Assessing and Managing Regulatory Risk In China's CDM Market

A Carbon Finance Perspective

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STATEMENT OF AUTHENTICITY

Except where otherwise stated and acknowledged, I certify that thesis is my sole and unaided work.

(YI QUN HUANG)

5th September, 2007

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List of Abbreviations

ACCA 21:	Administrative Center for China's Agenda 21
AHP:	Analytical Hierarchy Process
CCC:	Climate Change Capital
CDM:	Clean Development Mechanism
CDO:	Collateralized Debt Obligation
CCDO	Carbon-based Collateralized Debt Obligation
DEF	Default Exposure Function
DNA:	Designated National Authority
DOE:	Designated Operational Entity
ETS:	Emission Trading Scheme
ERPA	Emission Reduction Purchaser Agreement
EUA	European Union Allowance
IETA	International Emission Trading Association
IPCC:	Inter-governmental Panel on Climate Change
JI:	Joint Implementation
NCCCC:	National Coordination Committee on Climate Change
NDRC:	National Development and Reform Committee
OTC:	Over-the-Counter
PCF:	Prototype Carbon Fund
RSCD:	Research Center for Sustainable Development
SCC	Sindcatum Carbon Capital
SPV:	Special Purpose Vehicle
UNFCCC:	United Nation Framework Convention on Climate Change

Glossary

Beta An financial indicator which measures the marginal contribution of a single asset to the risk of the portfolio. In other words, beta measures risk that cannot be diversified away.

Black-Scholes-Merton Model An default probability model based on Black-Scholes asset pricing model and the concept of distance to default. The model assumes a company's asset follows a geometric Brownian motion and its equity is a call option whose strike price is the debt value.

Brownian Motion Random motion observed by botanist Robert Brown in 1828 of pollen grains in water. Variants of this are used as the assumed path of securities prices in many financial models.

Call Option A financial instrument whose holders have the right, but not the obligation to buy the underlying asset at a predetermined price.

Carbon Finance: One area of environmental finance that explores the financial risks and opportunities associated with a carbon-constrained society and that anticipates the availability and the use of market-based instruments that are capable of transferring environmental risks and achieving environmental objectives.

CER Gap: The discrepancy between expected CER and actualized CER.

Collateralized Debt Obligation Securities backed by pools of assets, mainly non-mortgage loans or bonds. In exchange for interest charges, buyers of the CDOs bear the credit risk of the collateral, which means that if any of the loans or bonds in the pool are not repaid, the holders of the CDOs take the loss

Composite Vector The vector that shows the ranking of decision options with regard to all decision making criteria in a hierarchy.

Diversification The practice of spreading investments over several different securities or types of investment vehicles to reduce risk.

Default Risk Intensity The loss incurred once default happens.

Drift A parameter to describe the expected value in Brownian motion.

Eigenvalue & Eigenvector In mathematics, a number is called an eigenvalue of a matrix if there exists a nonzero vector such that the matrix times the vector is equal to the same vector multiplied by the eigenvalue. This vector is then called the eigenvector associated with the eigenvalue.

Idiosyncratic Risk The risk that is not dependent on other risk factors.

Liberal Environmentalism The idea that free market and private ownership are essential for environmental protection.

Monte Carlo Simulation A method of generating values from a known distribution for the purposes of experimentation. This is accomplished by generating uniform random variables and using them in an inverse reliability equation to produce failure times that would conform to the desired input distribution.

Put Option A financial instrument whose holders have the right, but not the obligation to sell its underlying asset at a predetermined price.

Poisson Process A process useful for describing events which happen discretely but randomly in time, eg crashes, central bank rate hikes. It is frequently used as a component of jump diffusion processes to describe the occurrence of the discrete jumps.

Risk Risk is the potential harm that may arise from some present process or from some future event. It is often mapped to the probability of some event which is seen as undesirable.

Risk Chain A tool developed by this thesis to show the effect of the same risk on same stake-holders can be measured in different way over times.

Risk Equivalent Approach A approach developed by this thesis to show different measurement in the risk chain should yield the same result for the same risk.

Subprime Lending Activity about Issuing loans with less than A level credit rates.

Trace The sum of diagonal elements in a square matrix.

Tranche A particular class of bond or securities issue. A CDO typically has multiple tranches, each with a different maturity, coupon or payment structure.

Uncertainty The condition in which reasonable knowledge regarding risks, benefits, or the future is not available.

VaR Value at Risk. A technique which uses the statistical analysis of historical market trends and volatilities to estimate the likelihood that a given portfolio's losses will exceed a certain amount.

Wiener Process The description of movements in a variable when the change in its value in short interval is normally distributed and the changes in two non-overlapping periods of time are uncorrelated. Also known as arithmetic Brownian motion.

Interviewees Code

Since all interviewees' names are kept confidential as request, this section provides a useful table of interviewee code for the convenience of reader.

Policy makers	***Organization/location***
P001	National Development and Reform Committee, Beijing
P002	National Development and Reform Committee, Beijing
P003	Ministry of Science and Technology, Beijing
P004	Ministry of Foreign Affairs, Beijing
P005	Administrative Center for China's Agenda 21, Beijing
P006	Research Center for Sustainable Development, Beijing
Finance Practitioners	***Organization/location***
F001	Sindcatum Carbon Capital, Beijing
F002	Sindcatum Carbon Capital, London
F003	Climate Change Capital, Beijing
F004	Prototype Carbon Fund, Washington. D.C.
F005	Barclays Capital, London
F006	Ecosecurities, Oxford

Abstract

China has the lions' share of world's expected Certified Emission Reduction (CERs) produced from projects under Clean Development Mechanism (CDM). However, a huge gap between expected CERs and actualized CERs is observed in China. It is perceived China's regulatory risk is the main contributing factor. This thesis attempts to assess the effect of China's regulatory risk on project developers' ability to deliver CERs, and proposes effective risk management strategies. This can be achieved by employing a combination of financial theories, qualitative interviews and Analytical Hierarchy Process (AHP), a multi-criteria decision making tool. Assuming project diversification is common, regulatory risk can be modeled as carbon credit default risk. Based on this "risk-equivalent" approach, this thesis conducts 12 structured interviews and develops AHP assessment models to measure the regulatory risk effect. It is found that regulatory risk has cast an above-medium negative impact on CER delivery. At last, Carbon-based Collateralized Debt Obligation (CCDO), an innovative financial risk management instrument, is proposed and evaluated. Despite some shortfalls, CCDO can fully transfer the regulatory risk and improve carbon market, providing an innovative solution to a critical environmental problem. The approaches and outcomes in this thesis are expected to make important contribution to the subject of Carbon Finance.

Key words: CDM, regulatory risk, default risk, CCDO, Carbon Finance

Chapter 1 INTRODUCTION

Although it is widely recognized that anthropogenic climate change has emerged as one of the greatest challenges over the 21st century, there exist large uncertainties about the concrete impacts on the ecosystem and world economy (Stern, 2006; Pearce, 2005, Houghton, 2004). Consequently, the progress of setting commonly-accepted greenhouse-gas emission targets was slow. The 1997 Kyoto Protocol marks a milestone in the international climate policy: it not only set legally binding emission targets for industrialized countries for the period 2008-2012, but also introduced three flexible mechanisms to assist accession countries in achieving their quantified emission reduction target (UNFCCC, 1997). The mechanisms are Emission Trading Scheme (ETS), Joint Implementation (JI) and Clean Development Mechanism (CDM).

The ETS model traces its origin in USA's experience on limiting the emission of sulphur dioxide by cap-and-trade. To date, the most successful example is European Union Emission Trading Scheme (EU ETS), which commenced on 1 January 2005. It covered 27 member states and 45% of EU CO_2 emissions (European Commission, 2007).

In contrast, JI and CDM allow industrialized countries (so-called Annex B countries) to invest in emission reduction projects. **CDM refers to project developed in developing countries (non-Annex B countries)** whereas projects under JI are developed in other

Annex B countries (UNFCCC,1997). The purpose of CDM is to assist developing countries in achieving sustainable development and contribute to stabilization of atmospheric greenhouse-gas concentration (UNFCCC, Art.12, 1997:12). CDM projects are intended as a vehicle for investment and technology transfer into the developing world (Labatt and White, 2007).

The emission reductions achieved under CDM necessarily follow rather complex and ambiguous criteria. In order to avoid giving credits to projects that would have happened anyway, rules have been specified to ensure additionality of the project (World Bank, 2006a). Once emission reductions are certified by CDM Executive Board (EB), they become tradable Certified Emission Reductions (CERs). Under Linking Directive, CERs can be introduced in the second phase of EU ETS (Carbon Trust, 2006).

1.1 Problems Formulated

The major concern of this thesis is that CDM is unable to deliver its full potential of CERs. This is especially true in China. According to the May 2007 pipeline of CDM projects (until 31st May, 2007), only 3.59% out of a 178 million expected CERs by 2007 have been issued in China, while the corresponding figures for India and Brazil are 40.51% and 40.10%, respectively (UNEP, 2007). This indicates China's huge gap between actualized CERs and expected CERs[1], thereby seriously debilitating project developers' ability to

[1] The expected CER is based on two assumptions: 1. All activities will be registered successfully within average project circle, 2. All activities deliver simultaneously expected annual average CERs. (UNFCCC, 2007).

deliver CERs. Since China owns a lion share (43.21%) of the world's expected CERs, failure to deliver their potential means many capped countries which depend on these non-domestic efforts may not successfully achieve their emission targets. Even if some project developers are aware of the risk, they may still rush to China in pursuit of its market potential, which can even amplify the risk. Either case can seriously undermine the effectiveness of CDM and incur great **social welfare loss.**

It is perceived that CDM regulation is the major contributing factor to this problem (International Emission Trading Association (IETA), 2005). A critical reader might argue that the gap is mainly a result of **timing**. In other words, it is possible that many projects haven't started to generate emission reduction, and once they have, the problem will correct itself. But it is hardly convincing timing alone can contribute to such a wide gap. If one consider CERs only from **registered** projects, which are relatively less subjected to timing effect, China's CER issuance rate is a pathetic 9.1%, as opposed to 86.5% and 57.7% for India and Brazil (UNEP, 2007). Also, that China's CER price is much higher than in any other destination means market has indeed priced additional delivery risks in China (From Interviewee F001-F006, section 4.1). Since international modalities and procedures for CDM projects are the same no matter which country hosts them, these additional risks must come from domestic regulations (Zhuang, 2006). More explicitly, this refers to China's CDM management measure and institutional settings. This issue will be explored further in the following chapters.

1.2 Aim and Research Questions

The aim of this thesis is to determine to what extent regulatory risks in China have affected CER delivery for project developers and what strategies can be employed to manage such risks.

This aim can be achieved by pursuing the principal research question:

How do regulatory risks in China influence CER delivery and what can be done to manage them?

This question can be divided into two parts. The first part is to assess the effect of regulatory risk. The focus is to explore the problem through various approaches and from lens of different stakeholders. It can be divided into two sub-questions:

1. What are regulatory risks in China?
2. How do regulatory risks influence China's project developers' ability to deliver CER?

The second part discusses risk management practices. This part proposes an innovative financial solution and evaluates its merits based on respondents' judgments. There are two sub-questions.

3. How can the proposed instrument manage regulatory risk?

4. How effective is it compared with existing strategies?

1.3 Expected Contribution

There are two major projected contributions of this study. The first is to **develop a reliable assessment profile of China's regulatory risk effect.** This challenging topic has never been addressed systematically by previous literatures. Indeed, CER under-delivery in China can have serious implication on global effort to reduce emission, which should be addressed rigorously. The second is to **contribute to the subject of carbon finance.** Labbat and White (2007:1) defines carbon finance as an innovative subject "that explores financial risks and opportunities in a carbon-constrained society and anticipates the use of financial instruments that are capable of achieving environmental objectives." Currently, this area is dominated by experts who are sometimes uncomfortable with the idea of "profiteering" from a system designed to cut pollution. Literature sources employing rigid financial analysis have been thin. This study attempts to fill this gap by emphasizing the role of financial market, which can provide ideal mechanism to transfer environmental risk.

1.4 Research Approach

This thesis will adopt a combination of qualitative and quantitative research approach. The major approach to answer sub-question 1 is literature review. In addressing sub-questions

2, the main methodologies are structured interview and Analytical Hierarchy Process (AHP), a multi-criteria decision making tool which can provide a quantified assessment based on judgments from respondents. Answering sub-question 3 requires a review of literatures in financial risk management approaches. The last question will be solved based on interview and AHP assessment.

1.5 Scope and Focus

The scope of this thesis is narrowed to CDM projects in China. This is because China is the largest developing emitter and therefore has the greatest CDM potential. China is thus regarded as an extremely attractive investment destination. However, risks arising from China's regulation remain concerns for investors (Siegel, 2006).

In addition, this thesis only evaluates regulatory risk. Such risks as operational risk and construction risk can be diversified away in an ideal project portfolio. Yet regulatory risk is the systematical risk—— risk cannot be eliminated by diversification (Brealey et al., 2005). Managing such risk is difficult but of vital importance.

1.6 Assumptions

There are four fundamental assumptions in this research. Firstly, project developers are also foreign carbon funds (including carbon originators and financial institutions). Here the phrase “buyers” means compliance/terminal buyers. In practice, carbon funds are mainly acting as intermediaries, who buy CERs from developers and sell them to terminal buyers. See Figure 1-1.

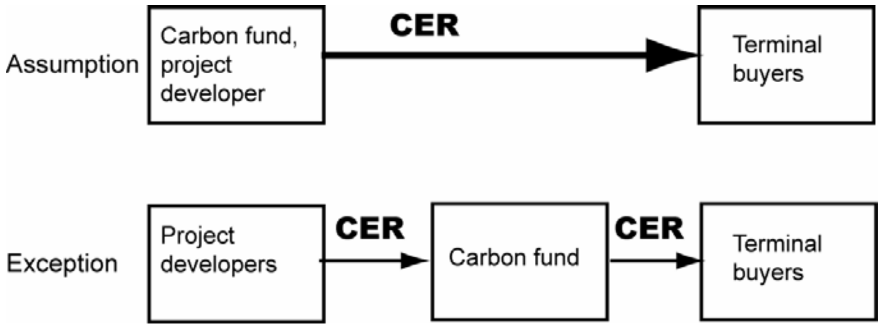

Figure 1-1: Illustration of assumption one.

This simplified case will not influence the validity of result, as foreign funds take stake in most China’s CDM projects (CCChina, 2007). A second assumption is that all project developers have a well-diversified portfolio of projects. This means project risks can be fully diversified. Thirdly, measuring regulatory effect is equivalent to measuring default risk of carbon credits. Indeed, assumption 3 is true if the assumption 2 holds (see section 2.4.3 for detail). In practice, these two assumptions may not work for small players, who don’t own diversified portfolios. But the deviation is limited since China’s CDM market is dominated by such big players as Enel and Ecosecurties (CCChina, 2007). Lastly, it is assumed that CERs will be delivered as soon as they are issued. In other words, “CER issuance” and “CER delivery” can be used interchangeably, a close approximation to the reality.

1.7 Structure

The structure of the thesis is organized as follows: Chapter 2 reviews fundamental debates of CDM, answers sub-question 1 under a risk management framework and introduces relevant financial theories. Chapter 3 critically reviews the methodologies employed. The results of interview and AHP will be addressed in Chapter 4. These results are then combined to answer sub-question 2.

The risk management practices and financial instrument design are described in Chapter 5. The potential pros and cons of the proposed financial solution will be evaluated in the context of China. Not only sub-question 3-4 will be answered, but suggestions about improving carbon market will also be addressed. The final chapter concludes.

Chapter 2 THEORECTIC FRAMEWORK

There are two parts in this chapter. The first (2.1-2.2) introduces some key concerns of CDM. The second (2.3) systematically explores sub-question 1, raises debates of China's regulatory risk and examines relevant financial theories.

2.1 Debate of CDM

CDM is a classic example of liberal environmentalism theory, which states that free market and private ownership are necessary for environmental protection (See Hardin, 1968; Anderson, 1991). A list of criticisms of CDM includes the following:

1. The iterated procedure in CDM governance, combined with ambiguous definition of additionality, has seriously undermined the effectiveness of CDM (Nordhaus, 2001).
2. CDM can be viewed as a subsidy that performs very inefficiently: it enables buyers to pay a much higher price than the actual marginal abatement cost (Wara, 2007).
3. CDM projects don't have an equitable geographic distribution: most projects are clustered in countries such as China and India, whereas African nations seldom receive such benefits (Schelling, 1998; Barret, 1998; Nelson, 2004).
4. CDM's principles of emission reduction are flawed: implementing CDM projects may impede the technological development (Grubb and Brack, 1999). It is even responsible for a net increase in emissions (Liverman, 2006).

Interestingly, most of the above critiques (except for the last one) have only focused on the shortcomings of system design. To start with, the ambiguous additionality criteria and complex governance system can be improved by future political negotiation. Besides, current governance system could be regarded as a hedging strategy to avoid perverse incentives (Bohringer and Finus, 2005). Secondly, CERs are actually valuable financial assets rather than mere environmental commitments (Tuner, 2007). Thus, using abatement cost as an indicator of economic efficiency cannot reflect the full value of CER. Thirdly, equity principles refer to normative concepts of distributive fairness that are perceived very differently (Ringius et al., 1998). In this sense, equity can be interpreted as treating people in the most appropriate way, rather than in exactly the same way. In current stage, installing CDM projects in the poorest countries can be counter-productive, due to the unstable political environmental and under-developed infrastructure. The last argument directly challenges the validity of CDM's principles. It is based on three assumptions: a）the Kyoto targets would have been identical without CDM; b) the targets can be achieved without CDM; c) a proportion of emission reduction is not real. Hepburn (2007) argues this conclusion is only as good as these assumptions. Yet the conclusion might still be invalid even if the assumptions hold, as it has overlooked the "intangible benefits" brought by CDM, such as capacities, technologies and awareness, which might otherwise not exist in developing countries.

Indeed, CDM is well-founded in principle as it addresses economical efficiency by improving flexibility of geographic locations and addresses equity issue by allowing transfers to developing countries（Bohringer and Finus, 2005）. Adopting CDM can drastically reduce abatement cost and increase international financial flows. For example, IPCC (2001) has projected GDP losses for OECD Europe with full use of CDM and JI to 0.13%-0.81%, as opposed to 0.31%-1.50% with only domestic action. Studies by Bollen et al. (1998) even show that CDM can potentially reduce the overall cost of Annex B to close to zero. Also, nearly 6 billion USD financial flows for carbon-reduction projects are established through the CDM (IPCC, 2007). This implies the importance of **exploiting full potential of CDM**.

2.2 CDM governance system

As indicated above, the CDM governance follows a rather strict and iterated process. An industrialized country that wishes to get CERs must obtain the consent of the Designate National Authority (DNA) from the hosting country that it will contribute to sustainable development. Then, using methodologies approved by CDM Executive Board (EB), the applicants must make the case that the project would not have happened anyway and must establish a baseline estimating the future emission in the absence of the registered project. The case is then validated by a third party agency, a so-called Designated Operational Entity (DOE) to ensure the project results in real, measurable and long term emission reduction. The EB then decide whether to register the project. If a project is registered and implemented, the EB issues credit (CER) with the prerequisite of the verification of another DOE. The whole process is called **project cycle** (UNFCCC, 2001).

See Figure 2-1.

