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Harmonizing the Emission Trading System and Environmental Taxes

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Summary

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As concerns regarding climate change grows, many advanced countries are setting goals to reduce greenhouse gas emissions, and are adopting various policies such as an Emission Trading System(ETS) and a carbon tax to achieve these goals. Korea has decided to reduce its greenhouse gas emissions by 30 percent of the 2020 Business As Usual(BAU) emissions, and has adopted an ETS as the major policy mean to achieve it. Considering Korea's economic condition, policy environment, and greenhouse gas emission trend, the 2020 greenhouse gas reduction goal is rather highly set, and the policy effort to achieve this goal is rather weak.

This study analyzes the introduction of an environmental tax as additional policy measure to achieve the greenhouse gas reduction goal, with a particular focus on how such a tax would harmonize with the current ETS. A case study of the United Kingdom and Germany was conducted for this purpose. Also, based on our theoretical model, we estimated the "optimal" price for emission rights in Korea.

The policy implications deduced from this study results were as follows. First, the "optimal" price of emission rights estimated in this study is 26,300 KW/ton. The current price is about 10,000 KW/ton, which is about 16,300 KW/ton lower than the estimated price. In our study, the optimal emission right price is the price necessary to achieve the 2020 greenhouse gas reduction goal. Therefore, if the current emission right price remains the same, it would be difficult to achieve the 2020 greenhouse gas reduction goal. Also, if Korea would not be able to put a proper burden on carbon emission, it would be hard to facilitate green investment for carbon technology development. In this case, to promote green investment, we can consider to impose an environmental tax equal to the price difference between the proper emission right price and the actual

emission right price, limited to electricity sector, to supplement the ETS, as is done in the United Kingdom. Second, to prevent a double burden on carbon emissions when introducing an environmental tax as a new tax subject, an environmental tax should be imposed on economic agents such as households and commercial and industrial enterprises that do not participate in the emission trade. Third, the "optimal" emission right price estimated by this study can be used as the benchmark to determine the rate of the environmental tax imposed on those groups not subject to emission trades. However, for industrial groups not subject to the ETS, the environmental tax rate should be set lower than other economic groups, considering that emission rights are distributed free to firms who are subject to the ETS. Fourth, when introducing an environmental tax in ways that strengthen the existing environmental energy tax system, the environmental tax rate should be calculated so as to take into account the social cost of greenhouse gas emissions. Also, Korea does not currently tax electricity use, so we can consider introducing an electricity consumption tax and in this case energy sources used to produce electricity should be exempt from taxes.

I

Introduction

Natural disasters such as typhoons, drought, freezing temperatures, floods, and heavy snow caused by climate change are now being observed all over the world. Participants in the 2010 UN Climate Conference in Cancun agreed that any further rise in the global temperature should be kept under 2℃. The United Nations Environment Programme (UNEP) has estimated the difference between the greenhouse gas emission levels needed to achieve this goal and the greenhouse gas emission levels that reflect greenhouse gas reduction efforts made by each country, and is constantly discussing ways to narrow the gap between the two (UNEP, 2014).

Korea emits more greenhouse gases than many other countries: it ranks seventh in terms of carbon-dioxide emissions both per person and per GDP. Korea has recognized its international responsibility in this regard and has made a commitment to the international community to reduce its greenhouse gas emissions by 30 percent of the 2020 Business as Usual(BAU) emissions. However, considering Korea’s economic condition and increasing net greenhouse gas emissions, achieving this goal will be difficult.

To achieve the greenhouse gas reduction goal, a diverse assortment of policy efforts in is needed. The key policy means to achieve the reduction goal in Korea is the implementation of the ETS. However, additional policy efforts are also needed, as have been made in other major countries. Korea’s environmental energy tax system is focused on oil; taxes are not properly imposed on coal or electricity, which also produce a great deal of carbon-dioxide emissions. As pointed out by Jeon, et al.(2012), this demonstrates that the environmental energy tax system does not properly reflect the cost of the social damage done. In this sense, imposing a tax on bituminous coal from July 2014 was a desirable reform, but the tax base for coal still needs to be expanded to properly reflect the social damage cost to the energy price system. Therefore, to induce greenhouse gas reduction and reasonable energy consumption, the introduction of an environmental tax should be considered.

However, introducing an environmental tax clumsily and without consideration for how it relates to other systems will undermine the effectiveness of the policy and have a negative effect on industrial competitiveness. The purpose of this study, therefore, is to examine how an environmental tax can be smoothly implemented under the ETS. An environmental tax can encourage the public to use reasonable amounts of energy by imposing prices on carbon. Because inducing reasonable energy consumption through an ETS has its limitations, an environmental tax can be used to supplement the ETS. Therefore, if the policy combination of an ETS and an environmental tax achieves desirable results, it will play an important role in efficiently reducing greenhouse gas emissions.

In order to assess whether the policy combination of an ETS and an environmental tax is desirable, this study included: 1) a foreign case analysis; and 2) an “optimal” environmental tax rate estimation analysis using a theoretical model analysis. Developed countries in Europe are actively dealing with climate change using various policy measures. Of these, this study focuses on the United Kingdom and Germany, which contribute a large part of the total greenhouse gas emissions from Europe. The United Kingdom and Germany set policy goals of reducing greenhouse gas emissions and improving energy efficiency using an ETS, and each country introduced an environmental tax suited to their conditions. Greenhouse gas emissions are decreasing in both countries, so it seems that these diverse policy efforts are effective. This study will therefore look at how the United Kingdom and Germany introduced and are implementing environmental taxes under their ETS, and will look at the ways to introduce an environmental tax in Korea.

Also, one of the most important factors when introducing an environmental tax is determining the appropriate tax rate. The emission right price is generally the carbon price, so the appropriate benchmark for an environmental tax rate is the emission right price. To date there have been no studies that have estimated the optimal emission right price in Korea, so this study will: 1) build a theoretical model and estimate the optimal emission price based thereon; and 2) examine the difference between the estimated emission right price and the actual emission right price. The basic idea of estimating the optimal emission right price is to estimate the price necessary to achieve the 2020 greenhouse gas reduction goal through a theoretical model, so in this study, the "optimal" emission right price means the carbon price necessary to achieve Korea's greenhouse gas reduction goal. Estimating the emission right price offers a rough guess as to whether Korea can achieve its greenhouse gas reduction goal. It can also be an important index for determining the environmental tax rate when introducing an environmental tax under the ETS.

Ⅱ

The Features and Current Conditions of the Emission Trade System and the Energy Tax System

Recently, the introduction of an environmental tax has been actively discussed in government, industry, and academic circles, but the Korean government has thus far failed to provide a concrete and clear blueprint for the future of its environmental tax. The government introduced and conducted the Greenhouse Gas and Energy Target Management System and the Emission Trading System(ETS) in 2012 and 2015 respectively to achieve the greenhouse gas reduction goal, rather than introducing an environmental tax(or carbon tax). In this chapter we will look at the theoretical backgrounds and current conditions of the the Target Management System and the ETS. Also, to examine the necessity of the introduction of an environmental tax, we look at how these systems could contribute to achieving the greenhouse gas reduction goal.

1 The Emission Trading System (ETS)

A. The features and current condition of the system

To achieve the 2020 greenhouse gas reduction goal, the government introduced the Greenhouse Gas and Energy Target Management System in 2012. These were supplemented with an ETS that became operational in 2015. Unlike the Target Management System, the ETS uses the market function to achieve the greenhouse gas reduction goal. The government decides how much the total greenhouse gas emissions should be reduced during a certain period, and allocates permissible greenhouse gas emission amounts to firms based on that. However, this leaves a gap between the permitted emission amount and the actual emission amount, so the government has created emission trade market so that a firm whose actual emissions exceed the permitted amount and a firm whose actual emissions are under the permitted amount can trade emission rights with each other voluntarily.

According to a press release from the Ministry of the Environment (2014), the current ETS deals with 23 types of energy and fuel, organized into five groups: process (generation, energy), industry, building, transportation, and waste. The emission rights are distributed to the firms that emitted greenhouse gases amount of 125,000 tons last three years or the firms which possess business place with emission over 20,500 tons. The firms include 526 firms, and the emission of the firms is about 66 percent of the total Korean emission amount (Ministry of Environment, 2014).

The first trade of emission rights took place on January 12, 2015: 1,190 tons of emissions were traded, and the final price of the emission right was 8,640 KW/ton. The emission trade lasted only three days after January 12, and there was no trade between January 16th and August. Looking at the emission right price trend, it increased sharply in early February, a little more later that month, and again in late April. The total trade amount until August 2015 was 1,340 tons, and the total trade scale was 11,550 thousand KW. The emission price increased to 10,300 KW/ton in late April, after which it remained the same until August 2015.

The government started to allow offset credits in April 2015 to facilitate the emission trade market. This was the first acknowledgement of the effort to reduce emissions due to the external greenhouse gas reduction project: the firms are permitted to buy offset credits, generated by a greenhouse gas reduction project, to compensate for their emissions. However, the offset credits are only allowed for a maximum of 10 percent of the emission right that must be submitted to the government every year. The first trade for an offset credit took place on April 6 for 1,500 tons at a price of 10,100 KW/ton. The trade of offset credits is higher than that of general emission right. On April 10 the amount traded was 75,000 tons, which grew to 200,000 tons on April 28 and 500,000 on June 19. These amounts are quite high, considering that the total emission right trade so far has been only 1,380 tons.

To date, no trade of emission rights have taken place since the few days of trading at the beginning of the introduction of the ETS. Since the trades of offset credits were recognized, they have taken place relatively more often than those of emission rights, which means that there may be a greater demand for the former than for the latter. This may be because the price of emission rights is lower than that of the proper level. The government calculated the burden of emission right trade subject firms using the price increase of September of 2014 (as well as the penalty for violations thereof), and set the emission right standard price as 10,000 KW/ton to stabilize the market (Ministry of Finance, 2014). The current emission right price is based on a certain range of standard price fluctuations. Under current conditions, the government can adjust it using the backup supplies if the emission price is too high compared to the standard price (Law of Greenhouse-Gas Emission Right Distribution and Trade, Article 23). This means that when the government decides that the emission right trade market is unstable, it can intervene to influence the price of emission rights.

The key point of the ETS system is the emission right price. If the emission right price is lower than the optimal level, a firm has an incentive to emit more greenhouse gases, resulting in excess demand. Under these conditions, if insufficient emission rights are supplied, demand increases the emission right price, and many firms can be subject to penalties as a result. When the emission right price is expected to increase, firms have no increase to sell emission rights; this situation is expected to worsen, because the permitted amount of greenhouse gas emissions will decrease starting next year.

Firms have more incentive to use and invest in the development of new green technologies under the ETS than they did under the direct regulation system, because they can now expect to profit from selling emission rights. However, if the emission right price is kept low because of government intervention, the incentive to use and invest on new green technology will naturally decrease. This is not consistent with the government’s policy to grow green industries as a new power source, so the government should leave the emission right price to be shaped freely in the market. If this is not done, the effectiveness of the ETS will decrease and it will not work as a cost-effective means to reduce greenhouse gases. If the emission trade market does not work properly, achieving the 2020 greenhouse gas reduction goal will be very difficult.

2 Environmental tax

In this chapter, we will determine whether it is possible to introduce an environmental tax under the ETS. To do so, we will examine the current conditions of greenhouse gas emission and energy consumption, as well as the features of the current environmental energy tax system.

Greenhouse gas emissions per GDP (1,000 USD) and per capita in Korea were 0.47ton CO2eq and 14.02ton CO2eq respectively in 2011; Korea ranked seventh among OECD countries for both metrics. Korea is thus a country that emits a lot of greenhouse gases, and the effort to reduce emissions must be consistent with international responsibilities and statutes.

