Securitizing Green

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Abstract

In this study, we consider a development of the CO2 emission-backed security that is designed as a securitization based on CO2 emission amounts of each country. For the construction of the securitization, we used “CO2 Emissions from Fuel Combustion” data supplied by IEA(International Energy Agency). The designed securities consist of several tranches having specific coupon rate which is determined by the probability of achievement of the threshold (or, target emission) for each nation. This securities can sold on a financial market without interference of other countries, and if the holders are increase, we expect that public opinion from the holders affects to the highly ranked countries emitting CO2 gas.

Key words: Securitization, Green, CO_2 emission, Global climate change

1. Introduction

The greenhouse effect, which is the main driver of global warming, is a natural phenomenon of the earth but human activities such as fossil fuel combustion and land use, particularly deforestation, are enhancing this effect, which is unprecedented in the last 10,000 years. According to the Intergovernmental Panel on Climate Change (IPCC), the average temperature of the earth's surface has risen by 0.74^{o}C since the late 1800s and this trend is predicted to accelerate by 1.8^{o}C and 4^{o}C by 2100 if no action is taken (Solomon et.al (2007)). As a result, sustainability of the earth is becoming threatened by a number of devastating consequences: melting of the polar ice caps, flooding of coastlines, severe storms, changes in precipitation patterns, and widespread changes in the existing ecological balance.

The primary international effort to combat global warming is the United Nations Framework Convention on Climate Change (UNFCCC), which is an international environmental treaty and entered into force on March 21, 1994 with 194 parties participating as of May 2011. The eventual objective of this treaty is *to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system*[1]. While this treaty is considered non-binding in a legal sense, which means that no compulsory emission limits are enforced, it provides protocols which would set mandatory emission limits. The principal update of this initiative is the Kyoto Protocol, which came into force on 16 February 2005 with 191 states, excluding the U.S. among major signatories. The parties to the UNFCCC are classified into three groups according to the phase of economic development and to the fact whether it pays for costs of developing countries to attain their goals[2]. Under the Protocol, Annex I countries commit themselves to reduce greenhouse gas (GHG)[3] by 5.2% from the 1990 level for the first commitment period from 2008 to 2012[4].

The Kyoto Protocol defines three flexible mechanisms with which the overall costs

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[1]Article 2,The United Nations Framework Convention on Climate Change., http://unfccc.int/essential_background/convention/background/items/1353.php, Retrieved on November 09, 2011

[2] Industrialized countries and economies in transition are in Annex I and a subgroup of them which satisfies the second condition is also in Annex II; a country can be included both Annex I and Annex II. Developing countries are categorized as non-Annex I countries. 37 countries are categorized as Annex I countries.

[3]Basically the reduction target applies to four greenhouse gases (carbon dioxide, methane, nitrous oxide and sulphur hexafluoride) and two types of gases (hydrofluorocarbons and perfluorocarbons) produced by the former through translating into CO_2 equivalents. The target is set in addition to the industrial gases (chlorofluorocarbons or CFCs) under the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer while international aviation and shipping are not included.

[4] Mandatory reduction targets after the first commitment period yet to be agreed in spite of ongoing negotiation.

of accomplishing emission reduction targets can be lowered; Emissions Trading (ET), the Clean Development Mechanism (CDM) and Joint Implementation (JI)[5]. The ET mechanism is implemented as a market-based cap-and-trade scheme in which a regulatory authority enforces a limit (or a cap) on emissions and then allocates or sells permits for the emissions to firms. The permits are called assigned amount units (AAUs) and are tradable domestically or across state nations who have ratified the Protocol. While the ET is a market-based mechanism, the CDM and JI are project-based mechanisms. Specifically an Annex I country is eligible to acquire other forms of emission permits if it finances an emission-reducing project in a non-Annex I country under the CDM framework or in another Annex I country under JI. The permits created by a CDM and a JI project are called certified emission reductions (CERs) and emission reduction units (ERUs) respectively. The trading of these permits takes place at climate exchanges and these exchanges provide a spot market as well as futures and option market[6].

So far the European Union Emission Trading Scheme (EU ETS) and the New Zealand Emissions Trading Scheme (NZ ETS) are the only mandatory emission trading mechanisms while similar initiatives in other countries have been halted or delayed[7]. The EU ETS launched by the 25 EU countries on January 1, 2005, which only covers carbon dioxide (CO_2), including over 11,000 installations; it covers almost half of the European CO_2 emissions (Hepburn (2007)). The NZ ETS entered into force on July 1, 2010 and it aims to reduce the carbon price to NZ$12.50 until December 31, 2012[8]. The global carbon market experienced stagnation in 2010 at the market value of US$141.9 billion after it recorded consecutive robust growth from 2005 to 2009; the market value accumulated dramatically from US$11 billion in 2005 to US$143.7 billion in 2009[9]. One outstanding feature in this market is an increased dominance of the European Union Allowances (EUAs) market; the market value grew from US$7.9 billion in 2005 to US$119.8 billion in 2010 constituting 84

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[5] For further details, see Hepburn (2007).

[6] Major climate exchanges are European Climate Exchange, NASDAQ OMX Commodities Europe, PowerNext, Commodity Exchange Bratislava and the European Energy Exchange.

[7] Federal cap-and-trade legislation is not supported in the U.S., the Japanese government lost its control of the upper house so that the Japanese Basic Act on Global Warming is halted, the Australian government chose to freeze a domestic trading scheme and the Republic of Korea's scheme is delayed until 2015 (Linacre et al. (2011)).

[8] Emissions trading bulletin No 11: Summary of the proposed changes to the NZ ETS, http://www.mfe.govt.nz/publications/climate/emissions-trading-bulletin-11/, Retrieved on November 14, 2011

[9] Markets for the primary CDM, the U.S. Regional Greenhouse Gas Initiative (RGGI) and the assigned amount unit (AAU) were main drivers of the stagnation. The primary CDM market fell from US$2.7 billion to US$1.5billion due to regulatory uncertainty after 2012. The latter two markets dropped from US$4.3billion to US$1.1billion collectively partly because federal cap-and-trade legislation failed to receive enough support.

percent of the global market value (Linacre et al. (2011))[10]. In 2009 a total of US$119 billion worth of allowances and derivatives are traded in the EU ETS; 73 percent of this volume is accounted for futures contracts while the carbon options market reached US$10.6 billion in value (Kossoy and Ambrosi (2010)).