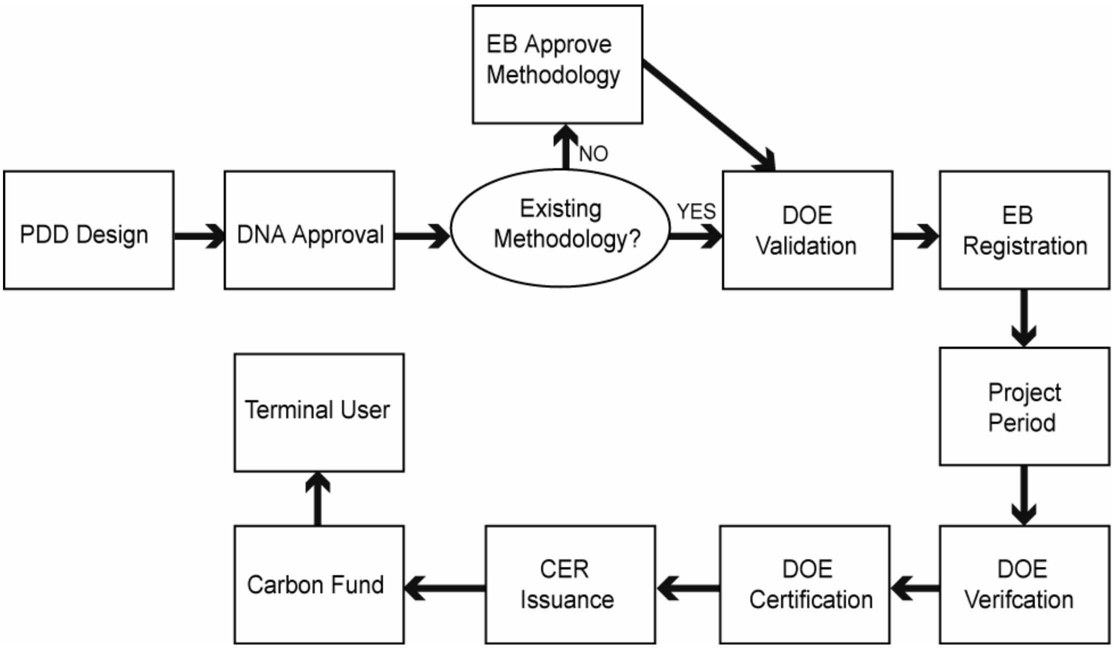

Figure 2-1: CDM project cycle

2.3 Risk Management Framework

Generally speaking, risk management is a human activity which integrates recognition of risk, risk assessment and developing strategies to manage it. Chapman and Ward (1996) present a sophisticated nine-phase risk management structure. Considering the focus of this thesis, an adapted three-phase framework is employed: risk identification, assessment and management. The first phase summarizes major regulatory risk factors, and “evaluation” phase measures the risk effect on CER issuance. The last phase provides insights into risk management practices.

2.3.1 Risk Identification

This section will answer sub-question 1. Miller and Lessard (2000) classify risks involving in a large engineering project, such as political risk, operational risk, and completion risk. Based on this classification, RWE, the German energy giant, has specified risks related to CDM, as shown in table 2-2 (Adam, 2006).

Risk category	*Risk sub-category*
Project risk	Operational risk Implementation risk Technical risk Performance risk
Regulatory risk	Host country risk Methodology risk Validation risk Registration risk Verification/Certification risk Risk of Transfer of certificate to Annex B national account
Risk of contract fulfillment	Intentional breach of contract

Table 2-1 Risk identification in CDM project

Source: Adam (2006)

As noted in Chapter 1, this thesis only measures **regulatory risk**, the risk incurred by regulation provisions which can not be eliminated by diversification. Under the category of regulatory risk, "Risk of Transfer of Certificate to nation account" will not be considered as it happens *after* CER is delivered. Thus, **regulatory risks in China** can be shown in table 2-2. This composition is consistent with the procedures in the project cycle. Some project risks will also be discussed briefly in Chapter 4 in order to assist AHP analysis.

Regulatory risk factor	***Incurred by***	***Definition***
Host country risk	Chinese government	The risk that the project might not be approved or seriously delayed in DNA approval process and that the domestic CDM rules will negatively influence project progress.
Methodology risk	CDM Executive Board	The risk that new methodologies may not be approved or the methodologies may be inapplicable for the candidate project.
Validation risk	DOE	The risk that project may fail to pass the DOE validation, or the process is somewhat delayed.
Registration risk	CDM Executive Board	The risk that it takes excessively long time for a project to register in EB.(Currently around 8 weeks)
Verification/certification risk	DOE	The risk that certain or all proportions of emission reductions are not verified by DOE.

Table 2-2 Definitions of regulatory risk factors

Source: adapted from Miller and Lessard (2000) and Steenbergen (2006)

In this table, two issues should raise special attention. The first is methodology risk. A CDM methodology is a procedure for baseline-scenario identification, determination of additionality, calculation of emission reductions and monitoring the relevant parameters (World Bank, 2006a). Initially, methodology risk is mentioned as the single biggest risk factor. However, recent documents show that methodology risk is not as significant as before (Zhang, 2006; Liu, 2006).

The second issue is “host country risk (China specific risk)”, **the only risk factor that distinguishes China’s overall regulatory risk from that of other countries.** It involves two parts: **DNA approval risk and risk of China’s CDM regulation** (Abele, 2007). See next section for lengthy discussions.

2.3.2 Debate of China Specific Risk

Institutions	*Responsibilities*	*Composition*
NCCCC	■ Formulate and coordinate national climate policies ■ Review CDM policies and rules ■ Approve members of CDM Board	Chaired by NDRC; Vice Chairman and other members from 15 ministerial agencies
National CDM Board	■ Examine and assess CDM projects ■ Transfer CERs generated in unilateral projects ■ Make recommendations on the measure ■ Report to NCCCC on the progress of CDM activities ■ Supervise implementation and monitoring	**Co-chairs**: NDRC Ministry of Science and Technology (MOST) **Vice Chair**: Ministry of Foreign Affairs (MOFA) **Members**: State Environmental Protection Agency (SEPA) China Meteorological Administration (CMA) Ministry of Finance (MOF) Ministry of Agriculture(MOA)
NDRC(China's DNA)	■ Accept CDM project application ■ Issue national approval letter, based on decision of the Board ■ Supervise implementation	NDRC

Table 2-3: Composition of China's CDM administration body
Source: based on CCChina (2007)

To strengthen the management of CDM projects and safeguard national interests, in June 2004, Chinese government promulgated the *Interim Guidelines for Operation and Management of CDM projects in China* (hereinafter referred as "Interim Guideline"), specifying DNA approval criteria and regulation issues (National Development and Reform Committee (NDRC), 2004). It was then replaced by a more clearly-articulated *Measures for Operation and Management of CDM projects in China* (hereinafter referred as “New Measure”) (NDRC, 2005). According to the New Measure, there are three levels of institutions for CDM management: National Coordination Committee on Climate Change (NCCCC), National CDM Board and DNA. Indeed, major compositions and functions of these institutions are highly intertwined with each other (see table 2-3). All three major institutions have somewhat participated in assessing projects and supervising implementation. NDRC is the China’s DNA, co-chair of CDM Board and chair of NCCCC. Both the CDM Board and NCCCC consist of a wide range of government departments (Sun, 2006).

Controversial Provision/pattern	Interim Guideline	New Measures
Project ownership	Joint Venture with Chinese partner a majority stake	Same
Ownership of CER	Jointly owned by government and project developer	Same
Royalty fees	No specific amount mentioned, which is decided by government	2% of CER revenue for “priority areas”; 30% for N2O projects; 65% for HFC and PFC projects; Projects approved by DNA before Dec, 2005 are exempted.
Price floor for CER	Mandate price floor	Same
Conflict interests	Conflicting interests among different political parties	Same
Intervention	Not elaborated but the NDRC can have the right to cut emission reduction when necessary	Same

Table 2-4: The Interim Guideline and New Measure

Source: adapted from CCChina and interview (2007)

The change of policy term in the New Measure is shown in table 2-4. Many scholars insist the above regulatory provisions have imposed great risks for CDM project developers to effectively deliver CER. Koch (2005) argues that Chinese majority ownership can seriously delay CER issuance, that joint ownership of CER causes unprofitable cooperation with state, and that price floor reduces the volume of deliverable CERs. Szymanski (2002) and Michaelowa (2003) noted that Chinese government appeared tentative and noncommittal about formally endorsing CDM projects. Although some problems are addressed in the New Measure, the improvements are regarded as very limited. Abele (2007) criticizes that Chinese government adheres to the criteria of joint ventures despite the international criticism. In his view, the royalty fees will add financial burdens to investors. Another potential risk is the conflicting interests and bureaucratic decision making caused by multi-roles of NDRC and multi-compositions of CDM Board and NCCC (Liu, 2006). Project developers might be subjected to the risk of "double regulation", in which different institutions have posed different standards on a single project during implementation. Also, according to New Measure, NDRC can cut emission reductions volume even after verification process. "No one can say for sure how many CERs will be produced," said interviewee F001 (2007).

However, some scholars suggest the "host country risk" is not as big as previously believed. Liu (2007) asserts that the New Measure will even boost CER issuance. In his eye, the China specific risk is small and the major regulatory risk is methodology risk. He also attributes the huge gap of issued CERs between China and India to time lag. As mentioned, if this were true, one would observe that CER price in China is around world's average. This is exactly the opposite (F001-F006, 2007). Also, some potential risks arising from the New Measure are justified by scholars. Zhuang (2006) argues charging levy of CER revenue is beneficial to sustainable development and supported by World Bank. Climate Thinker (2007), a climate forum, even argues China has set such loose standard that CDM now almost becomes “China Development Mechanism.” The evidence is that China has accounted for 63% of projects in public stakeholder consultation stage (till 31st May, 2007).

The debate exactly corresponds to the sub-questions 2, which will be resolved in Chapter 4 through both qualitative and quantitative methods.

2.3.3 Risk Effect: “Risk Chain” and “Risk-equivalent”

Regulatory risk factor in question	*Intermediate risk effect*
Host country risk	Volume/delay/cost
Methodology risk	Volume/delay
Validation risk	Volume/delay
Registration risk	Delay
Verification/Certification risk	Volume/cost

Table 2-5 Intermediate regulatory risk effect

World Bank (2006b) has defined six types of CER under-delivery, including delivery failure, material delay of delivery and insolvency of project developers. Based on this definition and table 2-2, regulatory risk can directly affect the **volume of CER**, or indirectly affect it either by **delaying CER issuance or increasing cost burden**. This is regarded as the **intermediate risk effect** (see Table 2-5). According to assumptions 2 in section 1.6, regulatory risk is the only risk that cannot be diversified in CDM projects. Since the majority of CERs are sold through forward contracts (Streck, 2007; interviewee F004, 2007), if regulatory risk has dampened project developers' ability to deliver CER, they have to default on the forward contract. **So it is reasonable to say measuring regulatory risk effect is equivalent to measuring default risk effect.** This is a **risk-equivalent approach.** Thus, for project developers, **carbon credit default risk**[2] has **the proximate effect** on **CER delivery**. In the event of default, both parties suffer, and the market doesn't function efficiently since the cheap abatement option is not available. In other words, under-delivery of CER causes social welfare loss. This is deemed as the **ultimate risk effect**.

In order to further clarify the notions mentioned above, an innovative idea is introduced, namely, **risk chain**. It means the effect of the same risk on same stake-holders can be measured in different way over times (see table 2-6).

Risk Chain Parameters	***Measurement***
Basic scale of regulatory risk	Project beta[3]
Intermediate effect	Volume of CER/delay/cost
Proximate effect	Default risk exposure
Ultimate/Macroeconomic effect	Social Welfare function

Table 2-6 CDM regulatory risk chain

2 Default risk in this thesis refers to "unintentional default risk."
3 Beta is the basic risk indicator in project finance, which measures the non-diversifiable risk.

2.3.4 Modelling Credit Default

Risk effect assessment is the most important yet the most tedious part of the whole risk management cycle. According to table 2-6, measuring either intermediate effect or proximate effect can determine how regulatory risks affect CER delivery. To measure the intermediate effect, one should trace the effects of individual regulatory risks and take numerous steps of calculations. However, the modeling approach can be significantly simplified by directly measuring default risk effect, the proximate effect. This innovative "risk-equivalent" approach only requires two parameters: the default probability p and the loss V if default actually happens. There are many techniques for assessing default risk on financial assets. A selection is briefly discussed in the following paragraphs. For detailed mathematic derivations, please see Appendix D.

1. Calculate default probability. Let $p(t)$ denotes the probability of survival at time t, or the probability that default doesn't happen for t years. Then $p(k/t)$, the probability of surviving at time k given survival at t, can be derived according to Bayes's Rule:

$$p(k/t) = \exp(-\int_t^k f(x)dx) \quad (2.1)$$

Where $f(t) = \frac{-p'(t)}{p(t)}$. Logically, $1 - p(k/t)$ is the probability of default at k given *only conditional* on survival at time t. However, for CDM projects, the default probability should be contingent on *all the relevant information* available at t. Consequently, this approach can't yield information needed.

A second approach is the robust model developed by Black and Scholes (1973) and Merton (1974):

$$p(X_k \leq 0 / X_t) = N[z(k,t)] \quad (2.2)$$

Where X_t X_k are distances to default, $N[z(k,t)]$ is the probability that a normal variable is less than a multivariate function $z(k,t)$, of which $z(k,t) = [X_t + m(k-t)] / \sqrt{k-t}$, m is a constant drift (mean value) of *Wiener Process* (See Appendix D). The idea of this model is default only happens when the actualized CERs are smaller than the contract liabilities. This model is adopted in the thesis due to its robust underlying theories (Duffie and Singleton, 2003).

2. Impact on volume of CERs. One standard approach to address this question is to determine **Value at risk (VaR)**, a statistical measurement of how market value of assets is likely to decrease over a certain period of time (J.P. Morgan, 1994). For example, if 10-day VaR of a carbon portfolio is 1 million CERs at 99% confidence level, this implies there is a less than 5% chance that CERs portfolio will decrease by at least 1 million. In the context of this thesis, however, the approach is probably too complex: computing it requires knowing the exposure of every individual risk factor and their inter-correlations. This method also has some inherent technical weakness (See Appendix D).

Since one only needs to know the exposure of *one-side default* risk on forward contract, there is a simple and credible method available. Emission Reduction Purchase Agreement (ERPA) of World Bank (2006b) has specified different risk allocations for carbon credits. For forward CERs whose risk is allocated to project developers, an amount equal to $CER\ shortfall \times (Spot\ rate - Forward\ exercise\ price)$ is payable to compliance buyers in the event of default (World Bank, 2006b). Thus, suppose forward price is T, the spot price on the delivery day is S_k and risk-free interest rate is variable r(t), then the *present value of default risk exposure* for project developers, if they are obliged to purchase carbon credit in spot market , can be easily computed by discounting the loss at risk-free interest rate:

$$V = E[\exp(-\int_t^k r(x)dx)L(S_k - T)] \quad (2.3)$$

Where $\exp(-\int_t^k r(x)dx)$ is the continuously discount factor, L is the fraction of loss, and $E[X]$ is the expected value (weighed average) of variable X, and especially, $E[L(S_k - T)] = L(S_k - T)$.

Combining the two steps, and assume there are N players in the market, the default risk exposure function **(DEF)** can be expressed as:

$$V = E[\sum_{i=1}^{n} \exp(-\int_{t_i}^{k_i} r(x)dx)] \bullet L(S_{ki} - T_i) \bullet p_i(X_k \leq 0 / X_t) \quad (2.4)$$

Where $p_i(X_k \leq 0 / X_t)$ denotes the Black-Scholes-Merton default probability, and the subscript i denotes the "i-th" player. The three key assumptions are that default probability of projects is independent, all CERs are traded through forward contract and forward contracts of a single company have same price and same maturity (See Appendix D). The last assumption is only a coarse approximation. Alternatively, one can model the contract number as a *Poison Process*, and compute the loss distribution through Monte

Carlo Simulation, a computerized probabilistic risk analysis technique. But the DEF model is more straightforward, considering the limited size of China's CDM market. If statistical data are available, this model can offer a relative accurate assessment of regulatory risk effect on both CER delivery and can determine to what extent regulatory risk contributes to China's CER gap.

2.3.5 Risk Management

This section introduces risk management strategies. Here, the central consideration is: **how can risk management be used as a strategic opportunity rather than mere risk control?**

Once risk is identified and assessed, all techniques to manage the risk fall into one or more of the following four categories (Dorfman, 1997; Bodie and Merton, 2001), referred as 4 T's, see Table 2-7

Risk Management Category	***Definition***
Tolerate	Accept the loss(insure against the risk is expensive)
Terminate	Not perform risky project
Treat	Risk control
Transfer	Transfer the risk to counterparties

Table 2-7 Risk management category
Source: Dorfman (1997)

Since managing regulatory risk is equal to managing default risk, a strong case exists to utilize credit derivatives, a typo in credit default risk management, to *transfer* CDM regulatory risk to the financial market. Financial instruments also have the potential to improve the condition of carbon market. **Collateralized Debt Obligation (CDO)**, an important credit derivative, deserves our special attention. A traditional CDO packages a diversified pool of usually illiquid assets into multiple classes of bonds. This process involves the establishment of Special Purpose Vehicle (SPV), an independent third party issuing asset-backed bonds to investors (Barclays Capital, 2002). These bonds often have several "tranches" (classes), each attaching to different risk exposure tailored for various risk appetite. Any default or loss will go against the last tranche, before going against the next one, etc. The last tranche therefore has the highest return in exchange for "first loss". The most senior tranche normally carries a triple-A credit rating (Duffie and Garleanu, 2001). This structure is extremely popular with investors: it is estimated that the size of CDO by the end of 2006 is approximately 2 trillion dollars (Pierron, 2006).

In this thesis, some innovative modifications to traditional CDO model are suggested. The fundamental idea is to see carbon credits as "carbon currency"——investors use carbon credit, rather than cash, to purchase the asset-linked bond. This is equivalent to "borrowing" carbon credits from investors to cover the default risk. See Chapter 5 for a lengthy and detailed discussion.

Yet the recent American subprime mortgage collapse has made CDO somewhat notorious (Financial Times, 2007a). One should recognize, however, the cause of global credit contagion is multifaceted, including rising interest rate and US property market bubble. Despite the fact that CDO has somewhat amplified the risk, the fundamental cause is the investors' excessive risk-taking behavior, not CDO (Christie, 2007). If used properly, CDO can be a very effective risk management instrument.

Chapter 3 METHODOLOGY

3.1 Facing the Challenge: Methodological Triangulation

Despite the conceptually-elegant DEF model, estimating the effect of regulatory risk is still challenging. Indeed, the conditional default probability can only be computed convincingly with sufficient accounting and statistical details. However, these data are often kept confidential. An alternative modeling approach, presented by Steenbergen (2006), employers so small a sample size that surely lacks statistical significance. Nagai (2005), based on idea from Lecocq and Capoor (2005), suggests the spread between buyer’s and seller’s risk-adjusted price can represent the regulatory risk. However, since CDM market is inactive and inefficient, price spread is not a reliable measure of the actual risk. In reality, the limited accessible data, combined with the complex political prospects of CDM market, significantly undermines the credibility of numerical models.

A potential solution is to quantify people’s perception of the risk effect through survey. Nonetheless, relatively few people have possessed the essential expertise—— the qualified respondents should have a comprehensive understanding of CDM or financial markets and should be familiar with China’s domestic CDM rules. Such small sample size cannot yield the desired confidence level in a standard statistics analysis. On the other hand, qualitative interview alone can’t perform the task of assessing regulatory risk effective objectively.

