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Does the Emission Trading System Reduce Greenhouse Gas Emissions & Coal Consumption and Lead to an Increase in Renewable Energy? – Evidence from OECD Member Countries

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Table of Content

Executive Summary

The Emission Trading System (ETS) on greenhouse gas (GHG) is a climate change policy well-known as a market-based mitigation mechanism. However, policymakers have faced strong opposition of many stakeholders and failed to persuade them in the process to introduce the ETS. Objective evidence on ETS impact not only provides information to policymakers but also may help alleviate controversy between stakeholders and policymakers. Also, empirical results on ETS will be able to contribute to the theoretical economic study of cap-and-trade. In this context, this research aims at empirical analyses of ETS impact with regard to GHG emissions, coal consumption, and renewable energy supply by analyzing panel data from 36 OECD member countries from 1990 to 2016 with fixed effect regression.

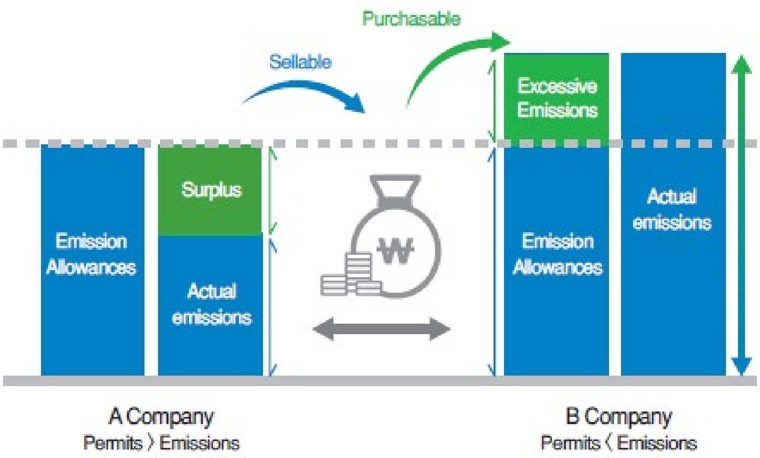
The analysis conducted in this capstone shows that ETS introduction helps reduce GHG emissions by an average of 14.8% in comparison with the policy decision that does not introduce ETS as GHG mitigation instrument. In particular, ETS appears to have a significant effect of mitigating emissions of carbon dioxide (CO_2) by an average of 21.6%. The other analysis findings reveal that ETS implementation has an effect on the decrease of coal consumption by an average of 58.2% and the increase of renewable energy supply by an average of 41.3%. Meanwhile, the regression predicting coal consumption indicates that the increase of natural gas consumption and nuclear electricity production links with coal consumption reduction. Overall, this research provides evidence that the introduction or implementation of ETS definitely has impact on the mitigation of GHG emissions, the reduction of coal consumption, and the increase of renewable energy supply. Though this research has limitations that ETS may be accompanied by other policies at the same period and that the degree of ETS alone effects may be overestimated accordingly, it makes sense that ETS alone or together with other policy initiatives is achieving environmental effects.

1. Introduction

Overview of Emission Trading System

The Emission Trading System (ETS), called cap-and-trade, is a well-known policy for greenhouse gas[1] (GHG) mitigation to address climate change. As shown in Figure 1, the ETS operates in a manner that government allocates the amount of GHG emission permits to businesses and the businesses decide on which is most cost-effective GHG reduction method by comparing the direct cost of GHG reduction with the purchase cost of emission permits through trading.

Figure 1. Concept of ETS Operation



Source: Korea Environmental Policy Bulletin from Ministry of Environment of South Korea

Originally, the ETS on GHG was initiated as one of the market-based mitigation mechanisms in the Kyoto Protocol in 1997 (United Nations Climate Change Convention, 1997). The Paris Agreement which is scheduled to begin from the year 2020 stipulates all countries to

[1] Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

achieve national GHG mitigation targets, if necessary, by introducing various GHG mitigation policies such as ETS (United Nations Climate Change Convention, 2016). As of 2019, a limited number of countries have introduced ETS as a climate change policy. In 2005, the countries of the European Union (EU) introduced ETS in the EU dimension as a key climate change policy to reduce GHG emissions. New Zealand and South Korea (Appendix A) enacted national-level ETS in 2010 and in 2015, respectively. In contrast, the United States, China, India, Russia, Japan, Canada and Australia have been hesitant to legislate national-level ETS in spite of being among the largest GHG emitters as shown in Table 1. For example, in the United States, the American Clean Energy and Security Act, which is an ETS bill, was passed in the House of Representatives in 2009, but failed in the Senate (Congress.Gov). In Australia, the Clean Energy Act for ETS introduction was passed in 2011, however the new government which took power after the 2013 federal election repealed the ETS law (CDC Climate Research, EDF and IETA, 2015).

Table 1. Highest CO_2 Emitting Countries

Country	Emission Amount ($MtCO_2$)			Country	Emission Amount ($MtCO_2$)		
	1990	2005	2016		1990	2005	2016
China	2 122	5 448	9 102	South Korea	232	458	589
United States	4 803	5 703	4 833	Iran	171	418	563
European Union	4 027	3 922	3 192	Canada	420	540	541
India	529	1 072	2 077	Saudi Arabia	151	298	527
Russia	2 164	1 482	1 439	Mexico	257	412	445
Japan	1 037	1 164	1 147	Australia	260	372	392

Source: IEA (International Energy Agency) estimates of CO_2 emissions from fuel combustion in 2016

Background of Research

Climate change is a serious threat to the survival of humankind. The Intergovernmental

Panel on Climate Change, called IPCC, has warned that the global average temperature has already risen 0.74 degree over the past 100 years (1906-2005) and that the temperature will rise faster if the current GHG emissions are not abated in the future (Climate Change 2007 Synthesis Report). According to IPCC, reducing the GHG emissions caused by human activities is a key factor to address climate change. In the context of GHG mitigation, many countries have set the national target of GHG reduction for the year 2030 as shown in Table 2. The necessity of GHG reduction makes it difficult for policymakers to give up ETS legislation, because cap-and-trade theoretically has been perceived as solving the negative externalities problem in environmental issues (Pigou, 1950).

Table 2. The 2030 GHG Target of Each Country

Country	2030 GHG Target	Country	2030 GHG Target
China	Reduce CO_2 per unit of GDP by 60-65% below 2005	South Korea	37% below BAU (Business-As-Usual) emissions of 850.6 $MtCO_2$-equivalent in 2030
United States	26-28% reduction by 2025 below 2005 levels	Iran	4% below BAU of 1540 $MtCO_2$ in 2030; 12% with international support
European Union	40% reduction compared to 1990 levels	Canada	30% below 2005 levels
India	Emissions/GDP 33-35% below 2005 levels	Saudi Arabia	Annual GHG-emission abatement of up to 130 $MtCO_2$-equivalent
Russia	25-30% below 1990 levels	Mexico	22% below BAU
Japan	26% below 2013 levels	Australia	26-28% below 2005 levels

Source: IEA (International Energy Agency) estimates of CO_2 emissions from fuel combustion in 2016

However, many policymakers have faced strong opposition from the industrial stakeholders in the process to propel the ETS legislation. Opponents of national-level ETS introduction believe that mandatory reduction of GHG may hurt the national economy. Even in countries that already enacted the ETS, many businesses want to repeal ETS legislation. In fact, the various voices about ETS are not based on empirical analytical evidence. The coalition that supports ETS introduction and opposite coalition that objects to ETS introduction have been making their own claims. A good example is the process of ETS legislation in South Korea. The policy process of ETS introduction in South Korea can be explained by applying the Advocacy Coalition Framework Model (Appendix B). In the process to ETS introduction in South Korea, there was severe controversy on the effect of ETS between two distinct coalitions, environment-friendly coalition and industry-friendly coalition. During the legislative process, the two coalitions had fierce debate about ETS effects. With the doubts that ETS has effects on GHG reduction, the industry-friendly coalition claimed that ETS would lower national technology and economic competitiveness. In contrast, the environment-friendly coalition claimed that ETS would reduce GHG emissions, decrease dependence on fossil fuels, and enhance national competitiveness of low carbon technology.