A well-functioning market is crucial for successful implementation of the ET because it is the market under which any movement and volatility of the carbon price are determined. Market efficiency can be improved further by introducing carbon derivatives since these instruments play as a tool of price discovery as well as they provide liquidity in the market. Across the globe, around 84 percent of financial derivatives are over-the-counter (OTC) products as of June 2007 and the carbon derivative market is no exception[11]. Key advantages of these OTC contracts are customizability and flexibility while counterparty credit risk can be significant in the absence of a clearing house and liquidity is limited especially for exotic risks such as the risk of interest in this paper: GHG emission allowance. Among various noble approaches of constructing derivative products, securitization has been gaining its popularity since its introduction in the late 1970s[12]. In principle, counterparty credit risk can be eliminated by establishing a special entity for cash flows administration which is independent and secured against bankruptcy. Also the liquidity of these instruments can be improved by suitably structuring their tranches so as to provide best possible risk and return profiles to various groups of investors.

The contribution of this research is the application of the advantageous securitization mechanism to emission reductions. We design the securities underlying CO2 emissions of main emission countries with the securitization, and illustrate the method calculating premiums of the securities by using CO2 emissions data. Most of all, if the securities are issued, the issuer would facilitate to secure funds from capital markets for investing directly to reducing CO2 emissions. The securities can be sold to sovereign wealth funds, mutual funds, institution investors, or normal investors, and this public expansion would increase the attention of the rating for CO2 emissions which decides the premiums of the securities owned. The attention makes public opinion, and this public opinion would oppress any increase of the CO2 emissions of the main emission countries. Therefore, normal investors can act

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[10] If the secondary CDM is taken into account the proportion of the EU ETS rose to 97 percent.

[11] Refer to Deutsche Börse and Eurex (2008).

[12] Securitization is the process of pooling assets, liabilities or cash flows of an issuer or issuers and conveying them to third parties after tranching according to the levels of risk exposed (Banks (2004)).

indirectly on emission reductions simply by holding the securities. Naturally this application of the securitization mechanism is able to be applied to any harmful gasses.

The rest of this paper is organized as follows. Section 2 documents related studies and literature survey. Section 3 explains the current status of EU ETS for reducing GHG. Section 4 discuss considering CO2 emission modeling along with the Kyoto protocol and data. Section 6 describes the securitization underlying CO2 emissions of several countries and the pricing the premium of the securities. Section 7 concludes with the brief summary and the main results of the paper.

2. Literature Survey

Similar to pollution, CO_2 emission is an example of negative externality of which the market prices do not reflect the full costs including impacts of global warming so that emitters gain benefits excessively while undermining the welfare of future generations and threatening the natural environment. In order to internalize these external costs, academics, policy makers and regulators have been focusing on market-based emission reduction mechanisms. Unlike prescriptive command-and-control regulation, these market-based mechanisms provide participants with economic incentives to comply so that the goal of emission reduction can be achieved more efficiently while producing information of compliance procedures more transparently and encouraging development of alternative reduction technologies more actively. Furthermore, by enforcing the amount of emission allowances allocated, the regulatory body can accomplish its goal to a substantial degree. At present the European Union Emission Trading Scheme (or EU ETS), launched by the 25 EU countries on January 1, 2005, is the largest multi-national, greenhouse gas emissions trading scheme in the world. The EU ETS only covers carbon dioxide (CO_2) and includes over 11,000 installations. In this scheme, the right to emit or allowance is allocated as European Union Allowances (EUAs) and 1 unit of EUA is equivalent to 1 tone of CO_2. EUAs are treated as commodities so that financial derivatives can be constructed based on these allowances as well as they are traded in the spot market. Therefore the primary concerns of the market participants in the spot and the derivative market such as risk management consultants, brokers and traders are the price behavior and the dynamics of this new asset class: CO_2 emission allowances in general and European Union Allowances (EUAs) in specific. In this regard, modeling and pricing the CO_2 derivatives in this paper are apart from conventional research areas of environmental economics and environmental policy studies.

So far most empirical research regarding the price behavior and dynamics of allowances are based on the EU ETS since this scheme is rich in liquidity and has a well-developed market mechanism. It is important to note that the scheme's Phase I (2005 – 2007) and Phase II (2008 – 2012) should be separated for the analysis of the price behavior due to the difference of market development. Early studies fail to show consistent results about market efficiency. For example, Uhrig-Homburg and Wagner (2007) found that futures contracts whose maturities expire within Phase I reveal the cost of carry pricing mechanism while Truck et al. (2007) showed that convenient yield is statistically significant among futures contracts which mature in Phase II. Also weak form of market efficiency hypothesis is rejected with spot and futures price data from the Powernext, Nord Pool and EXC because of the restriction of short-selling and banking (Daskalakis and Markellos (2008)). Moreover, according to Daskalakis et al. (2005), market participants are found to follow conventional no-arbitrage pricing.

Paolella and Taschini (2006) modeled the unconditional tail behavior and the heteroskedastic dynamics of the returns on CO_2 and SO_2 allowances using their econometric structure. The authors found that the unconditional tails can be represented well by the Pareto distribution while the conditional dynamics can be approximated by a new GARCH-type structure. Benz and Truck (2009) applied a regime-switching model in order to model the dynamics of the allowance spot price. Chesney and Taschini (2008) constructed an endogenous model to describe the dynamics of the spot price and demonstrated asymmetric information in the market. Seifert et al. (2008) discussed stylized facts of the EU ETS data with a stochastic equilibrium model of typical economic theory. Main findings are that the CO2 process does not have a seasonal pattern, which means it has a martingale property, and that the process has a time- and price-dependent volatility structure.

3. EU ETS and Global CO_2 level

In this Section, we discuss the current status of efforts for reducing GHG by assessing EU ETS and its impact on GHG reduction. Since EU ETS is the first and largest GHG emission certificate trading system, we will work with EU ETS to appraise the efforts for reducing global GHG emission so far.