Korea's total greenhouse gas emissions were 688 million tons CO2eq in 2012. To meet its international responsibility to reduce emissions, the greenhouse gas reduction goal was set as 30 percent of the BAU emissions.[1] Therefore, the government set the goal to reduce total emissions from now until 2020 to 543 million tons CO2eq, which is between the total greenhouse gas emissions for 2002 and 2003.

To achieve this goal, Korea implemented the Target Management System in 2012 and the ETS in 2015, but these systems are of limited use in achieving the greenhouse gas reduction goal. So achieving the 2020 reduction goal of government is impossible. The Target Management System and the ETS may slow the increase of the total greenhouse gas emissions, but given the current trends, this approach will be limited to alter the trend of increasing the emission. Therefore, to achieve the goal promised to international society, additional policy

1) The BAU emissions for 2020 are 776,000,000 tons CO2eq이다.

efforts are required and introducing an environmental tax is one of policy means to consider.

Two things should be considered in introducing an environmental tax: first, its relationship with the existing environmental energy tax system, and second, its relationship with the ETS. To assess the former, we examine the current trends in energy consumption and the environmental energy tax system in this chapter. The policy mix of the ETS and an environmental tax will be analyzed using the case study of the United Kingdom and Germany in Chapter Ⅳ, and policy implications arising therefrom will be discussed.

We will look first at energy consumption trends in Korea, which have been constantly increasing since 1981: it was rapid in the late 1980s, and almost leveled off during periods of financial instability (for instance, in 1998 when Korea suffered from the IMF crisis in 2008~2009 during the Great Recession), but the growth has never fully ceased, and has resumed accelerating since 2010. Although the 10-year increase that began in the late 1980s is understood to have slowed down in the 2000s, when this trend is broken down by energy source it is evident that the consumption of most sources (such as oil and coal) resembled the total energy consumption, but electricity consumption increased constantly, even in the 2000s.

Next we shall compare Korea’s environmental energy tax system burden with the various tax burden indexes of other OECD countries. First, looking at the proportion of tax burden to total income of household of the same year, the transportation, energy, and environmental tax burden was 1.78 percent in 1999 but decreased 0.74 percent to 1.04 percent in 2010. This decrease in the effective tax rates of transportation and energy seems to be due to international increases in oil prices, the consumption substitution of oil, the diesel tax rate increase from energy tax reforms(Korea Institute of Public Finance, 2012). Second, comparing the proportion of the environmental energy tax to the actual prices of oil traded with major countries—that is to say, the proportion of the transportation, energy, and environmental tax burden as compared to the after-tax oil price—gasoline and diesel are neither too cheap nor too expensive in Korea, but the actual tax is comparatively lower than diesel prices. Also, in countries that consume a lot of energy, gasoline and diesel prices and the actual effective tax rate are generally kept low. Third, comparing the tax rates per calorie (unit of energy) generated from using fuel for 34 OECD countries, Korea is the eighth-lowest country of these, consuming only 53.7 percent of the OECD average (3.28 euro). Korea's low energy tax rate is more often applied in using energy than is done in other OECD countries. Lastly, comparing the actual effective tax rate to the amounts of carbon-dioxide emissions of other major countries, the total energy tax rate in Korea is about 26.47 euro per ton of carbon dioxide, which is only 50.9 percent of the OECD average of 52.04 euro.

In summary, energy consumption in Korea is consistently increasing. The increase in energy consumption in the 2000s was less than that of the preceding decade, but we have not seen an actual decrease. Looking at individual energy sources, the consumption rates of oil, coal, etc., mirrored the overall rate of energy consumption, but electricity consumption constantly increased, even in the 2000s. Also, Korea's environmental energy tax system is focused on oil. However, looking at the volume of carbon-dioxide emissions by energy source in Korea, coal and electricity emit more carbon dioxide than oil and taxes have not yet been properly imposed on coal and electricity. Comparing the energy tax burden with OECD countries using various tax burden indexes, Korea's energy tax burden is much lighter than that of OECD countries, especially for heating and conversion fuels, which produce a high volume of carbon-dioxide emissions. The tax burden is very low in Korea.

Korea presented the 2020 greenhouse gas reduction goal to fulfill its international responsibility as a country that emits a lot of greenhouse gases, and in the effort to achieve this goal, the Target Management System and the ETS has been implemented. However, it seems that these policy efforts are not enough to achieve the greenhouse gas reduction goal. Furthermore, energy consumption in Korea is constantly increasing, and its energy tax burden is relatively low compared to that of other major countries. Therefore, to reverse the constant increase in greenhouse gas emissions, another economic incentive policy, such as an environmental tax to supplement the ETS, is needed.

Ⅲ

Theoretical Model Analysis

Most countries have made efforts to decrease their greenhouse gas emissions through a command and control method, but recently several advanced European countries have introduced carbon taxes and the ETS. These advanced countries recognize the seriousness of climate change and are choosing economic incentive tools instead of command and control. In 2012 Korea passed a law to implement the ETS, which commenced operations in 2015. In Korea, a carbon tax has been actively studied along with the ETS. The carbon tax is a policy mean based on price: when economic agents use energy, pollutants are created incidentally, which in turn incurs the cost of social damage. In general, if the carbon tax is not imposed, economic agents do not take social damage costs into account and use energy to maximize their own profits. The carbon tax acts as a price signal to economic agents to indicate the cost of marginal damage, so that pollutants are kept down to a socially desirable level. Unlike the carbon tax, the ETS is a based on emission amounts, and the government determines the total amount of greenhouse gas emissions permitted. The emission right price is calculated according to this amount and the total demand from the emission trade market. Firms consider marginal abatement costs and emission right price, and trade emission rights that are over or under the permitted emission volume in the emission trade market. As a result, greenhouse gas emissions are determined by the conjunction of marginal abatement costs and the emission right price, so the ETS is cost-effective. The environmental tax and the ETS can be expected to have the same effect to an extent, but each has its own advantages and disadvantages. The introduction of the ETS and carbon taxes therefore differs from country to country.

The most important aspect of harmonizing the ETS and the carbon tax is deciding the tax subjects and the most effective and fair tax rates. We will discuss carbon tax subjects in detail in the next chapter, which analyzes the case study of the United Kingdom and Germany, but first we must discuss the optimal tax rates for an environmental tax. This study assumes that the carbon tax is to be introduced as a new tax subject under the ETS and estimates the “optimal” tax rate. The optimal carbon tax rate should in theory be the same as the marginal damage costs of carbon emissions, but estimating the social damage cost of carbon emissions is not easy; even when it is possible, it is difficult to get a social agreement on the estimated social damage costs. For this study, therefore, the emission right price to achieve the 2020 greenhouse gas reduction goal in Korea will be estimated and used as the “optimal” carbon tax rate.

Before commencing our main discussion, we must first look at the foreign and domestic literature on the harmonizing method of a carbon tax and an ETS.

1 Foreign literature

Weitzman(1974)’s paper, which compared an ETS and a carbon tax, has had a great influence on all subsequent research. Weitzman(1974) compared policies that directly control pollution emission quantity (such as quotas and Target Management System, rather than the ETS) with policies that indirectly control pollution emission by price.[2] Quantity and price controls are policy means that can get same results, but there might be differences in the efficiency of the two systems, depending on the conditions. Weitzman(1974) addressed this question in his theoretical analysis of a firm profit-maximizing model, to determine whether quantity control was relatively better than price control or vise versa for a given set of conditions. Using mathematical calculation and

2) Although Weitzman(1974) does not mention an ETS, considering that they are a kind of quantity control method, they can be included in his comparison of an ETS and a carbon tax.

the economic model, Weitzman(1974) found that quantity control was more effective than price control when the benefit function is more curved or when cost function is more linear. On the other hand, price control was a more attractive policy when the benefit function was more linear. It was also evident that a mixed policy of quantity control and price control may produce the best results. For example, suppose we have to choose whether to fish in a big lake and a lake that is small but full of fish. When fishing in the big lake, the average cost curve is relatively flat; when fishing in the small lake, the average cost curve is more curved, and so the benefit function is at the proper point. In this case, mixing quantity and price control by applying quotas for fishing in the big lake and imposing a tax on fishing in the small lake will be the best policy. The policy implication from this is that even when a carbon emission control policy is in place, if the slope of the marginal abatement cost curve and the marginal abatement benefit curve differ greatly by group, the best policy result can be achieved by mixing quantity control (an ETS) and price control (a carbon tax). The ETS in Korea is managed by focusing on groups that emit a lot of greenhouse gases, as is done in other major countries. Weitzman(1974)'s results therefore imply that imposing an environmental tax on subjects where an ETS is not applied is more efficient than introducing only an ETS or an environmental tax.

Mandell(2008) assumed a situation where the economy is regulated partly by an ETS and partly by a carbon tax (or an environmental tax), and assessed the proper proportions for mixing each policy. Compared to operating only an ETS or a carbon tax, if there is a choice between the two systems then social welfare at least does not worsen. Weitzman(1974) asserted that when one knows both the marginal abatement cost (MAC) and the marginal abatement benefit (MAB), a carbon tax and an ETS can both achieve the same efficient policy result, but this equivalence is possible only when the marginal abatement cost is known; in practice, the marginal abatement cost is often uncertain. Mandell(2008) first considered what losses are incurred in applying such a system with regard to efficiency if there is error in estimating the MAC. Mandell(2008) mathematically estimated the efficiency lost using theoretical model when operating a single policy of either an ETS or carbon tax, and when a mixed policy is applied. His results showed that the policy combination is ultimately more efficient because, while it may lose some efficiency in terms of cost, this is more than made up for by fixing market failures.

Mandell(2008) theoretically showed that policy effects can be maximized by mixing the ETS and the carbon tax, but this was not always accompanied by a empirical analysis. Mandell(2008)'s model was built under the assumption of a complete competitive market and estimated policy efficiency from a policy combination using mathematical calculation. Compared to the model presented in this paper, one can guess that a policy combination of the two systems would be a more effective means of achieving Korea's policy goal.

Another study on the policy mix of an ETS and a carbon tax was conducted by Sorrell & Sijm(2003), who focused on how these policies interact: one is how much can one mechanism makes other policies contribute or harm the purpose of an ETS and the other is evaluating whether the coexistence of other policies and an ETS can be justified. Looking at the interaction of an ETS and a carbon tax (the analysis that is most relevant to this study), Sorrell & Sijm(2003) discussed both advantages and disadvantages. They pointed out the problem that this alternative relationship is distorted by the increase of marginal emission costs. Imposing an additional carbon tax on firms already taking part in an ETS creates a double burden. If a carbon tax is added when costs have already increased due to additional emissions because of an ETS, the price for marginal greenhouse gas emissions is calculated twice. This is double burden that does not fall on those economic agents not participating in the trade system. Despite such problems, it has been pointed out that applying an additional carbon tax also brings compensating benefits. These benefits arise not when emissions are distributed by auction, but when they are provided by free distribution. If emission rights are distributed freely, a firm's incentive to develop a greenhouse gas reducing technology decreases. The carbon tax policy was therefore predicted to supplement this limitation of free distribution. On the other hand, if emission rights are distributed by auction, the incentive to develop a greenhouse gas reducing technology is already present, so there may be little benefit to introducing a carbon tax. Furthermore, in the case of free distribution the government derives no revenues from the process. When emission rights are distributed by auction, however, the government has revenues from the auctions that can be used again for the public sector. This has major implications for

Korea's ETS. Korea's current ETS distributes emission rights freely, so according to Sorrell & Sijm(2003), little incentive is offered for developing a greenhouse gas reducing technology. Their results thus imply that an ETS can use a carbon tax to impose the proper burden on firms. Also, the government has no revenues from distributing emission rights, which implies that, as a supplementary system, a carbon tax could be an effective policy alternative.