In this regard, it is necessary for policymakers to analyze the impact of ETS implemented in the past and clarify its direction in the future. The government that is or plans on implementing the ETS needs to conduct quantitative and empirical research on the ETS effectiveness. Research information helps policymakers to make more desirable decisions whether government will introduce or continue to implement a national-level ETS. Thereby, the governments can obtain the justification of ETS legislation and continue to implement ETS without unnecessary controversy in the future.

Apart from this, ETS has been regarded to be one of important economic theories with regard to the governmental intervention. Economists as well as environmentalists may want to know more about what effects ETS has in reality, not just within the theoretical domain, and may wonder whether ETS works in accordance with the way it is explained in economic theory. Empirical evidence will contribute to the theoretical economic study of cap-and-trade, not only on the reduction of pollutants but also on other influences such as technological and economic effects.

In this context, this research is expected to give some evidence about the impact of ETS. For the most basic question about the effectiveness of ETS, this research aims at analyzing the ETS effects from the perspective of GHG emissions, coal consumption, and renewable energy supply empirically. The questions of this research are set as follows:

Question 1: Does the Emission Trading System Reduce Greenhouse Gas Emissions?

Question 2: Does the Emission Trading System Reduce Coal Consumption?

Question 3: Does the Emission Trading System Lead to an Increase in Renewable Energy?

2. Literature Review

Effect of Greenhouse Gas Mitigation

For a long time, whether ETS reduces GHG emissions has been a major research topic to many researchers who have an interest in climate change policies. Most research claimed that ETS could reduce GHG emissions both theoretically and practically. In theoretical perspectives, Stavins (2001) argued that ETS is a market-based approach, which is regulation to induce behavioral change through market signals rather than command-and-control. Montgomery (1972) also proved theoretically that ETS is more efficient in reducing emissions than conventional policies. In addition to theoretical effects of ETS, many researchers have evaluated empirically GHG mitigation on the basis of implementation results. As the EU is the world's first and biggest trading market of GHG emissions today, the EU ETS has been the subject of research for most researchers who have studied GHG mitigation effects. The EU ETS, launched in 2005, has been implemented as real policies for about 15 years over four consecutive periods: 1st trading period (2005-2007), 2nd trading period (2008-2012), 3rd trading period (2013-2020), 4th trading period (2021-2030) (European Commission, 2016).

Many findings of the EU ETS evaluation primarily are based on a counterfactual (BAU: Business-As-Usual) baseline, which represents the amount of emission that would have occurred without GHG mitigation such as ETS. For example, Anderson and Maria (2011) estimated total abatement of 247 $MtCO_2$ (Million tonnes[2] of carbon dioxide) during 1st trading period. They took advantage of the counterfactual (Business-As-Usual: BAU) emission scenario to compare verified emissions, using a dynamic panel data model. However, while researchers have insisted that EU ETS has a positive GHG reduction effect, they have also criticized the use of the counterfactual baseline. Specifically, Ellerman et al. (2008) estimated the reduction by 7 to 8% of what emissions would otherwise had been in both 2005 and 2006, assuming that baseline emissions reflect the pre-existing trend as of 2002. They pointed out the problem that the baseline emissions analyses do not reflect other factors such as weather and energy prices that would affect GHG emissions. As a result, estimates of baseline emissions are imperfect. Also Convery (2009) criticized that many studies were missing discussion of the counterfactual in the process of evaluating the EU ETS. Furthermore Egenhofer et al. (2011) found that many studies conducted about the first trading period of the EU ETS suggested the evidence of significant GHG abatement. They criticized the causality based on historic trends because it is hard to separate factors that have affected abatement other than EU ETS. Recently, Vaidyula et al. (2018) claimed that estimating counterfactual emissions has significant technical difficulty as well as uncertainty in order to account for baseline targets in nationally determined contributions.

[2] Unit of mass commonly called metric tons in the United States, and equal to 1,000 kilograms.

On the other hand, Abrell et al. (2011) estimated an econometric model using panel data in order to evaluate the ETS effect on European companies during the first trading period and the beginning of the second trading period. While controlling economic activity such as employment and profit data, they shed light on the mitigation effect at the firm level and claimed that the second trading period of EU ETS had a stronger abatement effect than the first trading period. Also, they found that the initial allocation was correlated with ex-post emissions. Carbon (2009) produced counterfactual scenarios with an alternative, surveying EU ETS participants. Sixty percent of participating companies reported emission mitigation in both 2008 and 2009. Yoon et al. (2018) evaluated the ETS of South Korea, which has been implemented at the national level since 2015. They tried to analyze the results of ETS operation by tracking companies' ETS participation, emission permits flows in the ETS market, and survey results from companies. They identified that in South Korea, carbon dioxide (CO_2) emission amount in absolute value decreased by 2.15% in 2015 but increased by 2.04% in 2016.

Effect of Coal Consumption

Another set of important research studies on ETS examines whether an ETS helps diminish the fossil fuel dependence including coal consumption. Literature on the ETS effect on coal consumption in itself remains limited. However, much research on the ETS effect on GHG emissions provides the relevant information of coal consumption. For example, Delarue et al. (2008) claimed that if ETS economically incorporates appropriate GHG cost to the coal price, gas power plants can be more attractive than coal power plants. They evaluated that at CO_2 prices around 150 to 200 euro per CO_2 ton, GHG mitigation through fossil fuel substitute reaches to 300 Mton per year. In electric power sector, the main GHG mitigation option would be to switch coal-based power plants into gas-based power plants, which leads the decrease of coal consumption.

Effect of Renewable Energy Supply

The other important research on ETS is whether an ETS influences renewable energy supply in a positive or negative way. In that carbon pricing theoretically solves the negative externalities problem (Pigou 1950, Baumol 1972), it increases the price of fossil fuel and gives benefits to low carbon emission energy such as renewable energy in the energy market. Though the empirical research on the ETS impact on renewable energy remains limited, some recent studies have analyzed renewable energy effects of the EU ETS. Blanco et al. (2008) evaluated whether EU ETS can replace the existing policies for wind power which is an important source of renewable energy. They found that EU ETS does not provide enough incentive to promote wind power, and that other policies should be used to deploy the wind power. Polzin et al. (2015) evaluated a sample of OECD countries to clarify an effective policy mix for renewable energy, while using random effects, and panel corrected standard error models. They claimed that feed-in-tariffs[3], ETS, regulatory measures, and long-term strategic planning could improve the investment of renewable energy. Also, Yu et al. (2017) assessed the effect of ETS on renewable energy output by using a difference-in-difference design with the panel data of 60 countries covering the years 2002 to 2013. They found that ETS elevates the percentage of renewable electricity generation in total electricity supply.

3 An energy policy in which the government subsidizes the renewable energy producers when the price of electricity produced by renewable energy is more expensive than the price of electricity produced by other energy sources.