Regarding the significant challenges involved, methodological triangulation is essential. The logic of triangulation is based on the premise that:

"No single method ever adequately solves the problem of rival casual factors. Because each method reveals different aspects of empirical reality, multiple methods of observation must be employed. This is termed triangulation." (Denzin 1978: 28)

As pointed earlier, studies using only one method are more prone to errors linked to that particular type of method (eg, surveys with no statistical significance). In this sense, methodological triangulation provides us with "an arsenal of methods that have non-overlapping weakness in additional to their complementary strengths." (Brewer and Hunter, 1989:71) In the context of this thesis, triangulation means using both **qualitative interview and AHP** to mutually enhance the credibility of the outcomes.

However, Guba and Lincoln (1988), Simth and Hesusius (1986) argue that the internal inconsistency and logic of each approach mitigate against methodological mixing of different inquiry modes and strategies. Yet adopting such purist view overlooks the possibility that methodologies themselves may evolve to adapt to each other. Just as machines originally created for separate aims, such as copying and printing, is now increasingly combined into an integrated unit, so too methods initially functioning as distinct approaches can now be combined fruitfully. In this thesis, the combined methodologies are essential to assess regulatory risk effect.

3.2 Structured open-ended Interview

Structured open-ended interviews play two major aims in this thesis: First, it attempts to **shed light on** people's perceptions of regulatory risk and **evaluate** the credibility of results from AHP analysis (section 4.1 & 4.3). Second, it **provides valuable insights** of the proposed instruments and standard regulatory risk management practice (section 5.1 & 5.3.1)

There are three reasons why structured interviews are employed in this study: First, structured interviews are more efficient in locating answers and organizing data, the follow-on analysis can become much easier and more revealing (Patton, 2001). Second, structured interview is highly focused so that interview time is used efficiently. This point is important especially as most respondents in this thesis have very tight schedule. Last, since the research subject is controversial and politically-sensitive, a structured interview can ensure consistency across different stakeholders. Although Patton (2001) and Bryman (2004) argue semi-structured and unstructured interviews permit greater flexibility, it is likely that more information is obtained from some participants than others. Difference in qualitative information may be especially harmful for contentious themes (Fontana and Frey, 2000). In practice, the format is standardized during most part of the interview, but certain subjects of particular interest are pursued without pre-determined format. Thus, the inflexibility of structured interview can be effectively mitigated.

A critical issue of structured interview is sampling. Unlike statistical analysis which depends on random sampling, qualitative interview typically focuses on relative small samples, selected purposefully. Scholars such as Powdermaker (1966) and Stewart (1979) criticize results obtained from purposeful sampling cannot be generalized, but this is exactly what quantitative interview aims for: studying information-rich cases for in-depth understanding rather than empirical generalizations. Given the challenging nature of this thesis, it is pivotal to find the right combination of respondents. Patton (2001) and Bernard (2000) have discussed 14 sampling strategies, and this thesis attempts to combine five of them to set systematic sampling criteria. See Table 3-1.

Sampling Strategy	***Strategy Description***	***Priority***
Critical case sampling	Find a group with essential expertise so that if this group can't give an authoritative answer, others are also unlikely to offer as well, thus permitting logical generalization.	High
Typical case sampling	Find samples typical and average in the critical case group.	Medium
Snowball sampling	Ask respondents to recommend other information-rich samples.	Low
Criterion sampling	Pick cases meeting the pre-determined criteria: authoritative and politically important. Also, two groups of people are needed: **policy makers and carbon finance practitioners.**	High
Convenience sampling	Find samples that are accessible with existing resources.	Medium

Table 3-1: Sampling strategies employed
Source: Patton (2001) and Bernard (2000) adapted by author

According to the above sampling criteria, 35 interview samples were chosen and 12 of them were actually interviewed. Respondents are divided into two groups: **policy makers** and **finance practitioners.** The former is all comprised of government officers and academic consultants while the later group consists of foreign project managers and carbon traders. The financial practitioners either specialize in projects in China, or have essential knowledge of China's market.

A caveat here is suggested by Clark (1998) of **interviewing elites**. He argues in finance industry and political arena, the social status and knowledge of respondents are often significantly higher than researchers. So it is possible that respondents "deliberately represent issues in a manner beneficial to their own interest, but in a manner not easily detected by researchers." (Clark, 1998: 81) Thus, Lewontin (1995) simply questions whether one can trust respondents' claims. But we don't need to believe so. The focus is the how and why interviewees are constructing their own worlds, and how this process might influence the risk assessment. Besides, some obvious inconsistent answers can be easily eliminated by AHP analysis. .

3.3 Analytical Hierarchy Process (AHP)

As presented above, many mathematic models aiming to evaluate regulatory risk effect are unsuccessful because the required quantitative information is not available, a major limitation of probabilistic models defined by Kangari and Riggs (1989). The proposed DEF model also can't avoid such weakness. On the other hand, the information provided by high-profile interviewees may suffer from manipulation and arbitrary decision. Here is an area where AHP can be especially useful.

AHP is a robust technique for multi-criteria decision making where the sample size is limited and some attributes are difficult to formalize (Saaty, 1980). The outcome of AHP is a composite vector that shows the weights of different decision options with regard to pre-determined criteria. It helps capture **both subjective and objective evaluation** measure, at the same time providing a useful mechanism for checking the consistency of the respondents' answers (Saaty, 1990). The common themes of AHP application include **assessment, cost-benefit analysis, priority and ranking** (Vaidya and Kumar, 2006). For example, Al Khalil (2002) applied AHP to select the most appropriate project delivery method as key project success factor; Sarkis (1999) considered AHP for evaluation of various environmental conscious manufacturing programs. Yet this approach is relatively less frequently used in risk assessment (Saaty, 1994). Partovi et al. (1989) provides a useful example of using AHP to assess overall risk of constructing the Jamuna Multipurpose Bridge. A four-layer hierarchy comprising of three risk measurements and eight sub-risk factors is presented. Their result showed the project was fundamentally a low risk one. Such structure can be adapted to this thesis. Indeed, AHP serves for two purposes in this thesis: first, it **ranks** the various regulatory risk factors and offers a reliable and primary **assessment** of regulatory risk effect (section 4.2); second, it **evaluates** the most effective risk management instruments (section 5.3.2).

AHP is based on a three-step approach to the final output. First, one should formulate a decision-making problem in a hierarchical structure: elements of the same level should be comparable and related to components in the next higher level. The top level is the overall objective: for example, choosing a house. The intermediate level consists of elements affecting decision, for example, choosing a house depends on price, location and environment. Decision options are presented in the lowest level.

Saaty Scale	***Measure Description***
1,	equally preferred/important
3,	moderately preferred/important
5,	strongly preferred/important
7,	very strongly preferred/important
9	extremely preferred/important"
2, 4, 6, 8	Intermediate indicator

Table 3-2: Saaty Scale
Source: Saaty (1980)

Second, interviewees are asked to compare pairwise elements with regard to criteria in the higher level. The question can be: How do you like house A when compared with house B regarding price? Respondents can express their preference according to Saaty Scake (1980) listed in table 3-2. The results of all pairwise comparisons can be summarized as several $n \times n$ comparison matrices. The relative weights of elements of each level with respect to the criteria in the adjacent upper level can be determined by the normalized eigenvector associated with the largest eigenvalue of the comparison matrix (known as **priority vector**). The **composite weights/importance** of decision options are computed by aggregating the weights through hierarchy. Please see Appendix C for a detailed mathematic proof.

The last step is to check the consistency of the responses. This produces a "consistency index (C.I.)[4]" where a value greater than 0.1 means intolerable inconsistency:

$$C.I. = (\lambda_{\max} - n)/(n-1) \quad (3.1)$$

Where $\lambda_{\max}$ is the maximal eigenvalue, n represents the number of rows of the matrix. To further enhance the credibility, Saaty (1995) suggested the C.I. should be divided by the same index obtained from an average of many random matrices of the same order. This new ratio (called consistency ratio C.R.) should also not exceed 0.1. Such rigorous method will significantly reduce the possibility of arbitrary decision making during interviews.

Still, two key questions should be addressed. First, what's the appropriate sample size? Sato (2004) is in favor of a large sample size. In a survey aiming to explore students' political perception, he used 834 samples, which he thought can achieve a margin of error of 4% at 95% confidence level. However, a distinguishable feature of AHP is that the priority is given to purposeful sampling. The critical point is to gather the right mix of people to represent the stakeholder positions and expertise, rather than the sample size. Decision Making Forum (2007), a technical platform, suggests participants should be no more than 15-20. In this regard, the AHP analysis basically employs the same sample for interviews, which means interviewees are also required to answer scale questions. But the overall sample size is slightly larger, as some non-interviewed respondents answer scale questions by email. Second, how can one combine preference of different people to obtain a representative judgment of the group? It is imperative for group judgment to

[4] Comparison matrices are thought inconsistent when item A is preferred to item B, B preferred to C, but C preferred to A.

satisfy the reciprocal rule: combining the judgments of all respondents and then taking the reciprocal must give the same result as taking the reciprocal of each person's judgment then combing them (Saaty and Aczel, 1983). This means one should compute the **geometric mean** of respondents' preference, rather than the arithmetic mean. A more rigid method is allowing respondents to exchange preferences and make compromises, but such approach is unrealistic with available resources. Consequently, this thesis uses the geometric mean method.

Like other research methods, AHP cannot go uncriticized. Perez et al. (1995, 2001) argue AHP suffers from "indifferent criterion" flaw. This means if options A, B, C are ranked according to certain criteria, adding another criterion for which A, B, C and D are equal may influence the ranks. This flaw, however, is a shortcoming of any pairwise comparison process, not just AHP. One can largely avoid it by re-calculating the priority vector. Another problem is "rank reversal", noted by Dyer (1990), and Belton and Gear (1983). This means if one option is eliminated, the rank of remaining option can be reversed. Yet this is again a common problem in any pairwise system. Fundamentally, the attractiveness of APH highly outstrips its weakness in this research.

Chapter 4 REGULATORY RISK EFFECT ASSESSMENT

This chapter will answer the sub-questions 2-3 using the combination of techniques introduced in the previous chapter. It organizes as follows: section 4.1 discusses patterns revealed from the qualitative interviews; section 4.2 discusses the result from AHP analysis; section 4.3 and critically evaluates the results and concludes.

4.1 Patterns from Structured Interview

There are 12 interviewees altogether, which are divided into two groups: **policy makers** and **finance practitioners**. The first interview took place on June 23rd, Beijing and the last on August 8th, Oxford. The majority of interviews are face-to-face, but three interviews were conducted through phone due to location problems. Basically, every respondent is asked the same questions, and three more questions about risk management strategies are covered for finance practitioners, as answering them requires specialized financial knowledge. The average interview time is 55 minutes. Table 4-1 provides a check list of interviewee codes. Names and positions are kept secret as requested.

The two groups are so selected that conflicting interests and perceptions are expected. Therefore, it is important to conduct a stakeholder analysis to evaluate their interests and positions, as shown in table 4-2.

Policy makers	Organization/location	Finance Practitioners	Organization/location
P001	NDRC, Beijing	**F001**	SCC, Beijing
P002	NDRC, Beijing	**F002**	SCC, London
P003	MOST, Beijing	**F003**	CCC, Beijing
P004	MOFA, Beijing	**F004**	PCF, Washington.D.C.
P005	ACCA 21, Beijing	**F005**	Barclays Capital, London
P006	RCSD, Beijing	**F006**	Ecosecurities, Oxford

Table 4-1: Check list and code of interviewees

Abbreviation: **ACCA21**: Administrative Center for China's Agenda 21; **RCSD**: Research Center for Sustainable Development; **SCC**: Sindcatum Carbon Capital; **CCC**: Climate Change Capital; **PCF**: Prototype Carbon Fund, World Bank Carbon Finance Unit

Theme	Policy Makers	Finance Practitioners
Components	Government officers, academic consultant for CDM policy	Project managers, originators and carbon traders
Main interest	Safeguard national power, domestic economic development	Profit maximization, future growth potential
Value indicator	Political performance	Profit/other financial indicator
Risk concern	Domestic instability	Under-delivery, high cost
Philosophy	In favor of Maoist that frequent government intervention is necessary and beneficial to the market	In favor of laissez-faire economic liberalism, in which market plays a predominant role

Table 4-2: Stakeholder comparison

During the interview, every respondent is asked 6 open-ended questions (finance practitioners asked 9 questions), and some scale questions. The data can be more systematically structured by coding the questions into three major themes: 1) China's position in CDM market 2) host country risk judgment 3) policy recommendation.

First, this thesis explores China's fundamental attitude and current status quo in the CDM market. Here the sensitizing (critical) concept is "**prudent**", that is, can China's attitude towards CDM projects be called prudent? The majority respondents in policy maker group denied using this phrase.

“Uhmmm……I personally think the attitude might be better described as “responsible”, as government should make sure the project brings real environmental benefits”. (P001)

“This might be true before 2004, as CDM projects were perceived as low-hanging fruits for international companies. However, as the 2004 Interim and 2005 Measure were in place, and as government has increasingly realized the benefit brought about by CDM, this attitude has changed dramatically. Now I think government even takes a proactive approach.” (P005)

Only one respondent in this group described the attitude as “prudent”, though he immediately tried to justify his argument.

“*The attitude is prudent, but essential. After all, there exist many political uncertainties, such as the timeline of Kyoto Protocol and new methodologies. We need to help investors realize the risk involved in the project.*” (P003)

In contrast, all finance practitioners argue China’s policy is so prudent that it has already undermined CER issuance.

"Definitely. This attitude has already put us in a very bad position…shortage of CER, so that we need to set high price to break-even." (F003)

"This is a typical Chinese way of doing things. They are more concerned about domestic development rather than international cooperation." (F004)

Indeed, clues of "political rhetoric", the statement to fit one's aim but with little substance or supporting evidence, can be found in above citations from both sides. This pattern can also be witnessed in next theme.

Another key concept is "**project competition**", which is very helpful to decipher the attitude of both stakeholders:

"Although there is strong competition for CDM projects, I think China will automatically become the most popular host country." (P006)

"Project competitions do happen in such countries as India, while China seems to stand by. However, I should say we come here not because the infrastructure is perfect, but because we value China's future potential." (F003)

The above responses reveal that policy makers are almost indifferent to "project competition," as they think foreign investors will come anyway. There are also clues of the tendency that project developers rush into China's market regardless of the risk.

The second theme concerns how respondents perceive the host country risk effect and overall regulatory risk effect in China's CDM market. It is found that the central concept "**host country regulatory risk**" seems to be interpreted in fundamentally different ways, which is especially salient among policy makers. Readers should pay special attention to some alternative vocabularies used, such as "uncertainty" and "barrier."

*"China has not set any regulatory **barriers** for CDM projects. I have said this again and again in many international conferences."* (P002)

"China's regulation is transparent and reasonable. On the other hand, China is not risky… (compared with other countries), if China were a very risky place to invest, why are there so many CERs generated here?" (P003)

"Regulatory risk in China is trivial, if there is any. The CDM board has almost ratified every project. Also, the maximal 60-day-period for project approval is short compared with almost 2 years spent on registering in EB. Methodology risk is certainly much bigger."(P006)

*"I don't think there is any **uncertainty** in China's CDM policy. In comparison, Methodology risk is much higher. The gaps you have mentioned is mainly due to **time lag**. Also, the*

*New Measure is clearly articulated and known with **certainty**, thus, shortfall happens largely because of investors' own mistakes. This is operational risk, rather than regulatory risk."* (P005)

The above citations have expressed a unanimously and understandably positive attitude towards China's CDM policy. However, no claims had clarified the term "host country regulatory risk". What's more, response from P005 has attributed the perceived CER gap to three alternative factors: time lag, methodology risk and project risks. He first stated "methodology risk is much higher", then argued "*mainly* because of time lag", and at last claim "*largely* because of their own mistakes." It is, however, impossible that all three alternative factors have played major roles simultaneously. This contradiction has at least shown interviewee P005's ignorance of the cause of CER gap. Such phenomena are not uncommon: interviewee P002 arbitrarily defines "risk" as "barrier" and gives no supporting evidence, a typical example of political rhetoric. The evidence offered by P003 and P006 is invalid, which will be discussed in section 4.3. In contrast, "host country risk" and "regulatory risk" have been more clearly defined by finance practitioner group. Generally, group respondents share the same understanding, and frequently use financial jargons to interpret it. Often, strong supporting details are employed to buttress their positions.

*"Regulatory risk is considerable in China. Our projects in China have a very high **beta**. Even so, we doubt that we have under-estimated the risk. Considering the effect of diversification, project may only generate 40%-50% of expected CER, while sometimes as*

little as 10%." (F002)

"Now new methodology approval is not a significant risk factor in China, as most projects have adopted existing methodologies. The New Measure still has substantial implication on CERs (delivery), especially such issues as joint venture with a Chinese partner and government intervention. Having to price this risk will undermine our competitiveness in the market." (F003)

*"Regulatory risk has been widely mentioned as the largest risk of project-related mechanisms under Kyoto Protocol. However, these risks have been diminishing in the last two years, such as methodology risk. But China was a really special case(host country risk). On average, China's CER price is over 50% more expensive. And I'd agree with you that **default risk** is an indicator of regulatory risk…… (given a diversified pool of projects)"* (F004)

The debate of "conflicting interest" has revealed the similar confrontational patterns. For example:

"There is no conflicting interest in government. All parties share the same interest." (P005)

"We do need to conform to different requests. Sometimes they make a simple case quite complex. Once, a small-hydro project is put off because of the various financial

requirements. It is often difficult for us to anticipate…… (issued CERs)." (F006)

Overall, arguments are consistent within the group. Policy makers think China's policy is proactive or justifiably prudent (theme 1), so they perceive trivial host country risk (theme 2). Based on their opinion that China's policy is prudent, finance practitioners argue host country risk has strongly negative impact on CER delivery. Given the highly conflicting positions, it is interesting to see comments from one group on the other.

"Investors complain about the regulatory risk largely because they want to bargain with government and try to influence policy. Bear in mind that no investors will ever be satisfied with policies." (P006)

"Government officers are only concerned about revenue and domestic economic development. They do pose the foreign investors like us in a very bad position." (F001)

According to the citations, it is clear that a sufficiently high overall regulatory effect must be caused by a sufficiently high host country risk effect. Indeed, claims of project developers are immersed with political rhetoric and vague conceptions (for example, citations of P002, P005 in theme 2), and some justifications given by finance practitioners are also ill-conceived. Section 4.3 will provide a critical assessment. There also exist inherent biases between these two stakeholder groups.

The **third** theme seems to be the one where two groups have the least disagreements, though some still exist. See the following two citations:

"The New Measure is certainty not perfect. The improvement should focus on enhancing efficiency and reducing transaction cost. However, the crucial issue is that project developers should build strong capacity on CDM practice, and they must also strictly follow the regulation." (P004)

"I think the future policy should focus on reducing government intervention. Now no one can say for sure how much CER can actually be produced." (F006)

Clearly, both groups have claimed that future improvements should be done, but when speaking of policy recommendations, they have *per se* re-iterated their conflicting positions. In additional, all interviewees agree the New Measure will remain unchanged for quite a while, since they understand government has no incentive to modify existing policy, a pattern presented in theme 1.

Table 4-3 has summarized major patterns in this thesis. These patterns will be further analyzed and evaluated in section 4.3..