EU ETS has received much attention as the first and largest (and the first) emission trading system in the world. There have been on-going debates on the effectiveness of EU ETS with certain criticisms. EU ETS' achievements can be summarized as: the first working emission trading system; and some success in reducing carbon emission by participating members. On the other hand some critics disapprove it for reasons such as: excessive flexibility, over-estimation of GHG emission by many members, superfluous grandfathering (granting free-of-charge certificates), encouragement of frau and profiteering, and exclusion of countries that are responsible for most GHG emissions.

First, let us introduce a few research results that assessed the effectiveness of EU ETS. In Martin Muûls and Wagner (2012), the authors performed a thorough search of the literature regarding EU ETS and reviewed 179 research papers pertaining EU ETS. Among papers that were reviewed, we introduced several of them that estimated the EU ETS' effect on CO_2 emission. Anderson and Di Maria (2011) estimated that there was 2.8% reduction in CO_2 emission from BAU (business-as-usual) in the Phase I, which is considered as a pilot period of EU ETS.[13] Anderson and Di Maria (2011) considered various factors that affect CO_2 emission (such as economy, weather, and price of electricity) to construct BAU estimates and compared them to actual CO_2 to come up with an estimation of 2.8% CO_2 reduction in Phase I. Estimated 2.8% reduction in CO_2 emission by Anderson and Di Maria (2011) is similar to a preceding work of Ellerman, Convery, and De Perthuis (2010), which estimated that CO_2 emission reduction in Phase I (2005-2007) is around 3.3% from BAU (or 70 MT per year). Another noteworthy study regarding EU ETS' impact on CO_2 emission reduction is Abrell, Ndoye, and Zachmann (2011). In Abrell, Ndoye, and Zachmann (2011) the authors matched firm-information database in CITL to AMADEUS[14] to estimate the CO_2 emission reductions in Phase I and Phase II (2008-2012). Matching CITL data to AMADEUS data is a challenging task because they had to do it by matching addressed of 3,680 installations. (One company may have more than one installation.) According to Abrell, Ndoye, and Zachmann (2011), CO_2 emission reduction was 3.6% lower in Phase II than Phase I. However, since Abrell, Ndoye, and Zachmann (2011) does not take exogenous factors, there is a good chance that certain portion of 3.6% drop in CO_2 emission in Phase II might be caused by other factors such as economy, weather, and energy price. Refer to Martin

[13] 2.8% reduction in CO_2 emission in parties that involved in EU ETS is equivalent to 58 MT (metric ton) of CO_2 per year.

[14] CITL is a transaction log for EU emission trading data and Amadeus is a commercial database that is distributed by Bureau Van Dijk for most European firms.

Muûls and Wagner (2012) for more research results on the CO_2 emission reduction during EU ETS.

Even with numerous research findings that support the effectiveness of EU ETS, its cap-and-trade system also received quite a bit of criticisms. Gilbertson and Reyes (2009) criticized many aspects of EU ETS as follow.

First, they claim that EU ETS' flexibility allows some of its members to emit more CO_2 rather than making efforts to reduce GHG emission. Flexibility of EU ETS involves excessive grandfathering (issuing CO_2 emission certificate free-of-charge), inaccuracy in assessing CO_2 emissions of participating members, and existence of CDM (Clean Development Mechanism) and JI (Joint Implementation). Anderson and Di Maria (2011) showed that EUA (European Union Allocation) quantities for European countries during Phase I were quite a bit off. In other words, excessive EUA were assigned to some countries and insufficient EUA to others.[15] According to Gilbertson and Reyes (2009) installation that needed to emit more CO_2 could simply purchase certificates from countries with excess permits instead of trying to develop technologies that reduce CO_2 emission. This tendency of passing the responsibility for reducing CO_2 emission was further boosted by excessive grandfathering[16]. Furthermore, Gilbertson and Reyes (2009) also criticized CDM and JI for sponsoring projects that are ineffective in improving environment. In addition, some participating members in EU ETS were accused of exploiting CDM and JI[17] instead of trying to reduce CO_2 emission.[18] The fact that purchasing CO_2 emission certificates is usually cheaper than reducing CO_2 emissions for most energy companies also leaves room for criticism.

Although EU ETS has received some criticisms, it is hard to deny the fact that EU ETS is the first working GHG emission trading system that has made certain contributions to reducing GHG emission. Yet, when viewed from a larger perspective, EU ETS' efforts have been insignificant in actual reduction of global GHG level largely because of nonparticipation of heavy CO_2 emitters. For example, the Bush government rejected the Kyoto protocol in March 2001 and announced later in February 2002 that the U. S. will rely on domestic

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[15] Czech Republic, France, Germany and Poland had excessive amount of EUA, while Spain, Italy and UK did not have enough.

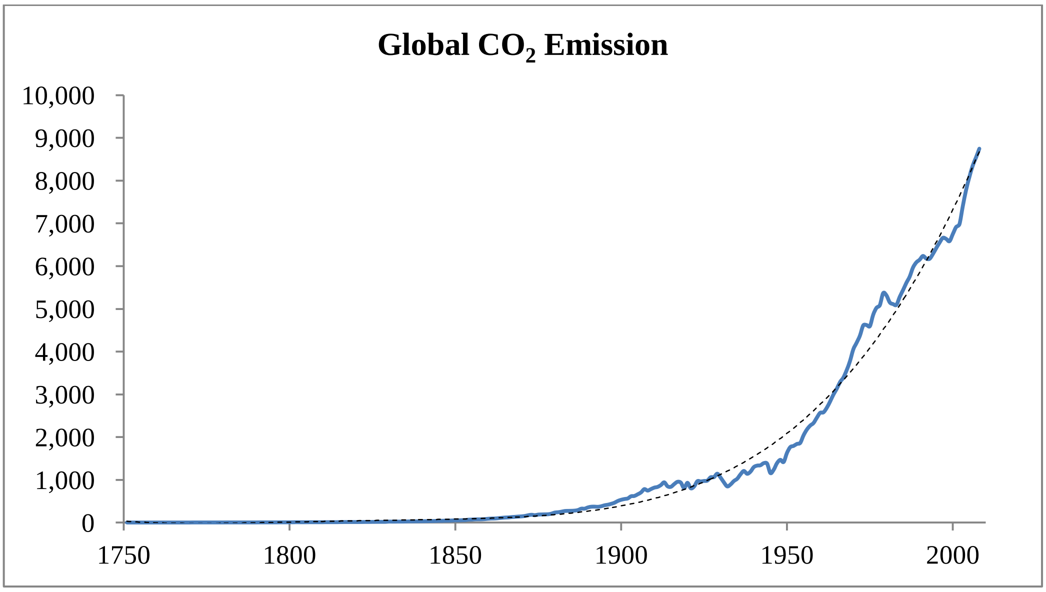
[16] Daily closing price of EUA spot plummeted in 2006 and 2007 when EU ETS participants realized that supply of permits exceeded demands.