On the other hand, much research on the effect of ETS has been conducted from the perspectives of overall low carbon technology innovation which includes fuel type change, renewable energy generation, and carbon-intensive process reduction. Though the range of the research is broader, those results are also important in order to understand the ETS impacts on renewable energy generation. Similar to the above studies on the renewable energy effect of ETS, research on the effects of low carbon technology innovation have also shown mixed results. For one thing, before the first trading period of EU ETS, the studies on ETS in terms of low carbon technology innovation focused on theoretical work, comparing the ETS with other policies like an emission tax or command-and-control regulation. Milliman and Prince (1989) claimed that auctioned marketable emission permits provide the biggest incentives to promote technological change and that direct regulation provide the lowest incentives to technological change. Malueg (1989) argued that the introduction of ETS does not necessarily increase the adoption of environmental technology. Rather, this incentive may depend on the firm's position in ETS market. Montero (2002) asserted that innovation incentives vary widely across market structures. If products are substitutes, ETS can provide the most incentives. In contrast, if markets are competitive, ETS offer comparatively lower incentives than taxes. Fischer et al. (2003) and Requate et al. (2003) concluded that ETS would induce higher innovation incentive than emission taxes, but questioned whether ETS would be better than direct regulation. Gagelmann et al. (2005) conducted a literature survey on the innovation effect initiated by the pioneering US ETS like the Acid Rain Program. They concluded that it is difficult to identify the true innovation effect as a technology innovation effect is not the sole result of an ETS.

After the launch of EU ETS, most studies depended on the interview-based methodology, which was a survey of companies about whether ETS would influence their innovation activities. Hoffmann (2007) found the German electricity sector integrated costs for

GHG in investment decisions, and that there was a limitation on large-scale investment in R&D efforts. He suggested long-term reduction intentions, more incentives for increasing efficiency, and regulatory uncertainty reduction in order to get over the limitation of innovation investments. Rogge et al. (2010) performed studies with the German power sector in both 2008 and 2009. They found that the innovation effect of EU ETS was small due to the lack of stringency and predictability of ETS implementation, and that the impact varied across technologies and firms. Also, they claimed EU ETS might not provide enough incentive to increase the innovation activities of companies. On the other hand, Anderson et al. (2011) estimated that EU ETS stimulated moderate technological change. They found that 48 percent of responding Irish firms installed new equipment, 41 percent changed fuels in order to produce emission abatement, and 74 percentage experienced process or behavioral changes from 2005 to 2007. Martin et al. (2011) made a survey of about 800 manufacturing companies across six European countries. They found that EU ETS influenced both product innovation and process innovation, and the effect was dependent on the stringency of the emission allowance. Additionally, Calel et al. (2014) conducted comprehensive patent research about the relationship between innovation and carbon pricing. They found that EU ETS had increased environmental innovation among regulated companies by 10 percent, and that EU ETS had not influenced patenting beyond regulated companies.

3. Research Design

Data Collection

To reflect the characteristics of the GHG emissions and renewable energy production, a set of panel data was employed from 1990 to 2016 for the Organization for Economic Co-operation and Development (OECD) member countries. OECD consists of 36 countries shown in Table 3. In Table 3, it is possible to identify the OECD member countries that introduced ETS and the OECD countries that have not yet introduced ETS, and brackets indicate the year in which ETS was introduced. The OECD provides a variety of data about many countries including OECD member countries. Through the OECD data website (https://data.oecd.org/), it is possible to find and compare countries' statistical information in the field of agriculture, development, economy, education, energy, environment, finance, government, health, innovation and technology, jobs, and society. In addition to the data from OECD, a lot of information on the energy sector is provided from the International Energy Agency (IEA). Many data from IEA can be obtained on the IEA website (http://www.iea.org). The OECD data website also provides much energy data by linking the statistics of IEA, which includes coal, oil, natural gas, electricity, nuclear energy, renewable energy and so on.

Table 3. OECD Member Countries and Countries of ETS introduction

- Australia
- <u>Austria (2005)</u>
- <u>Belgium (2005)</u>
- Canada
- Chile
- <u>Czech Republic (2005)</u>
- <u>Denmark (2005)</u>
- <u>Estonia (2005)</u>
- <u>Finland (2005)</u>
- <u>France (2005)</u>
- <u>Germany (2005)</u>
- <u>Greece (2005)</u>
- <u>Hungary (2005)</u>
- <u>Iceland (2005)</u>
- <u>Ireland (2005)</u>
- Israel
- <u>Italy (2005)</u>
- Japan
- <u>South Korea (2015)</u>
- <u>Latvia (2005)</u>
- <u>Lithuania (2005)</u>
- <u>Luxembourg (2005)</u>
- Mexico
- <u>Netherlands (2005)</u>
- <u>New Zealand (2010)</u>
- <u>Norway (2005)</u>
- <u>Poland (2005)</u>
- <u>Portugal (2005)</u>
- <u>Slovak Republic (2005)</u>
- <u>Slovenia (2005)</u>
- <u>Spain (2005)</u>
- <u>Sweden (2005)</u>
- Switzerland
- Turkey
- <u>United Kingdom (2005)</u>
- United States

Source: OECD Homepage (http://www.oecd.org/about/membersandpartners/), EU Homepage (https://ec.europa.eu/clima/policies/ets_en), Underlined countries are countries that implement ETS, and in parentheses is start year of the ETS.

Summary of Variables

Table 4 shows the units and description of all variables, which are used as dependent variables and explanatory variables in statistical models. For one thing, ETS is the dummy variable to indicate whether ETS is enacted per country by year. For example, since Germany introduced ETS in 2005, it is marked as 1 from 2005, and it is marked as 0 before 2005. Next, GHG refers to total emission amount of CO_2 and the other GHG such as CH_4. The CO_2 comes from fuel combustion, meanwhile the other GHG come from human activities such as manufacturing and agriculture. As CO_2 and the other GHG have different greenhouse effect, the data of GHG are expressed in the unit of CO_2 equivalents. As shown in Table 4, the GHG emissions per country by year are expressed in Thousand tonnes CO_2-equivalent, and the CO_2 per country by year are measured in Million tonnes. Next, Coal indicates total final consumption of coal and coal product per country by year, and is expressed in the unit of Kilotonnes of coal equivalent. Also, Renewable, Oil, and Natural Gas represent total renewable energy supply per country by year, total oil demand per country by year, and observed gross inland consumption per country by year, respectively. As shown in Table 4, Renewable uses the unit of Thousand toe (tonnes of oil equivalent), Oil uses the unit of Kilotonnes, and Natural Gas uses the unit of Million cubic meters. Moreover, Nuclear and Electricity represent gross nuclear energy production per country by year and total electricity generation per country by year, respectively. They both have the unit of Gigawatt hours (GWh). In addition, Country indicates each OECD member country, and is numbered from 1 to 36 for each country in an alphabetical order of the 3-letter country codes. Year is set by a year from 1990 to 2016.