Pattern	*Policy Makers*	*Finance Practitioners*
Position on Theme 1	Government's attitude proactive or justifiably prudent	Government's attitude unjustifiably prudent
Patterns revealed 1	1. Political rhetoric 2. Indifferent to competition	1. Political rhetoric 2. Willingness to invest in China regardless of the risk
Position on Theme 2	Host country risk has little influence on CER delivery	Host country risk has prominent influence on CER delivery
Patterns Revealed 2	1. Political rhetoric 2. Vague perception of the concept "regulatory risk," unfounded supporting evidence 3. Inherent bias to foreign investors	1. Logical reasoning 2. Clear and technical definition of "regulatory risk." 3. Inherent bias to policy makers
Position on Theme 3	The focus of future improvement is on project developers' side	The focus of future improvement is on policy makers' side
Patterns revealed 3	1. Opinions consistent with those stated in Theme 1, 2	1. Opinions consistent with those stated in Theme 1,2

Table 4-3 Patterns revealed in the qualitative interview

4.2 AHP Risk Assessment Model

The sample size for AHP risk assessment is 19, including all the interviewees. Among them, 8 belong to policy maker group, and 11 belong to finance practitioners' group. The questionnaires are sent before interviews so that respondents can better grasp the questions. All respondents have been asked to give quantitative scores based on Saaty Scale (1995) to compare the relative importance of different elements (see Appendix A for a sample of scale questions). This thesis employs only samples with C.R. smaller than 0.1. The ratios of samples satisfying this threshold were 75% (=6/8) and 72.7% (=7/11), respectively. Only one interviewee's (in policy maker group) answer was inconsistent, which shows the relative high quality of interviewees' judgments.

According to the risk types introduced in 2.4.2, and interviewees' responses, the proposed risk classification system includes three major type of risk: project risk, regulatory risk and risk of contract fulfillment. The latter two are introduced as a basis for comparison.

Project risk refers to operational risk, implementation risk and technical risk. Operational risk refers to the risk that the equipments don't function adequately, mainly caused by low-quality systems and operation mistakes. Implementation risk is the risk associated with initializing a project, often resulting from project construction. Technical risk reflects the engineering difficulties and novelty. For example, interviewee P005 mentioned the problem of wind turbine led to the delay of issued CER.

The meaning of **regulatory risk** has already been discussed in Chapter 2. In essence it incorporates all five types of risks: host country risk (China's regulatory risk), methodology risk, validation risk, registration risk and verification/certification risk. See table 2-2 for definitions.

The risk of contract fulfillment represents the risk that buyers intentionally breach the contract. This is different from carbon credit default risk, which is defined as unintentional breach.

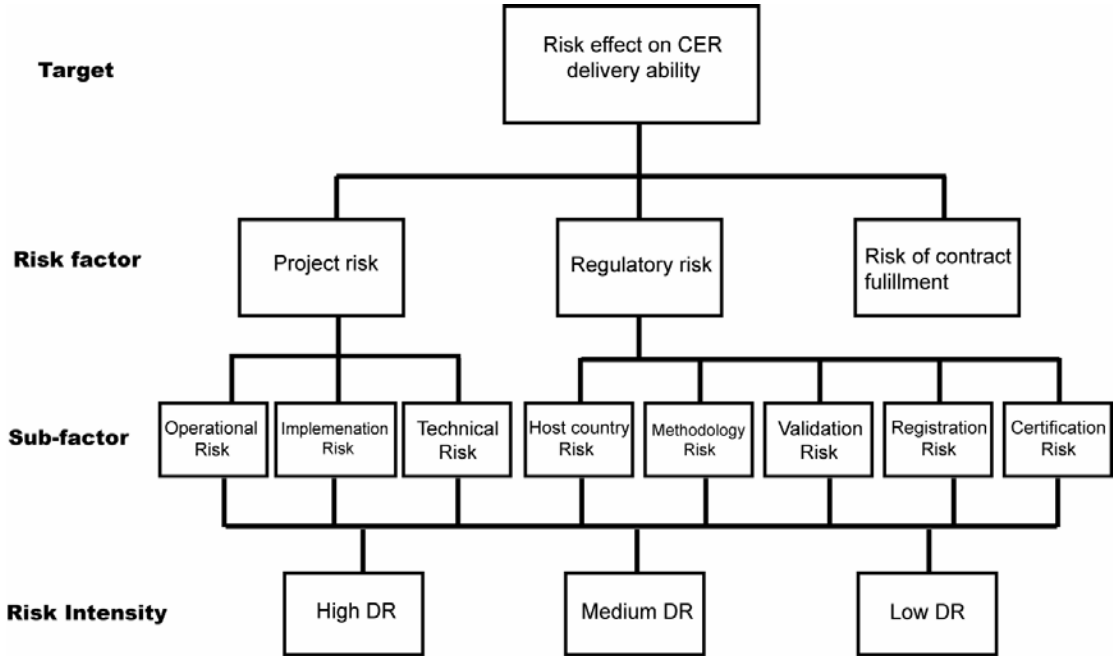

Figure 4-1: AHP model for risk assessment

DR: Default risk

The three-step approach mentioned in section 3.3 is adapted here for applying AHP to regulatory risk effect assessment.

Step 1: Structuring the elements of the problem into a hierarchy, shown in Figure 4-1. The overall object is to assess how regulatory risks can influence project developer's ability to deliver CER. Level 2 and level 3 list the risk factors and sub-factors. Level 4 contains three level of default risk, measuring the default risk intensity once the default happens (see Table 4-6). Thus, the hierarchy follows the same philosophy as the DEF model, namely **regulatory risk effect=probability of regulatory risk×default risk intensity.**

Step 2: This step determines relative importance of factors and sub-factors in Level 2-3. Considering the conflicting ideas of respondents, two sets of AHP matrices are needed, corresponding to each group. Software *Expert Choice* and *Matlab* are used to derive the priority vectors. Table 4-4 offers examples of comparison matrices, where "P" refers to policy makers and "F" refers to finance practitioner group.

P	*R1*	*R2*	*R3*	**Priority Vector**
R1	1	6.45	3.46	**0.686***
R2	0.16	1	0.41	**0.097**
R3	0.29	2.44	1	**0.217**

CR=0.07

F	*R1*	*R2*	*R3*	**Priority Vector**
R1	1	0.18	0.31	**0.092**
R2	5.62	1	3.88	**0.679***
R3	3.27	0.26	1	**0.229**

CR=0.01

Table 4-4 Level 2 comparison matrix

R1: project risk, R2: regulatory risk, R3: risk of contract fulfillment

Clearly, for policymakers, the operational risk has the highest rank (0.686), followed by risk of contract fulfillment (0.217) and regulatory risk (0.097). On the other hand, finance practitioners rank regulatory risk as the primary factor (0.679), while project risk is put as the least important one (0.092). It also appears that finance practitioners' judgments are more consistent than those of policy makers (CR 0.01 VS CR 0.07), a sign of clearer risk perceptions.

Repeating the procedure produces the weighed-average priority vectors for each set of matrices, thus determining the rank of all risk sub-factors (See Table 4-5). For policy makers, operational risk (0.378) is most likely to jeopardize CER delivery while host country (0.007) risk is among the least important factors. The opposite is true in finance practitioner group, who argue host country risk is the foremost contributing factor (0.391). But both groups regard methodology risk among the greatest regulatory factors (rank 4^{th} in P and 2^{nd} in F). Again, the composite CR for finance practitioner is lower than that for policy makers.

Influence on CER **(P)** Composite CR=0.06		Influence on CER **(F)** Composite CR=0.04		**rank**
Sub-factors	**Weighed priority vector**	Sub-factors	**Weighed priority vector**	
R11	**0.378**	R21	**0.391**	**1**
R12	**0.291**	R22	**0.197**	**2**
R13	**0.117**	R23	**0.092**	**3**
R22	**0.054**	R25	**0.057**	**4**
R23	**0.018**	R12	**0.053**	**5**
R25	**0.008**	R24	**0.038**	**6**
R21	**0.007**	R11	**0.022**	**7**
R24	**0.007**	R13	**0.017**	**8**

Table 4-5 Overall ranks of risk sub-factors

R11: operational risk, R12: implementation risk, R13: technical risk, R21: host country risk, R22: methodology risk, R23: validation risk, R24: registration risk, R25: certification/verification risk;

Step 3: As a final step for calculating composite vector, the **chance of each default risk intensity** (see table 4-6) with regard to every regulatory risk factor should be determined. The definition is based on Point Carbon (2007a) and pre-interview communications with F001 and F003. Default intensity is a relatively reliable indicator, and can be provided with confidence by finance practitioners. Thus, their judgments will be employed by both groups. Project risk will not be assessed due to our assumptions (see section 1.6).

Intensity Level	***On average, default forward CERs by %***
High	Over 50%
Medium	30%-50%
Low	Less than 30%

Table 4-6 Default risk intensity definition

Source: Adapted from Point Carbon (2007a) and interviewers

Since composite vectors can only reflect the judgments from the specific group, a *synthesis vector* combining preference of *all* respondents is needed for overall assessment. There are two approaches. The first is to calculate the two composite vectors from two sets of comparison matrices and multiply the results by their corresponding weights (0.679 vs 0.097 see Table 4-4). The geometric mean of them is the final result (See table 4-7). The second is to obtain the geometric means of all 13 valid responses and input them in a single set of matrices, and compute the composite vector (See table 4-8).

Composite assessment	Priority Vector(F)	**Weighted by 0.679**	Priority Vector(P)	**Weighted by 0.097**	**Composite (Normalized)**	**Rank**
High DR	0.453	**0.308**	0.354	**0.034**	**0.426**	**2**
Medium DR	0.394	**0.268**	0.475	**0.046**	**0.464**	**1**
Low DR	0.153	**0.104**	0.171	**0.017**	**0.108**	**3**

C.R.=0.03 for F; C.R.=0.06 for P

Table 4-7 Composite assessment: method 1

Synthesis	**Composite Vector**	**Composite Vector from 4-7**	**Rank**
High DR	**0.386**	**0.426**	**2**
Medium DR	**0.440**	**0.464**	**1**
Low DR	**0.173**	**0.108**	**3**

C.R.=0.04

Table 4.8 Composite assessment: method 2

According to table 4-8, It is clear that results from both methods are largely consistent with each other. As assumed, all default loss is caused by regulatory risk. **On average, regulatory risk has a 38.6%-42.6% chance to cause over 50% CER default loss (high), a 44.0%-46.4% chance to cause 30%-50% default loss (medium) and a**

10.8%-17.3% chance to cause less than 30% default loss (low) . Consequently, the overall regulatory risk effect on CER delivery should be **above medium.**

This is surely not a perfect measurement. Policy makers are not asked to provide judgments for default intensity, as it is expected they have vague perceptions of default risks. Yet there is no guarantee that finance practitioners won't manipulate answers to influence policy. There is also concern about innate weakness of AHP. However, this assessment result is still regarded as reliable. First, consistency tests have already eliminated some of potential biased answers. The final result obtained is largely in line with the CER gaps observed. Second, the problems of AHP, such as rank reversal, have been reduced by using two methods to calculate the synthesis vector: the two results are consistent with each other.

Sensitive Analysis: How respondents' judgments might influence final outcome can be answered by sensitive analysis options of *Expert Choice*. Figure 4-2 shows the sensitivity of outcomes to changes in relative importance of host country risk , the key determinant of overall regulatory risk effect. When the importance score declines, the overall risk effect diminishes steeply. When the weight of host country risk is zero, the risk effect on CER delivery is still regarded as medium. This means that respondents perceive a modest level of world's average regulatory risk effect, which is consistent with existing literatures (See Labatt and White, 2007). Thus, China's host country risk has *de facto* raised CER default risk from medium level towards a higher level. Sensitivity of other factors can be determined in a same manner.

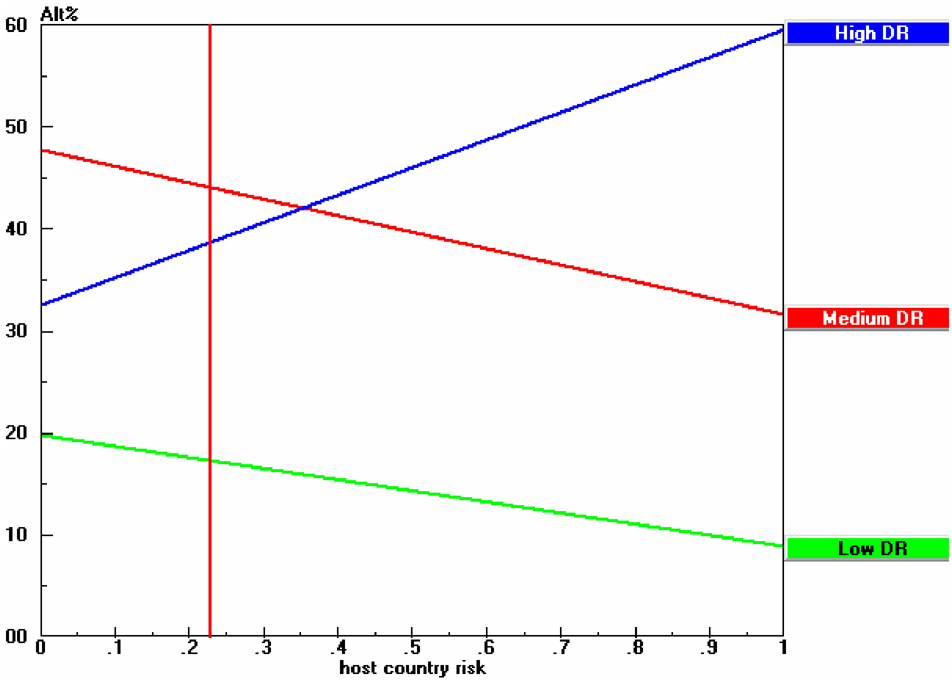

Figure 4-2 Sensitivity analysis for host country risk in method 2

4.3 Synthesis, Discussion and Conclusion.

This section will critically evaluate the credibility of the assessment result from AHP analysis and answers sub-question 2. This can be done by combing arguments from interviews and patterns revealed in Table 4-3. Table 4-9 provides a checklist of interviewees' arguments.

According to the table, Policy makers first argue there is no additional risk and time will correct the problem anyway. If this is true, the disparity in CER price mentioned can only be explained by general risk aversion to investing in China. However, according to a comparative study conducted by Liu et al. (2001), China and India has the similar efficiency and openness index for foreign investors. This means if risk aversion is the reason, we shall observe the same CER price in both countries. We have not!

Conclusions from both stake holders	***Argument/supporting ideas (from interview)***	***Proportion of respondents holding the idea***
Policy maker: China's host country risk is low. The overall regulatory risk effect is modest and	**1. The gap is mainly due to timing and will resolve itself.**	**50.0%**
	2. Effect of project risk and methodology risk are much higher.	**83.3%**
	3. China's policy is very certain and clear.	**100.0%**
	4. The DNA approval rate is almost 100%.	**16.7%**
	5. Risk is low because China has most issued CER in the world and is a popular destination.	**66.7%**
Finance Practitioner: China's host country risk is foremost. The overall regulatory risk effect is high.	**1. Most projects in China can only produce 40%-50% expected CER.**	**50.0%**
	2. The cost of producing CER is expensive.	**100.0%**
	3. Delay is often in DNA approval procedure.	**83.3%**
	4. Conflicting interest can hamper the project.	**50%**
	5. Default risk is high in China, and sometimes default is inevitable.	**83.3%**

Table 4-9 Qualitative argument checklist

Secondly, project risk can be diversified away in a portfolio. As most project developers have well-diversified portfolios (eg. Ecosecurities own a portfolio of 137 projects), under-delivery in some projects will not dampen their capability to deliver CERs as long as the expectation at the portfolio level is reasonable. Interestingly, both groups rank methodology risk as the one of the major risk factors, despite the frequent use of existing methodologies in China. This is probably because some approved methodologies may be inapplicable to specific projects, and therefore new methodologies must be submitted. Also, the strong incentive in exploring new methodologies on projects such as programmatic CDM[5] might increase the risk (Bosi and Ellis, 2005). Thirdly, the fact that China's regulation is clear doesn't necessarily mean there is little risk. The policy makers clearly confuse "uncertainty" with "risk". Indeed, "risk" simply means potential harm caused by policy provisions, while "uncertainty" means destitution of reasonable knowledge of risks. Regulations in China's stock market are also certain, but few can assert regulatory risk is small there (Financial Times, 2007b). As such confusions often occur in the interview (many also confuse "barrier" with "risk"), policy makers' perceptions of regulatory risk should be strongly questioned. Fourthly, it is suspicious whether DNA approval rate is almost 100%: the only respondent who has raised this issue actually failed to passed the consistency test. Also, regulatory risk can affect CER delivery even after the projects are approved. For example, the tedious negotiation and bargaining with Chinese partners can seriously delay the CER issuance. Fifthly, most credits of China come from several big HFC (Hydrofluorocarbon) projects, which is not a real indicator of China's popularity. Also, there is evidence that project developers crowd to China regardless of the risk, betting on the future potential (Table 4-3). Likewise, the fact that China has accounted for 63% of projects in recent Public Stakeholder Consultation cannot dismiss the regulatory risk in China. Therefore, many of policy makers' supporting arguments are invalid.

The first argument of finance practitioners seems to be very powerful. However, as interviewee F001 has pointed out, CERs in excess of the expected number stated in PDD

[5] Programmatic CDM allows developers gain credit from programs bundling up many small emission reductions.

might be cut by NRDC after emission reductions are verified by DOE. Thus, project developers may have incentive to exaggerate the expected CERs so that the real discount rate might not be as large as 40%-50%. Secondly, the high production cost of CER will undermine project developers' profit but may not seriously dampen CER delivery. Here, one may argue the risk premium of CER price can also be a measurement of risk effect. Yet it is only an indicator of risk, rather than a reliable assessment since the market is inactive and incomplete. In practice, the premium values drastically varied with each other (F001-F008, 2007). Thirdly, the DNA maximal approval time is short compared with time required to register in EB. It is therefore groundless to complain "delay" in DNA approval. Fourthly, the actual effect of conflicting interests on CER delivery is uncertain. It is even doubtful whether "double regulation" is a common situation. The last point is largely legitimate. However, one still needs to differentiate whether the developers default unintentionally or intentionally. All in all, the positions held by finance practitioners are also weakened.

Recall patterns in table 4-3. Although both groups have somewhat displayed political rhetoric, finance practitioners can support their conclusion more logically by citing solid financial data, such as discount rate of CERs. Also, almost all Consistency Ratios (an indicator of inconsistency) from their judgments are lower than those from policy makers. Thus, despite the shortcomings in reasoning of both groups, finance practitioners' argument is more convincing. Combining the above analysis, AHP analysis and the observed CER gap, **the result of AHP analysis that regulatory risk effect has an**

above medium influence on project developer's ability to deliver CER is credible. It can also be logically judged that host country risk in China is the foremost regulatory risk factor (greater than methodology risk). Although one might criticizes the result is largely based on respondents' judgments, this outcome can be logically generalized due to the critical sampling strategies mentioned in table 3-1.

Since the quantitative estimate and the outcome are still very rough, there are three potential approaches to improve their *accuracy*. Firstly, one can divide the default risk intensity into more levels, for example, level 1-level 10. However, doing this will significantly increase the workloads of respondents, who might even refuse to respond. Secondly, the DEF model in Chapter 2 can be employed if the statistic data required are available. Lastly, all AHP respondents are required to exchange ideas and make some compromise on their results. However, this method is difficult in practice due to resource constraints and may raise problems such as group conspiracy. All in all, it is believed that the methodologies employed in the thesis are **the most sensible combinations** and the outcome is the **best that can be achieved with available resources.**

The last part of this section devotes to answering three important questions of regulatory risk.