[17] CDM and CI can be traded for CO_2 emission certificates.

[18] Gilbertson and Reyes (2009) also mentions that entrepreneurs in India and China built factories whose primary purpose is to produce greenhouse gases. These entrepreneurs have made billions dollars by trading their GHG emissions through CDM and JI.

voluntary actions to reduce GHG emitted by the U. S. economy by 18% over the next 10 years.[19] (Although CO_2 emission within the U. S. shows a downward trend between 2007 and 2009, it can be due to the global financial crisis within the same period.) In 2010 Canada, Japan and Russia announced that they would not accept new Kyoto commitments. In addition, Canada entirely withdrew from the Kyoto Accord in December 2011 probably because Canada was not going to be able to avoid paying $14 billion penalty for not meeting its goal without repudiating Kyoto Accord. Canada also argued that the Kyoto protocol cannot work because the U. S. and China (the world's largest GHG emitters) are not participating.[20] (China and India, two of the major GHG emitters, were not included in the Annex I countries list because they are classified as developing countries.)

The following figure shows the historical global CO_2 emission.[21] (Dotted line is a 4^{th} order regression line with R^2=0.989.)



[Figure 1: Global CO_2 emission between 1751 and 2008 in Metric Ton]

The first difference of yearly CO_2 emission can be drawn as [Figure 2]. According to [Figure 1] and [Figure 2], we are emitting around 9,000 million MT of CO_2 each year and it is expected that additional 200 million MT of CO_2 emission would occur each year in the

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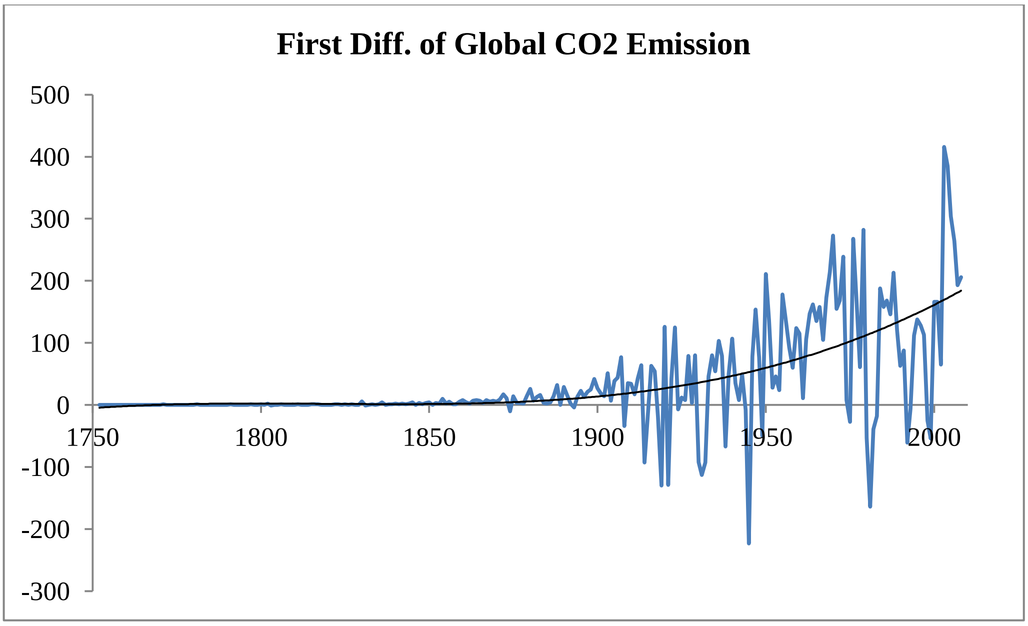
19 http://www.eoearth.org/article/Kyoto_Protocol_and_the_United_States, an article in The Encyclopedia of Earth.

20 Canada pulls out of Kyoto protocol, The Guardian (UK). December 13, 2011.

21 Boden, T.A., G. Marland, and R.J. Andres (2010). Global, Regional, and National Fossil-Fuel CO2 Emissions.

near future. As we mentioned before Anderson and Di Maria (2011) estimated that there was 2.8% reduction in CO_2 emission from BAU in the Phase I of EU ETS and Abrell, Ndoye, and Zachmann (2011) estimated that CO_2 emission reduction was 3.6% lower in Phase II than Phase I. (Again note that Abrell, Ndoye, and Zachmann (2011)'s estimation is probably over-estimated because they did not take crucial factors such as economy, weather and fuel price into account.). As mentioned already, 2.8% reduction from BAU in EU ETS is equivalent to 58 MT per year. When we consider the fact that global CO_2 emission per year is around 9,000 million MT and additional 200 million MT of CO_2 emission increase is expected each year, we can see that EU ETS' endeavor has a long way to go.



[Figure 2: First difference of global CO_2 emission between between 1751 and 2008 in Metric Ton]

Documented previous sections, we are suggesting a new approach to resolve the present questions of the international society about the GHG emission. The approach is the device of the financial commodity which restrains the GHG emission of the nations included in UNFCCC with the way of the securitization. This study is impressive on the view of the probability that the financial markets can settle the external diseconomies of the GHG emission by the other ways. It also has a positive purpose to appeasement the real-life problems by academic efforts. The advantages and contributions of the designed financial commodity are following:

1. The securities pay more coupons as low as the GHG emissions. Hence, the investors of these securities try to act on the various activities related to reduce the GHG

emissions.

