and separated type joint ventures. In Chapter 5, the efficiency of the integrated type and the separated type joint venture schemes is analyzed. Different types of the joint venture agreement define different types of risk shares between the partners. The effect of the joint venture type on the effort levels of the partners is also analyzed. The efficiencies of different type of joint ventures are compared. The main results of this research can be summarized as:

In both types of joint ventures, the sponsor style joint venture which is based on the trust between the partners is more efficient than the partner style joint venture in which the partners are equal. The separated type of joint venture is more suitable for the project which can be divided into several independent subprojects. Because it is not always possible that the partners can agree with each other about the extension of the project time, the partners have to undertake some cost to negotiate. When the project can not be divided into subprojects because of the technology needed, and it is impossible to set up a separated type joint venture, it is impossible that the project can be executed efficiently.

To give an incentive to the partners to execute the project efficiently compensations which are larger than the real losses are needed to make sure the partner choose optimal choices. Under this condition it is possible for the contractors to get no profit.

In Chapter 6, a model about how to share risks between partners (all of the partners are risk-aversion) in the joint venture when there are multiple risks is introduced. In this model, the partners are permitted to define the rules of risk sharing between them by bargaining. Their shares of the project risks are not defined as their participation shares or other exogenously given parameters. When bargaining is permitted, the results of bargaining are always Pareto optimum. In this chapter, the risks are classified into controllable risks and uncontrollable risks. About the controllable risks, if the partners can share all the costs of dealing with the risks, risks can be shared between the partners without moral hazard problem. About the uncontrollable risks, partners can construct their portfolios by bargaining.

7.2 Future Research

There are many topics about construction joint ventures. In this thesis, risk-sharing problem is focused on. In this thesis the problem that how the contractors make the decisions whether to set up a joint venture or undertake the whole project. As a traditional cooperation way, subcontracting is neglected. How the contractors would make the choice between a joint venture and subcontracting. A way that Pareto Efficient risk-sharing between two partners can be realized without moral hazard problem is proposed. The optimal shares can be obtained by bargaining between the partners. How the bargaining cost would affect the optimal shares is also an important topic. Which factors can affect the relative bargaining power of the partners' is also an important topic in the construction industry. How can Pareto Efficient risk-sharing be realized in the joint venture in which there are three or more than three partners is also an important problem that should resolved.

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Appendix A

Proof of the Monotonicity of the Certainty Equivalent Function

To prove the monotonicity of the certainty equivalent function, the certainty equivalent function can be rewritten by neglecting the same parts in the two function (4.3) and (4.4) and change b and c to x, and try to find if Q is a monotony function of x when $x > a$.

$$Q(x) = \sigma\frac{g(a)-g(x)}{G(a)-G(x)} - K\sigma^2\{1+\frac{ag(a)-xg(x)}{G(x)-G(a)} - [\frac{g(a)-g(x)}{G(x)-G(a)}]^2\} \tag{A.1}$$

The first-order function of the function (A.1) is:

$$\begin{aligned}\frac{dQ(x)}{dx} &= \frac{e^{-\frac{x^2}{2}}[e^{-\frac{a^2}{2}}-e^{\frac{-x^2}{2}}]\sigma}{\pi[\psi(\frac{a}{\sqrt{2}})-\psi(\frac{x}{\sqrt{2}})]^2} + \frac{x\sigma e^{\frac{-x^2}{2}}}{\sqrt{\frac{\pi}{2}}[\psi(\frac{a}{\sqrt{2}})-\psi(\frac{x}{\sqrt{2}})]} \\ &-K\sigma^2\{\frac{2}{\pi}\frac{e^{-\frac{x^2}{2}}[e^{-\frac{a^2}{2}}-e^{\frac{-x^2}{2}}]}{[\psi(\frac{x}{\sqrt{2}})-\psi(\frac{a}{\sqrt{2}})]^3} - \frac{2}{\pi}\frac{xe^{-\frac{x^2}{2}}[e^{-\frac{a^2}{2}}-e^{\frac{-x^2}{2}}]}{[\psi(\frac{x}{\sqrt{2}})-\psi(\frac{a}{\sqrt{2}})]^2} \\ &-\frac{2}{\pi}\frac{ae^{\frac{-x^2}{2}}-xe^{\frac{-x^2}{2}}}{[\psi(\frac{x}{\sqrt{2}})-\psi(\frac{a}{\sqrt{2}})]^2} - \sqrt{\frac{2}{\pi}}\frac{e^{\frac{-x^2}{2}}(x^2-1)}{[\psi(\frac{x}{\sqrt{2}})-\psi(\frac{a}{\sqrt{2}})]}\}\end{aligned} \tag{A.2}$$