First, can the regulatory risk be fully responsible for the CER gap? One may use data from table 4.6 and 4.7 to have a rough estimate:

$$E = \frac{100\% + 50\%}{2} \cdot \frac{0.386 + 0.426}{2} + \frac{50\% + 30\%}{2} \frac{0.440 + 0.464}{2} + \frac{30\%}{2} \frac{0.173 + 0.108}{2} = 51.4\%$$

Where E is the weighed-average default loss of CERs. This calculation is surely not accurate since it is based on the assumption that the risk intensity is uniformly distributed. However, one can still determine that regulatory risk is the major contributing factor to China's CER gap, albeit not the only one. Two other important factors might be timing, and the overcrowded market in China, caused by project developers' risk-tolerating behavior. The result is consistent with the numerical model developed by Steenbergen (2006), which suggests timing effect for existing system only accounts for 8% of CER shortfall till 2012.

Second, why, as both groups suggest, does government lack incentive to change the regulation? A primary reason might be that Chinese government regards CDM as exogenous to its domestic development. This is supported by Jackson et al. (2006), who argue the CDM fail to prevent China from rapidly adding coal-fired power generating capacity. Another reason is policy makers think investors will rush to the country anyway, considering the growth potential of China's market.

Last, is there any legitimate ground to enact the New Measure? It is perceived a strict regulation may be helpful to set a high environmental standard. For example, the levy on HFC projects can actually depress perverse incentives. Kolshus et al (2001) argue rigid regulation is a necessary means to avoid cheating, leakage, and uncertainties. In addition, P003 (2007) argues that the controversial price-control aims to keep international price at a stable level. Given the recent collapse of carbon price in EU ETS Phase I, a price floor might be necessary to send a long-term price signal. Understanding these can be helpful to eliminate the **inherent bias** between stakeholders, a key pattern revealed in Table 4-3.

Chapter 5 RISK MANAGEMENT STRATEGIES

Generally speaking, there are two ways to manage the regulatory risk in China. The fundamental solution is to change governments' CDM regulation. Since this seems less possible in short term (see table 4-3), this section focuses on the second path: risk management techniques. Section 5.1 summarizes risk management strategies employed by project developers; Section 5.2 answers sub-question 3 by explaining principles of the proposed instrument; Section 5.3-5.4 answers sub-question 4 using interviews and AHP analysis.

5.1 Current Risk Management Practice

This section focuses on some widely-used regulatory risk management strategies among carbon finance practitioners. These include business strategies, insurance products and financial instruments. See Table 5-1.

Of the products above, portfolio reduction, ER guarantee and spot only are the most widely-used strategies[6]. For example, a London-listed carbon fund has trimmed its portfolio in China because of the delay in projects. Some companies only trade CER in spot market to reduce exposure regulatory risk, while others pay insurance premium to

[6] All company names are kept confidential as requested.

their projects to transfer the risk to insurers. Call options and put options are also popular but not as frequently used. Although these strategies can be somewhat effective, they can't achieve the aim of serving as profitable vehicles to expand the carbon market, a key criterion for ideal risk management strategies. With this thought in mind, an innovative instrument is proposed in next section.

Strategy	*Description*	*Principle*
Portfolio reduction	Trim the portfolio because of expected delays in some projects	Risk treat
Emission Reduction (ER) Guarantee	Products provided by insurers and re-insurers to guarantee future delivery of CER or money used to purchase in spot market	Risk transfer
Spot Only	Only trade in spot market	Risk terminate
Contract Frustration Insurance	Products that protect against non-payment or arbitrary non-honoring of contract	Risk transfer
Call option with other CER holders	Financial instrument that gives the owner the right, but not the obligation to purchase CER at a pre-determined price.	Risk transfer

Table 5-1 Various regulatory risk management instruments
Source: Interview with F001-F008

5.2 Proposal: Carbon-based Collateralized Debt Obligation (CCDO)

CDO serves no purpose in a perfect capital market because the cost of constructing and marketing it would impede its creation (Barclays Capital, 2002). In practice, CDO has addressed many market imperfections, such as transferring default risk and improving liquidity of some illiquid asset (Duffie and Garleanu, 2001). These desirable features make it appropriate to manage regulatory risk in CDM market, see Table 5-2.

Features of CDO	***Fact of CDM market***
Transfer default risk	Default of CER caused by regulatory risk
Improve liquidity of assets, enhance return	CER is illiquid, leading to reduction in value
Distribute risk according to personal preference	Few instruments available to meet a range of risk appetites.
Expand and create market	The carbon market is fragmented and has limited tradable products

Table 5-2 Features of CDO and application for CDM

Source: Duffie and Singleton (2003), adapted by author

The proposed instrument, CCDO, is based on the *synthetic cash flow* CDO, which has a structure that fits in with the need of CDM projects—— only the default risk, rather than the ownership of underlying asset, is transferred to SPVs and investors. CCDO has two key differences from traditional synthetic cash flow CDO. First, CER is treated as a "carbon currency" whose spot price can be regarded as foreign currency spot exchange rate. Investors use this "currency" to purchase different classes of carbon bonds according to their preference. The yields from these bonds can be either cash or CERs. Second, the collateral is the projected CERs. Traditionally, banks re-packaged the underlying assets to a portfolio as the collateral. In our case, the underlying assets are *de facto* incoming CERs from an already well-diversified project portfolio. Once regulatory risk begins to negatively influence project developer's ability to deliver CERs, the loss will first be applied to the third tranche (see Figure 5-1). If loss exceeds the size of the most junior tranche, it will go against next most junior class of securities (mezzanine tranche). This is equivalent to investors lending CERs to project developers at different rates. In this way, regulatory risk effect has been **fully** transferred to investors, who can therefore **get access to a pool of carbon-based asset in a single investment that satisfies each**

investor's appetite for risk. Also, CER can become more liquid when it is actively traded and used as a payment "currency". As a result, value of CER can rise and investors get enhanced return. CCDO have great potential to expand carbon market. The current carbon market value is only 30 billion USD, and value of CDM accounts for 17% (Hepburn, 2007). There are strong signs that firms are far from fully exploiting carbon-trading opportunities, a serious hurdle for achieving emission mitigation. One root cause is the limited tradable products are not attractive enough to major market players (Labbatt and White, 2007). In contrast, while the global CDO market value is around 2000 billion USD (Pierron, 2006). The expectation for CCDO is that it can drive carbon market toward "on demand" carbon credit default risk. This is to say that **investors can specify desired risk/return ratio and the project developers provide some portfolios as "raw materials" and delivers new products to clients.** If this happens, the market can be boosted drastically.

However, there are some weaknesses associated with CCDO. First, new risks can be created, due to issues such as *moral hazard* and *adverse selection*. The former means with CCDO, the project developer have incentive to take excessive risk in the project (eg. using new methodology). The latter means information regarding risk exposure of CDM project might be inaccessible, and investors may be concerned about being "picked off" and hence they offer a lower price, a phenomenon called a *lemon's premium* (Akerlof, 1974). Also, structuring and underwriting CDO can be very expensive. If the spread from spot and forward market is not large enough, project developers may prefer to purchase spot credit to comply with their obligation. The crucial concern is whether carbon currency can be simulated as cash——it is often illiquid and limited in size. Using CER as payment might also subject investors to carbon price volatility. However, these shortfalls can well be mitigated through sensible design, see section 5.4.

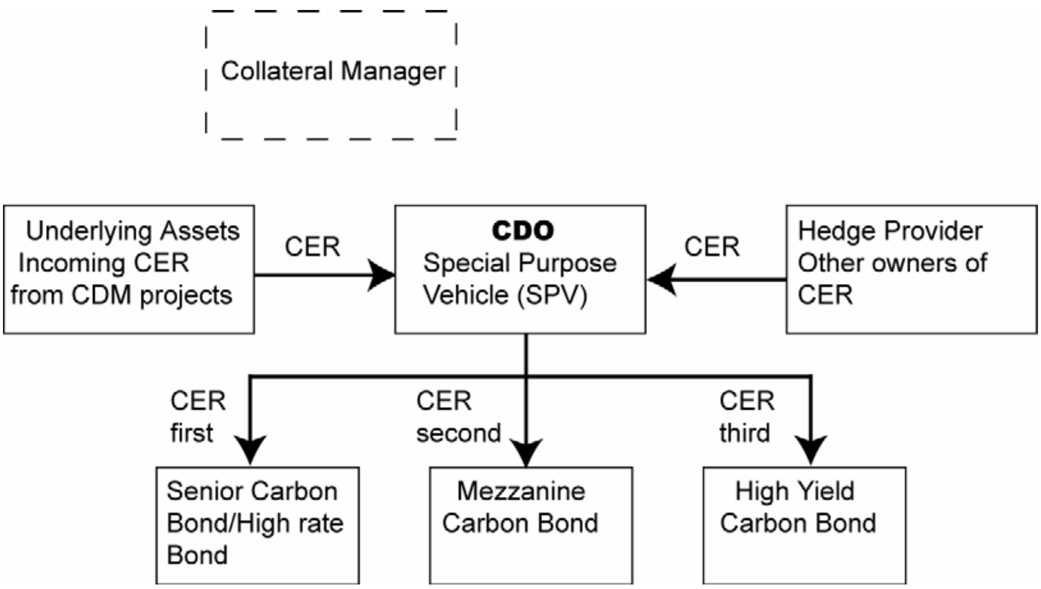

Figure 5-1 Structure of CCDO

5.3 Comments and Benchmark

5.3.1 Qualitative Assessment

In the interviews, finance practitioners have been asked additional open-ended questions regarding risk management. At first a briefly introduction of the principles and advantages of CCDO was presented. Respondents were then invited to comment on this idea. Five of the six respondents have expressed some positive attitudes:

“This instrument is at least useful in China’s CDM market, where the high regulatory risk can justify the fees paid to structure CCDO.”(F001)

“I agree with you that such credit derivatives can play an important role in providing additional guarantees.” (F003)

One respondent opposed the adoption of this instrument. See the following citations.

“It is probably not worthwhile to structure such a complex instrument. You must consider the expense. And you even need a rating agency specialized in carbon bond. Using “carbon currency”? It’s a novel idea but I doubt whether investors are willing to purchase this instrument. Considering the collapse of subprime credit market and global credit crunch, CCDO is too risky an instrument.” (F005)

Even those positively disposed towards CCDO still pointed out some useful caveats:

“It is a promising idea. I think CCDO has great potential if administration issues are well-addressed.” (F004)

Table 5-2 has listed the major arguments against using CCDO. Most concerns and caveats are well-founded, such as the criticism on administration fee and additional risk posed on investors. Yet it is suspicious whether the future of CDM is unclear. The respondents' argument is that CDM is thought as merely a transitional mechanism. This is largely consistent with Stern (2006) and Liverman (2006). However, if the market is really pessimistic about the future of CDM, the price of forward CER should rise drastically as such cheap credit might be no longer available. This condition hasn't happened yet (F004, 2007). In addition, though China's market is not capable of administering CCDO, it is quite possible to launch the instrument in HongKong, where the market is quite mature. However, the shortcomings of CCDO can't **dismiss its potential benefits.** Bear in mind almost all successful novel ideas, including emission trading and CDM, have inevitably some weaknesses.

Arguments against CCDO
1. The administrative fee is high, and specialized rate agency is needed.
2. The underlying asset is very risky for investors, especially in the context of global credit crunch.
3. CCDO involves additional risk, such as price risk, legal issue risk and asymmetrical information.
4. The future of CDM is unclear and sometimes domestic mitigation is much cheaper.
5. China's financial market is not mature enough.

Table 5-3 Arguments against CCDO

5.3.2 AHP Evaluation

The respondents for AHP instrument evaluation are the six interviewees in finance practitioner groups. Based on the strategies they have mentioned, an assessment questionnaire was composed and sent to them by email after the interview. All respondents have passed the consistency test. The assessment criteria are based on risk management literatures. Baker and Golly (2000) has elicited several conditions for risk management strategies, such as Sharpe ratio. But these conditions are too technical and narrowly defined. More reasonable criteria are: usability, infrastructure feasibility, administration cost (Ojanen et al., 2005). Also, as mentioned before, an ideal instrument should create strategic advantage and increase market efficiency. Thus, two more criteria are added: capital gain and market making. Table 5-3 provides brief definitions of these terms.

Criterion	*Description*
Usability	Whether the instrument is intellectually genuine, theoretically sound and effective in managing regulatory risk.
Infrastructure feasibility (infra-feasibility)	Whether the instrument can be practiced with current market infrastructure.
Administration Cost	Whether the administration cost (including all relevant issuance cost) is cost-effective.
Capital Gain	Whether the instrument can generate satisfactory return
Market Making	Whether the instrument can expand market size, reduce market imperfection and improve liquidity.

Table 5-4 Description of judgment criteria

The analysis also follows three-step procedure introduced in section 4.2.

Step 1: Build a hierarchy, see Figure 5.2. This is a three-level hierarchy. The overall target is to assess the merit of regulatory risk management strategies. Level 2 has listed the five assessment criteria. The four strategies, elaborated on list 3, are CCDO, portfolio reduction, spot-only and ER guarantee, which are among the most widely used ones.

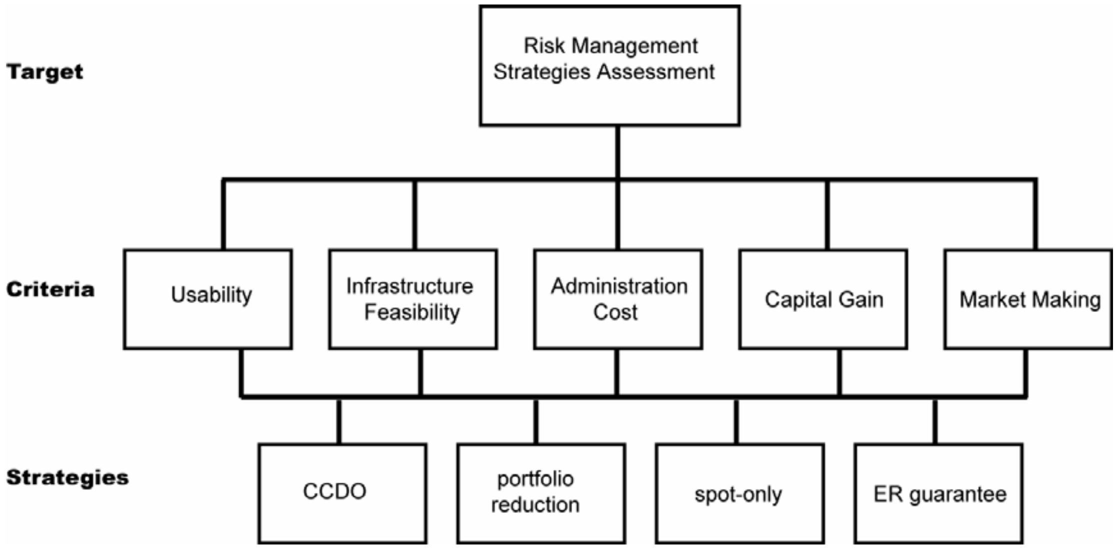

Figure 5-2 AHP analysis for risk management instruments assessment

Step 2: This step determines relative merit of criteria in level 2 on the basis of the judgments given by the finance practitioners. Table 5-4 is the result of comparison matrix of criteria level.

Criteria Level	*Usability*	*Infra-feasibility*	*Administr-ation cost*	*Capital gain*	*Market making*	**Priority Vector**
Usability	1	3.96	1.41	5.25	2.45	**0.376***
Infra-feasibility	0.25	1	0.42	2.74	1.9	**0.143**
Administration cost	0.71	2.40	1	4.14	3.71	**0.306**
Capital gain	0.19	0.36	0.24	1	0.29	**0.055**
Market making	0.41	0.53	0.27	3.46	1	**0.120**

CR=0.05

Table 5-5 Criteria level comparison matrix

The table shows that finance practitioners think “usability” is the most important criteria, followed by “administration cost”. The preference of “infrastructure feasibility” and “market making” is similar to each other, while “capital gain” ranks at the bottom.

Step 3: This step attempts to compute the composite priority vector. Table 5-5 offers an example of comparison matrix with regard to criteria “administration cost”. CCDO is regarded as the most expensive instrument while portfolio reduction cheapest. However, in the composite ranking shown by Table 5-7, the CCDO is the most favored, due to its strong performance with regard to other conditions. Overall, respondents have similar preference about “portfolio reduction” and “spot-only”, while the ER guarantee is least preferred.

With respect to: administration cost	CCDO	Spot-only	Portfolio reduction	ER guarantee	**Priority Vector**
CCDO	1	0.14	0.13	0.36	**0.049**
Spot-only	6.98	1	0.49	4.47	**0.331**
Portfolio reduction	7.48	2.03	1	6.13	**0.524***
ER guarantee	2.75	0.22	0.16	1	**0.095**

CR=0.04

Table 5-6 Comparison matrix with respect to administration cost

Composite Ranking	*Weighed priority vector*	**Rank**
CCDO	0.293	**1**
Portfolio reduction	0.275	**2**
Spot-only	0.236	**3**
ER guarantee	0.195	**4**

Overall CR=0.03

Table 5-7 Synthesis comparison matrix

Sensitivity Analysis: Imagine an extreme case that the weight given to “capital gain” and “market making” is zero. This result is shown in Figure 5-3. The intersection between criteria lines and instrument lines shows the weights of instruments under this specific criterion. This figure implies, if profit making and market expansion are ticked out, expensive financial instrument will be significantly downplayed. But the reality is that the two criteria are so important that one should consider them. Figure 5-4 shows the change in ranks when the weight given to administration cost has changed. CCDO’s preference score has diminished steeply when that weight increases. When the weight of administration cost reaches around 0.8, CCDO has become the least favored instrument, which means cost can drastically affect the potential of CCDO.