Table 4. Units of Variables

Variable	Unit	Description
ETS	Dummy	Emission Trading System
GHG	Thousand tonnes CO_2-equivalent	Total GHG Emission Amount
CO_2	Million tonnes	Total CO_2 Emission Amount
Coal	Kilotonnes of coal equivalent	Total Final Consumption of Coal and Coal Product
Renewable	Thousand toe	Total Renewable Energy Supply
Oil	Kilotonnes	Total Oil Demand
Natural Gas	Million cubic meters	Gross Inland Natural Gas Consumption (observed)
Nuclear	Gigawatt hours (GWh)	Gross Nuclear Electricity Production
Electricity	Gigawatt hours (GWh)	Total Electricity Generation
Country	1 to 36	OECD Member Countries
Year	1990 to 2016	Each Year

Source: Data extracted on 09 Feb 2019 17:04 UTC (GMT) from OECD.Stat

The Table 5 shows the summary statistics of all variables, which are used as dependent variables and explanatory variables. CO_2 and Renewable data are available for all countries for all years, however some of GHG, Coal, Oil, Natural Gas, Nuclear, and Electricity data are missing. The missing data are primarily for Lithuania and Israel.

Table 5. Summary Statistics

Variable	Obs	Mean	Std.Dev	Min	Max
ETS	972	.32	.47	0	1
GHG	955	448641.6	1140096	3323.419	7351465
CO_2	972	334.53	872.71	1.9	5729.9
Coal	945	5666.69	10121.29	0	79509.98
Renewable	972	10061.4	19870.27	18.2	156227.8
Oil	945	61092.3	144971.4	612	947400
Natural Gas	945	40482.22	108751.9	0	776661
Nuclear	945	60286.25	147500.9	0	839918

Electricity	945	267259.9	642140.6	1008	4190552
Country	972	18.5	10.39	1	36
Year	972	2003	7.79	1990	2016

Source: Data extracted on 09 Feb 2019 17:04 UTC (GMT) from OECD.Stat

Question 1: Does the Emission Trading System Reduce Greenhouse Gas Emissions?

Variables / Statistical Model

Table 6 summarizes the dependent variables and explanatory variables in terms of reasons for inclusion, and expected direction in statistical model.

Table 6. Variables

Variable	Reason	Expected Direction
Dependent Variables		
GHG	Expressing effect of the policy	
CO_2	Expressing effect of the policy	
Explanatory Variables		
ETS	Expressing policy treatment	Negative
Coal	Influencing GHG or CO_2	Positive
Oil	Influencing GHG or CO_2	Positive
Natural Gas	Influencing GHG or CO_2	Positive
Country	Controlling the characteristics of countries	
Year	Controlling the changes in year	

Both GHG and CO_2 are used in log form as dependent variables. The emission amount of GHG and CO_2, which are influenced by the explanatory variables, represent the effect of the policy. With respect to explanatory variables, four variables are used in the statistical model. First, the explanatory variable, ETS, is included to express treatment of policy in statistical model. It is expected that the direction of ETS is negative, because ETS has the effect of reducing GHG and CO_2. Second, another explanatory variable, Coal, is included because coal combustion is one of the sources of CO_2 generation. The chemical reaction formula shows that carbon-based materials generate CO_2 and energy (heat) by combining with oxygen (O_2) in the air in below Figure 2. From the chemical reaction formula, it is expected that the direction of Coal is positive. Similarly, Oil and Natural Gas are included as explanatory variables because they are carbon-based materials and main energy sources. From the chemical reaction formula in Figure 2, both Coal and Natural Gas are expected to have positive effects. Country and Year are included to control the characteristics of countries and the changes in year.

Figure 2. Chemical Reaction Formula

$$C + O_2 \rightarrow CO_2 + Heat$$

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_20 + Heat$$

The fixed effect regression is used as the statistical model. The data are organized with the panel data, 36 countries over 27 years (1990 to 2016). The fixed effect model can remove the effect of time-invariant characteristics in order to estimate the net effect of explanatory variables. The fixed effect regression models used in this research are as follows:

$$Log\ (GHG) = \beta_0 + \beta_1 * (ETS) + \beta_2 * (Coal) + \beta_3 * (Oil) + \beta_4 * (Natural\ Gas) + \alpha_i + \gamma_t + \varepsilon_{it}$$

Where i = 1, 2, 3, …... , 35, 36

t= 1990, 1991, 1992, …… , 2015, 2016

$$Log\ (CO_2) = \beta_0 + \beta_1 *(ETS) + \beta_2 * (Coal) + \beta_3 * (Oil) + \beta_4 * (Natural\ Gas) + \alpha_i + \gamma_t + \varepsilon_{it}$$

Where i = 1, 2, 3, …... , 35, 36

t= 1990, 1991, 1992, …… , 2015, 2016

Findings

The regression statistics with dependent variable of Log (GHG) are shown in Table 7. Among four explanatory variables, three coefficients of ETS, Coal, and Natural Gas are statistically significant at the significance level of 0.05. Therefore, ETS introduction, coal consumption, and natural gas consumption show the evidence of impact on GHG emissions statistically. The expected direction in Table 6 appears to be correct in terms of explanatory variables, ETS, Coal, and Natural Gas. That means that ETS introduction reduces GHG emissions and that coal consumption and natural gas consumption increase GHG emissions. With respect to coefficient magnitude, the introduction of ETS is found to have an effect of reducing GHG emissions by an average of 14.8% as compared to the case where does not introduce ETS. Also, the coal consumption by 1,000 Kilotonnes is found to have an effect of increasing GHG emissions by an average of 1.39 %. Moreover, the natural gas consumption by 1,000 Million cubic meters is found to have an effect of increasing GHG emissions by an average of 0.27 %.

Table 7. Regression Statistics with Dependent Variable of Log (GHG)

Log (GHG)	Coefficient	Std. Err.	t-statistic	P-Value
ETS **	-.148	.049	-3.00	0.005
Coal (units of million) **	13.9	4.28	3.24	0.003
Oil (units of million)	2.00	1.27	1.58	0.124
Natural Gas (units of million)*	2.72	1.22	2.23	0.032
Constant **	11.5	.132	86.94	0.000

Source: Data extracted on 09 Feb 2019 17:04 UTC (GMT) from OECD.Stat

Significance: **p<.01 *p<.05; n= 928

The regression statistics with dependent variable of Log (CO_2) is shown in Table 8. Among explanatory variables, the coefficients of ETS and Coal are statistically significant at the significance level of 0.05. Specifically, the coefficient of ETS is -0.216, which means that the introduction of ETS has an impact on abating CO_2 emissions by an average of 21.6% as compared the policy decision which does not implement ETS. The coefficient of Coal is almost same as that of Coal in Table 8, which indicates that most coal consumption generates CO_2, not the other GHG such as CH_4.

Table 8. Regression Statistics with Dependent Variable of Log (CO_2)

Log (CO_2)	Coefficient	Std. Err.	t-statistic	P-Value
ETS **	-.216	.069	-3.14	0.003
Coal (units of million) **	14.5	4.45	3.25	0.003
Oil (units of million)	2.25	1.40	1.62	0.115
Natural Gas (units of million)	2.29	1.42	1.61	0.117
Constant **	4.19	.138	30.30	0.000

Source: Data extracted on 09 Feb 2019 17:04 UTC (GMT) from OECD.Stat

Significance: **p<.01 *p<.05; n= 945

Question 2: Does the Emission Trading System Reduce Coal Consumption?

Variables / Statistical Model

Table 9 summarizes the dependent variables and explanatory variables in terms of reasons for inclusion, and expected direction in the statistical model.