2. If a government agency may invest to these products, they will have the incentives about reducing the GHG emissions. It would relieve the problems from shrinking the CO2 emission markets or nonfulfillment of the international agreements for the carbon emission.

3. Institutional investors and private investors are concerned on the reduction of the carbon emission problems, and these concerns may derive consents for the environment problems.

4. Since the securities have a zero or negative correlation (in the Russian case) with the financial market, it may be help to diversify the financial markets.

5. If GCF(Green Climate Fund) may become the issuer of the securities, these should be good tools to save the funds for the GHG emission reductions.

Meanwhile, we need to price clearly and to design the correct commodities to obtain sufficient market demand. For this work, we should analysis the emission data from various angles and refer many previous studies for deriving best results.

In this Section, we introduced some research results on the effectiveness of EU ETS and showed that its efforts have been insufficient in quenching the drastically increasing global CO_2 emission. From the discussion of this Section, we can see that effective reduction of global GHG emission requires active participation of heavy GHG emitters, enforcement of global-wide regulations, and devising various forms of financial (or non-financial) instruments that intended for reducing GHG emission. This research can be considered as an effort for developing an effective financial instrument for reducing GHG.

4. CO2 Emission Modeling and Expanded Kyoto protocol

4.1 CO2 Emission Modeling

First of all, self-immolating reduction efforts of all countries are most important for monotone reducing the world-wide CO2 emissions. The withdrawal of Canada from Kyoto Accord in 2011 shows that international agreement for the emission reduction is not enough to confine the emission without the self efforts. For this reason, it is necessary to construct a mechanism that can induce the self efforts to reduce CO2 emissions in each nation. These models or financial commodities should associate with the amount of the CO2 emission for each nation, and control this amount. Prior to construct the financial model associated with the total amount of CO2 emission, we need to know properties of the data for the amount of

CO_2 emissions on countries. Since the financial model should induce the emission reduction "until specific time, within specific amount", the expected emission amount have to be estimated.

The data of CO_2 emissions have to guarantee the clarity of the subject emitting CO_2 gas and the reliability of the measurement itself. Since some subjects such as animals or trees are not suitable to measure the amount of the emissions, and generates obscure measurement problems, these subjects are not compatible for an underlying asset for the financial commodities. In this paper, we therefore limit the subject of CO_2 emissions to fossil fuels. Fossil fuels are not only related to other emitting subjects such as automobile, factory, but also one of the influenceable factors to the total CO_2 emission amount. In addition, the data of the CO_2 emissions of all countries from fuel combustion is opened to the public by international organizations such as IEA(International Energy Agency), EIA(Energy Information Administration). For this paper, we used the time-series data of CO_2 emission amounts by countries from 1971 to 2010 provided by IEA. We additionally repeat pricing the premium of the securities underlying top three GHG(CO_2, CH_4, and N_2O) data.

For the given time-series data, we need to estimate the expected emission amount after few years. However, Since the prior researches (Mastrandrea and Schneider (2005), den Elzen and Mainshausen (2006), Jones, Cox and Huntingford (2006)) are based on much longer period such as 100 years, or 200 years unit, it is not appropriate to apply to the financial commodities. Therefore, we will estimate the emission amounts during relatively short periods less than 10 years.

4.2 Expanded Kyoto Protocol

Along with the revision accepted at COP18(the 18th Conference of the Parties to the UNFCCC), second commitment period is extended 3 years from 2013 to 2020. If we call α the emission reduction target suggested at Kyoto Protocol, Annex 1 countries should reduce the amount of GHG emissions by $(1+\alpha)$ times of the emission amount at 1990.

Based on 2010, the top 10 countries emitting CO_2 are Canada, China, Germany, India, Iran, Japan, South Korea, Russia, UK and USA, and these countries dominate 65.50% of the total amount of the world-wide CO_2 emission. Among these, the countries included at Annex 1 were Canada, Germany, Japan, Russia and UK. Now Canada withdrew from Annex 1, this paper will conclude Canada for the securitization, and will calculate the premium of the securities based on the limitation of the cumulated CO2 amount suggested at the Kyoto Protocol. Table 1 summarizes the target reduction basis, CO2 amounts at 1990, and permitted cumulative CO2 emission data of the five countries.

Unit : Tg CO2 equivalent

Top 5 countries among Annex 1	Emission reduction target	CO2 amounts at 1990	Permitted cumulative CO2 emission amount during 2nd period	GHG amounts at 1990	Permitted cumulative GHG emission amount
Russian Fedration	0%	2,559.6	20,476.8	3,471.1	27,769.0
Japan	-6%	1071.0	8,053.92	1,258.5	9,463.8
Germany	-8%	1014.2	7,464.5	1,230.3	9,055.0
UK	-8%	591.8	4,355.6	785.0	5,777.4
Canada	-6%	384.5	2,891.4	532.5	4,004.4

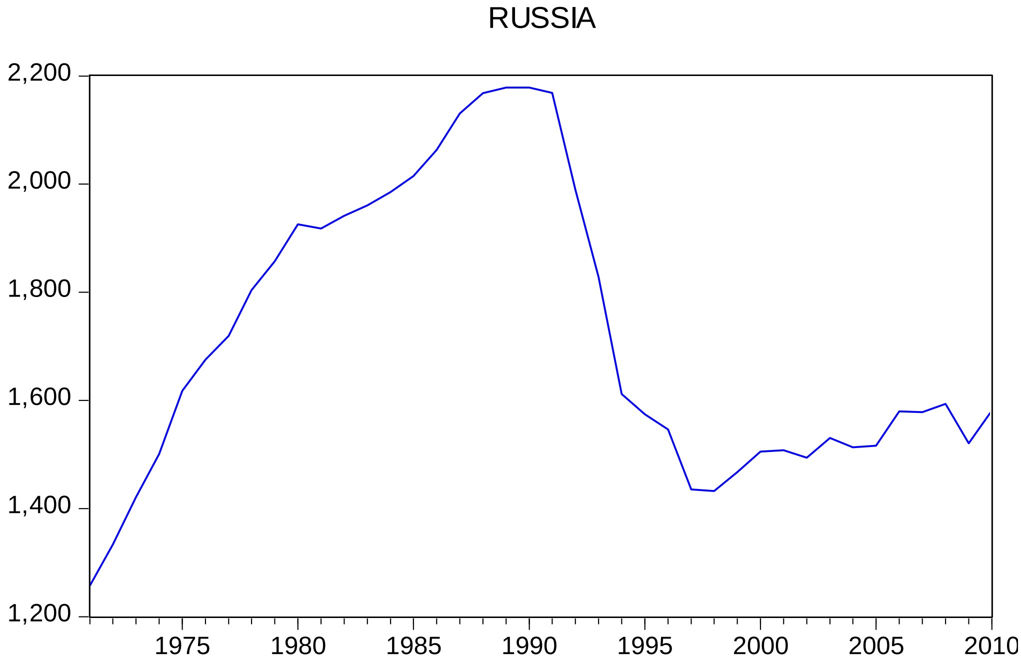
[Table 1: The emission reduction target and GHG emission amount of top 5 countries]