Wittneben(2009) analyzed the EU's emission trading system, called the "European Union Emission Trading System" (EU-ETS), and pointed out that such a system might not be the most cost-effective policy means to reduce greenhouse gases. Also, Wittneben(2009) argued that a carbon tax adjusted between countries is a better policy means than ETSs for reducing greenhouse gases worldwide. Currently Korea only implements an ETS, not a carbon tax. Regarding Wittneben's (2009) statement, in this case introducing a carbon tax based on international adjustments to reduce greenhouse gases should be considered. The setting of the 2020 and 2030 national greenhouse gas reduction goals based on the recent international society agreement (the UN Climate Change Agreement Committee) was an adjustment relating to international greenhouse gas reduction, and it is implied that introducing a carbon tax based on this might be an efficient policy.

Krysiak & Oberauner(2010) insisted that firms must choose whether a price or quantity control policy is applied to them. Given the uncertainty, the regulated firm's technology level is used to determine which policy is best for them, but technology levels are kept confidential by the firm, so each firm must be given a choice as to which system should applied, so that the most reasonable policy is implemented. This kind of greenhouse emission regulation is currently used in Switzerland's climate policy. Switzerland proved that proper policies can be implemented despite limitations on information, and that by letting firms choose the policies they are governed by, all firms can profit, unlike the case of designating a single price or quantity control.

Generally, firms know more about their MAC than the authorized government, proving that a carbon tax or an ETS is more effective than the Target Management System. Krysiak & Oberauner(2010) went further, proving that under the uncertainty or information asymmetry, making a firm choose which system of a tax or an ETS is to be applied brings better results. They also asserted that, even when compared with hybrid regulations regarding conditions, the method of giving firms a choice of policy can be superior. Considering this, if Korea is to impose an additional environmental tax under the current ETS, rather than government choosing a single blanket policy, it would be important to reflect the opinion of firms.

2 Domestic literature

Looking at the foreign literature, there are many theoretical studies on whether the policy mix of an ETS and a carbon tax is more efficient than either one alone. However, Korean researchers have tended to focus on the specific way of the policy mix of an ETS and a carbon tax.

In Korea, research on the policy mix has mainly been carried out since 2001. Lim(2001) compared and analyzed the advantages and disadvantages of the policy mix, and estimated the economic effect using computable general equilibrium model in order to identify the implications of the policy mix for greenhouse gas reduction. Lim(2001) sought a method of using an ETS as the key policy means for greenhouse gas reduction, and introducing a carbon tax as a complementary policy in sectors that are not involved in the ETS, such as households, transportation, and related sub-sector). Lim(2001) insisted that the revenues obtained from a carbon tax should be used: 1) primarily for abatement knowledge, such as the development of an environmental or energy sector abatement technology; and 2) to reduce the income tax or corporate tax rates in a tax-neutral way if possible. This could be a method to build a basis for sustainable abatement knowledge, and enhance the efficiency of the tax system.

Lim & Kim(2003) used the computable general equilibrium model to conduct an economic effect analysis of the policy mix. Their results showed that the ETS is relatively less expensive than a carbon tax when it comes to reducing greenhouse gases. Lim & Kim(2003) also found that the more firms and economic agents participate in the emission trade, the greater will be the economic effect of an ETS. Based on their results, Lim & Kim(2003) insisted that an ETS should be introduced as a key policy for greenhouse gas reduction, and a carbon tax should be introduced as a complementary policy for economic sectors where an ETS does not apply. On the other hand, Kim, et al. (2009), Kim(2010), and Kim & Kim(2011) all insisted that the key policy means should be consolidating the environmental energy tax system and introducing a carbon tax, whereas an ETS should be implemented as a complementary policy to enhance synergy. Kim, et al. (2009) and Kim(2010) insisted that as a major policy means to encourage low-carbon green development, a carbon tax should be introduced or the existing energy tax system should be strengthened. Kim, et al. (2009) and Kim(2010) in particular insisted that the future tax system should be reformed so as to strengthen the price function of the environmental energy tax system to correct negative externalities caused by energy use, and a carbon tax should be introduced for new tax subjects to reflect social damage costs. Also, Kim, et al. (2009) insisted that environmental tax revenues should be used to facilitate green investment and growing related industries in order to achieve green development. Furthermore, they insisted on the importance of the policy harmonizing with an environmental tax and other non-tax policy means. According to them, a carbon tax should be applied as a low tax rate to all economic sectors (transportation, household, commerce and other sub-sectors, industry, and electricity), while an ETS is also in place to cover those areas where more management is needed with regard to greenhouse gases. Here, Kim, et al. (2009) maintained that because weaken industrial competitiveness is anticipated in the short term, systemic tools should be prepared to make it possible to decrease a firm’s tax burden according to its greenhouse gas reduction performance, while strengthening all kinds of tax system supports to facilitate the transfer of abatement knowledge to sectors that emit a great deal of greenhouse gases and consume a lot of energy. Kim & Kim(2010)’s study indicated that it is more efficient to use carbon tax revenues to decrease corporate taxes and support new renewable energy investment than to simply lower corporate taxes. Kim & Kim(2011) also insisted that the environmental energy tax system does not properly reflect the social damage costs of pollution, so the environmental tax system should be strengthened and a carbon tax should be introduced. They also agreed with Kim, et al.(2009) and Kim & Kim(2011) in insisting that the carbon tax should be applied to all economic sectors, and that the government must implement the Target Management System and the ETS in the industrial sectors, which are responsible for much of Korea’s domestic greenhouse gas emissions, to enhance synergy.

On the other hand, Shin & Park(2011) and Jeon, et al.(2012) insisted that a carbon tax is needed, and looked at specific ways of harmonizing the carbon tax with an existing environmental energy tax system and an ETS. Shin and Park(2011) and Jeon et al.(2012), unlike Kim, et al.(2009), Kim(2010), Kim & Kim(2011), insisted that a carbon tax should be introduced first in industry, transportation, and household sectors, which do not take part in the ETS. This argument is supported by the results of empirical analysis of Shin & Park(2011). Shin & Park(2011) and Jeon, et al.(2012) also argued that the sectors where taxes are not imposed (such as bituminous coal, anthracitic coal, electricity, etc.) should be included first in the new tax range. Also, because it is not possible to estimate the exact cost of social damage from greenhouse gas emissions, they adjusted Europe’s emission right cost for Korea’s conditions, estimated the carbon tax rate, and used this figure for analysis. Shin & Park(2011) and Jeon, et al.(2012) insisted in particular that a carbon tax should be introduced as an additional tax in the existing environmental energy tax system, not as a new tax subject. Jeon, et al.(2012) insisted that a carbon tax be introduced before an ETS is operated, but that a tax be imposed first on coal and electricity, and once the ETS is operational the tax range can be expanded to those economic sectors that do not take part in the ETS, in order to maintain the tax balance between the ETS and non-ETS sectors.

Jeon, et al.(2012) estimated the economic effect of introducing a carbon tax through the computable general equilibrium mode and they found that the introduction of carbon tax causes the Gross Domestic Production (GDP) to decrease in the short-term (although it later increased greatly). Consequently, based on Jeon, et al.(2012)’s results, which indicated that national competitiveness would be temporarily weakened for a time after a carbon tax is introduced, the tax burden should initially be set low and gradually normalized. Shin & Park(2011) looked at the economic effect of a carbon tax by income levels: the lower-income class was relatively higher than the high-income class with regard to their energy burden compared to expenditure and income, which shows that a carbon tax is regressive.

While the existing research has focused on foreign cases and economic effect analyses, Oh, et al. (2012) discussed the optimal tax rate of a carbon tax and whether a general tax or a purpose tax is superior when introducing a carbon tax. Oh, et al. (2012) showed that if a carbon tax is designed to reduce greenhouse gas emissions, it must be set high when the reduction goal is high and the refund rate to the economic agents is high. They also showed that the best policy is to set the carbon tax rate high and the return rate low when the marginal cost of using non-green-technology is higher than that of green technology. In addition, since efficiency is emphasized can the income distribution structure be worsened, Oh, et al. (2012) insisted that when a carbon tax is introduced, equality between industries and improvement of tax regressivity should be considered along with efficiency. Oh, et al. (2012) lastly found that a purpose tax is superior to a general tax.

In summary, the existing literature indicates that the ETS and the environmental tax harmonize in two respects: (1) the tax range of an environmental tax introduced under an ETS and (2) the optimal level of carbon tax rate. As seen above, Korea’s energy tax system is focused on oil, so taxes are not properly imposed on coal and electricity. Coal in particular is a major fossil fuel that emits a lot of carbon-hydrate but is not properly taxed. Electricity also emits a lot of carbon-hydrate, and electricity consumption is also (gradually) on the rise. This shows that Korea’s energy tax system does not properly reflect social damage costs, as Jeon, et al. (2012) pointed out. In this regard, to properly reflect the social damage cost to the market price structure, either an environmental tax on coal, electricity, etc., should be introduced as a new tax subject or an electricity consumption tax should be introduced to enhance the price function of the existing environmental energy tax system; in this case, energy sources used to generate electricity should also be considered.

Also, as Shin & Park(2011) and Jeon, et al.(2012) insisted, it is preferable to not impose a carbon tax on firms that participate in the ETS. Those consider their MAC and emission right price in determining how much to reduce their greenhouse gas emissions. In this case, imposing a carbon tax on firms will result in over-buying or under-selling emission right. That is to say, firms would regard the carbon tax as raising the emission right price, resulting in further reducing firms’ greenhouse gas emissions. If a carbon tax is imposed when the emission right price reaches the proper level, it will inefficiently increase the burden of carbon emission on firms. Looking forward to the next chapter, it is clear that in case of major countries the system is designed so as not to impose or reduce the carbon tax for sectors that take part in the ETS.

However, this suggestion is only persuasive when firms bear an appropriate burden for carbon emissions. Under the current ETS: 1) emission rights are freely assigned; and 2) the emission right price is kept about 10,000 KW/ton by the government so that carbon emission burdens would not be established at the proper level. Thus, to encourage the development of carbon abatement technology under these conditions, the burden of proper carbon emissions must be imposed on firms by introducing an environmental tax so as to give supplementary function to the ETS for participating sectors. Rather than targeting the all the industries that participate in the ETS, an environmental tax should be introduced focusing on industry sectors that have high carbon-hydrate emissions, are not properly taxed under the existing environmental energy tax system, and have a great need for carbon abatement technology development. In the United Kingdom, a carbon price floor is in place only for the electricity sector, to keep emission prices at a proper level. This system supplements the problem that the carbon emission burden is not appropriately distributed among firms because of emission price fluctuations. (The United Kingdom’s carbon price floor will be discussed in detail in the next chapter).

If the ETS does its job, it would be desirable to introduce an environmental tax for households and the commerce sector, which do not currently participate in the ETS. In this case, the most important discussion would be how to estimate the optimal environmental tax rate. It is not easy to estimate social damage costs, because the scale can vary according to the theoretical model used, as well as data and the estimating method. Kim & Kim(2010), Shin & Park(2011), Heo, et al.(2012), and Jeon, et al.(2012) basically used the EU emission right price to estimate and analyze Korea’s carbon tax rate. Here, Jeon, et al.(2012) departed from previous research to use the carbon tax rate differently for industries involved in the ETS and those that are not in their analysis. This is because, as in major foreign major countries, the carbon tax rate is set high for industries where any weakening of international competitiveness is not a concern. Also, when the carbon tax rate is applied in sectors that do not participate in the ETS, it is necessary to apply a carbon tax rate differently between industry and non-industry sectors. The ETS currently freely distributes emissions rights to economic agents, so if the carbon tax rate is set the same as the emission right price, those firms that participate in the ETS will bear a relatively lighter burden than those that do not. In the interest of preserving equality among firms, the carbon tax rate should be set lower than the emission right price for those firms not participating in the ETS.