Here $\psi(z) = \frac{2}{\sqrt{\pi}}\int_0^z e^{-t^2}dt$. When $x > a$, it is obvious that the first part of (A.2) is greater than 0. That is $\frac{e^{-\frac{x^2}{2}}[e^{-\frac{a^2}{2}}-e^{\frac{-x^2}{2}}]\sigma}{\pi[\psi(\frac{a}{\sqrt{2}})-\psi(\frac{x}{\sqrt{2}})]^2} > 0$. Because $e^{\frac{-x^2}{2}}$ is monotonously decrease with x. It can also be found that $\frac{x\sigma e^{\frac{-x^2}{2}}}{\sqrt{\frac{\pi}{2}}[\psi(\frac{a}{\sqrt{2}})-\psi(\frac{x}{\sqrt{2}})]} > 0$ when $x > a$. The other parts of formula (A.2) are also greater than 0 when $x > a$. Because $xe^{\frac{-x^2}{2}}$ is also a monotonous function of x and $\psi(z)$ is a monotonous function of z. So the function $Q(x)$ is monotonously increase with x. With the increasing of x, the value of $Q(x)$ also increase, that is $\frac{dQ(x)}{dx} > 0$. Then the value of certainty equivalent of project profit under the condition of limited liability is greater than the one under the condition of unlimited liability (full liability).

Appendix B

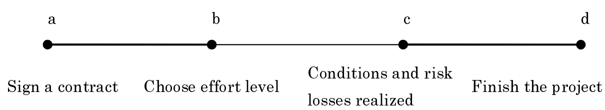
The Limited Liabilities Can Not Cover the Losses

B.1 The Structure of the Model

There are two partners: partner A and partner B who set up a joint venture, and bid for a project. Both partners are risk-averse. The partners will execute the project according to the procedure showed by Figure B.1. At point a, partner A and partner B sign a joint venture agreement. In this agreement the participants' shares are defined. γ denotes the share of partner A, and the share of partner B is denoted by $(1-\gamma)$. At point a, joint venture and the client sign the contract. In this contract they define their limited liabilities. Both the partners of the joint venture are limited liability companies, their limited liability are denoted by L_A and L_B.

At point b the real conditions realize, the losses of the risks occur. Partners can make decisions whether to continue to stay in the joint venture or quit.

Figure B.1: The Procedure of the Analysis



B.2 Assumptions

In this part, the whole project can be divided into two subprojects clearly. Each partner undertakes the responsibility to finish one subproject. Each subproject includes only one project risk.

B.2.1 Project Risks

Each partner faces with a project risk denoted by R_1 and R_2 during the periods of their cooperation respectively. These two project risks are independent and belong to each subproject. Each risk will realize as two states: small loss and great loss with probabilities as the following table.

Table B.1: The Distribution of Risks

	Probability (small loss)	Probability (great loss)
R_1	$P_1^s(C_1^s)$	$P_1^l(C_1^l)$
R_2	$P_2^s(C_2^s)$	$P_2^l(C_2^l)$

As for risk R_1 it can realize as two states: loss C_1^s with probability P_1^s and loss C_1^l with probability P_1^l. As for risk R_2 it can realize as two states: loss C_2^s with probability P_2^s and loss C_2^l with probability P_2^l.

B.2.2 Partner Risks

The two partners in the joint ventures undertake joint liability to the owner. When the losses of the risks beyond the sum of the partners' limited liabilities, they can choose to quit from the joint venture. Here their limited liabilities are assumed as the part of the performance bond paid to the owner undertaken by them. If the losses realized beyond the sum of their limited liabilities both of them have the right to stop their jobs. Under this condition, they will loss their performance bonds.

The relation between risk losses and limited liabilities of the partners are assumed as: $C_1^s < C_1^l < L_A$, $C_2^s < L_B < C_2^l$. Under this condition, because when the project risk of subproject 2 realized as great loss, partner B can not cover his loss, that is his loss beyond his limited liability. Under this condition, partner A will have to undertake the loss of partner B's project risk, because in the joint venture they undertake joint liability. The part of losses of partner B's project risk undertaken by partner A is called partner A's partner risk.