Table 2 summarizes the brief statistics of increase of the CO2 emission for the 5 countries.

Country	Mean	STD	Jarque-Bera	P-value
Canada	5.051282	13.94321	2.245775	0.325339
Germany	-5.5641	28.10613	1.172992	0.556273
Japan	9.853846	38.62117	0.548827	0.760018
Russia	8.305128	72.37046	21.63193	2.01E-05
UK	-3.58974	18.66279	1.874165	0.391769
Russia(1995~)	-1.8875	46.37873	1.360495	0.506492

[Table 2: The statistics of the increase of CO2 emission for the 5 countries]

In Table 2, we need to know the background knowledge of the fact that Russia's Jarque-Bera statistics are particularly high. At the end of 1991, after the collapse of Soviet Union, Russia suffered political instability and inflation until president Putin seize power. Since it had affected to the CO2 emissions of Russia, rapidly increased CO2 emission from 1970 took the peak at 1991, and dramatically decreased until the 70% level of the one at 1991 and stabilized. Therefore, it is desirable to use the Russian data after 1995 for a normal analysis. With the data, the increase of the Russian CO2 emission amount rejects the unit root(ADF: -3.5373) and have a low Jarque-Bera statistics(1.36).



[Figure 3: Annual Russian CO2 emission amount data[22]]

The Russian data after 1995, and other 4 countries' time-series data don't reject Jarque-Bera normality, which implies that the increase of annual CO2 emission amount are stable and supposed to follow normal distribution. An important component of this study is an estimation of cumulative emission amount during from 2013 to 2020. Let S_t be the CO2 emission amount of a country at t year, and $\Delta S_t := S_t - S_{t-1}$ be the increase of the CO2 emission amount at t year. Let T_0 be the start year of 2[nd] commitment period and $A_{T_0,T} := \sum_{i=0}^{T-T_0} S_{T_0+i}$ be the cumulative CO2 emission amount until T year. To calculate the future cumulative CO2 emission amount $A_{2013,2020}$ based on the Kyoto Protocol, we generate ΔS_t with the given mean and variance of the increase of CO2 emission amount, and calculate $S_t = \Delta S_t + S_{t-1}$. Finally, we will get $A_{T_0,T}$ by integrating S_t's.

5. Designing and Pricing the Securities

In this section, we derive pricing the premium of securities underlying cumulative CO2 emission amounts. We suppose that $A_{T_0,T}$ have a bell-shape distribution whose probability

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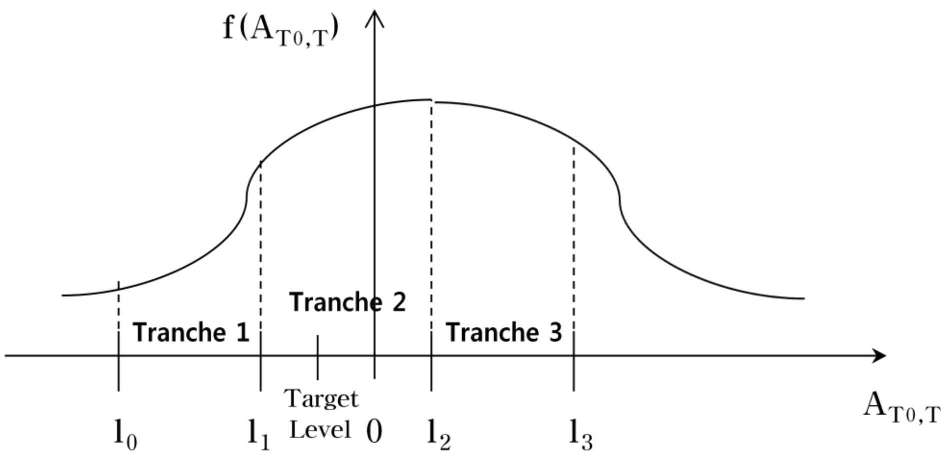
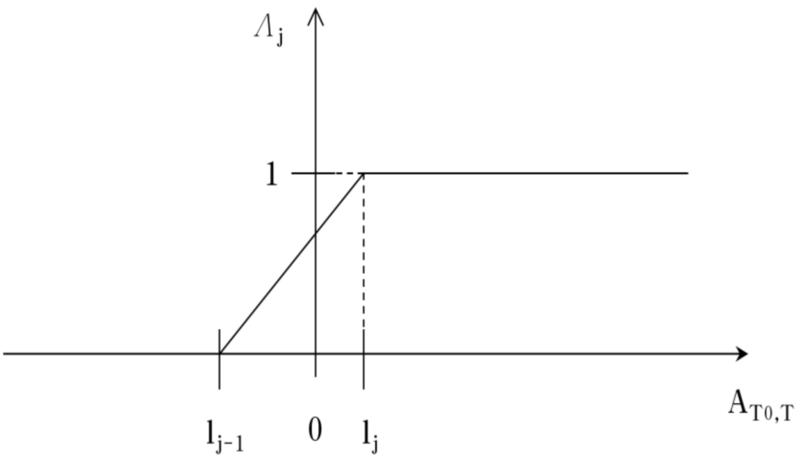
density function(pdf) has many frequencies on the medium values and little on the both tails. We divide the distribution of $A_{T_0,T}$ by several tranches, and the securities have an important property that the coupon of a security belonging to each tranche is grater as the frequency of the tranche is smaller. Finally we want to design the mechanism of the security, which let the security of a country belong to a low frequency tranche below the target level of CO2 emission reduction suggested at Kyoto Protocol. Consider the Figure 4.