Previous studies were conducted before the ETS was operational, so the carbon tax rate could only be estimated based on the EU-ETS price. In this study we can now estimate the "optimal" level of environmental tax rate for the Korean policy environment. Here, the emission right price at the "optimal" level means the emission right price necessary to achieve the greenhouse gas reduction goal.[3)]

The estimated carbon tax rate is the same as the emission price and MAC, and firms get the same carbon price signal regardless of their participation in the ETS or the environmental tax. This means that, in case of firms that do not participate in the ETS, there can be no preference between the ETS and the carbon tax, so the distortion of decision-making on the part of firms participating in the ETS can be voluntarily minimized. The next chapter includes a detailed discussion of estimating the carbon tax using the theoretical model.

3 The theoretical model

This study offers a theoretical model related to the policy mix of an ETS and a carbon tax that do not distort market participants' choices. The ETS is currently operated in such a way that it became important to introduce a carbon tax as much as to maintain the number of ETS participants and not weaken the market. Thus, the key point of our theoretical model is to match the participating firms' average burden between the two systems.

3) Though there is controversy over whether the greenhouse gas reduction goal is appropriate, it is beyond the range of this research; it is, however, an important research subject for future studies.

A. Composition of the model

This model assumes that there is one firm emitting greenhouse gas, which represents all the distributed firms in the ETS and determines the greenhouse gas reduction amount. When assuming the existence of one representative firm, the net purchase between firms is set to 0 so that, as Seifert et al.(2008)'s model, it has the advantage of excluding emission right trades between multiple firms. Any ETS needs to consider the total emission right distribution during a certain period, so it needs the model with multiple periods. For this reason following the Yu & Mallory(2015) model, a representative firm and a government decide the greenhouse gas reduction amount and emission right distribution for every period, respectively in the model. Every period, the representative firm decides the greenhouse gas reduction amount and carries forward the gap between actual emissions and total distributed emissions to use in the next planning year.[4)]

In the model, first, the purpose or social welfare function of the government minimizes the representative firm's reduction costs ($C(\bullet)$) and environmental damage costs ($D(\bullet)$) from the greenhouse gas emissions, which is discounted each program year. It is assumed that the government is risk-neutral. The government can suggest the proper greenhouse gas reduction amount for the representative firm to minimize its total cost. The purpose and function of the government is as (Equation III-1) below, and the state variables transfer equation is as follows:

$$Min_{u_t} E[\sum_{t=0}^{\infty} \beta^t (C(u_t) + \delta D(X_t + y_t - u_t))] \qquad \text{(Equation III-1)}$$

$$X_{t+1} = \alpha (X_t + y_t - u_t) \qquad \text{(Equation III-2)}$$

Parameter β is the discount rate, X_{t+1} and X_t is the total greenhouse gas emissions for the t+1 and t period, repsecitvely, y_t is the greenhouse gas

4) According to Emission Trade System Law Article 28, an emission right holder can move the emission right to the year following the first planning year, but loans are prohibited during the planning year.

emissions for the t period, and u_t is the amount of abatements for the t period. Here, y_t is the amount of greenhouse gas emissions when there is no greenhouse gas reduction effort, which is called as Business as Usual(BAU) emissions. To simplify the model, we assumes that BAU emissions has an even distribution function at the [0, $\overline{y}$] section. Parameter δ is the coefficient for the damage costs from greenhouse gas, and parameter α is the natural reduction rate of greenhouse gases accumulated in the atmosphere.

The above model can be converted according to the Bellman equation to solve it in the form of discontinuous dynamic programming, as follows:5)

$$V(X) = Min_u E[C(u) + \delta D(X + y - u) + \beta V(X')] \quad \text{(Equation III-3)}$$

Here the state variable transfer equation is as follows:

$$X' = \alpha(X + y - u) \quad \text{(Equation III-4)}$$

Following Ljungqvist & Sargent(2000), this study uses the Benveniste & Scheinkman method to solve the Bellman equation. Here, if (Equations III-3) and (Equations III-4) are differentiated by the reduction amount, the result is the following (Equation III-5):

$$0 = E[\frac{\partial C(u)}{\partial u} + \delta\frac{\partial D(X + y - u)}{\partial u} + \alpha\beta\frac{\partial V(X')}{\partial u}] \quad \text{(Equation III-5)}$$

Also, when it is differentiated by the state variable X_t, we get (Equation III-6):

$$\frac{\partial V(X)}{\partial X} = E[\delta\frac{\partial D(X + y - u)}{\partial u} + \alpha\beta\frac{\partial V(X')}{\partial u}] \quad \text{(Equation III-6)}$$

5) The ETS program lasted for three years in Korea, but in countries operating an ETS it may last as long as four to seven years, so this study uses a discontinuous model rather than solving continuous dynamic programming.

Combining the above (Equations III-5) and (Equation III-6) produces the following (Equation III-7).[6)]

$$\frac{\partial V(X)}{\partial X} = \frac{\partial C(u)}{\partial u} \qquad \text{(Equation III-7)}$$

When it is applied the same way for the next period, we get (Equation III-8):

$$\frac{\partial V(X')}{\partial X'} = \frac{\partial C(u')}{\partial u'} \qquad \text{(Equation III-8)}$$

Following that, substituting (Equations III-7) and (Equation III-8) for (Equation III-6), we get a Euler formula (Equation III-9):

$$\frac{\partial C(u)}{\partial u} = E[\delta \frac{\partial D(X+y-u)}{\partial X} + \alpha\beta \frac{\partial C(u')}{\partial u'}] \qquad \text{(Equation III-9)}$$

The Euler formula in (Equation III-9) quantifies the government authority's rule between periods regarding the optimal reduction.

Separate from the government social welfare function, we need the model minimizing the costs of firms caused by participating in the ETS. The government does not consider policy variables other than the necessary greenhouse gas reduction. The policy variable is the factor that influences a firm's profit, so it is included in the objective function of the firm; regarding social welfare, the cost to a firm of participating in an ETS directly translates to government revenues, so it is a zero sum game for the whole society and no cost arises from the policy variables.

The objective function of the representative firm is defined in (Equation III-10), which is a function that minimizes greenhouse gas reduction costs and the total penalty imposed by the government when greenhouse gases are not

6) $\frac{\partial D(X+y-u)}{\partial u} = -\frac{\partial D(X+y-u)}{\partial X}$ 및 $\frac{\partial V(X')}{\partial u} = -\frac{\partial V(X')}{\partial X}$

reduced enough, which is discounted every planning year. By minimizing the costs and the total penalty, the representative firm can deduct the greenhouse gas reduction at the optimal level, as defined in (Equation III-11). The unit price of penalty by ton for the t period is P_t, and the total distributed emission right is defined as e_t. That is to say, the total penalty is the total distributed amount of greenhouse gas emissions minus the total reduced amount, multiplied by the unit penalty. Here not only the distributed total emission right for the t period but also the emission right brought from the preceding period can be used, defined as B_t.

$$Min_{u_t} E[\sum_{t=0}^{\infty} \beta^t (C(u_t) + P_t \max[0, y_t - (e_t + B_t + u_t)])] \quad \text{(Equation III-10)}$$

Here, emission rights carried over from past periods follow the state variable transfer equations such as (Equation III-11).

$$B_{t+1} = \gamma(B_t + e_t + u_t - y_t) \quad \text{(Equation III-11)}$$

Parameter γ is defined as the proportion of the emission rights accumulated from the previous planning period can be used in the next period (Leiby & Rubin, 2001). According to current law, in Korea emission rights carried over from the past can be used without limits, so one can say $\gamma = 1$. Also, to simplify the model, parameter β (the welfare discount according to the period in the multi-period model) is assumed to be the same as the discount rate of the government.

The Bellman equation and the state variable transfer equation needed to solve the above model in the form of discontinuous dynamic programming are as follows:

$$V(B) = Min_u EC(u) + Pmax[0, y - (e + B + u)] + \beta V(B') \quad \text{(Equation III-12)}$$

$$B' = \gamma(B + e + u - y) \quad \text{(Equation III-13)}$$

Here the state variable B' is the total amount of emissions carried over and used in the next planning year. The second part of (Equation III-12) becomes as follows:

$$Emax[0, y-(e+B+u)] = \int_{-\infty}^{e+B+u} f(y)dy + \int_{e+B+u}^{\infty} y-(e+B+u)f(y)dy$$

$$= \int_{e+B+u}^{\infty} yf(y) - (e+B+u)\int_{e+B+u}^{\infty} f(y)dy \qquad \text{(Equation III-14)}$$

So the Bellman equation is redefined as follows:

$$V(B) = Min_u [C(u) + P\int_{e+B+u}^{\infty} yf(y)dy - (e+B+u)\int_{e+B+u}^{\infty} f(y)dy + E\beta[V(B')]]$$

(Equation III-15)

If the government uses the Benveniste & Scheinkman(1979)'s method to first differentiate by greenhouse gas reduction, the following (Equation Ⅲ-16) will be generated:

$$0 = \frac{\partial C(u)}{\partial u} + P\{-(e+B+u)f(e+B+u) - \int_{e+B+u}^{\infty} f(y)dy + (e+B+u)f(e+B+u)\}$$

$$+ E\beta \frac{\partial V(B')}{\partial B'}\frac{\partial B'}{\partial u} = \frac{\partial C(u)}{\partial u} - P\int_{e+B+u}^{\infty} f(y)dy + E\gamma\beta\frac{\partial V(B')}{\partial B'}$$

(Equation III-16)

Differentiating it by the state variable and carrying over the emission amount B produces the following (Equation III-17):

$$\frac{\partial V(B)}{\partial B} = P\{-(e+B+u)f(e+B+u)$$

$$- \int_{e+B+u}^{\infty} f(y)dy + (e+B+u)f(e+B+u)\} + E\beta\gamma\frac{\partial V(B')}{\partial B'}$$

$$=-P\int_{e+B+u}^{\infty} f(y)dy + E\beta\gamma\frac{\partial V(B')}{\partial B'} \qquad \text{(Equation III-17)}$$

When the above (Equations III-16) and (Equation III-17) are combined, the result is as follows:

$$\frac{\partial V(B)}{\partial B} = -\frac{\partial C(u)}{\partial u} \qquad \text{(Equation III-18)}$$

Applying this same formula to the next period, we get (Equation III-19):

$$\frac{\partial V(B')}{\partial B'} = -\frac{\partial C(u')}{\partial u'} \qquad \text{(Equation III-19)}$$

Afterwards, by inserting (Equations III-18) and (Equation III-19) into (Equation III-17), the Euler formula suggested in (Equation III-20) can be deduced:

$$\frac{\partial C(u)}{\partial u} = P\int_{e+B+u}^{\infty} f(y)dy + E\beta\gamma\frac{\partial C(u')}{\partial u'} \qquad \text{(Equation III-20)}$$

The Euler formula in (Equation III-20) illustrates the firm's rule between periods about the optimal reduction.