B.2.3 Limited Liability

In this paper the two partners are assumed to have different limited liabilities. One of the partners' limited liabilities is greater than the great loss of his project risk; while the other partner's limited liability is smaller than the great loss of his project risk. When both of the project risks realized as great ones, the sum of their limited liabilities is smaller than the sum of the great losses of the two subproject risks. Expressed by parameters as: $C_1^s < C_1^l < L_A$, $C_2^s < L_B < C_2^l$, $L_A + L_B > C_1^l + C_2^l$ and $L_A < L_B$.

B.3 Model

B.3.1 Joint Venture Style

When the partners undertake limited liabilities, partners choose to set up a joint venture to undertake a project. Partners not only undertake the losses of project risks but also they have to undertake their partner risk. When the loss undertaken by the partner is greater than his limited liability, his utility will be 0.

At point b, the real conditions can realize as four conditions. The expected utilities of the two partners' can be calculated under each condition.

(1) Both project risks realize as small loss. The relation between the losses and the limited liabilities can be divided into two: $L_B > C_1^s + C_2^s$ and $L_B < C_1^s + C_2^s$. When the relation between the losses and the limited liabilities satisfies with $L_B > C_1^s + C_2^s$ the utilities of the partners under each condition can be expressed as:

$$U_A = P_1^s P_2^s U_A(\gamma I - C_1^s) \tag{B.1}$$

$$U_B = P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] \tag{B.2}$$

When the relation between the losses and the limited liabilities satisfies with $L_B < C_1^s + C_2^s$, the utilities of both partners' are 0. To make the analysis meaningful, the second condition ($L_B < C_1^s + C_2^s$) can be neglected.

(2) R_1 realized as small loss, R_2 realized as great loss. The relation among the losses and the limited liability can also be divided into: $L_A + L_B < C_1^s + C_2^l$ and $L_A + L_B > C_1^s + C_2^l$. The expected utilities of the partners can be calculated under the following two conditions: When the relation between the losses and the limited liabilities satisfies with $L_A + L_B < C_1^s + C_2^l$ the utilities of both partners under this condition would be 0.

When the relation between the losses and the limited liabilities satisfies with $L_A + L_B > C_1^s + C_2^l$ the utilities of the partners under this condition can be expressed as:

$$U_A = P_1^s P_2^l U_A(\gamma I - C_1^s - C_2^l + L_B) \tag{B.3}$$

$$U_B = P_1^s P_2^l U_B[(1-\gamma)I - L_B] = 0 \tag{B.4}$$

(3) R_1 realized as great loss, R_2 realized as small loss. Under this condition, the utilities of the partners can be expressed as:

$$U_A = P_1^l P_2^s U_A(\gamma I - C_1^l) \tag{B.5}$$

$$U_B = P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \tag{B.6}$$

(4) Both project risks realize as great loss. Under this condition the utility of both of them are 0.

When the partners choose to set up a joint venture to undertake the project, their utilities in the joint venture will be:

Under the condition: $L_A + L_B > C_1^s + C_2^l$

$$U_A^J = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^s P_2^l U_A(\gamma I - C_1^s - C_2^l + L_B) + P_1^l P_2^s U_A(\gamma I - C_1^l) \tag{B.7}$$

$$U_B^J = P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] + P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \tag{B.8}$$

Under the condition: $L_A + L_B < C_1^s + C_2^l$

$$U_A^J = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^l P_2^s U_A(\gamma I - C_1^l) \tag{B.9}$$

$$U_B^J = P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] + P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \tag{B.10}$$

B.3.2 One Partner Style

(1) Model of Partner A Style

For simplification, the whole project is also divided into two subprojects as before. All the parameters are same as before. The whole project is undertaken by partners respectively.

The utility of partner A when he undertakes the whole can be calculated in the following way.

(1) Both project risks realize as small loss. The relation between the losses and the limited liabilities can be divided into: $L_A > C_1^s + C_2^s$ and $L_A < C_1^s + C_2^s$. When the relation between the losses and the limited liabilities satisfies with $L_A > C_1^s + C_2^s$ the utilities of the partners under each condition can be expressed as:

$$U_A^1 = P_1^s P_2^s U_A(\gamma I - C_1^s) \tag{B.11}$$

$$U_A^2 = P_1^s P_2^s U_A[(1-\gamma)I - C_2^s] \tag{B.12}$$

Here Q_A^1 and Q_A^2 denote the utility when partner A undertakes subproject 1 and 2.

When the relation between the losses and the limited liabilities satisfies with $L_A < C_1^s + C_2^s$, the utilities of partner A to undertake these two subprojects will be 0.

(2) R_1 realized as small loss, R_2 realized as great loss. the expected utilities of the partner A will be 0 to undertake the whole project.