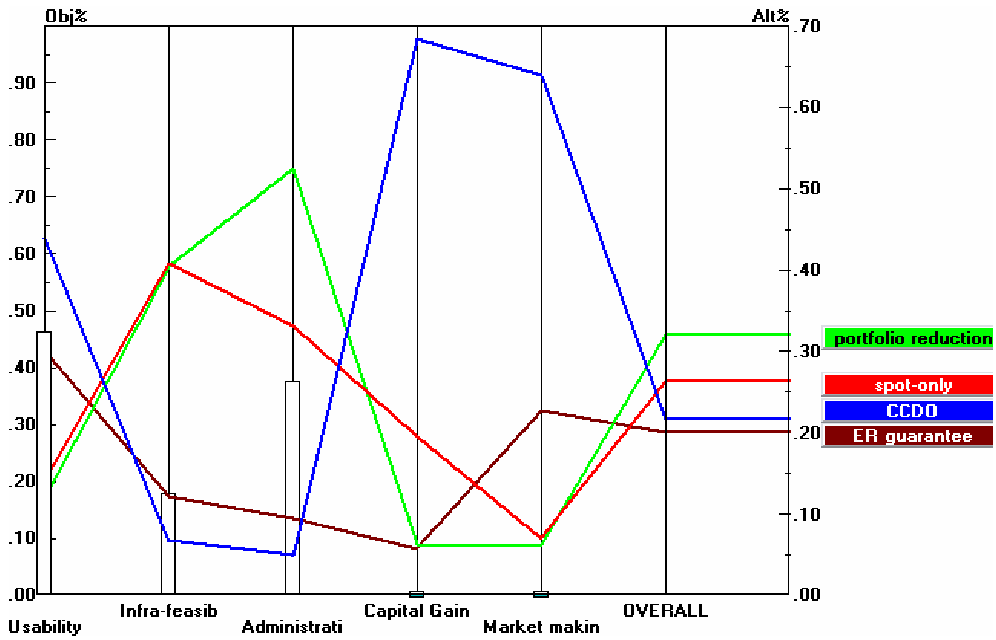

Figure 5-3: Sensitivity analysis: extreme case

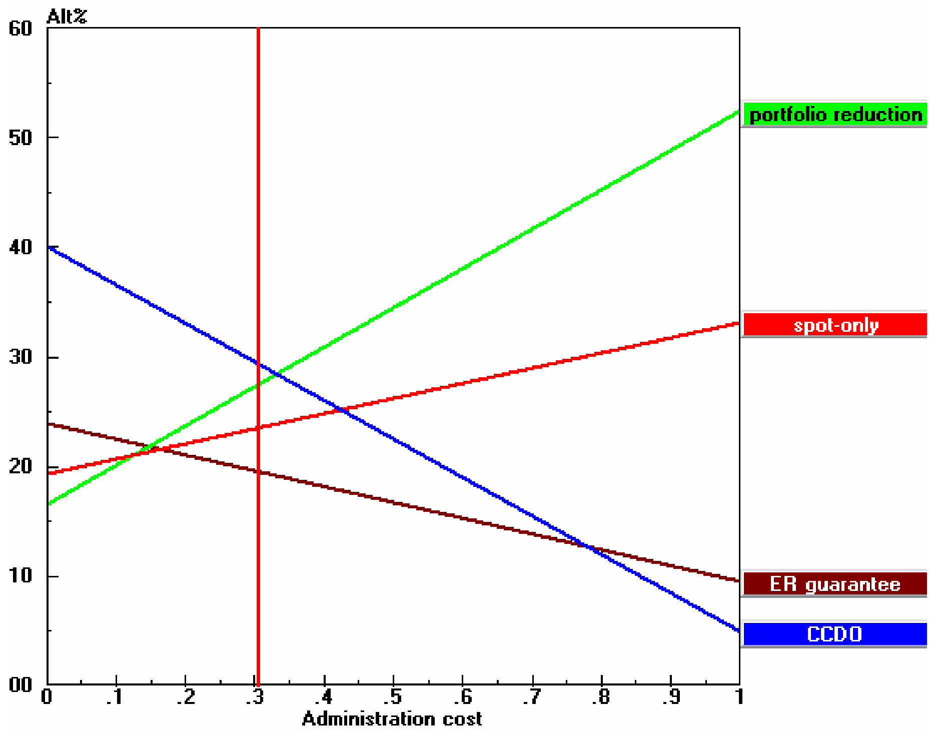

Figure 5-4: Sensitivity analysis: administration cost

5.4 Summary and Designing Issue

Although almost all respondents in the interview extolled CCDO, it is not overwhelmingly favored in AHP analysis. There are two possible reasons. First, it is quite natural for many financial veterans to encourage a young guy with novel ideas, by saying "I think it is fantastic." But these respondents tend to treat quantitative evaluation more seriously. Thus, AHP analysis is more likely to reflect their preference. Second, CCDO is conceptually elegant but has many weaknesses. It is ranked highest because respondents highly value its *potential* of managing regulatory risk, improving CER liquidity and expanding market. Yet such potential can hardly become reality unless some key concerns are addressed. The following paragraphs will tentatively discuss these concerns.

1. **Administration fees.** This can be reduced by economy of scale. Expected CERs from different project developers can be pooled together as the underlying assets. Project developers can even band into a *cartel*, thus reducing the average underwriting cost and boosting the price of carbon bonds. A tripartite joint venture mentioned by UNEP (2004) can also offset a certain part of administration fees. This includes a regulated boutique developing product strategies, a public sector agent as mediator and sponsor and a large financial institution as underwriter.
2. **Moral hazard and adverse selection.** One way to eliminate risk incurred by asymmetric information is to so design CCDO structure that majority of risk about

which there might be risk of adverse selection can be concentrated into small junior tranches. Thus, large senior tranches can be relative immune to the effects of adverse selection (DeMarzo, 1998). Moral hazard can be reduced if project developers are required to hold a specific proportion of most junior tranches, thus showing a degree of commitment to investors. In addition, the default risk can be diversified if the underlying collateral involves not only incoming CER, but also other carbon-based assets independent of CDM regulatory risk, such as EUA derivatives.

3. **Carbon currency.** Using carbon currency can increase the liquidity of CER but might expose investors to price risk. The CCDO can be so designed that some senior tranches give investor the flexibility to choose payment currency while the most junior tranche mandates CER as interest payment. Thus, risk-averse investors can avoid their exposure to CER price volatility.

4. **Marketing.** Since only a few investors in the broad financial market hold CERs, searching for them can be expensive. However, carbon credits have increasingly attracted investors who desire an asset which is uncorrelated to major financial risk (interest rate risk, etc). Indeed, the market has shown positive signs: Many prestigious hedge funds, such as Man Investments, have actively engaged in China's CDM projects (Point Carbon, 2007b). Also, the prospective Personal Carbon Allowance can permit more individual investors access to the CCDO (Boardman, 2004). It is a reasonably auspicious time for CCDO to model the success of other novel instruments, such as weather derivatives (Randalls, 2006)

5. **Infrastructure.** Rating agencies specializing in rating carbon-based assets are

necessary. New techniques are demanded to systematically assess the risk/return profiles of CDM project, thus helping these agencies to implement new methodologies and standards.

In sum, the shortfalls of CCDO can be reduced with sensible designing. Compared with other instruments, **CCDO can goes well beyond managing regulatory risk in China's CDM market** if used properly. Such instrument needs to be developed in time. It is most likely to appear when supported and even mandated by regulation, within a market-based framework.

Chapter 6 CONCLUSION

At the background of this research is the major concern that there is a huge gap between expected and actualized CERs in China. A major cause is the regulatory risks involved in host country and during project cycle. The research has achieved its claimed aim —— understanding to what extent regulatory risks in China have affected project developer's ability to deliver CERs and the effective strategies to manage regulatory risks. The major conclusions of this thesis are organized as answers to the four sub research questions:

1. Regulatory risks in China include host country risk, methodology risk, validation risk, registration risk and verification/certification risk. Among them, host country risk is the foremost regulatory risk factors.
2. On average, China's regulatory risks have a 38.6%-42.6% chance to cause over 50% CER default loss, a 44%-46.4% chance to cause 30%-50% default loss and a 10.8%-17.3% chance to cause less than 30% default loss. Thus, the overall regulatory risk effect is above medium level.
3. CCDO is a conceptually elegant and effective instrument to fully transfer China's regulatory risk to financial market. This is done by packaging expected CERs as underlying asset and issuing different class of asset-backed carbon bonds to investors with different risk appetites.
4. Compared with other risk management strategies mentioned, CCDO is a more promising instrument. It can not only effectively manage the regulatory risk but also

have the potential to improve efficiency of carbon market, a critical issue for emission reduction. Some of its weaknesses can be reduced by proper design.

An ancillary conclusion of this thesis is: Regulatory risk is the major but not the only contributing factor to the CER shortfall in China.

Also, this study has accomplished and even gone beyond the two expected contributions stated in Chapter 1:

1. This thesis has employed both qualitative interview and AHP to assess regulatory risk effect based on a relatively small sample size. This combination can be very effective to offer credible measurement of regulatory risk in China. Since results from both methods are mutually-supportive, it is believed the assessment is reliable.
2. This thesis contributes to the subject of Carbon Finance by using “risk chain” analysis and diversification theory to simplify the regulatory risk assessment to a problem of measuring default risk, by developing default exposure function (DEF) to assess CER default and by designing an innovative financial risk management instrument (CCDO). This provides solid evidence that financial markets can play a prominent role in solving environmental problems.
3. The thesis goes beyond risk control in China’s CDM market. It emphasized that emission reductions should not be regarded as mere environmental commitment but valuable financial assets whose values need to be fully exploited. Indeed, a robust

carbon market with diverse financial products is pivotal to stabilize greenhouse gas emission. The valuable insights provided by policy makers and finance practitioners are seldom available in existing literature of carbon markets.

In addition to the contributions, there are inevitably some weaknesses and caveats in subjects, methodologies and findings of this thesis:

1. Given the complexity of the interview and scale questions, interviewees might guess the answers or manipulate them to fit vested interest. These phenomena cannot entirely be eliminated by methodological triangulations.
2. The pros and cons for CCDO are both large. CCDO can only transfer the regulatory risks rather than eliminate them. And if used inappropriately, it might even amplify the risks. Evaluating CCDO using AHP only reflects the preference of a specific group of people. Government officers, for example, may seriously oppose to it.
3. This thesis is based on the assumption that project risk can be absolutely diversified. While this may be true for some dominant players, such assumption may prejudice medium and small players, who don’t possess a portfolio of projects. Also, perfect diversification may not always be available even among big players.

The future focus of this study is to gather up-to-dated data required to run the DEF model, thus further improving the credibility of the outcome.

Appendix A Sample of AHP Analysis Questionnaire

This section provides a sample of questionnaire for AHP analysis in risk assessment model. The questionnaire is first sent to interviewees before interview, in order that they can grasp the questions well. There are two versions of questionnaires on risk assessment: one is for policy makers and the other for finance practitioners. They are almost the same except for introductory words and additional default risk intensity assessment for investors. The AHP analysis for instrument choice is conducted separately, after all qualitative interview information is gathered. The sample presented here is for finance practitioners, and other samples are designed in similar manner.

Questionnaire starts:

Hello! My name is Yiqun Huang, a student in Oxford University reading environmental change and management. Currently, I am doing master thesis research on assessing and managing regulatory risk in China's CDM market. Indeed, many literatures have argued regulation in China has strongly dampened project developers'/carbon funds' ability to deliver CER, causing default on CER. Since project risk can be diversified in a portfolio, I think measuring regulatory risk effect is equivalent to measuring default risk effect. This questionnaire is about using Analytical Hierarchy Process (AHP) to assess the scale of regulatory risk. To finish it, one should give quantitative scores based on his judgment of risk. As a pioneer in the field of carbon finance, your answer will be invaluable to my research. I know you are very busy, but it will be highly appreciated if you can spare some time finishing this questionnaire. I sincerely look forward to your illuminating answers!

Definition of all types of risk factors:

Project risk refers to operational risk, implementation risk and technical risk. **Operational risk** refers to the possibility that the equipment in the project will not function adequately. This can be caused by low-quality system and operation mistakes. **Implementation risk** is the risk associated with initializing a project, especially resulting from cooperation with local partners. **Technical risk** reflects the engineering difficulties and novelty.

Regulatory risk refers to the risk brought about by the whole project cycle of CDM. It is equal to the sum of host country risk, methodology risk, validation risk, registration risk and verification/certification risk. **Host country risk** is the risk that project might not be approved or seriously delayed by host country DNA (NDRC in China) and that the domestic CDM rule will negatively influence project progress. **Methodology risk** is the risk that new methodologies may not be approved or methodology may be inapplicable to candidate project. **Validation risk** is the risk that project might fail to pass DOE validation, or the process is delayed. **Registration risk** is the risk that it takes excessively long time for a project to register in EB. **Verification/certification** is the risk that certain or all amounts of emission reductions may not be verified by DOE.

Risk of contract fulfillment is the risk of intentional breach of contract.

The **high default risk intensity** means once regulatory risk happens, over 50% of forward CERs cannot be delivered. The **medium default risk intensity** means once regulatory risk happens, about 30%-50% forward CERs cannot be delivered. The **medium default risk intensity** means once default happens, less than 30% forward CERs cannot be delivered.

Please give the score according to the following criteria:

Saaty Scale	Measure Description
1, 2	1 means "equally preferred/important", 2 is intermediate value
3, 4	3 means "moderately preferred/important", 4 is intermediate value
5, 6	5 means "strongly preferred/important", 6 is intermediate value
7, 8	7 means "very strongly preferred/important", 8 is intermediate value
9	9 means "extremely preferred/important"

1. Please evaluate which of the following risk factors are more likely to influence project developer's ability to deliver CER.

Extremely important ←→ Extremely important

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Project risk																		Regulatory risk
Project risk																		Risk of contract fulfillment
Regulatory risk																		Risk of contract fulfillment

2. Please evaluate which of the following sub-risk factors are more likely to influence

project developer's ability to deliver CER.

Extremely important ← → Extremely important

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Operational risk																		Implementation risk
Operational risk																		Technical risk
Implementation risk																		Technical risk

3. Please evaluate which of the following sub-risk factors are more likely to influence project developer's ability to deliver CER.

Extremely important ← → Extremely important

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Host country risk																		Methodology risk
Host country risk																		Validation risk
Host country risk																		Registration risk
Host country risk																		Verification Certification risk
Methodology risk																		Validation risk
Methodology risk																		Registration risk
Methodology risk																		Verification Certification risk
Validation risk																		Registration risk
Validation risk																		Verification Certification risk
Registration risk																		Verification Certification risk

4. Please evaluate which intensity level of default risk is likely to happen when **host country risk** has influenced project developer's ability to deliver CER?

Extremely important ◄──────────────────► Extremely important

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High DR																		Medium DR
High DR																		Low DR
Medium DR																		Low DR

5. Please evaluate which level of default risk intensity is likely to happen when **methodology risk** has influenced project developer's ability to deliver CER?

Extremely important ◄──────────────────► Extremely important

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High DR																		Medium DR
High DR																		Low DR
Medium DR																		Low DR

6. Please evaluate which level of default risk intensity is likely to happen when **validation risk** has influenced project developer's ability to deliver CER?

Extremely important ◄──────────────────► Extremely important

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High DR																		Medium DR
High DR																		Low DR
Medium DR																		Low DR

7. Please evaluate which level of default risk intensity is likely to happen when **registration risk** has influenced project developer's ability to deliver CER?

Extremely important ⟵⟶ Extremely important

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High DR																		Medium DR
High DR																		Low DR
Medium DR																		Low DR

8. Please evaluate which level of default risk intensity is likely to happen when **verification/certification risk** has influenced project developer's ability to deliver CER?

Extremely important ⟵⟶ Extremely important

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High DR																		Medium DR
High DR																		Low DR
Medium DR																		Low DR

Thank you very much for your cooperation. The thesis will be sent back to you by email once it is finished. If you require a hard copy, please inform me of your post address.

I wish you every success in the future career!

University of Oxford

Msc Environmental Change And Management

Yiqun Huang

Appendix B A Complete List of Comparison Matrices

This section has listed all the comparison matrices used in AHP analysis so that the reader can have a clear view of all the judgment by different stakeholders. For convenience of readers, we divide the matrices according to different groups.

AHP Analysis One Regulatory Risk Effect assessment:

1. Weighting risk factors

Stakeholder Group: Policy makers

	Project risk	Regulatory risk	Risk of contract fulfillment	Priority vector	Rank
Project risk	1	6.45	3.46	0.686	1
Regulatory risk	0.16	1	0.41	0.097	3
Risk of contract fulfillment	0.29	2.44	1	0.217	2

CR=CI/RI=0.07

Stakeholder Group: Finance Practitioners

	Project risk	Regulatory risk	Risk of contract fulfillment	Priority vector	Rank
Project risk	1	0.18	0.31	0.092	3
Regulatory risk	5.62	1	3.88	0.679	1
Risk of contract fulfillment	3.27	0.26	1	0.229	2

CR=CI/RI=0.01

2. Weighting sub risk factors

Stakeholder Group: Policy makers

	Operation risk	Implementation risk	Technical risk	Priority vector	Rank
Operational risk	1	1.34	3.14	0.481	1
Implementation risk	0.75	1	2.56	0.370	2
Technical risk	0.32	0.39	1	0.149	3

CR=CI/RI=0.00

	Host country risk	Methodology risk	Validation risk	Registration risk	V/C risk	Priority vector	Rank
Host country risk	1	0.14	0.29	0.59	1.41	0.073	5
Methodology risk	7.31	1	3.46	7.48	6.98	0.571	1
Validation risk	3.42	0.29	1	2.94	1.82	0.192	2
Registration risk	1.69	0.13	0.34	1	0.59	0.076	4
Verification/certification risk	0.71	0.14	0.55	0.59	1	0.088	3

CR=CI/RI=0.06

Stakeholder Group: Finance Practitioners

	Operation risk	Implementation risk	Technical risk	Priority vector	Rank
Operational risk	1	0.44	1.25	0.240	2
Implementation risk	2.29	1	3.30	0.577	1
Technical risk	0.80	0.30	1	0.183	3

CR=CI/RI=0.00

	Host country risk	Methodology risk	Validation risk	Registration risk	V/C risk	Priority vector	Rank
Host country risk	1	3.77	4.44	5.77	5.31	0.504	1
Methodology risk	0.27	1	1.90	5.11	6.48	0.254	2
Validation risk	0.23	0.53	1	2.94	1.62	0.119	3
Registration risk	0.17	0.20	0.34	1	0.46	0.049	5
Verification/certification risk	0.71	0.15	0.62	1.67	1	0.074	4

CR=CI/RI=0.04

3. Weighting default risk (finance practitioners only)

As mentioned, since it is unlikely for policy makers to judge loss of default events for detailed contracts, the answer of this part will be only by finance parishioners, who are believed in a better position to answer these questions.