We can now add (Equation III-9), the Euler formula for the government's optimal (or target) greenhouse gas reduction for social welfare, and (Equation III-20), the Euler formula for the representative firm's optimal reduction, which minimizes the total penalty for failing to reduce greenhouse gases or emission rights, in order to obtain the optimal policy variable. In other words, the policy variable that matches the government's optimal greenhouse gas reduction is deducted from the representative firm's optimal greenhouse gas reduction. The coefficient that the government can determine is the total distribution and penalty per ton under the ETS, which is (P, e). The optimal greenhouse gas reduction of the government is marked as $u_s(X)$, which is a function of the state variable; the existing total emissions (the representative firm's optimal greenhouse gas reduction) is also a function of the state variable, and the total accumulated carried-over emission rights under the given policy variable is marked $u_f(B|P,e)$. To match the greenhouse gas reduction of the other two economic agents, it is written as:

$$u_s(X) = u_f(B|P,e) \qquad \text{(Equation III-21)}$$

If the level of certain state variable (the existing total emissions and the carried-over total emissions for this period) is given, the optimal combination of policy variables can be computed using the above equation. The ETS confers the right to emit a certain amount of greenhouse gases, so it always satisfies $e > 0$; the idea of this model is to compute the carbon tax by getting rid of the total distribution ($e = 0$) and computing the carbon tax rate, which is the level of penalty needed to make the representative firm bear the same burden (Yu & Mallory, 2015).[7)]

B. Calculating the "optimal" carbon tax rate through calibration

Assume that the greenhouse gas reduction cost function and the environmental damage function take the form of the quadratic functions in (Equations III-22) and (Equations III-23) as below:

$$C(u_t) = \frac{1}{2}cu_t^2 \qquad \text{(Equation III-22)}$$

$$D(u_t;X_t,y_t) = \frac{\delta}{2}(X_t + y_t - u_t)^2 \qquad \text{(Equation III-23)}$$

7) Regarding the ETS, in Europe for the non–satisfied responsible amount, 40 euros for the first planning year and 100 euros for the second planning year. In Korea, a penalty of less than 100,000 KW is imposed under Article 33 of the Emission Trade Law. In Europe, after paying the penalty, the non–submitted emission right from the previous program year must be separately submitted, whereas in Korea whether to submit or not is not predetermined. This report assumes that when a penalty is paid, in the ensuing planning period it becomes a safety value where the submission of emission right is exempted. New Zealand, which has dropped out from the Kyoto Protocol system, currently implements this system.

The reason for this is that, if these two functions take the form of quadratic functions, the marginal cost function can utilize a linear form, making it convenient to solve the closed-form solution for calibration, as is done in this study. If we use (Equations III-22) and (Equation III-23) and a Euler formula to solve the closed form solution, we can thus assume (Equations III-24) and (Equation III-25) for the optimal greenhouse gas reduction function. The optimal amounts of greenhouse gas reduction of the government and the representative firm take the form of a linear function of the state variable:

$$U_s(X) = \phi + \phi_1 X \qquad \text{(Equation III-24)}$$

$$U_f(B|P, e) = \phi_2(P, e) + \phi_3(P, e)B \qquad \text{(Equation III-25)}$$

The process of solving the closed-form solution based on this solution is presented in the Appendix. The parameters after solving the closed form solution are detailed in <Table III-1> as below.

〈Table III-1〉 **Parameters used for the model**

Parameters	Values
Parameter of the marginal abatement cost function	42000
The social discount rate of the first program year, β	0.854
Stochastic emission upper limit, $\bar{y}$	40.42

The parameters for calibration are chosen using the following logic. First, for the discount rate by time, we use the 5.5 percent used by the Korean Development Institution (KDI)'s general guideline research report (vol. 5) for the preparatory investigation of a project's validity. Calculating backwards from the proportion of benefit per period produces a β value of approximately 0.85.[8] In this model, the BAU emissions is assumed to be the probability variable

8) $\beta \approx \left(\frac{1}{(1+0.055)}\right)^3$ The first program year currently comprises the three years of 2015-2017.

that requires a certain probability distribution, because this is the amount that the firm can actually emit. We have therefore used the numbers designated by the industries. For the assumption regarding the decrease from the BAU emissions, we first need the expected BAU emissions, so we used the firm's BAU emissions in the ETS during the first planning period (2015~2017 years) announced and assumed by the government. There is an estimate for the country's current BAU emissions, but in the case of the ETS there is no BAU emissions available to the public, so the participating firm's requested amount of emissions must be used to estimate the BAU emissions of the whole country for this model. It is reasonable to assume that the firms will request a total emission amount roughly equal to the amount of emissions they would produce if they make no reduction efforts at all (the actual emission rights requested during the first plannung period were determined based on 2011~2013 emissions); the parameters are also set based on the firms' requested amount. As for the changes in the greenhouse gas reduction, the 30 percent reduction expected by 2020 is used, and it is assumed that the government's reduction goal, $u_s(X)$ is set as 30 percent of BAU emissions during the first planning period.[9] Therefore, without having to assume the state variable X (the accumulated greenhouse gases in the atmosphere) in this model, we can immediately use the reduction goal. Also, if emission rights are carried over between program periods in this model, the discount rate, γ, should be assumed; in the case of Korea, unlimited carrying-over is possible without penalty between program periods, so $\gamma = 1$ where the carried-over emission rights from the previous program period can all be used. The biggest assumption is the marginal abatement cost, c. The model used in this study assumes a linear marginal abatement function, so it needs a certain c value, but most actual marginal abatement costs take a non-linear form and there is as yet insufficient credible research on the estimation of the marginal abatement cost function in Korea. Thus, as was done in Yu and Mallory (2015), the marginal abatement

9) The Greenhouse-Gas Emission Distribution and Trade Law Article 5.1.1. total permitted emission is ETS BAU = National BAU mitted emission t emission proportion ETS (National greenhouse-gas emission / greenhouse-gas emissions).

cost coefficient assumes a value where the policy combination from the model (penalty tariff and total distribution) is calculated using the value given during the current first planning period (100 thousand KW per 1,650 million tons). There is no guarantee that the current policy combination can achieve the 30 percent abatement compared to the BAU emissions, but when determining the distribution total amount the abatement goal is considered and it can be assumed that the penalty will force the distribution subject firms to comply with the distribution total amount, so we have chosen the current policy combination as the second-best solution.

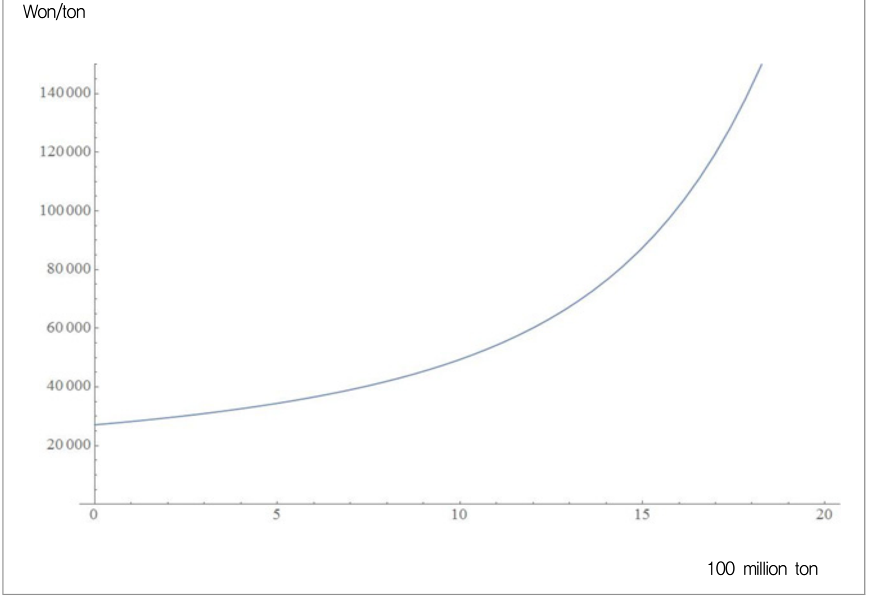
To obtain policy combination (P, e) one needs assumptions not only of the constant parameter value suggested in <Table III-1>, but also the state variable, because, as is seen in (Equation III-25), to solve the policy combination (P, e) one needs the assumption of the firm's greenhouse gas reduction and the accumulated emissions, which is a state variable.

$$\overline{u_f(B|P,e)} = \phi_2(P,e) + \phi_3(P,e)\overline{B} \qquad \text{(Equation III-26)}$$

This study assumes that $\overline{B}$ is the value of 0 ($\overline{B}=0$) because the policy combination that this model aims to deduce is the distributed amount and penalty of the first planning period, and there is no accumulated or carried-over emission prior to the first planning period. On the other hand, as in (Equation III-24), the state variable X used when determining the social optimal greenhouse gas reduction needs no separate assumption, because Korea's distributed amount is already fixed. That is to say, $u_s(X)$ is assumed to be the 30 percent of BAU emissions during the first planning period.

The results obtained from deducting the proper policy combination based on the assumptions of the various parameters are presented in [Figure III-1] as below:

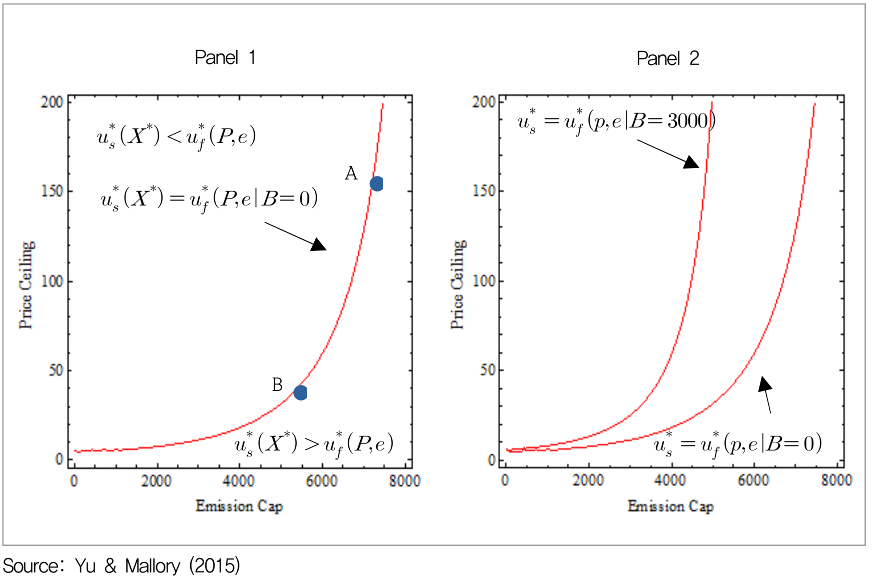
[Figure III-1] Optimal Policy Mix



[Figure III-1] illustrates the combination of free distribution and penalty that must be mobilized for the abatement of the same amount (30 percent of BAU emissions). The policy combination of the current law is 1,650 million tons of free distribution and 100 thousand KW per ton penalty, so the above figure should include the current policy combination. The penalty for unpaid emissions under the current law is three times the average market price, and the upper limit of the penalty is fixed at 100 thousand KW. However, the penalty system connected with the market price merely fixes the penalty at 100 thousand KW in the event that the actual emission right is insufficient, as occurs when the representative firm is assumed and the distributed emission right is less than the actual emission amount. As explained by Yu & Mallory (2015), the emission right price paid to avoid the penalty will always be close to the penalty level, and the penalty will again reach 100 thousand KW. In this case, if there is no free distribution the penalty level would be about 26,300 KW per ton. The penalty when there is no free distribution is by definition the same with a carbon tax.

[Figure III-2] below shows how the additional policy variable should be calculated when the other state variable fixed in the above [Figure III-1] (the greenhouse gas reduction goal and the emission carried over and accumulated from the previous emission amount) changes.

[Figure III-2] **Examples of policy combination according to the state variable**



Source: Yu & Mallory (2015)

In [Figure III-2], Panel A shows the policy combination when B = 0, as in [Figure III-1], and shows how such a policy combination can be interpreted. For example, in the case of the upper space of the optimal policy combination, which is the higher penalty for the given distributed amount (or the lower distribution amount for the given penalty), this occurs when the actual forced greenhouse gas reduction amount of the firm exceeds the social optimal greenhouse gas reduction. In other words, when facing a strict regulation that exceeds the penalty or a distribution amount lower than the optimal policy combination, firms exhibit excessive regulation adaptation ($u_s^*(X^*) < u_f^*(P,e)$). However, the lower space of the optimal policy combination means imposing a lower penalty (or a more spare distribution amount for the given penalty) on the given distribution amount, so the actual forced greenhouse gas reduction of the firms is less than the social optimal reduction. That is to say, when facing a penalty less than or a distribution amount higher than the optimal policy combination, the firms' regulation adaptation does not reach the optimal amount, ($u_s^*(X^*) > u_f^*(P,e)$).