(3) R_1 realized as great loss, R_2 realized as small loss. The relation between the losses and the limited liability of partner A can be divided into: $L_A > C_1^l + C_2^s$ and $L_A < C_1^l + C_2^s$. When the relation between the losses and the limited liabilities satisfies with $L_A > C_1^l + C_2^s$, the utilities of the partner A to under the whole project can be calculated in the following ways:

$$U_A^1 = P_1^l P_2^s U_A(\gamma I - C_1^l) \tag{B.13}$$

$$U_A^2 = P_1^l P_2^s U_A[(1-\gamma)I - C_2^s] \tag{B.14}$$

When the relation between the losses and the limited liabilities satisfies with $L_A > C_1^l + C_2^s$, the utilities of the partner A to undertake the whole project will be 0.

(4) Both project risks realize as great loss. Under this condition the utilities of undertaking both subprojects will be 0.

When partner A undertakes the whole project, his utility can be calculated by dividing the relation between the risks losses and his limited liability into two conditions: $C_1^L + C_2^s < L_A$ and $C_1^L + C_2^s > L_A$.

When the relation between the losses and the limited liability of partner A satisfies with $C_1^l + C_2^s > L_A$ and $c_1^s + C_2^s < L_A$, the utility of partner A can be expressed as:

$$U_A^w = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^s P_2^s U_A[(1-\gamma)I - C_2^s] \tag{B.15}$$

When the relation between the losses and the limited liability of partner A satisfies with $C_1^l + C_2^s < L_A$, the utility of partner A can be expressed as:

$$Q_A^w = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^s P_2^s U_A[(1-\gamma)I - C_2^s] + P_1^l P_2^s U_A(\gamma I - C_1^l)$$
$$+ P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \tag{B.16}$$

(2) Model of Partner B Style)

The utility of partner B when he undertakes the whole can be calculated as in the same ways as the one used in the former section.

(1) Both project risks realize as small loss. The relation between the losses and the limited liability can be divided into: $L_B > C_1^s + C_2^s$ and $L_B < C_1^s + C_2^s$. When the relation between the losses and the limited liabilities satisfies with $L_B > C_1^s + C_2^s$ the utility of partner B under each condition can be expressed as:

$$U_B^1 = P_1^s P_2^s U_B(\gamma I - C_1^s) \tag{B.17}$$

$$U_B^2 = P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] \tag{B.18}$$

Here U_B^1 and U_B^2 denote the utilities of partner B when he undertakes subproject 1 and 2 respectively.

When the relation between the losses and the limited liabilities satisfies with $L_B < C_1^s + C_2^s$, the utility of partner B to undertake these two subprojects will be 0.

(2) R_1 realized as small loss, R_2 realized as great loss. The expected utilities of the partner B will be 0 to undertake the whole project.

(3) R_1 realized as great loss, R_2 realized as small loss. The relation between the losses and the limited liability of partner B can be divided into: $L_B > C_1^l + C_2^s$ and $L_B < C_1^l + C_2^s$. When the relation between the losses and the limited liabilities satisfies

with $L_B > C_1^l + C_2^s$, the expected utilities of the partner B to undertake the whole project can be expressed as:

$$U_B^1 = P_1^l P_2^s U_B(\gamma I - C_1^l) \tag{B.19}$$

$$U_B^2 = P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \tag{B.20}$$

When the relation between the losses and the limited liabilities satisfies with $L_B > C_1^l + C_2^s$, the expected utility of the partner B to undertake the whole project will be 0.

(4) Both project risks realize as great loss. Under this condition the expected utility of undertaking both subprojects is 0.

When partner B undertakes the whole project, his expected utility can be calculated by dividing the relation between the risks losses and his limited liability into two conditions: $C_1^l + C_2^s < L_B$ and $C_1^l + C_2^s > L_B$.

When the relation between the risks losses and the limited liability of partner B satisfies: $C_1^l + C_2^s > L_B$ and $c_1^s + C_2^s < L_B$, the expected utility of partner B can be expressed as:

$$U_B^w = P_1^s P_2^s U_B(\gamma I - C_1^s) + P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] \tag{B.21}$$

When the relation between the risks losses and the limited liability of partner B satisfies: $C_1^L + C_2^s < L_B$ and $C_1^s + C_2^s < L_B$, the expected utility of partner B can be expressed as:

$$\begin{aligned} U_B^w = & P_1^s P_2^s U_B(\gamma I - C_1^s) + P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] \\ & + P_1^l P_2^s U_B(\gamma I - C_1^l) + P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \end{aligned} \tag{B.22}$$

B.4 Comparing the Joint Venture Style and One Partner Style

The reservation utilities of the partners are denoted by U_A^R and U_B^R respectively.