Table 9. Variables

Variable	Reason	Expected Direction
Dependent Variables		
Coal	Expressing effect of the policy	
Explanatory Variables		
ETS	Expressing policy treatment	Negative
Oil	An energy source that can replace coal	Negative
Natural Gas	An energy source that can replace coal	Negative
Nuclear	An energy source that can replace coal	Negative
Country	Controlling the characteristics of countries	
Year	Controlling the changes in year	

The dependent variable of Coal is used both in log form and in non-log form. The coefficient for Coal, which is influenced by the explanatory variables, represents the effect of the policy. In the statistical model, four variables are used as explanatory variables. First, explanatory variable, ETS, is the dummy variable to indicate whether ETS is enacted per country by year, and is included to express treatment of policy in statistical model. It is expected that the direction of ETS is negative, because the introduction of ETS has the effect of reducing coal consumption. Next, in the perspective of energy alternative, Oil, Natural Gas, and Nuclear are included as explanatory variables in that they are one of important energy sources. In the perspective that they can replace coal, the explanatory variables, Oil, Natural Gas, and Nuclear, are expected to have negative impact. Furthermore, Country and Year fixed effects are included to control the characteristics of countries and the changes in year.

A panel data with fixed effects for the Country and Year is used as statistical models. The data are organized with the panel data, 36 countries over 27 years (1990 to 2016). The fixed effect regression models used in this research are as follows:

$$\text{Log (Coal)} = \beta_0 + \beta_1 * (\text{ETS}) + \beta_2 * (\text{Oil}) + \beta_3 * (\text{Natural Gas}) + \beta_4 * (\text{Nuclear}) + \alpha_i + \gamma_t + \varepsilon_{it}$$

Where i = 1, 2, 3, …... , 35, 36

t= 1990, 1991, 1992, …… , 2015, 2016

$$Coal = \beta_0 + \beta_1 * (ETS) + \beta_2 * (Oil) + \beta_3 * (Natural\ Gas) + \beta_4 * (Nuclear) + \alpha_i + \gamma_t + \varepsilon_{it}$$

Where i = 1, 2, 3, …... , 35, 36

t= 1990, 1991, 1992, …… , 2015, 2016

Findings

The regression statistics with dependent variable of Log (Coal) are shown in Table 10. Among four explanatory variables, the coefficients of ETS and Oil are statistically significant at the significance level of 0.05. Therefore, the analysis provides evidence that the ETS introduction and oil demand have an impact on coal consumption. The coefficient of ETS has negative direction as expected in Table 9, thus ETS influences toward reducing the consumption of coal. With respect to the degree of policy effect, the implementation of ETS is found to have an effect of reducing the consumption of coal by an average of 58.2% in comparison with the absense of ETS implementation. Meanwhile, the coefficient of Oil shows positive value unlike the expected direction in Table 9. That means that coal consumption and oil demand have a complementary relationship rather than a substitution relationship. Also, the oil demand by 1,000 Kilotonnes is found to have an effect of increasing the consumption of coal by an average of 0.33%.

Table 10. Regression Statistics with Dependent Variable of Log (Coal)

Log (Coal)	Coefficient	Std. Err.	t-statistic	P-Value
ETS **	-.582	.212	-2.75	0.009

Oil (units of million) *	3.34	1.29	2.58	0.014
Natural Gas (units of million)	1.97	3.03	0.65	0.520
Nuclear (units of million)	-1.06	.674	-1.58	0.124
Constant **	7.74	.176	43.91	0.000

Source: Data extracted on 09 Feb 2019 17:04 UTC (GMT) from OECD.Stat

Significance: **p<.01 *p<.05; n= 935

The regression statistics with dependent variable of Coal is shown in Table 11. The Table 11 indicates that the coefficients of explanatory variables, ETS, Natural Gas, and Nuclear, are statistically significant in significance level of 0.05. The coefficients of ETS, Natural Gas, and Nuclear have negative directions as expected in Table 9. It makes sense given that ETS is intended to move away from coal consumption and that natural gas has substituted for coal in recent years. The natural gas consumption of 1,000 Million cubic meters appears to decrease coal consumption by 119 Kilotonnes on average. Also, nuclear electricity production reduces coal consumption, while supporting the assumption that nuclear energy replaces coal energy. The nuclear electricity production of 1,000 Gigawatt hours (GWh) appears to reduce coal consumption by 18 Kilotonnes on average.

Table 11. Regression Statistics with Dependent Variable of Coal

Coal	Coefficient	Std. Err.	t-statistic	P-Value
ETS **	-3266.985	1095.486	-2.98	0.005
Oil	.0288	.0172	1.68	0.102
Natural Gas **	-.119	.0254	-4.69	0.000
Nuclear *	-.0179	.00654	-2.74	0.010
Constant **	12128.86	2323.761	5.22	0.000

Source: Data extracted on 09 Feb 2019 17:04 UTC (GMT) from OECD.Stat

Significance: **p<.01 *p<.05; n= 945

Question 3: Does the Emission Trading System Lead to an Increase in Renewable Energy?

Variables / Statistical Model

Table 12 summarizes the dependent variables and explanatory variables in reasons for inclusion, and expected direction in the statistical model.

Table 12. Variables

Variable	Reason	Expected Direction
Dependent Variables		
Renewable	Expressing effect of the policy	
Explanatory Variables		
ETS	Expressing policy treatment	Positive
Coal	An energy source that can replace renewable energy	Negative
Oil	An energy source that can replace renewable energy	Negative
Natural Gas	An energy source that can replace renewable energy	Negative
Nuclear	An energy source that can replace renewable energy	Negative
Electricity	Influencing overall amount of energy sources	Positive
Country	Controlling the characteristics of countries	
Year	Controlling the changes in year	

A variable, Renewable, is used as a dependent variable, which is measured as the contribution of renewable energy[4] to total primary energy supply. The dependent variable of Renewable is used in log form, and represents the effect of the policy. With respect to

[4] Energy derived from hydro (excluding pumped storage), geothermal, solar and wind, tide, and wave source, including solid biofuels, biogasoline, biodiesels, other liquid biofuels, biogases and the renewable fraction of municipal waste.

explanatory variables, six variables are used in the statistical model. First of all, the explanatory variable, ETS, is the dummy variable to indicate whether ETS is enacted per country by year, and indicates the treatment of policy in the statistical model. It is expected that ETS has a positive direction, because ETS has influence on increasing renewable energy production as explained in literature review. Next, another explanatory variable, Coal, is included because coal combustion is one of energy sources that is an alternative to renewable energy. Oil, Natural Gas, and Nuclear are also included as explanatory variables in that they are important energy sources. Because coal, oil, natural gas, and nuclear energy can be alternative energy resources of renewable energy, coal consumption, oil demand, natural gas consumption, and nuclear electricity production are expected to have negative effects on renewable energy supply. Furthermore, a variable, Electricity, is used as an additional explanatory variable, which indicates total electricity produced from fossil fuels, nuclear and hydro power plants, solar energy, biofuels, wind, and so on. From overall national perspective, an explanatory variable, Electricity, is not related to the relative amount of various energy sources, but it is related with absolute energy, including renewable energy generation. Therefore, Electricity is assumed to be a positive direction in correlation of Renewable. Additionally, Country and Year fixed effects are included to control the characteristics of countries and the changes in year.

Panel data with fixed effects is used as the statistical model. The model uses the panel data, 36 countries over 27 years (1990 to 2016). The fixed effect regression model used in this research is as follows:

$$\text{Log (Renewable)} = \beta_0 + \beta_1\text{*(ETS)} + \beta_2\text{* (Coal)} + \beta_3\text{* (Oil)} + \beta_4\text{* (Natural Gas)} + \beta_5\text{* (Nuclear)} + \beta_6\text{* (Electricity)} + \alpha_i + \gamma_t + \varepsilon_{it}$$

Where $i = 1, 2, 3, \ldots\ldots, 35, 36$

$t= 1990, 1991, 1992, \ldots\ldots, 2015, 2016$

Findings

The regression statistics with dependent variable of Log (Renewable) is shown in Table 13. Among six explanatory variables, Table 13 reveals that the coefficient of ETS is statistically significant at the significance level of 0.01. The coefficient of ETS has positive direction as expected in Table 12. The introduction of ETS has the impact of increasing the production of renewable energy, and appears to have an effect of increasing the renewable energy supply by an average of 41.3% in comparison with the policy decision that does not introduce ETS.