Host country risk	High DR	Medium DR	Low DR	Priority vector	Rank
High DR	1	2.37	5.31	0.595	1
Medium DR	0.25	1	4.47	0.316	2
Low DR	0.19	0.22	1	0.089	3

CR=CI/RI=0.05

Methodology risk	High DR	Medium DR	Low DR	Priority vector	Rank
High DR	1	0.55	5.55	0.356	2
Medium DR	1.81	1	6.98	0.571	1
Low DR	0.18	0.14	1	0.072	3

CR=CI/RI=0.04

Validation risk	High DR	Medium DR	Low DR	Priority vector	Rank
High DR	1	2.23	1.90	0.504	1
Medium DR	0.45	1	1.78	0.289	2
Low DR	0.53	1.56	1	0.207	3

CR=CI/RI=0.06

Registration risk	High DR	Medium DR	Low DR	Priority vector	Rank
High DR	1	0.15	0.13	0.065	3
Medium DR	6.79	1	1.51	0.523	1
Low DR	7.63	0.66	1	0.413	2

CR=CI/RI=0.03

Verification/certification risk	High DR	Medium DR	Low DR	Priority vector	Rank
High DR	1	0.21	0.12	0.077	3
Medium DR	4.70	1	0.81	0.394	2
Low DR	7.55	1.23	1	0.530	1

CR=CI/RI=0.00

4. Composite Analysis

Composite analysis method 1

Composite	**Priority Vector (Policy maker)**	**Priority Vector (Finance practitioner)**	Synthesis	**Normalized**	**Rank**
High DR	0.453	0.354	0.102	**0.426**	**2**
Medium DR	0.394	0.475	0.111	**0.464**	**1**
Low DR	0.153	0.171	0.026	**0.108**	**3**

CR=CI/RI= 0.06 for Policy maker
CR=CI/RI=0.03 for Finance practitioner;

Composite analysis method 2

	Host country risk	Methodology risk	Validation risk	Registration risk	V/C risk	Priority vector	Rank
Host country risk	1	0.85	1.13	1.85	2.74	0.228	2
Methodology risk	1.17	1	1.90	6.18	6.73	0.429	1
Validation risk	0.88	0.39	1	2.94	1.72	0.177	3
Registration risk	0.54	0.16	0.34	1	0.52	0.072	5
Verification/certification risk	0.36	0.15	0.58	1.92	1	0.093	4

CR=CI/RI=0.04

5. Final result

Synthesis	**Composite Vector method 2**	**Composite Vector(Normalized) method 1**	**Rank**
High DR	**0.386**	**0.426**	**2**
Medium DR	**0.440**	**0.464**	**1**
Low DR	**0.173**	**0.108**	**3**

CR=CI/RI=0.04

AHP Analysis Two Risk Management Strategy Assessment:

1. Weighting the criteria

	Usability	Infra-feasibility	Administration cost	Capital gain	Market making	Priority vector	Rank
Usability	1	3.96	1.41	5.25	2.45	0.376	1
Infra-feasibility	0.25	1	0.42	2.74	1.9	0.143	3
Administration cost	0.71	2.40	1	4.14	3.71	0.306	2
Capital gain	0.19	0.36	0.24	1	0.29	0.055	5
Market making	0.41	0.53	0.27	3.46	1	0.120	4

CR=CI/RI=0.05

2. Weighting the strategies

Usability	CCDO	Spot-only	Portfolio reduction	ER guarantee	Priority vector	Rank
CCDO	1	2.94	3.7	1.54	0.439	1
Spot-only	0.34	1	1.18	0.44	0.141	3
Portfolio reduction	0.27	0.85	1	0.41	0.120	4
ER guarantee	0.65	2.29	2.45	1	0.300	2

CR=CI/RI=0.00

Infra-feasibility	CCDO	Spot-only	Portfolio reduction	ER guarantee	Priority vector	Rank
CCDO	1	0.20	0.20	0.39	0.067	4
Spot-only	5.06	1	1.07	3.96	0.408	1
Portfolio reduction	5.11	0.93	1	4.23	0.403	2
ER guarantee	2.57	0.25	0.24	1	0.121	3

CR=CI/RI=0.03

Administration cost	CCDO	Spot-only	Portfolio reduction	ER guarantee	Priority vector	Rank
CCDO	1	0.14	0.13	0.36	0.049	4
Spot-only	5.06	1	0.49	4.47	0.331	2
Portfolio reduction	7.48	2.03	1	6.13	0.524	1
ER guarantee	2.75	0.22	0.16	1	0.095	3

CR=CI/RI=0.04

Capital gain	CCDO	Spot-only	Portfolio reduction	ER guarantee	Priority vector	Rank
CCDO	1	5.44	9.00	8.66	0.684	1
Spot-only	0.18	1	3.77	4.23	0.195	2
Portfolio reduction	0.11	0.27	1	1.12	0.062	3
ER guarantee	0.12	0.24	0.89	1	0.058	4

CR=CI/RI=0.04

Market making	CCDO	Spot-only	Portfolio reduction	ER guarantee	Priority vector	Rank
CCDO	1	8.23	9.00	3.46	0.640	1
Spot-only	0.12	1	3.77	0.28	0.071	3
Portfolio reduction	0.11	1.15	1	0.26	0.063	4
ER guarantee	0.29	3.60	3.89	1	0.227	2

CR=CI/RI=0.00

3. Getting the result

	Weighed priority vector	Rank
CB credit derivative	0.293	1
Portfolio reduction	0.275	2
Spot-only	0.236	3
ER guarantee	0.195	4

Overall CR=0.03

Appendix C Mathematical Foundation of AHP

This section provides a brief introduction of the underlying mathematical theory of AHP. Saaty (1980) has mathematically proved the validity of this approach. The basic idea is that the rank of a reciprocal matrix must equal one so as to make the matrix satisfy transitivity for all pairwise comparisons. Since this means the remaining eigenvalues are all 0 for any a_{ij}, **the priority vector can be interpreted as the degree of importance.** Suppose there are n judgments, $J_1, J_2, ...J_n$ and their weight (importance) is $\omega_1, \omega_2, ...\omega_n$. Thus, we can compose a comparison matrix J :

$$J = \begin{vmatrix} \frac{\omega_1}{\omega_1} & \frac{\omega_1}{\omega_2} & \cdots & \cdots & \frac{\omega_1}{\omega_n} \\ \frac{\omega_2}{\omega_1} & . & & & \\ . & & . & & \\ . & & & . & \\ \frac{\omega_n}{\omega_1} & \cdots & \cdots & \cdots & \frac{\omega_n}{\omega_n} \end{vmatrix}$$

One can easily see that every entry in this comparison matrix is akin to the preference score given by respondents. Also, we note:

$$J\omega = \begin{vmatrix} \frac{\omega_1}{\omega_1} & \frac{\omega_1}{\omega_2} & \cdots & \cdots & \frac{\omega_1}{\omega_n} \\ \frac{\omega_2}{\omega_1} & . & & & \\ . & & . & & \\ . & & & . & \\ \frac{\omega_n}{\omega_1} & \cdots & \cdots & \cdots & \frac{\omega_n}{\omega_n} \end{vmatrix} \bullet \begin{vmatrix} \omega_1 \\ \omega_2 \\ . \\ . \\ \omega_n \end{vmatrix} = n\ \omega \quad \text{(C1)}$$

This implies n is the eigenvalue of the matrix, and the vector ω, which shows the weight of each judgment, is actually the corresponding eigenvector.

Suppose the matrix has k eigenvalues, then we have:

$$\sum_{i=1}^{k} \lambda_i = \sum_{i=1}^{n} \frac{\omega_i}{\omega_i} = n \quad \text{(C2)}$$

Where λ_i is the eigenvalue of the comparison matrix. This means the sum of eigenvalues of a matrix is equal to its **trace**, the sum of diagonal elements, n in our case.

Also, we note the matrix J has the **rank** of one, since every row vector is a constant multiple of the first row vector (which means any row vector can be expressed as the linear combination of others). Thus, all eigenvalues of this matrix except one are zero. Unsurprisingly, we have:

$$\lambda_{\max} = n$$

Where n is the largest or principal eigenvalue of J. The corresponding vector ω can be made unique as one normalize its entries by dividing by their sums. This unique vector is thus our **priority vector**, which shows the weight of judgments.

Let $a_{ij} = \dfrac{\omega_i}{\omega_j}$, it is clear that the above matrix is consistent since $a_{jk} = \dfrac{a_{ik}}{a_{ij}}$, where $i, j, k = 1,.....n.$ However, in a real life decision-making environment, the judgments are not necessarily consistent. Indeed, the actual judgment has more or less imposed some small perturbations on our perfect consistent case. But the priority vector in the deviated matrix might still be a **close approximation** to the original underlying vector ω. We will show this below. Suppose the perturbation shifts the initial matrix $J\ (a_{ij})$ to $J'\ (a'_{ij})$, and $a'_{ij} = (1+\mu_{ij})a_{ij}$, where $\mu_{ij} \in [-1,\infty)$ is the perturbation factor. Thus, the difference between the new principle eigenvalues and the old one can be shown as:

$$\lambda'_{\max} - \lambda_{\max} = \lambda'_{\max} - n = \frac{1}{n}\sum \frac{\mu_{ij}{}^2}{1+\mu_{ij}} \geq 0 \quad \text{(C3)}$$

If the value of C3 is small enough, then the priority vector in the new matrix is still a reliable indicator of importance. But when it exceeds a specific value, the matrix is regarded as “inconsistency”, and some improvements must be made.

Recall in section 3.3 the consistency index can be expressed as $(\lambda'_{\max} - n)/(n-1)$. Now the reason seems clear to us. Also, Saaty (1990) argues consistency index should not exceed 0.1, which means

$$\frac{(\lambda'_{\max} - n)}{n-1} = \frac{1}{n(n-1)}\sum \frac{\mu_{ij}{}^2}{1+\mu_{ij}} \leq \frac{1}{10} \quad \text{(C4)}$$

Thus, as long as the number of options is known, one should be able to estimate the maximal perturbation allowed.

Appendix D Review of Relevant Financial Theories

This paper assumes reader has intermediate knowledge of calculus, probability and statistics (especially about stochastic process and Markov chain), and linear algebra.

1. Bayes's Rule and Conditional Probability:

The conditional probability of event k given event t can be expressed as: $p(k/t) = \frac{p(k \cap t)}{p(t)}$ and $p(t/k) = \frac{p(k \cap t)}{p(k)}$, where $p(k \cap t)$ is the rate that event k and t happens simultaneously. Thus, $p(k/t) = \frac{p(k \cap t)}{p(t)} = \frac{p(t/k)p(k)}{p(t)}$, this is known as the **Bayes's Rule** (Lindgren, 1998).

In case of default probability modelling, where k and t represent survival time, and if k>t, it is obvious $p(k \cap t) = p(k)$, since survival in time k also means survival in time t. So we have:

$$p(k/t) = \frac{p(k)}{p(t)} \quad \text{(D1)}$$

Logically, the fraction $1 - p(k/t)$ is the default probability conditional on contract survival until time t. Suppose $p(t)$ is strictly positive and is differentiable, then we let:

$$f(t) = \frac{-p'(t)}{p(t)} \quad \text{(D2)}$$

Solving the differential equation, and from 2.1, we have:

$$p(k/t) = \exp(-\int_t^k f(x)dx) \quad \text{(D3)}$$

Thus, $p(k/t)$ is the probability of survival to k given survival to t. This model, however, doesn't offer us enough information to compute the default probability in CDM project. First, the result is obtained *only* on the basis on survival at a specific time. In real life, the default probability should be contingent on *all* the information available at t (Duffie and Singleton, 2003).

2. Black-Scholes-Merton Default Probability Model

A second approach introduced here is the robust model developed by Black and Scholes (1973) and Merton (1974). They regard a firm's equity as a call option[7] on the total asset of the firm, struck at the face value of the debt. They further assume the market value of the company follows a log-normal diffusion process, and in this way the equity can be priced using the well-known Black-Scholes model. An important concept of this model is called **distance to default**. This is denoted by:

$$X_t = \frac{\log A - \log D}{\sigma} \quad \text{(D4)}$$

Where A is the total value of asset, the sum of market value of equity and book value of liabilities, D is the value of liabilities, and the case of CDM, it denotes the CER guaranteed to be delivered, σ is the standard deviation or **variance rate** of the underlying asset.

[7] For a thorough understanding for options valuation and Black-Scholes model, please refer to Options, Futures and Other Derivatives (5th edition) by Hull (2005).

Distance default measures the number of standard deviation by which assets (CERs) exceed liabilities.

The assumption here is that default *will and will only happen* if the distance to default X_t is close to zero. Assume the variation of the asset follow a log-normal distribution, or a geometric Brownian motion, thus the proportional return on asset can be expressed as:

$$\frac{dA}{A} = \mu dt + \sigma dW \quad \text{(D5)}$$

Where μ is the mean rate of return on assets, and W is a standard Brownian motion **(Weiner Process)**. Weiner process is the simplest continuous time stochastic process to describe Brownian motion. A feature of Brownian motion is its increments are independent and have a normal distribution.

According to Ito's lemma (Ito, 1951), suppose the value of variable x follows **Ito Process**:

$$dx = s(x,t)dt + u(x,t)dW \quad \text{(D6)}$$

And if G is a function about x and t, then G follows:

$$dG = (\frac{\partial G}{\partial x}s + \frac{\partial G}{\partial t} + \frac{1}{2}\frac{\partial^2 G}{\partial x^2}u^2)dt + \frac{\partial G}{\partial x}udW \quad \text{(D7)}$$

The following passages will give a derivation of Ito's lemma, which will be very helpful to establish the model:

Proposition: if x follows an Ito process and G is a continuous and

differentiable function of x and t, then it holds that the process of G follows formula D7.

Proof For a continuous and differentiable function G of two variables, x and t, we have:

$$\Delta G \approx \frac{\partial G}{\partial x}\Delta x + \frac{\partial G}{\partial t}\Delta t \quad \text{(D8)}$$

Using a Taylor series expansion of ΔG is:

$$\Delta G \approx \frac{\partial G}{\partial x}\Delta x + \frac{\partial G}{\partial t}\Delta t + \frac{1}{2}\frac{\partial^2 G}{\partial x^2}\Delta x^2 + \frac{1}{2}\frac{\partial^2 G}{\partial x^2}\Delta x \Delta t + \frac{1}{2}\frac{\partial^2 G}{\partial x^2}\Delta t^2 \quad \text{(D9)}$$

Equation A6 can be discretized to:

$$\Delta x = s(x,t)\Delta t + u(x,t)\varepsilon\sqrt{\Delta t} \quad \text{(D10)}$$

Where ε is a random variable drawing from standardized normal distribution.

$$\Delta x^2 = u^2\varepsilon^2\Delta t + o(\Delta t^2) \quad \text{(D11)}$$

Where $o(\Delta t^2)$ represents higher order of Δt. Thus, the component $\frac{1}{2}\frac{\partial^2 G}{\partial x^2}\Delta x^2$ cannot be omitted when taking the limit of ΔG, as it contains first order of Δt. Also, since the variance of standard distribution is 1.0, the expected value of ε^2 is equal to 1, and therefore the expected value of $\varepsilon^2\Delta t$ is Δt. It follows the term

$u^2\varepsilon^2\Delta t$ can become non-stochastic and close to u^2 when Δt tend to zero.

Thus, we have:

$$dG = \lim_{\Delta x \to 0, \Delta t \to 0} \Delta G = \frac{\partial G}{\partial x}dx + \frac{\partial G}{\partial t}dt + \frac{1}{2}\frac{\partial^2 G}{\partial x^2}u^2 dt \quad \text{(D12)}$$

Substituting for dx from equation D6, the formula becomes exactly the same as equation D7.

Since X_t is the function of A and σ, let us denote $G = X_t$, thus:

$$\frac{\partial G}{\partial A} = \frac{1}{\sigma}\frac{1}{A} \quad \frac{\partial G}{\partial t} = 0 \quad \frac{\partial^2 G}{\partial A^2} = -\frac{1}{\sigma}\frac{1}{A^2}$$

According to Ito's lemma we have just proved,

$$dG = (\frac{\mu - \sigma^2/2}{\sigma})dt + \sigma dW \quad \text{(D13)}$$

The constant drift $n = \dfrac{\mu - \sigma^2/2}{\sigma}$. Under the Black-Scholes-Merton model, the conditional default probability can be expressed as:

$$p(X_k \le 0 / X_t) = N[z(k,t)] \quad \text{(D14)}$$

Where $N[z(k,t)]$ is the probability that a normal variable is less than $z(k,t)$, of which $z(k,t) = [X_t + n(k-t)]/\sqrt{k-t}$.

The assumptions of this model are:

1. The asset of company follows a geometric Brownian motion (having a log normal distribution)
2. Companies can adjust their equity positions costly and continuously
3. Risk-free interest rate is known
4. Default happens and only happens when distance default is zero.

Economists such as Delianedis and Geske (1998) are impressed by this model's robust theory and strong predictive power. Such claim has overlooked the model's inherent weakness. For example, the assumption that asset follows a log-norm diffusion process may lead to contradictory results revealed by Duffie and Singleton (2003) and Duffie and Lando (2001), who argue the model tends to underestimate the conditional default rate and the distance to default, especially in the initial period of the assets in a rather risky firm. Yet Black-Scholes-Merton is still a relatively rigid model especially when the duration in question is long and sufficient statistical data is available.

3. Value at Risk: the Variance-Covariance Model

Now that we have discussed the default probability, we know turn to the other question: how default risk influence the volume of CER during a specific period, if default actually happens? One important approach to address this is to compute **Value at risk (VaR)**. It is a statistic measurement of how market value of assets is likely to decrease over a certain period of time (J.P. Morgan, 1994). For example, if we say 10-day VaR of a carbon portfolio is 1 million CERs at the 99% confidence level, this implies that one can expect, there is a less than 5% chance that the value of its portfolio will decrease by 1 million CER or more during 10 days. In practice, however, the typical holding period is one day. The choice of confidence level is rather arbitrage, though financial institutions often choose the level linked somehow to the level of losses at which financial-distress costs become relevant.

There are three common methodologies for VaR: variance-covariance (VCV), historical simulation and Monte Carlo simulation (Linsmeier and Pearson, 1996). We only discuss VCV here. There are two important assumptions: 1) the underlying market factors have a multivariate normal distribution. 2) The portfolio at risk is composed of delta-linear assets, to be more explicitly, the change in portfolio variables is a linear combination of all the changes in the value of assets.

First suppose the portfolio at risk (CER portfolio) has N assets. According to the property of normal distribution, the outcomes less than or equal to 1.65 standard deviations below the mean occur only 5 percent of time. If VaR is determined by a probability of 5 percent, then:

$$VaR = V_p(\mu_p - 1.65\sigma_p)\sqrt{T} \quad \text{(D15)}$$

Where V_p, μ_p and σ_p denote the value, the return, and the standard deviation of the portfolio, T denotes the holding period.

A key step for computing VaR is mapping the risk position into standard “base” position. For simplicity, we assume the risk position in the market portfolio is already standard and is equal to basic market risk factors. Also, it is understandable the covariance of change in assets value is the same as covariance of market risk factors. Let ω_i denotes the proportion of value of asset i in portfolio, and ω denotes the vector of all ω_i, and $\sum$ denotes the covariance matrix of between all assets return , in which

$$\sum = \begin{vmatrix} \sigma^2{}_1 & Cov(\mu_1,\mu_2) & \dots & \dots & \dots & Cov(\mu_1,\mu_N) \\ Cov(\mu_1,\mu_2) & \sigma^2{}_2 & & & & . \\ . & & . & & & . \\ . & & & . & & . \\ . & & & & . & . \\ Cov(\mu_1,\mu_N) & Cov(\mu_2,\mu_N) & \dots & \dots & \dots & \sigma^2{}_N \end{vmatrix}$$

Thus, the standard deviation and expected return of the portfolio is:

$$\sigma_p = \sqrt{\omega \sum \omega^T}, \mu_p = \sum_i^N \omega_i u_i \quad \text{(D16)}$$

Where T denotes transposed.

Although widely used in financial institutions, VaR has been strongly criticized in recent decades. Duffie and Singleton (2003) argue that a 99% 2-week VaR is actually exceeded by a 2-week loss roughly once every two year, a short time for banks. Artzner et al. (1999) argues VaR is not sub-additive, a serious technical problem for a risk assessment tool. This means, it is possible to construct two portfolio, in such a way that VaR(A+B)>VaR(A)+VaR(B). This is odd because we'd hope portfolio diversification can reduce risk. Consequently, Taleb (1997) argues VaR is "charlatanism and a dangerously misleading tool". I do admit the technical shortcomings, but Taleb's criticism seems too strong. It should always be noted VaR is only an assistance, or relative benchmark for risk assessment of assets. Indeed, few corporations nowadays use only VaR to determine the level of capital necessary to sustain the risk. In this sense, it is the misusing of VaR, rather than VaR itself, that causes dangerous outcome.

In the context of this paper, however, VaR is probably not the idea assessment instrument, not only because of the technical problems stated. After all, the VaR, with short holding period, can make limited sense to CDM projects, often involves long project cycle.