B.4.1 Partner A Has the Right to Choose Cooperation Style

(1) When the relation between the risk losses and limited liabilities satisfies: $L_A < C_1^s + C_2^l < L_A + L_B$ and $C_1^l + C_2^s < L_A$, the choice problem that how partner A makes

decision whether to set up a joint venture or to undertake the whole project is analyzed.

$$U_A^J = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^s P_2^l U_A(\gamma I - C_1^s - C_2^l + L_B) + P_1^l P_2^s U_A(\gamma I - C_1^l) \quad \text{(B.23)}$$

$$U_B^J = P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] + P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \quad \text{(B.24)}$$

$$U_A^w = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^s P_2^s U_A[(1-\gamma)I - C_2^s]$$
$$+P_1^l P_2^s U_A(\gamma I - C_1^l) + P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \quad \text{(B.25)}$$

Partner A will choose to set up a joint venture when the following conditions are satisfied:

$$U_A^J \geq U_A^R \quad \text{(B.26)}$$

$$U_A^J - U_A^w \geq 0 \qquad and \quad \text{(B.27)}$$

$$U_B^J \geq U_B^R \quad \text{(B.28)}$$

Substituting the formulas of utilities into the above:

$$U_A^J = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^s P_2^l U_A(\gamma I - C_1^s - C_2^l + L_B)$$
$$+P_1^l P_2^s U_A(\gamma I - C_1^l) \geq U_A^R \quad \text{(B.29)}$$

$$U_A^J - U_A^w = P_1^s P_2^l U_A(\gamma I - C_1^s - C_2^l + L_B) - P_1^s P_2^s U_A[(1-\gamma)I - C_2^s)$$
$$-P_1^l P_2^s U_A[(1-\gamma)I - C_2^s] \geq 0 \quad \text{(B.30)}$$

$$U_B^J = P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] + P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \geq U_B^R \quad \text{(B.31)}$$

From the above formulas, it is obvious that partner A will choose to set up a joint venture with partner B under the condition that the project risk 1 realized as small loss and at the same time he should face partner risk, his expected utility of undertaking subproject risk 1 is still greater than his expected utility of undertaking subproject risk 2. Otherwise, partner A will prefer to undertake the whole project. In other words, only when partner A is a technology superior at subproject 1 and he can get higher utility even he should face partner risk. Otherwise he will prefer to undertake the whole project himself.

(2) When the relation between the risk losses and limited liabilities satisfies: $L_B < C_1^s + C_2^l < L_A + L_B$, and $C_1^l + C_2^s < L_A$, the choice problem that how partner A makes

decision whether to set up a joint venture or to undertake the whole project is analyzed.

$$U_A^J = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^l P_2^s U_A(\gamma I - C_1^l) \quad \text{(B.32)}$$

$$U_B^J = P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] + P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \quad \text{(B.33)}$$

$$U_A^w = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^s P_2^s U_A[(1-\gamma)I - C_2^s] \quad \text{(B.34)}$$

Partner A will choose to set up a joint venture when the same conditions are satisfied. Substituting the partner A's expected utilities into the inequalities (B.26), (B.27) and (B.28):

$$U_A^J = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^l P_2^s U_A(\gamma I - C_1^l) \geq U_A^R \quad \text{(B.35)}$$

$$U_A^J - U_A^w = P_1^l P_2^s U_A[\gamma I - C_1^l] - p_1^s P_2^s U_A[(1-\gamma)I - C_2^s] \geq 0 \quad \text{(B.36)}$$

$$U_B^J = P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] + P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \geq U_B^R \quad \text{(B.37)}$$

From the above it is obvious that partner A chooses to set up a joint venture with partner B when his expected utility of subproject when the risk of subproject 1 occurs as great loss is greater than his expected utility of undertaking subproject 2 when the risk of subproject 2 occurs as small loss. In other words, even subproject risk 1 realized as great loss partner A prefer to undertake subproject 1 to undertake subproject 2 because that he can deal with subproject risk 1 at lower cost or he get higher expected utility compared with undertaking subproject 2. The conclusion that when partner A is a technology superior on subproject 1 he will prefer to set up a joint venture with others can be obtained.