Table 13. Regression Statistics with Dependent Variable of Log (Renewable)

Log (Renewable)	Coefficient	Std. Err.	t-statistic	P-Value
ETS **	.413	.081	5.12	0.000
Coal (units of million)	-14	8.19	-1.71	0.097
Oil (units of million)	-2.97	2.00	-1.48	0.148
Natural Gas (units of million)	-6.81	3.44	-1.98	0.056
Nuclear (units of million)	-.832	1.07	-0.78	0.441
Electricity (units of million)	.998	.927	1.08	0.289
Constant **	8.06	.139	58.02	0.000

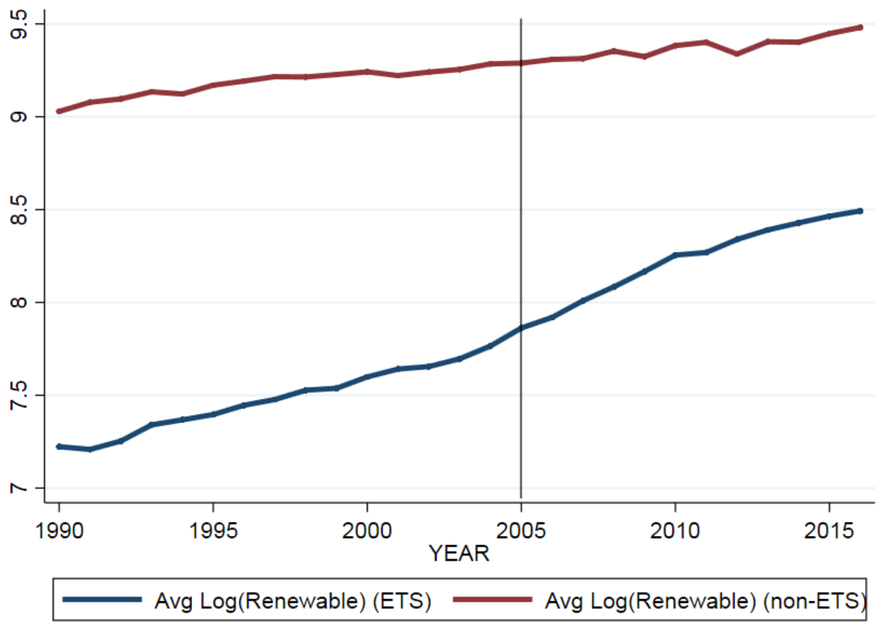
Source: Data extracted on 09 Feb 2019 17:04 UTC (GMT) from OECD.Stat

Significance: **p<.01 *p<.05; n= 945

Regardless of the statistical model, Figure 3 shows the comparison of renewable energy supply between countries that introduce ETS and countries that do not introduce ETS. The amount of renewable energy generated is converted into a log form and averaged. Since renewable energy production in the United States is absolutely greater than in other countries, countries that have not implemented ETS have a higher average renewable energy source.

However, it is seen in Figure 3 that the increasing rate of renewable energy supply is faster in the countries where have implemented ETS than in the countries where do not implement ETS. The year 2005 represents the time when EU introduced ETS for the first time.

Figure 3. Comparison of Renewable Energy between ETS and non-ETS Countries



Source: Data extracted on 09 Feb 2019 17:04 UTC (GMT) from OECD.Stat

4. Limitations

For the first question of this research, it was difficult to find the data on other explanatory variables that might cause the emissions of CO_2 and GHG. If other explanatory variables that should be considered in the statistical model were included, then it would have been able to more accurately estimate the magnitude that ETS influences CO_2 or GHG emissions. Specifically, when using CO_2 as dependent variable, the combustion of biofuels in addition to coal, oil, and natural gas should be considered. Besides, the data from waste should be included, because waste generates CO_2 when incinerated and generates CH_4 when buried in the ground. Furthermore, when using GHG as the dependent variable, the relevant data from industrial manufacturers and agriculture, such as cows, need to be considered, because CFCs, HFCs, PFCs, and SF_6 occurs in industrial manufacturing plants and agricultural region.

Next, for the second question of this research, some concern can be raised for not adding economic explanatory variables that can be included in the statistical model. Fuel consumption such as coal depends on levels of economic activity. For example, during economic slowdowns demand for goods and services is lower so less energy is required to produce goods and services. Adding economic variables to account for coal consumption may result in a better model. Notwithstanding, since the explanatory variables used in this research can be linked to the economic situation, it somewhat compensates for the absence of economic explanatory variables in the statistical model.

Also, for the third question of this research, there is a worry about whether only the ETS effect has been accurately assessed among the various policies affecting renewable energy production, because some countries introduced various other policies such as the R&D subsidy and tax for the supply expansion of renewable energy along with the implementation of ETS. Subsidy policies and tax policies on renewable energy might cause overestimation of renewable energy production impacts on ETS. That is, there is limitation of a statistical model that does not include the imaginable explanatory variables in terms of policies mix.

In addition the omitting concern of the explanatory variables regarding other policies is not confined to the third question. The concern is not also exceptional in case of the research of the first and second questions. It is important to note that ETS can be accompanied in the same period by other policies which might be driving similar results. If there is an omission of explanatory variables regarding influential policies, this research can overestimate the degree of ETS effects. However, this research, which focuses on ETS effects, cannot answer the concern whether other policy initiatives may significantly influence the reduction of GHG emissions, the decrease of coal consumption, and the increase of renewable energy.

5. Conclusion and Policy Implication

This research is intended to demonstrate the effect of ETS introduction empirically on GHG mitigation, fossil fuel reduction and technology innovation by taking advantage of cross-sectional time series data from OECD member countries from 1990 to 2016. Specifically, this study statistically analyzes the questions of whether ETS reduces GHG and CO_2 emissions, whether ETS reduces coal consumption, and whether ETS leads to an increase in renewable energy. The analyses of the three question are conducted with fixed effect models. The findings of this research indicate that ETS has the effects of reducing GHG and CO_2 emissions, reducing coal consumption, and increasing renewable energy production.

The analysis of the first question found that the policymaking of ETS introduction helps reduce GHG emissions by an average of 14.8% in comparison with the policy decision that does not introduce ETS as GHG mitigation instrument. In particular, ETS shows to have a significant effect of mitigating emissions of CO_2, which is one of GHG, by an average of 21.6%. The introduction or continuation of ETS is expected to play an important role in mitigation of GHG emissions. However, the case of South Korea, which announced the 37% below BAU (Business-As-Usual) emissions as GHG mitigation target in 2030, shows that the effect is insufficient, because the number of 14.8%, which this research found as the GHG mitigation effect of ETS, is much lower than number of 37%. Therefore, provided that the South Korean government does not introduce additional GHG reduction policies other than ETS, it is necessary to design ETS in a direction that is strengthened compared to the worldly average ETS regulatory level.