[Figure 4: An example for a distribution of $A_{T_0,T}$ and tranches]

Let $f(A_{T_0,T})$ be the pdf of $A_{T_0,T}$, and consider the example having three tranches on the distribution of $A_{T_0,T}$. For appropriate four real numbers l_j, j=0, 1, 2, 3, let tranche j be the interval $[l_{j-1}, l_j),\ j \in \{1,2,3\}$. If $A_{T_0,T}$ belongs to a specific tranche, a security on the tranche should have a payoff decided by the value of $A_{T_0,T}$. To construct the payoff for each tranche j, consider the Figure 5.



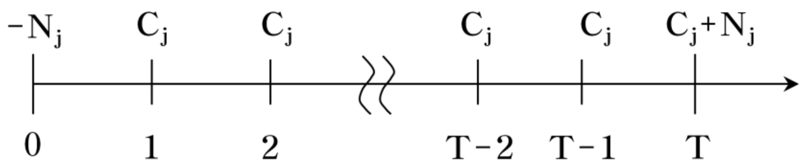
[Figure 5: An example of a payoff function on the security]

From a simple math, the payoff of tranche j can be decided by

$$\Lambda_j := \frac{[A_{T_0,T} - l_{j-1}]_+ - [A_{T_0,T} - l_j]_+}{l_j - l_{j-1}}, [a]_+ = Max\{a, 0\}$$

for a real number a.

The considered securities have higher coupon as lower as the value $A_{T_0,T}$ of a country at the maturity. Let the annually paid coupon of the security belonging on tranche j be C_j. Assume that the annual coupon C_j has paid constantly until the maturity.



[Figure 6: The cash flow of the coupon]

If one invests an amount of money N_j at the starting time of a security, a constant C_j would be paid annually until the maturity, and C_j and N_j will be paid together at the maturity. If r is the risk-free interest rate, because the present value of sum of all cash flow should be same with the notional, we have

$$N_j = E_Q[\sum_{i=1}^{T-T_0} C_j e^{-ri} \mid S_t] + N_j e^{-rT}, t \le T_0 \quad (1)$$

where t is the most recent year having CO2 emission data reported, and generally t< T_0. Let s_j be the risk premium of the security. Since C_j should be rational to the national N_j, the payoff function $1-\Lambda_j$, and the risk premium s_j, we can define

$$C_j := (1-\Lambda_j) N_j (s_j + r) \tag{2}$$

Substituting (2) to (1), we have

$$N_j = E_Q[\sum_{i=1}^{T-T_0} (1-\Lambda_j) N_j (s_j + r) e^{-ri} \mid S_t] + N_j e^{-r(T-T_0)} = \sum_{i=1}^{T-T_0} E_Q[1-\Lambda_j \mid S_t] N_j (s_j + r) e^{-ri} + N_j e^{-r(T-T_0)} \tag{3}$$

Solving (3) with respect to s_j, we have

$$s_j = \frac{1-e^{-r(T-T_0)}}{\sum_{i=1}^{T-T_0} E_Q[1-\Lambda_j \mid S_t] \cdot e^{-ri}} - r = \frac{1-e^{-r(T-T_0)}}{E_Q[1-\Lambda_j \mid S_t] \sum_{i=1}^{T-T_0} e^{-ri}} - r = \frac{1-e^{-r}}{E_Q[1-\Lambda_j \mid S_t] e^{-r}} - r \tag{4}$$

Here, since we know that $E[E_Q[1-\Lambda_j \mid S_{t+i}] \mid S_t] = E_Q[1-\Lambda_j \mid S_t], i > 0$, the second equation of (4) holds.

6. Numerical Examples

In this section, we generate a number of scenarios $S_t = S_{t-1} + \Delta S_t$ along with creating ΔS_t by using the Monte Carlo simulation. For the ΔS_t, we investigate the historical mean and variance of ΔS_t, and suppose that ΔS_t distributed normally. Based on this assumption and the reduction basis of Kyoto Protocol, we calculate the premium s_j numerically.

We consider the case of United Kingdom for example. Following the data of IEA, the CO2 emission amount of 2010 at UK is 483.52Tg. During 40 years from 1971 to 2010, the first difference of the CO2 emission data follows the normal distribution with the mean of -3.59Tg and the variance of 18.66Tg. Since the second reduction commitment period is from 2013 to 2020, the CO2 emission amount of UK at 2013, S_{2013}, is following;

$$S_{2013} = S_{2010} + 3\mu + \sqrt{3}\sigma\varepsilon = 483.52 + 3 * (-3.59) + \sqrt{3} * 18.66 * \varepsilon, \qquad \varepsilon \sim N(0,1)$$

On the other hands, the permitted cumulative CO2 emission amount of UK during the second commitment period(assigned amount) is following;

$$\text{assigned amount} = 1990\text{'s level} * (1 + \alpha) * 8 = 4042.49$$

See the Table 1 for the value of α and 1990's level.[23] We set $\{l_0, l_1, l_2, l_3\}$, the boundaries of tranches, as $\{\alpha - 0.03, \alpha - 0.01, \alpha + 0.01, \alpha + 0.03\}$, and figure them such as

$$l0 = 1990\text{'s level} * (1 + \alpha - 0.03) * 8 = 3910.67$$

$$l1 = 1990\text{'s level} * (1 + \alpha - 0.01) * 8 = 3998.55$$

$$l2 = 1990\text{'s level} * (1 + \alpha + 0.01) * 8 = 4086.43$$

$$l3 = 1990\text{'s level} * (1 + \alpha - 0.03) * 8 = 4174.31$$

Since we can compute $E_Q[\Gamma_j] = \frac{E_Q[A_{T_0,T} - l_{j-1}]_+ - E_Q[A_{T_0,T} - l_j]_+}{l_j - l_{j-1}}$ from each tranche, so we can find the value of (4). The results are follows:

$\{s_1, s_2, s_3\} = \{0.00705, 0.00461, 0.00295\}$

Table 3 gives the distributions of the top 5 countries for the CO2 emission amount in Annex 1 and the risk premiums of tranches.

unit: Tg CO2 equivalent, basis point

The top 5 Annex 1 countries	The emission amount at 2010	Mean of the increase	Variance of the increase	s_1	s_2	s_3
Russian Fedration	1581.37	-1.89	46.39	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$
Japan	1143.07	9.85	38.62	5.55824	2.45286	1.35866
Germany	761.58	-5.57	28.11	0.00089	0.00060	0.00043
United Kingdom	483.52	-3.59	18.66	0.00705	0.00461	0.00295
Canada	536.63	5.05	13.95	>10	>10	>10

[Table 3: The risk premiums of the securities underlying the CO2 emission amount]

We can find that the values of the spreads of Japan and Canada are greater than 100%. Especially, the Canadian spreads are much high values which are inappropriate to issue the security.

Below two tables, Table 4 and 5, are the results of the similar premium calculations with

[23] In this equation, we used the value of the 1990's level=549.2514. It is from IEA data set and slightly different with the one on Table 1 extracted from Kyoto Protocol. We guess the difference may be come from the difference of the estimating methods between IEA's and Kyoto Protocol's and the difference is not a main point in this paper. We only used the IEA's data for all calculating processes on this paper.

the top 3 GHG emission amount and the total GHG emission amount data[24], respectively.

unit: Tg CO2 equivalent, basis point

The top 5 Annex 1 countries	The emission amount at 2010	Mean of the increase	Variance of the increase	s_1	s_2	s_3
Russian Fedration	1540.90	-92.38	161.48	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$
Japan	1161.28	1.32	34.05	0.44394	0.25090	0.14249
Germany	938.67	-13.40	24.62	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$
United Kingdom	574.95	-9.12	17.27	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$
Canada	754.54	12.17	100.32	0.43146	0.37591	0.34416

[Table 4: The risk premiums of the securities underlying the top 3 GHG emission amount]

unit: Tg CO2 equivalent, basis point

The top 5 Annex 1 countries	The emission amount at 2010	Mean of the increase	Variance of the increase	s_1	s_2	s_3
Russian Fedration	1569.42	-95.08	164.82	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$
Japan	1208.33	-2.51	39.57	0.04652	0.03018	0.01950
Germany	1208.33	-13.07	24.53	0.04040	0.02030	0.01011
United Kingdom	605.40	-8.98	18.07	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$
Canada	772.83	12.02	100.62	0.40116	0.36642	0.34075

[Table 5: The risk premiums of the securities underlying the total GHG emission amount]

The differences of the countries' spread values with the top 3 GHG data and the total GHG data seems to be less than the one with the CO2 data. However, the values of Canadian and Japanese are still higher than the values of the other countries.

The Canadian reduction target, $\alpha = -0.06$

ΔS_t	[-0.11,-0.09]	[-0.09,-0.07]	[-0.07,-0.05]	[-0.05,-0.03]	[-0.03,-0.01]
0	>10	>10	>10	>10	>10
-5	>10	>10	>10	9.35995	4.05191
-10	4.74291	2.43371	1.09289	0.66079	0.34447
-15	0.40183	0.23396	0.13621	0.08488	0.05485
-20	0.06125	0.03842	0.02534	0.01653	0.01048

[Table 6: The sensitivity of the risk premium of the Canadian securities under ΔS_t and the tranche intervals]

In Table 6, we made some scenarios to investigate which ΔS_t values and tranche intervals are appropriate for practically issuing the Canadian security to financial markets. As

24 http://unfccc.int/ghg_data/ghg_data_unfccc/time_series_annex_i/items/3814.php

the results in Table 6, to have roughly 10% coupon level, the Canadian security may have the [-0.07, -0.05] tranche interval, and Canada should reduce consistently 15Tg of the CO2 emission amount in a year.

7. Conclusion

According to the global climate change is occurring more and more frequently for the global warming, the GHG reduction agreement from Kyoto protocol should be implemented faithfully. However, the implement of the agreement on the Kyoto Protocol has faced very tough situations because Unite States never ratified the agreement of Kyoto protocol, and Canada, Japan and Russia would not join a second round of carbon cuts under the Kyoto Protocol. Although the second commitment period is postponed by 3 years, we need to approach the problems to make many countries taking actively part in the GHG emission reduction with an argument of a new angle.

If the securities underlying each country's GHG emission amount, designed on this paper, are issued by UNFCCC or GCF, the investor holding the securities becomes a participant on the game of the GHG emission reduction. For example, if UK can reduce a significant amount of the CO2 emission after issuing the securities, the investors holding the securities can make a mint with a high probability. Therefore the investors will request harder reduction activities to UK.

As a part of this argument to design the securities, we found the distributions of the increase of the CO2 emission amount from 1971 to 2010 on the top 5 CO2 emitting countries belonged to Annex 1, with the data published by IEA. Accumulating the expected increase of the emission amount from 2013 to 2020, we computed the sum of the CO2 emitting amount during the second commitment period, and calculated the risk premiums of the securities associated with the given tranches, whose expected rate would be same with the risk free interest rate.

The Russian, Japanese, German, and UK's CO2 emission-backed-securities have relatively stable risk premiums or spreads, but the Canadian security seems not possible to issue practically because of the much high spread value. This is because the size of the CO2 emission amount between 1990 and 2010 is relatively bigger than other nations. We identified to issue practically the Canadian security with the stable coupon spread, Canada should reduce annually 15 Tg of the CO2 emission amount.

We expect that the designed securities are issued plentifully, the investors of the securities concerns about the GHG reduction activities of the countries, and the active public opinion for the GHG emission reduction is created. Finally the coupon spread calibration methods under risk aversion or the duty of the reduction, and the development for the methodology generating the CO2 emitting scenarios on a short period are remained for further researches.

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