B.4.2 Partner B Has the Right to Choose Cooperation Style

(1) When the relation between the risk losses and limited liabilities satisfies: $L_A < C_1^s + C_2^l < L_A + L_B$ and $C_1^l + C_2^s < L_A$, the choice problem that how partner B makes decision whether to set up a joint venture or to undertake the whole project is analyzed.

$$U_B^J = P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] + P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \geq U_B^R \quad \text{(B.38)}$$

$$U_B^J - U_B^w = -P_1^s P_2^s U_B(\gamma I - C_1^s) - P_1^l P_2^s U_B[\gamma I - C_1^l] \geq 0 \quad \text{(B.39)}$$

$$U_A^J = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^l P_2^s U_A(\gamma I - C_1^l) \geq U_A^R \quad \text{(B.40)}$$

Form the above formula, it is obvious that partner B will not choose to set up a joint venture with partner A. For partner B he can not get higher expected utility when he takes part in the joint venture than undertaking the project himself.

(2) When the relation between the risk losses and limited liabilities satisfies: $L_B < C_1^s + C_2^l < L_A + L_B$, and $C_1^l + C_2^s < L_A$, the choice problem that how partner B makes decision whether to set up a joint venture or to undertake the whole project is analyzed.

$$U_B^J = P_1^s P_2^s U_B[(1-\gamma)I - C_2^s] + P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] \geq U_B^R \tag{B.41}$$

$$U_B^J - U_B^w = P_1^l P_2^s U_B[(1-\gamma)I - C_2^s] - P_1^s P_2^s U_B(\gamma I - C_1^s) \geq 0 \tag{B.42}$$

$$U_A^J = P_1^s P_2^s U_A(\gamma I - C_1^s) + P_1^l P_2^s U_A(\gamma I - C_1^l) \geq U_A^R \tag{B.43}$$

If partner B has the right to choose whether to set up a joint venture with partner A, he will choose to set up a joint venture when his expected utility of undertaking subproject 2 is greater than his expected utility of undertaking subproject 1 when both risks realized as small losses. In other words, partner B can get higher expected utility from undertaking subproject 2 compared with undertaking subproject 1 when both risks realized as small loss. It can be concluded that when partner B is technology superior on subproject 2 he will prefer to set up a joint venture with others.

B.5 Conclusion

In realities most of companies are limited liability companies. In this part the choice problem under which conditions partners with limited liabilities will choose to set up a joint venture to undertake a project is analyzed. Here the case as the following one is analyzed. The two partners have different limited liabilities. One of the partners' limited liabilities is greater than the great loss of his project risk; while the other partner's limited liability is smaller than the great loss of his project risk. When both of the project risks realized as great ones, the sum of their limited liabilities is smaller than the sum of the great losses of the two subproject risks. The conclusions are summarized as:

(1) When the relation between the risk losses and limited liabilities satisfies: $L_A < C_1^s + C_2^l < L_A + L_B$, $L_B < C_1^s + C_2^l$ and $C_1^l + C_2^s < L_A$, in other words, when risks realized small loss for subproject 1 and great loss for subproject 2, and the sum of these two losses is greater than the limited liability of each partner but smaller than the sum of

their limited liabilities, and if subproject risk 1 realized great loss and subproject risk 2 realized as small loss and the sum of these two losses is smaller than the limited liability of partner A.

Partner A will choose to set up a joint venture with partner B under the condition that the project risk 1 realized as small loss and his expected utility of undertaking subproject risk 1 is still greater than his utility of undertaking subproject risk 2 even he should face partner risk. Otherwise, partner A will prefer to undertake the whole project.

While under this condition if partner B has the right to make decision he will not choose to set up a joint venture with partner A. For partner B he can not get higher expected utility when he takes part in the joint venture than undertaking the project himself.

(2) When the relation between the risk losses and limited liabilities satisfies: $L_B < C_1^s + C_2^l < L_A + L_B$ and $C_1^l + C_2^s < L_A$, in other words, when subproject risk 1 realized as small loss, subproject risk 2 realized as great loss and the sum of these two losses is smaller than the limited liability of partner A.

Partner A will choose to set up a joint venture with partner B when his utility of subproject when the risk of subproject 1 occurs as great loss is greater than his utility of undertaking subproject 2 when the risk of subproject 2 occurs as small loss. Partner B will choose to set up a joint venture when his expected utility of undertaking subproject 2 is greater than his expected utility of undertaking subproject 1 when both risks realized as small losses.

The following conclusion can be obtained: If partner A is technology superior on subproject 1 he will prefer to set up a joint venture with others who is technology superior on subproject 2. If partner B is technology superior on subproject 2 he will prefer to set up a joint venture with others who is technology superior on subproject 1.