The analysis of the second question points out that ETS enactment helps decrease coal consumption by an average of 58.2% as compared the case where a country does not enact ETS. The use of coal is a major cause of GHG emissions, and it also causes air pollutants such as fine particles, sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). In this perspective, ETS's ability to reduce coal consumption means that ETS can be an environmental policy to reduce both GHG and air pollutants simultaneously. For example, under the background that the problem of fine dusts has been serious in South Korea lately, ETS can be used as a policy instrument to deal with the problem of air pollution at the same time as the issue of GHG reduction. However, in areas such as Kentucky in the United States, where coal industry is a major economic base, it is necessary to be more cautious about introducing ETS because it can shrink economy and employment. At least, the introduction of ETS should be accompanied by countermeasures to shift people working in the coal industry to other industries without damage. Meanwhile, the regression model predicting coal consumption shows that the increase of natural gas consumption and nuclear electricity production is correlated with the decreased coal consumption. It makes sense given that natural gas and nuclear energy has substituted coal in recent years. In contrast, in case that the government establishes policies to reduce natural gas and nuclear energy, it may result in increased coal consumption.

The analysis of the third question found that ETS implementation has an impact on the increase of renewable energy supply by an average of 41.3% as compared to the case where a country did not introduce ETS. ETS has the effect of accelerating the increase in renewable energy production, and ETS needs to be considered as a policy to expand renewable energy production. In that ETS has a positive effect of increasing renewable energy production in addition to reducing GHG emissions, it is expected that not only environmental policymakers but also energy industry policymakers will be able to see ETS introduction or continuation more optimistically. However, it has a limitation to see ETS as a means to expand renewable energy, not as a means to reduce GHG emissions. Comparative analyses are required with other policies that encourage renewable energy supply. Such examples include policies like renewable energy technology development subsidies and carbon taxes.

This research analyzes only the effects of GHG and CO_2 emissions, coal consumption, and renewable energy supply among the various effects of ETS. In the future, much research about ETS effects needs to be conducted more actively in the areas of technology innovation and economic performance. Further diverse empirical research on ETS impact will provide more information to policymakers and researchers who work to address climate change. Research also provide objective analytic information about ETS for many stakeholders. Moreover, statistical analysis on ETS may give more evidence to the theoretical economic study of cap-and-trade. As time goes by, more data on ETS implementation will be accumulated and the data obtained will be helpful to get more accurate conclusions about ETS effects.

Appendix A: History of the ETS introduction in South Korea

South Korea joined the climate change convention in 1993. Since then, South Korea has initiated a series of activities at the government level to counter climate change including GHG mitigation. The Korean government established the first comprehensive plan in 2001, executed from 1999 to 2001. Also, the second comprehensive plan was established in 2002, executed from 2002 to 2004. The two plans included voluntary GHG reduction measures and development of reduction technologies. The climate change convention countermeasures committee led by the Prime Minister was launched in 2001, and the committee served as the control tower for climate change policies. However, the committee had difficulty in coordinating the positions of stakeholders which played a major role in climate change policies. The climate change policy was not promoted strongly. Most people and organizations did not see GHG reduction as an important policy. Also, there was a strong tendency to emphasize economic growth rather than environmental protection.

Since the Kyoto Protocol came into force in 2005, more active policies have been implemented in South Korea. The Korean government established the third comprehensive plan in 2005, executed from 2005 to 2007. The new climate change team in the Prime Minister's office was established in September 2007, and began to play a leading role in establishing and enforcing climate change policies. The newly elected President in December 2007 chose a new growth strategy called “Green Growth” in August 2008. Green growth means sustainable development that reduces GHG and pollutant emissions. Since South Korea was a member of the OECD and a country with a large amount of GHG emissions, the new administration discussed the preparation of countermeasures against climate change more aggressively. Also, as the development of low-carbon technologies could play a role in a new growth engine for the industry, The Korean government strongly promoted a climate change response policy to achieve a green growth strategy. The master plan for climate change response was established in September 2008. The committee on green growth was established to coordinate the green growth strategy within governmental ministries and stakeholders in November 2008. The national strategy for green growth was established in July 2009. In November of the same year, the national GHG mitigation target, BAU 30% reduction until 2020, was set and submitted to the United Nations framework on climate change convention, called UNFCCC, in January 2010. At the same time, the Framework Act on Low Carbon Green Growth was enacted as the institutional and legal basis for GHG reduction policies such as declaration of ETS introduction, reporting of emission amount by manufacturers, and emission information management system establishment. In May 2012, the Act on the Allocation and Trading of GHG Emission Permits was enacted to specify ETS execution. This act included setting regulation objects, details on the allocation method, and banking and borrowing of emission allowances and offsets.

The new President inaugurated in February 2013 continued the previous President's climate change policies. The new government launched the ETS planning committee, stipulated the detailed technical details required for the ETS system operation, and allocated the GHG emission allowance to the regulation objects. The committee determined the cap and allocated sectoral allowances of GHG emissions in September 2014. The ETS was started in full swing in January 2015. Because the allocation plan of emission allowances is three years, the second allocation plan of emission allowances was made in January 2017.

Appendix B. Application of Advocacy Coalition Framework Model

The main characteristic of the Advocacy Coalition Framework Model (ACF) is that a policy subsystem is composed of two or more advocacy coalitions with different belief systems. In the case of ETS policy that was legislated in South Korea, two distinct advocacy coalitions such as the environment-friendly coalition and the industry-friendly coalition clearly appeared. The following examines whether how ACF is applied to South Korean ETS legislation process by applying each ACF factor in detail:

(1) Relative Stable Parameters

The ETS has basic two attributes, which are the allocation of emission allowances and market-based trading. The allocation of emission allowance is considered as mandatory regulation that is effective with GHG reduction and is regarded as a strong constraint to businesses. While some environmental groups regard ETS as minimum means to prevent climate change, the other groups have a negative stance that ETS creates profits to the businesses.

On the other hand, over 80 percent of the Korean people perceived that climate change is caused by the combustion of fossil fuels, and over 90 percent of Korean people thought climate change was serious. More than half of the Korean people thought that the Korean government should play a leading role in GHG mitigation activities, and they were more inclined to think climate change problem only as the responsibility of the central government. (Ministry of Environment, 2009)

In addition, South Korea has stable constitutional provisions in terms of environmental regulation. The article 119 of the Korean Constitution provides the grounds for free market economic system and national economy regulation, and article 35 of the Korean Constitution provides the grounds for the national regulation for environmental rights.

(2) External Event

South Korea was classified as a developing country at the time of adoption of the Kyoto

Protocol in 1997 and was excluded from the target of the Kyoto Protocol, but it was highly likely to become a target country for mitigation by 2013. The Korean government announced its national GHG mitigation target at the Copenhagen Summit to meet the requirement from developed countries in advance.

Meanwhile, crude oil prices reached $ 150 a barrel around 2008 due to energy consumption increase by the rapid increase of energy demand in emerging economies such as China and India, and financial investment in oil and other resources. Developed countries such as Germany and France had been actively supporting the development of renewable energy to deal with the energy crisis. However, South Korea depended on importing 97% of its energy, and dependence on fossil fuel energy imports had continued to increase.

In addition, the new administration had interest in creating new growth engines such as renewable energy industry, electric car industry, LED light, and so forth. Concerns about the global economic slowdown strengthened new industrial areas. On the background of climate change issue, energy crisis, new growth engine industry issue, the Korean government declared green growth as a new paradigm for national development in August 2008. After the Korean President presented the green growth vision, GHG mitigation became an important agenda of all policies in governmental ministries and stakeholders in South Korea.