4. One-sided Risk and DEF Model

In reality, since we only need to consider risk exposure of *one-side default* on forward contract, there is much simpler yet powerful instrument available. Consider a case where current spot price of CER is S_t, forward price is T and the spot price on the delivery day is S_k. Suppose risk-free interest rate is r(t) and changes with time, then the *current* risk exposure for project developers, if they need to purchase carbon credit in spot market to fulfill their contract, can be easily computed by discounting the loss at the delivery day:

$$V = E[\exp(-\int_t^k r(x)dx)L(S_k - T)] \quad \text{(D17)}$$

Where $\exp(-\int_t^k r(x)dx)$ is the continuously discount factor, L is the fraction of exposure, and E is the expected value.

If there is no obligation for developers to accomplish the contract, the buyers will suffer the loss, which can be obtained in a similar way.

Combining the two steps, and assume there are N players in the market, the default risk exposure function **(DEF)** can be expressed as:

$$V = E[\sum_{i=1}^{n} \exp(-\int_{t_i}^{k_i} r(x)dx)] \bullet L(S_{ki} - T_i) \bullet p_i(X_k \leq 0 / X_t) \quad \text{(D18)}$$

Where $p_i(X_k \leq 0 / X_t)$ denotes the conditional default probability, determined by Black-Scholes-Merton Model, and the subscript i denotes the “i-th” forward contract.

The assumption of this model is:

1. The actual number of CERs follows a geometric Brownian motion.
2. All CERs are traded through forward contract.
3. The forward contracts of a single company have same price and same maturity.
4. Default events are not jointly distributed, that is, default on one contract will not influence the probability of default on others.
5. Default happens and only happens once distance to default is no more than zero.
6. The only factor leading to the loss is default event. This means other market factors, such as interest rate variation will not responsible for the loss in the event of default.

In practice, one can calculate the effect from a single contract, and assume the contracts follow a Poisson arrival. Thus, it makes sense to model the distribution of default effect through Monte Carlo Simulation. However, considering the limited size of carbon market, this model is not as straightforward as the DEF model.

Reference:

Artzner, P., Gregory, F. and Laurent, J. (1999): Coherent Measures of Risk. *Mathematical Finance* **9**: 203-228.

Abele, C. (2007): CDM Market Brief. Report for German Office for Foreign Trade and Deutsche Investitions.

Adam, H. G. (2006): RWE’s Approach to the CDM Market. Presentation on Beijing GHG Forum, March 2006.

Akerlof, G. (1974): The Market for ‘Lemons’: Qualitative Uncertainty and the Market Mechanism. *Quarterly Journal of Economics* **89:** 488-500.

Al Khalil, M. L. (2002): Selecting the Appropriate Project Delivery Method using AHP. *International Journal of Project Management* **20**: 469-74.

Anderson, T.L., and Leal, D.R. (1991): Free Market Environmentalism. Pac. Res. Inst, San Francisco.

Baker, T.G. and Gloy, B.A. (1999): A Comparison for Evaluating Risk Management Strategies. Selected Paper for the 2000 AAEA Annual Meetings, Tampa, Florida.

Barclays Capital (2002): The Barclays Capital Guide to Cash Low Collateralized Debt Obligations, CDO and Structured Funds Group, March 2002.

Belton, V. and Gear, T. (1983): On a Shortcoming of Saaty's Method of Analytical Hierarchies. *Omega* **11(3):** 228-230.

Bernard, H. R. (2000): Social Research Methods: Qualitative and Quantitative Approaches. Sage, Thousand Oaks, CA.

Black, F. and Scholes, M. (1973): The Pricing of Options and Corporate Liabilities. *Journal of Political Economy* **81**: 637-654.

Bodie, Z. and Merton, R. C. (2001): Finance. Prentice Hall Inc. New York.

Bohringer, C. and Finus, M. (2005): The Kyoto Protocol: Success or Failure, in Helm, D. (ed), Climate Change Policy, Oxford, UK: Oxford University Press, chapter 12.

Bollen, J., Gielen, A. and Timmer, H. (1998): Compliance with Kyoto Protocol, in Economic Modelling of Climate Change, OECD Workshop Report, 17-18 September, Paris, OECD.

Bosi, M., and Ellis, J. (2005): Exploring Options for Sectoral Crediting Mechanisms. *Pap. Organ. Econ. Co-op. Dev./Int. Energy Agency.* Accessible from http://www.oecd.org/dataoecd/55/61/34902644.pdf.

Brenda, B. (2004): New Directions for Household Energy Efficiency. *Energy Policy* **32(17):** 1921-1933.

Brealey, R. A., Myers S. C., and Allen, F. (2006): Corporate Finance (8th Edition). McGraw-Hill/Irwin, New York.

Brewer, J. and Hunter, A. (1989): Multi-method Research: A Synthesis of Styles. Sage, Newburry Park, CA.

Bryman, A. (1994): The Mead/Freeman Controversy: Some Implications for Qualitative Researchers, in Burgess, R. G. (ed.), Studies in Qualitative Methodology, Volume 4. JAI Press, Greenwhich, Conn.

Bryman, A. (2004): Social Research Methods (2nd Edition). Oxford University Press, New York.

Cagno, E., Caron, F. and Perego, A. (2001): Multi-criteria Assessment of the Probability of Winning in Competitive Bidding Process. *International Journal of Production Management* **19**: 313-24.

Carbon Trust (2006): Carbon Trust Submission to Consultation on Review of the UK Climate

Change Programme. Accessible from http://www.carbontrust.co.uk/.../0/CCP_Review_CarbonTrust_Submission_March05.pdf.

CCChina (2007): Approval Status of CDM Projects in China (up to 12 June, 2007). Accessible from http://cdm.ccchina.gov.cn/english/main.asp?ColumnId=28. Last updated on 12 June.

Chapman, C., and Ward, S. (1996): Project Risk Management: Process, Techniques and Insights. London, John and Wiley & Sons Inc.

Christie, L. (2007): Subprime Blame Games. Accessible from http://www.CNNMoney.com. Last Updated on April 20, 2007.

Clark, G. L.(1998): Stylized Facts and Close Dialogue: Methodology in Economic Geography. *Annals of the Association of American Geographers* **88(1)**: 73-87.

Climate Thinker (2007): CDM: China Development Mechanism? Accessible from http://climatethinkers.org/blog/?cat=6. Last updated on 13 July.

Decision Making Forum (2007): How Many People are Needed for a Good, Valid Judgment? Accessible from http://blog.decisionlens.com/. Last updated on 11 March 2007.

Deliandeis, G. and Geske, R. (1998): Credit Risk and Risk Neutral Default Probabilities:

Information about Rating Migration and Defaults. Working Paper, Working Paper 19-98, Anderson School of Business, University of California, Los Angles.

DeMarzo, P. (1998): Pooling and Tranching of Securities. Working Paper, Haas School of Business, University of California, Berkeley.

Denzin, N. K. (2001): The Research Act: A Theoretical Introduction to Sociology Methods (2nd Edition). McGraw-Hill, New York.

Dorfman, M. S. (1997): Introduction to Risk Management and Insurance. Prentice Hall Inc, New York.

Duffie, D. and Lando, D. (2001): Term Structure of Credit Spreads with Incomplete Accounting Information. Econometrica **69**: 633-664.

Duffie, D. and Garleanu, N. (2001): Risk and Valuation of Collateralized Debt Obligations. *Financial Analysis Journal* **57**: 41-62.

Duffie, D. and Singleton, K. J. (2003): Credit Risk: Pricing, Measurement and Management, Princeton University Press, Woodstock, Oxfordshire, UK.

Dyer, J. S. (1990): Remarks on the Analytic Hierarchy Process. *Management Science* **36 (3)**:

249-258.

El-Meouchi, C. (2007): Legal Considerations of ERPAs. Report for Badri & Salim El Meouchi Law Firm, Lebanon.

European Commission (2007): Emission Trading Scheme (EU ETS). Accessible from http://ec.europa.eu/environment/climat/emission.htm. Last updated on 27 April 2007.

Financial Times (2007a): Subprime Lending Crisis: In Depth. Accessible from http://www.ft.com/indepth/subprime. Last updated on 7 July 2007.

Financial Times (2007b): Beijing Rejects Midea Plan to Sell Stocks to Goldman Sachs. Financial Times Weekend, 1 Sept to 2 Sept.

Fontana, A. and Frey, J. H. (2000): The Interview: From the Structured Questions to Negotiated Text, in Denzin, N. K. and Lincoln, Y. S. (ed), *Handbook of Qualitative Research* (2nd Edition): 645-72. Sage, Thousand Oaks, CA.

Grubb, M., and Brack, D. (eds.) (199): The Kyoto Protocol: A Guide and Assessment. London, RIIA, Earthscan, 256 pp.

Guba, E. G. and Lincoln, Y. S. (1988): Do Inquiry Paradigms Imply Inquiry Methodologies? In

Fetterman D. (ed.) Qualitative Approaches to Evaluation in Education: The Silent Scientific Revolution: 89-115. Praeger, New York.

Hardin G. (1968): The Tragedy of the Commons. *Science* **162:**1243–48

Houghton, J. (2004): Global Warming: The Complete Briefing, 3rd edn, Cambridge University Press, Cambridge.

IETA (2005): IETA Rountable on the Clean Development Mechanism: Moderator's Personal Impression. London, 12-13 July 2005.

IPCC (2001): Climate Change 2001- Synthesis Report. Figure SPM-8. Accessible from http://www.grida.no/climate/ipcc_tar/vol4/english/figspm-8.htm.

IPCC (2007): IPCC Fourth Assessment Report, Working Group III. Accessible from http://www.mnp.nl/ipcc/pages_media/FAR4docs/chapters/TS_WGIII_220607.pdf.

J. P. Morgan (1994): RiskMetrics Technical Document. New York.

Kangary, R. and Riggs, L. S. (1989): Construction Risk Assessment by Linguistics. *IEEE Trans. Eng. Manag.* **36(2)**: 126-31.

Koch, T. (2005): Proposal for Further Development of Chinese CDM Rules, presentation at the

International Capacity Building, p.p.InWEnt gGmbH, Germany.

Kolshus, Hans H., Jonas Vevatne, Asbjørn Torvanger and Kristin Aunan (2001): Can the Clean Development Mechanism Attain Both Cost-effectiveness and Sustainable Development Objectives? CICERO Working Paper, August 2001.

Labatt, S. and White, R. R. (2007): Carbon Finance: The Financial Implication of Climate Change, Hoboken, New Jersey, John and Wiley & Sons Inc.

Lecocq, F. and Capoor, K. (2005): State and Trends of Carbon Market 2005. Report for World Bank Carbon Finance Business and the International Emission Trading Association. Accessible from http://carbonfiance.org/pcf/router.cfm. Last updated on June 27, 2005.

Lewontin, R. C. (1995): Sex, Lies and Social Science. *New York Review of Books* April **20**: 24-29.

Lindgren, B. W. (1993): Statistical Theory (4th Edition). Chapman & Hall/CRC, Boca Raton, Florida.

Linsmeier, T. J. AND Pearson, N. D. (1996): An Introduction to Value at Risk. Working Paper, University of Illinois at Urbana-Champaign, US.

Liu, G. S., Liu, X. and Wei, Y. (2002): Openness and Efficiency of India and China Relative to the World Economy: A Comparative Study. *Economics and Finance Working Papers*, Brunel

University: 02-18.

Liu, L. (2006): Clean Development Mechanism in China: Seeking Synergies to Achieve Sustainable Development, Master Thesis, TekSam, Roskilde University.

Liverman, DM. (2006): Survival into the Future in the Face of Climate Change, in Shuckburgh, E. (ed) *Survival: The Survival of the Human Race (2006 Darwin Lectures),*: 187-205. Cambridge, Cambridge University Press.

McKibbin, W.J. and Wilcoxen, P.J. (2002): The Role of Economics in Climate Change Policy, *Journal of Economic Perspective,* **16**(2): 107-29

Merton, R. (1974): On the Pricing of Corporate Debt: The Risk Structure of Interest Rates. *The Journal of Finance* **29**: 449-470.

Michaelowa, A. (2003): CDM Host Country Institution Building, *Mitigation and Adaptation Strategies for Global Change* **8**:201-220.

Miller, R. and Lessard, R. L. (2000): The Strategic Management of Large Engineering Projects: Shaping Institutions, Risks and Governance. Massachusetts Institutes of Technology, USA.

Mustafa M. A. and Al-Bahar J. F. (1991): Project Risk Assessment Using Analytical Hierarchy

Process. *IEEE Transactions on Engineering Management* **38(1)**: 46-52.

Nagai, H. (2005): How Cost-effective are Carbon Emission Reduction under the Prototype Carbon Fund? Master Thesis, Environmental Change Institute, University of Oxford.

NDRC (2004): Interim Guidelines for Operation and Management of CDM Project in China. Accessible from http://cdm.ccchina.gov.cn/web/main.asp. Last Updated 1 Dec 2004.

NDRC (2005): Measures for Operation and Management of CDM Projects in China. Last Updated 1 Dec 2005.

Nelson (2004): An African Dimension to the Clean Development Mechanism: Finding a Path to sustainable Development in the Energy Sector, *Denver Journal of International Law & Policy* **32**: 615-621.

Nordaus (2001): After Kyoto: Alternative Mechanism to Control Global Warming, presentation at the 20th Anniversary Meeting of the International Energy Workshop, IIASA, Laxenburg, Austria.

Ojanen, O., Makkonen, S. and Salo, A. (2005): A Multi-criteria Framework for the Selection of Risk. Int. J. Risk Assessment and Management **5 (1)**:

Patton, M.Q. (1980): Qualitative Evaluation Methods, Beverly Hills, CA Sage.

Pearce, D. (2005): The Social Cost of Carbon, in Helm, D. (ed), Climate Change Policy, Oxford, UK: Oxford University Press, chapter 5.

Pérez, J. (1995): Some comments on Saaty's AHP. *Management Science* **41(6):** 1091-1095.

Pérez, J. (2001): The Strong No Show Paradoxes Are a Common Flow in Condorcet Voting Correspondences. *Social Choice and Welfare* **18(3)**: 601-616.

Pierron, A. (2006): Collateralized Debt Obligation Market. Report for Celent, Paris.

Point Carbon (2007a): Interview: Carbon Credits Should be Rated Like Any Assets. Accessible from http://www.pointcarbon.com/article24242-474.html?articleID=24242&categoryID=474. Last Updated on 30 August.

Point Carbon (2007b): Man Eyes Coal Mine Methane CDM Projects. Accessible from http://www.pointcarbon.com/article24264-474.html?articleID=24264&categoryID=474. Last updated on 31 August.

Powdermaker, H. (1966): Stranger and Friend: The Way of the Anthropologist. W. W. Norton, New York.

Ringius, L., Torvanger, A., and Holtsmark, B. (1998): Can Multi-criteria Rules Fairly Distribute

Climate Burdens? OECD Results from Three Burden Sharing Rules, *Energy Policy* **26**(10): 777-93.

Rosseau, D. (1979): Reply to Reliability or Validity? *Administrative Science Quarterly* **24**: 313-14

Saaty, T. L. (1980): Multicriteria Decision Making: The Analytical Hierarchy Process. McGraw-Hill, New York.

Saaty, T. L. (1990): How to Make a Decision: The Analytical Hierarchy Process. *European Journal of Operational Research* **48**: 9-26.

Saaty, T.L. (1994): Highlights and Critical Points in the Theory and Application of the Analytical Hierarchy Process. European Journal of Operation Research **52**: 426-447.

Saaty, T.L. (1995): Decision Making for Leaders: The Analytical Hierarchy Process for Decisions in a Complex World. RWS Publication, Pittsburg.

Saaty, T.L. and Aczel, J. (1983): Procedure for Synthesizing Ratio Judgments. *Journal of Mathematical Psychology* **27(1)**: 93-102.

Samuel, R.C. (2006): Firms, Finance And the Weather: the UK Weather Derivative Market. Unpublished Doctoral Thesis, University of Birmingham.

Sarkis, J. (1999): A Methodological Framework for Evaluating Environmentally Conscious Manufacturing Programs. *Computers and Industrial Engineering* **36 (4)**: 793-810.

Sato, J. (2004): Comparison between Multiple-choice and Analytical Hierarchy Process: Measuring Human Perception. *Intl. Trans. In Op. Res.* **11**: 77-86.

Schelling, T.C. (1998): Costs and Benefits of Greenhouse Gas Reductions, Washington, DC, American Enterprise Institute.

Smith, J. K. and Heshusnus, L. (1986): Closing Down the Conversation: The End of the Qualitative-Quantitative Debate. Education Researcher **5(1)**:4-13.

Steenbergen, P.J. (2006): Impact of Current and Alternative System of CDM Governance on Issuance of CERs from CDM Hydroelectric Projects, Master Thesis, Faculty of Technology, Policy and Management, Delft University of Technology.

Stern, N. (2006): Stern Review on the Economics of Climate Change. Accessible from http://www.hm-treasury.gov.uk/independent reviews/.

Stewart, R. G. (1979): Reliability or Validity? A Comment on 'Characteristics of Departments, Positions and Individuals: Context for Attitude and Behavior." *Administrative Science Quarterly*

24: 312-13.

Strek, C. (2007): Carbon Contracts Potential for Disputes. Presentation in University of California, Berkeley, 22 February.

Sun, C.H. (2006): China's CDM Rules. Presentation on China's CDM Capacity Building Conference.

Szymanski, T. (2002): Clean Development Mechanism in China, *China Business Review*, November-December 2002.

Turner, G. (2007): Interview excerpt in article *Lightly Carbonated*, Economist, accessible from http://www.economist.com/research/articlesBySubject/displayStory.cfm?story_id=9587705&subjectID=348924&fsrc=nwl&emailauth=%2527%252A%2520%252A%253F4%252C%255BGV%2540%2520%2520%250A.

UNEP (2004): Financial Risk Management for Renewable Energy Projects: Summary Document (1st Edition). Words and Publications, Oxford, UK.

UNFCCC (1997): Kyoto Protocol to the United Nations Framework Convention on Climate Change, FCCC/CP/L7/Add.1, Kyoto. Accessible from http://unfccc.int/resource/docs/convkp/kpeng.pdf.

UNEP (2007): CDM Pipeline Overview, Accessible from Http:// www.UNEP.org. Last Updated on 31 May 2007.

UNFCCC. (2001): Modalities and procedures for a Clean Development Mechanism, Annex to the decision 17/CP.7. Accessible from http://cdm.unfccc.int/Reference/Documents/AnnexII.

Vaidya, O. S. and Kumar, S. (2006): Analytical Hierarchy Process: An Overview of Applications. *European Journal of Operational Research* **169**: 1-29.

Wara, M. (2007): Is the Global Carbon Market Working? *Nature* **445(8)**: 595-96

World Bank (2006a): Eligibility, General Rules, Methodological Tools, Approved Methodologies. Accessible from: http://carbonfinance.org/docs/CDM_MethodologyUpdateEB25_Sept18_2006.pdf.

World Bank (2006b): General Conditions Applicable to Certified Emission Reductions Purchase Agreement for Clean Development Projects, Accessible from http://carbonfinance.org/Router.cfm?Page=DocLib&ht=6&dl=1.

Zeng, L., and Yan J. (2005): Policy, Institutional and Market Barriers to the Implementation of Clean Development Mechanisms (CDM) in China, *International Journal of Green Energy* **2(3)**: 259-271.

Zhang, Z.X. (2006): Toward an effective implementation of Clean Development Mechanism Projects in China, Energy Policy **34**: 3691-3701

Zhuang, G. (2006): Role of China in Global Carbon Market, *China & World Economy*, **14(5)**: 93-104.