Appendix C

Proof of Proposition

At first $a = sb$.

$$\Xi_A(s) = \left\{ \left(\frac{s}{1+s} \right) s^{\frac{b}{2}} \right\}, \Xi_B(s) = \left\{ \left(\frac{1}{1+s} \right) s^{-\frac{b}{2}} \right\}$$

And then (5.26a) $i_A^\circ = \Xi(s)^{\frac{2}{a+b+2}} = i_A^*$, and (5.26b) can be change into $i_B^\circ = \Xi_B(s)^{\frac{2}{a+b+2}} = i_B^*$. s° denotes s which satisfies with $\Xi_A(s) = 1$. When $s = s^\circ$, $i_A^\circ = i_A^*$.

$$\frac{d\Xi_A(s)}{ds} = s^{\frac{b}{2}} \left\{ \frac{1}{(1+s)^2} + \frac{b}{2(1+s)} \right\} > 0$$

$\Xi(s)^{\frac{2}{a+b+2}}$ is monotonously increasing. When $s \geq s^\circ$, $i_A^\circ \geq i_A^*$; when $s < s^\circ$, $i_A^\circ < i_A^*$; when $s = \frac{1}{s^\circ}$, $\Xi_B(s) = 1$. Substituting $a = b$ and $b = a$ into $\Xi_A(s)$, $\Xi_B(s)$ can be calculated. s° which satisfies with $\Xi_A(s^\circ) = 1$, then $\Xi_B(1/s^\circ) = 1$.

$$\frac{d\Xi_B(s)}{ds} = -s^{-\frac{a}{2}-1} \left\{ \frac{s}{(1+s)^2} + \frac{a}{2(1+s)} \right\} < 0$$

So $\Xi(b)^{\frac{2}{a+b+2}}$ is also monotonously decreasing. When $s \geq 1/s^\circ$, $i_B^\circ \leq i_B^*$; when $s < 1/s^\circ$, $i_B^\circ > i_B^*$.

Appendix D

The Concavity of the Objective Function

The certainty equivalent values of the partners can be expressed as:

$$\begin{aligned} Q_A &= \gamma I - [c_A(e_1^A) + \phi_1] + \alpha[\phi_1 + 0.798\sigma_1] - f_A(e_1^A) \\ &\quad -\beta[\phi_2 + 0.798\sigma_2] - k_A\{(1 + 0.363\alpha^2)\sigma_1^2 + 0.363\beta^2\sigma_2^2\} \qquad (D.1) \\ Q_B &= (1-\gamma)I - [c_B(e_2^B) + \phi_2] + \beta[\phi_2 + 0.798\sigma_2] \\ &\quad -f_B(e_2^B) - \alpha[\phi_1 + 0.798\sigma_1] - k_B\{(1 + 0.363\beta^2)\sigma_2^2 + 0.363\alpha^2\sigma_1^2\} \qquad (D.2) \end{aligned}$$

The first order conditions and the second order functions of the certainty equivalent value functions can be expressed as:

$$\frac{\partial Q_A}{\partial \alpha} = \phi_1 + 0.798\sigma_1 - 0.726k_A\alpha\sigma_1^2 \qquad (D.3)$$

$$\frac{\partial Q_A}{\partial \beta} = -\phi_2 - 0.798\sigma_2 - 0.726k_A\beta\sigma_2^2 \qquad (D.4)$$

$$\frac{\partial Q_B}{\partial \alpha} = -\phi_1 - 0.798\sigma_1 - 0.726k_B\alpha\sigma_1^2 \qquad (D.5)$$

$$\frac{\partial Q_B}{\partial \beta} = \phi_2 + 0.798\sigma_2 - 0.726k_B\beta\sigma_2^2 \qquad (D.6)$$

$$\frac{\partial^2 Q_A}{\partial \alpha^2} = -0.726 k_A \sigma_1^2 < 0 \tag{D.7}$$
$$\frac{\partial^2 Q_A}{\partial \beta^2} = -0.726 k_A \sigma_2^2 < 0 \tag{D.8}$$
$$\frac{\partial^2 Q_B}{\partial \alpha^2} = -0.726 k_B \sigma_1^2 < 0 \tag{D.9}$$
$$\frac{\partial^2 Q_B}{\partial \beta^2} = -0.726 k_B \sigma_2^2 < 0 \tag{D.10}$$
$$\frac{\partial^2 CE_A}{\partial \alpha \partial \beta} = -0.726 k_A \sigma_1^2 = 0 \tag{D.11}$$
$$\frac{\partial^2 Q_A}{\partial \beta \partial \alpha} = -0.726 k_A \sigma_2^2 = 0 \tag{D.12}$$
$$\frac{\partial^2 Q_B}{\partial \alpha \partial \beta} = -0.726 k_B \sigma_1^2 = 0 \tag{D.13}$$
$$\frac{\partial^2 Q_B}{\partial \beta \partial \alpha} = -0.726 k_B \sigma_2^2 = 0 \tag{D.14}$$