(3) Policy Subsystem

(a) Advocacy Coalitions and Belief System

Policy actors are willing to find alliances with similar belief system to increase their chances of policy success. Two coalitions with the same core beliefs were fortified in the process to legislate ETS in South Korea. In fact, two coalitions have been existed since the climate change convention of 1992. One coalition thought that ETS legislation would help protect the environment by addressing climate change, but another coalition asserted that ETS legislation would result in decreasing the economic growth rate. The former was the deep normative core to the environment-friendly coalition, and the latter was that to industry-friendly coalition. To environment-friendly coalition, policy core was legislation of mandatory ETS, and secondary belief was earlier introduction of the ETS and auction revenue allocation. To industry-friendly coalition, policy core was voluntary agreement promotion instead of ETS legislation, and secondary belief was late introduction of ETS as well as free allocation of emission allowances.

The ministry of environment, the environment & labor committee of the national assembly, environmental NGOs, local governments, and liberal newspapers were the allies for ETS legislation for a long time. They placed importance on environment-friendly values. In contrast, the industry-friendly coalition consisted of the ministry of industry & resource, the industry & resource committee of the national assembly, industry associations, manufacturing businesses, and economy newspapers. They advocated the autonomous reduction of GHG emissions and the flexibility of ETS legislation time under the principle of minimum economic burden. The following shows the beliefs system and main actors for two coalitions.

Coalition	The Environment-Friendly Coalition	The Industry-Friendly Coalition
Deep Normative Core	✧ Environmental protection	✧ Economic growth
Policy Core	✧ Legislation of mandatory ETS ✧ Market intervention of government	✧ Voluntary agreement promotions ✧ Incentives for business activities
Secondary Belief	✧ Earlier introduction of ETS ✧ Auction revenue allocation ✧ Lead by ministry of environment ✧ Participation of over-sized workplaces and local government	✧ Later introduction of ETS ✧ Free allocation of allowances ✧ Lead by ministry of industry & resource ✧ Participation of major company
Policy Actors	✧ Ministry of environment ✧ Environmental & labor committee of the national assembly ✧ Korea environment corporation ✧ Environmental NGOs ✧ Local governments ✧ The Korea stock exchange ✧ Liberal newspapers	✧ Ministry of industry & resource ✧ Industry & resource committee of the national assembly ✧ Korea energy corporation ✧ Industry associations ✧ Manufacturing businesses ✧ Korea power exchange ✧ Economy newspapers

(b) Strategies of Advocacy Coalitions

The strategy of environment-friendly coalition is closely related to the external event. The environment-friendly coalition aggressively took advantage of the 'green growth' announcement of the President. Also, the environment-friendly coalition emphasized the international pressure of GHG mitigation and the development of green growth industry such as renewable energy. The ministry of environment took a strategy to lead the legislative proposals, and performed the pilot ETS project early to secure its position as ETS policy leader within the government. In addition, the ministry of environment exerted efforts to persuade the industry associations and manufacturers through persuasion and communication by public hearings and forums.

In contrast, the industry-friendly coalition continuously sought to postpone or stop the ETS legislation, while explaining the burden by total cap and auction revenue allocation. Also, the coalition took advantage of the case of the United States, China, Japan, Russia, and India as an ETS postponement reason. In addition, the businesses within the industry-friendly coalition sought delay, alleviation, or stopping of ETS legislation based on arguments such as lack of opinion gathering, economic deterioration, and cost increase. The ministry of industry and resource, which was the center of the industry-friendly coalition, made efforts to secure the initiative of the ETS by energy efficiency improvement and renewable energy enlargement, while maintaining a negative stance on the ETS legislation.

(c) Policy Broker

The President and Prime Minister played an important role in mediating ETS legislation process between environment-friendly coalition and industry-friendly coalition. The ETS legislation was regarded as major policy for green growth achievement. After the committee on green growth was established in November 2008, the committee became the main policy mediator. The committee was responsible for reviewing and coordinating the government's climate change policy, and at the same time, collecting and discussing various opinions of various social groups. The committee was chaired by the Prime Minister and a celebrity, and the minister of environment, the minister of industry & resource, experts, and interest groups participated as committee members.

(d) Policy-Oriented Learning

The committee on green growth led professional forums, public hearings and debate. However, policy-oriented learning was not successful in the process to the ETS legislation. The industry-friendly coalition did not actively participate at forums steered by environment-friendly coalition or the committee on green growth. Also, they opposed the ETS legislative progress by the national assembly, and have sought the ETS law's repeal or contraction by using industry association's suggestion and articles of economy newspapers after 2015. In specific, at the hearing held by the national assembly on November 3, 2011 the economy association on behalf of industry-friendly coalition claimed that the five economic groups and 15 groups of industry representatives had the position of opposing the legislation of the Act on the Allocation and Trading of GHG Emission Permits. (The National Assembly, 2011)

(4) Test of Hypotheses

Hypothesis 1: the lineup of allies and opponents of ETS legislation has been stable, and two coalitions have been in controversy for over a decade. The conflicts between two coalitions have not been alleviated, although ETS laws was enacted in full swing in 2015. As time goes on, the core belief seems to be strengthened more and more.

Hypothesis 2: Industry associations, manufacturers, and the ministry of industry and resource in industry-friendly coalition appear to have substantial empathy in both core beliefs and secondary beliefs. However, in case of the environment-friendly coalition, the core belief of the ETS has substantial empathy between environmental NGOs and ministry of environment, but the secondary belief between the ministry of environment and environmental NGOs seems to be different. The ministry of environment showed more flexibility with enactment time of ETS laws and free allocation.

Hypothesis 3: The ministry of environment, which is the main actor of the environment-friendly coalition, conceded some contents of the ETS policy in a situation where the confrontation with the industry-friendly alliances was sharp. This can be interpreted as the abandonment of secondary beliefs while retaining core beliefs related to policy.

Hypothesis 4: The environment-friendly coalition maintained its power in the process to ETS legislation. In fact, even after the ETS legislation in 2012, the industry-friendly coalition tried to repeal or cutback the ETS law. However, the ETS law could be implemented in 2015 after three years of preparations. Although the power of the environment-friendly coalition was not strong due to variation of external event, the subsystem of advocacy coalition has been unlikely to be significantly changed.

Hypothesis 5: Substantial changes outside the subsystem can be interpreted as a necessary condition to change the core of the ETS policy. A serious economic crisis and the abolition of the climate change convention could be serious changes that changed the subsystem. However, there have not been external shocks that made ETS policy be changed.

Hypothesis 6: During the policy formation process of the ETS, there has been no change in the attitude of environmental-friendly coalition and industry-friendly coalition. Among the actors of each coalition, the ministry of environment and the ministry of industry and resource seemed to give mutual concessions at the secondary belief level. However, industry associations and environmental NGOs did not change secondary beliefs.

Hypothesis 7: Neither the size of the cost increase claimed by the industry-friendly coalition nor the quantitative data that can confirm the effectiveness of the GHG reduction claimed by the environment-friendly coalition has been recognized by both coalitions. As the result, policy-oriented learning is not identified in the ETS legislation process.

Hypothesis 8: The ETS legislation is a policy issue that involves complex social and political issues rather than natural systems. Therefore, it is difficult to achieve policy-oriented learning in the ETS policy process.

Hypothesis 9: It is difficult to say that forums were carried out by authoritative and professional norms to such a level that experts from the environment-friendly coalition or industry-friendly coalition wanted to participate. Both the environment- friendly and industry-friendly coalition continued to argue for the absence of professional and authoritative forums. As a result, there was no policy-oriented learning through forums.

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