In [Figure III-2], Panel B shows how the optimal policy combination can change when the accumulated emission amount of the previous first planning period is given a value other than 0. For example, when the carried-over emission amount from the previous planning period increases, the optimal policy combination of the planning period becomes stricter—it requires a higher penalty and a lower distribution amount. This means that if more emissions are produced under previously accumulated emission rights, it is hard to achieve the optimal greenhouse gas reduction for the period, as this can then only be achieved by adjusting the optimal policy variable.

The biggest limitation of the model is the assumption that the marginal costs of greenhouse gas reduction are linear. There is no credible systematic data on MAC; in particular, no research has been done on MAC targeting firms that participate in the ETS, so the theoretical carbon tax rate deducted from this model is simply a number based on the mathematical model.

C. Policy implications

The implication of the optimal carbon tax rate (26,300 KW/ton), assuming the limitation of the above-mentioned model, is as follows. From our current perspective (2015~2016, which is the beginning of the first planning period) the 10,000 KW/ton as the standard of the government's emission right price stabilization measure is noticeably lower than the optimal marginal cost that should be imposed on firms to achieve the greenhouse gas reduction goal. If marginal costs are kept low, the greenhouse gas reduction achieved will be much lower than the optimal social level.

A more serious matter is that the greenhouse gas reduction goal could be achieved by consistent abatement facility investment and abatement activities throughout the three-year planning period. However, if the emission right price is kept lower than the optimal level in the beginning, firms might not invest in abatement facilities but will instead buy emission rights to cover the responsible amount of greenhouse gas reduction they are obliged to meet. Therefore, most of the three planning years could be wasted in purchasing emission rights although firms should be investing in greenhouse gas abatement facilities and commencing abatement activities. For example, if the emission price—the marginal cost for two-thirds of the first planning period (two years)—is limited to 10,000 KW/ton, a firm could overlook abatement activities and settle for the low emission right price. In this case, even if the emission trade market stabilization price of 10,000 KW/ton is applied for only the first two years and the emission price returns to the equilibrium price, the country will not be able to achieve an adequate greenhouse gas reduction for the remaining year of the period.

Furthermore the greenhouse gas reduction goal of the first planning period was lowered in 2014 (after free distribution of emission rights increased) so that the burden of the greenhouse gas reduction in the second planning year now seems to be set too high. In this situation, the emission right price stabilization policy considering the regulation burden of the beginning has failed to prompt firms to start greenhouse gas reduction activities at the right time. That is, the purpose of the ETS, which is to give firms incentive to voluntarily reduce greenhouse gas emissions using free-market principles, is completely distorted. If firms subject to distribution do not invest properly in the greenhouse gas reduction during the first planning period, when a relatively lower greenhouse gas reduction goal is set, the burden of the second planning period will inevitably increase. As a result, Korea might break its promise to international society, which is a 30 percent reduction of the 2020 BAU emissions, a promise that Korea made as a nation to the rest of the world in 2009 and vowed to uphold for more than ten years.

The carbon tax rate deducted from the mathematical model distributes the decreased amount emissions from representative firms involved in the ETS to other sectors, focusing on coal and electricity. The aim of this is to make it easier to achieve the reduction goal of the whole country. The ETS sector is the only part of the domestic industry that aims to reduce greenhouse gas emissions, and only the ETS sectors have a duty to purchase and submit emission rights, so without the participation of the non-ETS sector it will be hard to achieve the greenhouse reduction goal of the whole country. Thus, to achieve the goal we need to consider introducing a environmental tax for non-ETS sectors.

The environmental energy tax burden in Korea is relatively low compared to other countries, and tax is not properly imposed on coal and electricity, so it is necessary to introduce an environmental tax on coal and electricity in the household and commerce sector. This means that in the household and commerce sector, designing an environmental tax involves using the estimated carbon tax rate for coal and electricity, but one must be more careful in applying the estimated carbon tax rate to the firms in sectors not participating in the ETS.

To do so, we first must look at how it influences firms when applying the estimated carbon tax rate to non-ETS sectors of the ETS. When the emission right price is higher than the tax rate applied to the non-ETS sector, firms will not want to get involved in the ETS sector, and there will be inequality in that a higher marginal cost is applied to the ETS sector with regard to the greenhouse gas reduction. Strategically, if the purpose of policy is to not impose a penalty on the ETS sector, which includes industries that use a high volume of fossil fuels, there would be no reason the ETS sector should have a greater duty to reduce greenhouse gas emissions than the non-ETS sector. On the contrary, if the tax rate for the non-ETS sector is higher than the emission right price, many firms would want to be voluntary emission trade participants, but it would be impossible due to the administrative cost of emission trade management. Also, as in the opposite case, there is no reason the non-ETS sector should have a more marginal burden for emitting greenhouse gases. This study therefore assumes that the ETS and the non-ETS sector have the same reduction burden, and the marginal tax rate of the non-ETS sector has been computed with the intent to distribute the current greenhouse gas reduction burden.

One thing to be careful of is that the deducted carbon tax rate will not create the same burden as the ETS for non-ETS sector firms. “Burden” is the total value of emission purchase or the total tax that the firm ultimately bears.

When imposing a carbon tax with the previously estimated optimal tax rate, the total burden that the firm will bear is the amount of emission multiplied by the tax rate. In this case, a carbon tax plays a role as the emission right price. In the case of the ETS, Korea is currently operating a 100 percent free distribution system, so most actual emissions are exempted from financial burdens. When emissions exceed the preliminary distributed amount, the emission right price burden falls only on the additionally purchased emission rights, and most emission amounts covered by freely distributed credits. If a firm's actual emissions are less than the free preliminary distribution due to active the greenhouse gas reduction activity, emission rights will be left over, so the firm may sell and make a profit. Thus, if the efficient carbon tax rate to achieve the national greenhouse gas reduction goal is applied to the non-ETS sector, carbon emission burden of firms in the non-ETS sector is relatively greater than those in the ETS based on free distribution. To solve this problem, similar to free distribution in the ETS sector, we can consider basic deductions for certain emission amounts in the carbon tax. In this case, political resistance of introducing a carbon tax is reduced and enable financial revenues for amounts exceeding the basic deduction. However, as the freely distributed allowances in the ETS have provoked complex discussions, there is also a question of how much the basic deduction in a carbon tax should be discussed. Of course, it may be that free distribution will determine the way of the ETS implemented, but there are also concerns that the administrative costs will be too high.

Ⅳ

Policy Mix between Emission Trade System and Environmental Tax: Focusing on the United Kingdom and Germany

This chapter will examine foreign examples of the policy mix between an ETS and an environmental tax. The advanced countries of Europe all use an ETS and a carbon tax (or an environmental tax) as policy means to reduce greenhouse gas emissions. The EU-15 member states agreed to reduce the greenhouse gas emission by 8 percent more than a standard year (such as 1990) during the 1997 Kyoto Protocol first commitment period (2008~2012), and they achieved considerable success in meeting this target. The United Kingdom and Germany in particular, which accounted for 47.1 percent of the EU-15 member state total greenhouse gas emissions, reduced their emissions by 25.2 and 23.8 percent respectively compared to the base period. Their 2012 greenhouse gas reduction goals were 12.5 and 21 percent respectively, so the United Kingdom exceeded its goal by 12.7 percent and Germany by 3.8 percent. These two countries made active policy efforts to reduce greenhouse gases, such as introducing an ETS and an environmental tax.

This study looks closely at the United Kingdom and Germany, which have achieved their reduction goals, particularly with regard to how these two countries administer their ETS and environmental taxes; the policy implications thereof will also be assessed.

1 United Kingdom

The United Kingdom introduced its emission trade system (UK-ETS), the Europe Emission Trade System (EU-ETS), Carbon Reduction Commitment Energy Efficiency Scheme for efficiency of energy with carbon tax features, Climate Change Levy imposed on energy use, Climate Change Agreements (CCAs), Carbon Price Floors, etc., to achieve its reduction goal. Looking at the history of such policies, in 2001 and 2002 the UK-ETS and Climate Change Levy/Voluntary Reduction Agreement were introduced, followed by the EU-ETS, which became operational in 2005 and absorbed the UK-ETS. In 2010 the Carbon Reduction Commitment Energy Efficiency Scheme was introduced for non-ETS sector. The United Kingdom needed to increase the emission prices to an appropriate level because of the uncertainty over the emission right price, in order to provide an incentive to use new renewable energies and to invest in “green investment”. For this reason the Carbon Price Floor was introduced in 2013 to impose a tax in the form of an added tax in the amount of the difference between the proper emission price and the actual emission price.

To suggest a policy direction for Korea to achieve its future greenhouse gas reduction goals, we look more closely how The United Kingdom mixes and manages its policies. The EU-ETS is managed by industries that use large amounts of energy and emit high volumes of greenhouse gases. The EU-ETS applies to subjects operating power plants with capacities exceeding 35 MW, or whose greenhouse gas emissions exceed 25,000tCO_2. The EU-ETS applies to a number of specific sectors: there are 12 generation and industry sectors in the first period, the aviation industry sector was added in the second period, and 16 industries were added in the industry sector in the third period. When greenhouse gas limits were was expanded to trade subjects in the third period. Also, primary aluminum, nitrogen, adipic acid, and glyoxylic acid were added as EU-ETS subjects in the third period, demonstrating that the EU-ETS is gradually being expanded over time.

EU-ETS is putting prices on the specific uses of fossil fuels (e.g., natural gas, LPG, coal, etc.) in order to induce firms to rely less on fossil fuels in energy-concentrated-industry and greenhouse gas much-emission industry.

However, one of the problems that arose when the EU-ETS was introduced was the uncertainty over emission prices. Regarding the decrease in emission prices in particular, incentives to invest in carbon abatement technology, fuel substitution technology, energy saving technology, and low-carbon generation facilities will consequently decrease as well. The United Kingdom therefore introduced the Carbon Price Floor in 2013 to the electricity sector, which produces a high proportion of carbon-dioxide, to eliminate uncertainty over emission prices and build an investment environment that encourages the inflow of capital to low-carbon technology development(HM Treasury, 2010).

The basic idea of the Carbon Price Floor is to set the lowest possible price for carbon, regardless of the fluctuation of the actual emission right price, and, based on this, make firms trade emission rights. The government estimates the target emission price and then computes the difference between it and the actual emission price; this difference is designated the carbon price support rate and is used as the Climate Change Levy. Thus, the tax rate of the Climate Change Levy is classified as a basic rate and a carbon price support rate and the latter is imposed for energy sources used to generate electricity.

The United Kingdom also maintains a Climate Change Agreement System similar to Korea's Target Management System that determines the greenhouse gas reduction and energy efficiency improvement goals for industry sectors through voluntary agreements between the government and high-energy-consuming industries, and decreases the Climate Change Levy for participating firms that achieve the goal. In the case of electricity, the decrease rate of the Climate Change Levy is 90 percent of the announced electricity fee; it is 65 percent for other fuels.[10] The Climate Change Agreement applies to 51 energy-concentrated-industries.[11] Also, it is possible for firms to be affected by both the Climate Change Agreement and the ETS. It means that some of firms in the ETS can decrease the burden of the Climate Change Levy. This

10) Environment Agency, https://www.gov.uk/guidance/climate-change-agreementse-(Retrieved October 27, 2015).

11) Department of Energy & Climate Change and Environment Agency (DECCEA), https://www.gov.uk/government/news/industry-agree-stretching-energy-efficiency-targets-with-government(Retrieved October 27, 2015).

seems to be a systematic tool to induce reduction efforts and ensure that the burden of carbon emission borne by independent firms is not excessive.