So it is verified that certainty equivalent value functions are concave functions of the shares α and β. When the partners bargain over the shares of the project risks, they can decide their optimal shares by maximizing the following function.

$$\max_{\alpha,\beta} Q = \max_{\alpha,\beta} Q_A^{\delta} Q_B^{1-\delta} \tag{D.15}$$

The first order condition of the above formula:

$$\frac{\partial Q}{\partial \alpha} = Q_B^{-\delta} Q_A^{\delta-1} [\frac{\partial Q_A}{\partial \alpha} \delta Q_B + \frac{\partial Q_B}{\partial \alpha} Q_A (1-\delta)] \tag{D.16}$$
$$\frac{\partial Q}{\partial \beta} = Q_B^{-\delta} Q_A^{\delta-1} [\frac{\partial Q_A}{\partial \beta} \delta Q_B + \frac{\partial Q_B}{\partial \beta} Q_A (1-\delta)] \tag{D.17}$$

The second-order function of the function Q are:

$$\begin{aligned} \frac{\partial^2 Q}{\partial \alpha^2} &= Q_A^{\delta-2} Q_B^{-\delta} \{\delta Q_B^2 Q_A \frac{\partial^2 Q_A}{\partial \alpha^2} + Q_B Q_A^2 (1-\delta) \frac{\partial^2 Q_B}{\partial \alpha^2} \\ &-\delta(1-\delta)[Q_B \frac{\partial Q_A}{\partial \alpha} - Q_A \frac{\partial Q_B}{\partial \alpha}]^2\} < 0 \end{aligned} \tag{D.18}$$
$$\begin{aligned} \frac{\partial^2 Q}{\partial \beta^2} &= Q_A^{\delta-2} Q_B^{-\delta} \{\delta Q_B^2 Q_A \frac{\partial^2 Q_A}{\partial \beta^2} + Q_B Q_A^2 (1-\delta) \frac{\partial^2 Q_B}{\partial \beta^2} \\ &-\delta(1-\delta)[Q_A \frac{\partial Q_B}{\partial \beta} - Q_B \frac{\partial Q_A}{\partial \beta}]^2\} < 0 \end{aligned} \tag{D.19}$$
$$\begin{aligned} \frac{\partial^2 Q}{\partial \alpha \partial \beta} &= -\delta(1-\delta) Q_A^{\delta-2} Q_B^{-\delta} [Q_B \frac{\partial Q_A}{\partial \alpha} - Q_A \frac{\partial Q_B}{\partial \alpha}] \\ &[Q_A \frac{\partial Q_B}{\partial \beta} - Q_B \frac{\partial Q_A}{\partial \beta}] = \frac{\partial^2 Q}{\partial \beta \partial \alpha} \end{aligned} \tag{D.20}$$

From the above formulas the following inequality can be obtained:

$$\frac{\partial^2 Q}{\partial \alpha^2}\frac{\partial^2 Q}{\partial \beta^2} - \frac{\partial^2 Q}{\partial \alpha \partial \beta}\frac{\partial^2 Q}{\partial \beta \partial \alpha} = Q_A^2 Q_B^2 MN - Q_A Q_B \delta(1-\delta)[MP^2 + Q^2 N] > 0 \qquad \text{(D.21)}$$

Here, $M = \delta Q_B \frac{\partial^2 Q_A}{\partial \alpha^2} + Q_A(1-\delta)\frac{\partial^2 Q_B}{\partial \alpha^2}$, $N = \delta Q_B \frac{\partial^2 Q_A}{\partial \beta^2} + Q_A(1-\delta)\frac{\partial^2 Q_B}{\partial \beta^2}$, $P = Q_B \frac{\partial Q_A}{\partial \alpha} - Q_A \frac{\partial Q_B}{\partial \alpha}$ and $Q = Q_A \frac{\partial Q_B}{\partial \beta} - Q_B \frac{\partial Q_A}{\partial \beta}$. Then it can be verified that Q is a concave function of the shares α and β.