Finally, firms in the United Kingdom subject to the Climate Change Levy whose electricity consumption exceeds 6,000MWh also take part in the Carbon Reduction Commitment Energy Efficiency Scheme,[12] which is a policy designed to improve energy efficiency. Carbon emissions are computed based on the electricity and gas used in the private and public sector, and the emission rights for these must be purchased.[13] In this case the emission right price is the carbon tax rate. The emission price in 2010~2014 was 12 pound/tCO_2; in 2015 and 2016 this increased to 16.40tCO_2, and 16.90tCO_2 respectively. If participating firms predict carbon emissions and purchase emission rights for the same period, 15.60 and 16.10pound/tCO_2 respectively will be applied to the emission price so that they can purchased more cheaply than usual.[14] Although firms that take part in the ETS or the Climate Change Agreement system are excluded from the Carbon Reduction Commitment Energy Efficiency Scheme, other firms are subject to both the Climate Change Levy and the Carbon Reduction Commitment Energy Efficiency Scheme, so the carbon emission burden can be considerable (Bassi, Dechezleprêtre, & Frankhauser, 2013).

In summary, The United Kingdom actively uses various policy means to achieve its greenhouse gas reduction goal. The ETS is the core policy, and those economic sectors that do not take part in it are instead subject to the Climate Change Levy, the Carbon Reduction Commitment Energy Efficiency Scheme, and the Climate Change Agreement system. To achieve low-carbon green development, The United Kingdom built a carbon price support system that maintains the emission right prices at a proper level. This is predicted to have a positive influence on facilitating the use of new renewable energy for electricity generation and on inducing capital investment in low-carbon technology

12) 1) A meter that measures currents once every 30 minutes should be installed; 2) Environment Agency, https://www.gov.uk/guidance/crc-energy-efficiency-scheme-qualification-and-registration (Retrieved October 27, 2015).

13) DOE, CRC-Energy Efficiency Scheme, http://www.doeni.gov.uk/index/protect_the_environment/climate_change/crc.htm (Retrieved October 27, 2015).

14) DOE, CRC-Energy Efficiency Scheme, http://www.doeni.gov.uk/index/protect_the_environment/climate_change/crc.htm (Retrieved October 27, 2015).

development. However, there is a problem in that two systems with same policy purpose may overlap. One example is the Climate Change Levy and the Carbon Reduction Commitment Energy Efficiency Scheme. In this case, when an economic agent's carbon emission burden becomes too heavy, problems such as carbon leak could arise.[15)]

2 Germany

Germany participated in the 2005 EU-ETS, and in 2012 it was responsible for 48.6 percent of the EU-ETS's total emission amount. In Germany there are about 1,600 firms participating in EU-ETS, including electricity, steel, cement, and other high-energy-consuming and greenhouse-gas-emitting industries (Görlach, Homann & Wawer, 2013).

Germany expanded its energy tax base by introducing an ecological tax and an electricity consumption tax in 1999 (Capozza & Curtin, 2012). The features of the 1999 ecological tax reform can be summarized as an expansion of tax subjects and the way of managing tax revenues. First, natural gas, energy for heating, heavy oil, and electricity consumption for households, were brought in as new tax subjects. Second, most of the increased tax revenues from the introduction of an energy tax was used to: 1) reduce payroll taxes in a tax-neutral fashion; 2) support new renewable energy sources; and 3) support the manufacturing and development industry sector through the tax expenditure system to compensate for the weakening of industrial competitiveness (Parry, Norregaard & Heine, 2012; Capozza & Curtin, 2012). The ecological tax was designed to reduce greenhouse gas emissions and lessen tax distortion by lessening the income tax burden through revenue recycling (Knigge & Görlach, 2005).[16)] This is the so-called Double Dividend Hypothesis: imposing an

15) Carbon leak generally refers to firms moving to regions or countries where there is no environmental tax or ETS, in order to lessen the burden of carbon emissions.

16) Knigge & Görlach's (2005) work can be found at http://www.ecologic.eu/download/projekte/1850–1899/1879/1879_summary.pdf (Retrieved October 28, 2015).

ecological tax and using the increased tax revenues therefrom to reduce income tax rate and capital tax rate theoretically produces two effects, 1) fixing the negative(-) externality from pollution emission and 2) improving the tax efficiency.

There are two significant features of the German ecological tax. The first is that the fuel consumption tax on mineral-derived fuels (gasoline, diesel, heating oil, natural gas, LPG, LNG, etc.) increased five times between 1999 to 2003; the second is the introduction of an electricity consumption tax (Görlach, Homann & Wawer, 2013). The changes in the ecological tax rate between 1999 and 2003 are presented in <Table IV-1> below.

The effects of the ecological-tax-strengthening policy were positively evaluated. Ludewig et al.(2010) showed that strengthening the ecological tax reduced energy consumption and greenhouse gas emissions, and positively impacted economic development and employment (Capozza & Curtin, 2012). Also, Görres(2005) and Knigge & Görlach(2005) showed that strengthening the ecological tax positively influenced innovations in carbon abatement technology (Capozza & Curtin, 2012). However, looking at the energy tax rate trend for 2015 (including the ecological tax) presented in <Table IV-1>, all the energy tax rates for transportation and heating fuels are the same as they were in 2003; there was no additional tax rate increase after the ecological tax system reform. The reason for this is that even though the ecological tax was reformed as tax-neutral, people were dissatisfied with the drastic increase in their energy-related tax burden (Heine, Norregaard & Parry, 2012). Also, the revenue recycling effect was quite small, so public opinion on the additional tax rate increase was critical.

〈Table IV-1〉 **The eco-tax rate by energy source, 1999–2003**

Tax standard	Mineral-derived fuel tax[1]	Added ecological tax rate (stage of reform)					1999 ~ 2003	Energy tax (including environmental tax)
	1998	1999	2000	2001	2002	2003		2004[2]
Electricity (euro cent per kWh)	–	1.02	+0.26	+0.26	+0.26	+0.26	△2.05	2.05
Transportation fuel (euro cent per ℓ)								
diesel	31.70	+3.07	+3.07	+3.07	+3.07	+3.07	△15.34	47.04
gasoline	50.11	+3.07	+3.07	+3.07	+3.07	+3.07	△15.34	65.45
LNG	6.00	+1.00	–	–	–	+1.00	△2.00	8.00
LPG	6.00	+1.00	–	–	–	+1.00	△2.00	8.00
Heating fuel (euro cent per ℓ)								
light quality heating oil	4.09	+2.05	–	–	–	–	△2.05	6.14
middle quality heating oil	1.53	–	+0.26	–	–	+0.71	△0.97	2.50
natural gas	0.18	+0.19	–	–	–	+0.19	△0.37	0.55

Note: 1) Add the eco-tax rate to the shaded marked years; 2) Same as 2003 energy tax
Source: Capozza & Curtin (2012) [Table 1], p. 7; Re-written Using [Exhibit 1] in Görres(2005), p. 3. Original source of Capozza & Curtin (2012): BMU (2004), Die Ökologische Steuerreform: Einstieg, Fortführung und Fortentwicklung zur Ökologischen Finanzreform, Bonn.

Generally, the reason the Double Dividend Hypothesis is criticized is because the theoretical model overlooks the possibility that imposing an ecological tax increase on energy prices eventually decreases the actual income of the energy users and offsets the revenue recycling effect (Bovenberg & de Mooij, 1994). Capozza & Curtin (2012) insisted that because there was no additional tax system reform after 2003, the original purpose of introducing the ecological tax might fade. The total tax proportion compared to the total price of gasoline and diesel have decreased by 16.3 and 17.2 percent respectively since 2003. Also, looking at EU states' GDPs and the energy tax (including the ecological tax) compared to national taxes, the proportions in Germany are 2.05 and 5.38 percent respectively, lower than the EU average. Compared to the GDP, the energy tax has gradually decreased since 2003—this trend has reversed only once, when it increased slightly in 2009 following the car tax system reform. The same trend is evident in energy tax as compared to total tax. The reason for this phenomenon is that the energy tax system has not changed since 2003, and because the energy price signal is distorted by ecological tax decreases and exemptions (Capozza & Curtin, 2012).

On the other hand, in 2009 Germany reformed its car tax system in ways that were consistent with the original purpose of the ecological tax, and started imposing taxes for cars that satisfied specific conditions according to the amount of carbon they emitted (Capozza & Curtin, 2012; OECD, 2012). In other words, before 2009 the German tax office imposed a car tax according to the displacement, kind of car, and whether a dust removal filter was installed, but after 2009 the car tax was reformed, and taxes were imposed according to the carbon emission amount (Capozza & Curtin, 2012; OECD, 2012). The 2009 reform regulated the permitted carbon emission volume, relying on the existing tax method when emissions are below the permitted volume and imposing an additional carbon tax when emissions exceeded the permitted volume.

3 Policy Implications

The United Kingdom and Germany set specific greenhouse gas reduction goals and are each using two or more policy means to achieve it. They are implementing the EU-ETS as their core policy, and actively use environmental taxes in sectors where the ETS does not apply.

The United Kingdom and Germany manage their ETS and environmental taxes in complementary ways so as to prevent an overlapping burden of greenhouse gas emissions. That is, they introduced an environmental tax focused on sectors that do not participate in their ETS. However, they differ greatly with regard to how they introduced their environmental taxes. The United Kingdom uses a Climate Change Levy and Carbon Reduction Commitment Scheme separate from its existing energy tax system, while Germany introduced an environmental tax to strengthen the price function of the existing energy tax system, as well as to introduce an electricity consumption tax.

The environmental tax policies of the two countries each have advantages and disadvantages. The United Kingdom directly imposes a price on carbon emissions, so that economic agents recognize the social damage cost arising therefrom as an actual financial burden. Germany has added an environmental tax to the existing energy tax system to increase the energy tax burden and partly imposed a tax based on carbon-dioxide emissions in the case of transportation fuels. However, as detailed in <Table IV-2>, the environmental tax rate is not proportional to carbon-dioxide emissions.[17)]

Also, The United Kingdom's Climate Change Levy has problems. The application range of Climate Change Levy is quite wide: almost all economic sectors (excluding households, the transportation sector and small firms) are tax subjects, so the tax can overlap with other systems designed to meet similar policy goals, resulting in some economic agents bearing considerably higher carbon-emission burdens. For example, of the firms subject to the Climate Change Levy, those that also take part in the Carbon Reduction Commitment Scheme bear a greater carbon emission burden. Therefore, In the United Kingdom, policies with similar goals overlap for some groups, making these policies less effective, whereas in Germany the energy tax system was reformed in such a way as to add certain tax rates to the existing energy tax in form of an added tax, and thus it is not likely to put an overlapping burden on energy use.

17) The fact that the volume of carbon–dioxide emissions and the environmental tax rate are not proportional should not be interpreted as wrong. This occurs because, considering the carbon emission problem and other various atmosphere pollution emissions, the environmental tax is a result of reflecting factors that cause more social cost than carbon emission. However, considering greenhouse gas reduction as the primary assignment, there is a limit to achieving this goal with an environmental tax when the carbon emission volume and the environmental tax are not proportional.

〈Table Ⅳ-2〉 **The implicit eco-tax rate by per ton CO_2 price**

Classification	Total eco–tax rate	CO_2 emission factor (kg of CO_2/unit)	Implicit CO_2 tax (EUR/CO_2/ton)
Transportation fuel (euro cent per l)			
diesel	15.34	2.64	58.10
oils	15.34	2.30	66.70
LNG	2.00	1.23	16.30
LPG	2.00	1.49	13.40
Heating fuel (euro cent per ℓ)			
light quality heating oil	2.05	2.53	8.10
middle quality heating oil	0.97	3.19	3.00
natural gas	0.37	0.21	18.00

Source: Capozza & Curtin (2012) [Table 2], p. 11, adapted from Ludewig et al. (2010). Emission factors drawn from the UK Department for Environment, Food and Rural Affairs.

The cases of the United Kingdom and Germany provide an important policy model for how to impose an environmental tax and on whom. There are two choices when it comes to how the tax is introduced: it can be implemented for new tax subjects, as was done in the United Kingdom, or by taking in an additional tax rate as part of the existing energy tax system and imposing an electricity consumption tax on the electricity sector (which was formerly not taxed in this respect), as was done in Germany. In the first method, choosing the tax subject is important. To prevent placing an overlapping carbon emission burden on firms participating in an ETS, imposing a carbon tax on them is not desirable. If the ETS is properly operated by market principles, the proper emission right price will be established and those firms have already paid a just price for their carbon emissions, so an additional carbon tax might create an overlapping burden. In case of major countries that have introduced both a carbon tax and an ETS, firms participating in the ETS are exempted from or pay a reduced tax. However, when the ETS does not work properly and emission prices are lower than they should be, introducing a Carbon Price Floor, as was done in the United Kingdom, is a viable alternative. It is important to note that this policy applies only to the electricity sector, in order to facilitate renewable energy use and attract capital to carbon abatement technology, which is preferable to introducing it in all sectors.

In the second method it is desirable to strengthen the environmental energy tax system by adding certain tax rates to the existing energy tax rates according to carbon emission amounts, because the original purpose of an environmental tax is to impose a price on carbon to improve energy efficiency and induce reasonable energy use to counter the negative externalities. For example, diesel fuel always produces more carbon-dioxide emissions than oil, so the environmental tax should be strengthened in ways that increase the tax burden of using diesel. Finally, in Korea taxes are imposed on gasoline, diesel, propane, natural gas, lamp oil, heavy oil, and bituminous coal for energy generation, but as yet no direct taxes have been imposed on electricity users, so introducing an electricity consumption tax as was done in Germany seems desirable.

V

Conclusion and policy implications

Korea promised the international society to decrease its greenhouse gas emissions by 30 percent of BAU emissions by 2020, and chose the ETS as the core policy means to achieve this goal. This system is a cost-effective policy means of inducing greenhouse gas reduction, and is common in advanced European countries. To grow the ETS implemented in 2015 from its initial stage to mature functioning, emission prices should be determined in the market by supply and demand. However, in Korea it is possible for the government to affect the standard price of emission rights. When prices rise drastically as compared with 10,000 KW/ton, the government will artificially increase the supply to counter this and stabilize prices. The problem with this is the question of whether the emission right price of 10,000 KW/ton as determined by the government is the proper level.

According to this study, the 2020 reduction goal can only be achieved if the emission right price is at least 26,300KW/ton—it is impossible to achieve the stated goal using the emission right price determined by the government. Korea should therefore build a policy environment to normalize the ETS to correspond to climate change, and consider introducing an environmental tax (a price policy).

Korea is not properly reflecting the social cost of greenhouse gas emissions. Not enough tax is imposed on coal and electricity, which contribute a significant volume of carbon-hydrate emissions, so energy is not consumed reasonably. It is possible that the ETS does its job when it comes to firms emitting high volumes of greenhouse gases or consuming great amounts of energy, but it is limited when it comes to the household and commerce sectors. To induce all economic agents to maintain reasonable energy consumption and achieve the greenhouse gas reduction goal, an environmental tax should be introduced that focuses on sectors that do not participate in the ETS. This would also create a policy synergy with the ETS.

An environmental tax can be introduced as a new tax subject or by adding a certain rate to existing tax subjects. In the case of the former, an environmental tax should be imposed within a range that does not overlap with the ETS. Also, when determining the environmental tax, the distortion of communication between participants and non-participants in the ETS should be minimized, and tax equality should be taken into account. When imposing an environmental tax focused on coal and electricity on those sectors not involved in the ETS, the carbon tax rate estimated in this study can be applied in household and commerce sectors, but in industrial sectors the estimated carbon tax rate must be applied with greater care. The reason for this is that the firms taking part in the ETS receive free emission allowances. It means that firms bear a carbon emission burden in direct proportion to how far their emissions exceed their distributed emission rights. With regard to equality, since the firms currently engaged in the ETS are provided freely distributed emission rights, environmental tax rate for the industry sectors that are not involved in the ETS should be set lower than the estimated carbon tax rate recommended in this study. In Korea, high-emission, high-consumption firms are generally subject to the Target Management System so, as was suggested in the case of the United Kingdom, a system that decreases the carbon emission burden for those firms meeting their emission goals should be considered.

For the latter case to meet the basic purpose of the environmental tax, the environmental tax rate take into account the social cost of the energy source (e.g., carbon-hydrate emissions). In Korea, taxes are imposed at a limited level only for electricity and coal, so the tax base should be expanded in this regard. In the case of electricity in particular, a consumption tax should be introduced to expand the tax base, as is done in Germany. Korea’s electricity fees do not completely reflect the price of the energy source, so introducing an electricity consumption tax should be considered even if an environmental tax is introduced as a new tax subject. In this case, however, the environmental tax should not be imposed for energy sources used in electricity production.[18)]

In the mid- and long-term perspectives, the most important aspect of reducing greenhouse gases is creating the will for sustainable development. The use of new renewable energy should be facilitated and the investment environment for low-carbon technology development, energy-saving technology development, and fuel alternative technology development should be improved. To achieve this, emission prices must be normalized. If the emission price is lower than the proper level, one can consider the carbon price support system from the United Kingdom to the electricity sector only. In order to introduce this system, we must prepare a systematic frame designed specifically for Korea, with the full involvement of the government, industry, and academic sectors.

This study has the following limitations. First, the model designed in this study is abstract and simple. The economic sector in particular is not subdivided into households, commerce, and transportation, so the analysis is not as specific as it could be. Second, the "optimal" emission price estimated by this study is different to "optimal" emission price in the theoretical model, so any interpretation of the analysis should be done with caution. As evident in the work of Kim and Kim(2010), the relationship with other tax reforms such as income tax, corporate tax, and the income recycling method can influence the emission price, but this study does not take this possibility into account. Finally, the management plan for environmental tax revenues was not included in this study, but it is an important aspect of introducing an environmental tax, so it needs to be discussed in more detail in the future.[19)]

18) Before deciding on a method of introducing an electricity consumption tax, the following matters must be addressed: if electricity fees rise due to the ETS, an overlapping tax could be imposed when an electricity consumption tax is introduced; also, electricity consumption taxes are limited in that they cannot influence the energy sources used to generate electricity.

19) Please see Oh et al.(2012) and Kim & Kim(2010).

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Appendix

First, solving the Euler equation for the government using (Equations III-22) to (Equation III-25) to solve discrete dynamic programming, is as follows.

$$u_s = E\left[\left(\frac{\alpha\beta}{1+\frac{\delta}{c}}\right)u_s^{'} + \frac{\frac{\delta}{c}\left(X+\frac{y}{2}\right)}{1+\frac{\delta}{c}}\right] \quad \text{(Equation III-27)}$$

Assuming that the form of the optimal reduction of the function is $u_s = E\left[mu_s^{'} + nX + k\right]$, we get:

$$\left(m = \frac{\alpha\beta}{1+\frac{\delta}{c}}, n = \frac{\frac{\delta}{c}}{1+\frac{\delta}{c}}, k = \frac{\frac{\delta}{c}\cdot\frac{y}{2}}{1+\frac{\delta}{c}}\right)$$

Comparing the Euler formula with Equation (III-24), assuming linear algebra, is as follows:

$$\begin{aligned} u_s &= \phi + \phi_1{}^{*}X = E\left[m(\phi+\phi_1 X^{'}) + nX + k\right] \quad \text{(Equation III-28)} \\ &= m\left(\phi + \phi_1\alpha\left\{X + \frac{\overline{y}}{2} - u\right\}\right) + nX + k \\ &= m\left(\phi + \phi_1\alpha\left\{X + \frac{\overline{y}}{2} - (\phi + \phi_1 X)\right\}\right) - nX + k \\ &= \left(m\phi + \alpha m\phi_1\frac{\overline{y}}{2} - \alpha m\phi\phi_1 + k\right) + (\alpha m\phi_1 - \alpha m\phi_1^2 + n)X \end{aligned}$$

Solving (Equation III-24) using the unknown ϕ, ϕ_1 by variable comparison method, we arrive at a closed solution, such as the following:

$$u_s = \frac{-1+c\alpha\beta-\delta+\sqrt{4c\alpha\beta\delta+(1-c\alpha\beta\delta+\delta)^2}}{2c\alpha\beta}X$$
$$+\frac{\bar{y}(1-2c\alpha\beta+c^2\alpha^2\beta^2+\delta+c\alpha\beta\delta)}{4c\alpha\beta\delta}$$
$$-\frac{\bar{y}(\sqrt{4c\alpha\beta\delta+(1-c\alpha\beta\delta+\delta)^2}-c\alpha\beta\sqrt{4c\alpha\beta\delta+(1-c\alpha\beta\delta+\delta)^2})}{4c\alpha\beta\delta}$$

(Equation III-29)

Next, solving the Euler equation for the representative firm is as follows. Using the equal distribution assumption of BAU emissions, the second section of the Euler equation can be substituted:

$$\int_{e+B+u_f}^{\infty} f(y)dy = \frac{1}{\bar{y}}(\bar{y}-e-B-u_f) \qquad \text{(Equation III-30)}$$

The Euler equation is as follows:

$$u_f = E\left(\frac{\gamma\beta}{1+\frac{P}{c\bar{y}}}\right)u_f' + \frac{P}{c\bar{y}+P}(\bar{y}-e-B) \qquad \text{(Equation III-31)}$$

The function form of the optimal reduction is $u_f = E\left[mu_f' - nB + k\right]$, and we assume as follows:

$$\left(m = \frac{\gamma\beta}{1+\frac{P}{c\bar{y}}}\ , n = \frac{P}{c\bar{y}+P}\ , k = \frac{P}{c\bar{y}+P}(\bar{y}-e)\right)$$

Comparing the Euler formula with the linear algebra assumed in (Equation III-25) is as follows:

$$
\begin{aligned}
u_f &= \phi_2 + \phi_3{}^* B = E\left[m\left(\phi_2 + \phi_3 B'\right) - nB + k\right] \\
&= m\left(\phi_2 + \phi_3\left\{B + e + u_f - \frac{\bar{y}}{2}\right\}\right) - nB + k \\
&= m\left(\phi_2 + \phi_3\left\{B + e + (\phi_2 + \phi_3 B) - \frac{\bar{y}}{2}\right\}\right) B + k \\
&= \left(m\phi_2 + m\phi_3 e + m\phi_2\phi_3 - m\phi_3\frac{\bar{y}}{2} + k\right) + (m\phi_3 + m\phi_3^2 - n)B
\end{aligned}
$$

(Equation III-32)

Solving the unknown ϕ_2, ϕ_3 in (Equation III-25) using the variable comparison method brings us to the following closed solution:

$$
\begin{aligned}
u_f = &\frac{1}{2c\bar{y}\beta\gamma}\left(P + c\bar{y} - c\bar{y}\beta\gamma - \sqrt{4cP\bar{y}\beta\gamma + (P + c\bar{y} - c\bar{y}\beta\gamma)^2}\right)B \\
&+ \frac{1}{4cP\beta\gamma}\left(\begin{aligned}&-c^2\left(2e - \bar{y}\right)\bar{y}\left(-1 + \beta\gamma^2\right) + P\left(-P + \sqrt{P^2 + c^2\bar{y}^2(-1+\beta\gamma)^2 + 2cP\bar{y}(1+\beta\gamma)}\right) \\
&+ c\left(\begin{aligned}&-2e\left(P + P\beta\gamma + (-1+\beta\gamma)\sqrt{P^2 + c^2\bar{y}^2(-1+\beta\gamma)^2 + 2cP\bar{y}(1+\beta\gamma)}\right) \\
&+ \bar{y}\left(2P\beta\gamma + (-1+\beta\gamma)\sqrt{P^2 + c^2\bar{y}^2(-1+\beta\gamma)^2 + 2cP\bar{y}(1+\beta\gamma)}\right)\end{aligned}\right)\end{aligned}\right)
\end{aligned}
$$

(Equation III-33)