CARBON PRICING IN KOREA: EMPIRICAL STUDIES ON THE BUSINESS PERSPECTIVES

SUNHEE SUK

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ABBRIVIATION

AME	Asia Modeling Exercise
BAU	Business as usual
CCEJ	Citizens’ Coalition for Economic Justice
CEM	Carbon and energy management
CV	Contingent valuation
DC	Double-bounded dichotomous choice
EC	European Commission
EEA	European Environment Agency
ESCO	Energy saving companies
ETS	Emission trading scheme
EU	European
FKI	Federation of Korean Industries
GDP	Gross domestic product
GHG	Greenhouse gases
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
KAU	Korea Allowance Units
KCCI	Korea Chamber of Commerce and Industry
KCU	Korean Credit Units
KEEI	Korea Energy Economics Institute
KEPCO	Korea Electric Power Corporation
KIPF	Korea Institute of Public Finance
KMO	Kaiser Meyer-Olkin
KOC	Korean Offset Credit
KRW	Korean Won
KRX	Korea exchange
LC	Latent class
LCT	Low carbon technology
MBDC	Multiple-bounded discrete choice
MBIs	Market based instruments
ML	Mixed Logit
MOEK	Ministry of Environment
MOSF	Ministry of Strategy and Finance
MOTIE	Ministry of Trade, Industry and Energy
MOU	Memorandum of Understanding
MRV	monitoring, reporting, and verification
NAs	Negotiated agreements
OECD	Organization for Economic Co-operation and Development
OTC	Over the counter
RPL	Random Parameter Logit
SME	Small and medium-sized enterprises
TMS	GHG/energy target management
TOE	Ton of oil equivalent
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
USD	US dollar
VAs	Voluntary agreements
VAT	Value-Added Tax
WB	World Bank
WTA	Willingness-to-accept
WTP	Willingness-to-pay

CHAPTER I: INTRODUCTION

Climate change is an issue of growing concern. In order to stabilise greenhouse gas (GHG) concentrations in the atmosphere to a level that would minimise the risk of catastrophic climate change, it is generally acknowledged that there is a need to greatly reduce GHG emissions. To tackle it, attaching a price to carbon has become widely acknowledged as a central pillar in international efforts, as in economics theory this creates incentives for all players in the economy to seek out opportunities to achieve the GHG mitigation target in the most cost effective manner. This would usher in a paradigm shift in domestic industry toward sustainable economic development.

At the national level, carbon pricing usually comes in the form of two types of policy – carbon tax and emissions trading schemes (ETS). Carbon tax was first introduced in Finland in 1990 and then levied in some other EU countries, such as Sweden, Norway, the Netherlands and Denmark. This decade also witnessed GHG ETSs starting up in a number of countries and sub-national jurisdictions. European ETS started 2005, the largest carbon market in the world, and a number of others are at the planning and preparation stage. In the North East Asia region, China, Japan, and the Republic of Korea (hereinafter referred to as Korea), which together account for over a quarter of GHG emissions, each make use of the carbon market to reduce their emissions footprint. China has launched pilot carbon markets in five major cities and two key provinces, and is transitioning to a national system from 2017. Japan records credits from supporting emissions-reducing projects in developing countries, and now runs linked trading schemes in Tokyo and Saitama prefectures. The region's first ETS scheme started in Korea, in 2015, and this currently stands as the world's second largest carbon market.

However, theory is one thing, practice another. Despite the broad-based consensus at the governmental level in the region as to utilising the cost-based approach and adding a premium to the utilisation of carbon as a way of providing incentives for companies to reduce GHG emissions, actual implementation has been much tougher due to opposition from industry.

In Korea, carbon pricing met with heavy resistance from domestic industry, which has delayed or watered down the proposals – domestic ETS was revised twice and the low carbon car incentive scheme, initially due to start in 2013, was pushed back to 2015 and then 2020. Industry's argument in its defense is centered both on its concern over reduced international competitiveness due to increased energy costs resulting from carbon pricing policies, as well as its belief that the inherent advantages of market-based policies will not materialise and that the market will fail due to lack of readiness. The former, it argues, is significant owing to the export-oriented nature of the country's economy, which itself is mainly comprised of energy-intensive industries.

When any energy-saving or GHG mitigation policy is introduced, the chief concern that arises is how companies will react and respond to it, since they are the party mainly affected due to their high energy consumption or GHG emissions. Given the accountability of industry regarding energy consumption and GHG emissions, acceptance of policy and related practices on the part of companies is therefore an essential prerequisite for successful policy implementation as well as realisation of the policy goals.

The motivation for this study arose amid a climate of skepticism from Korean industry over carbon pricing, as well as its stagnated level of innovation and investment in energy saving and GHG mitigation, against a background of the country's rapid transition to the green economy. This study is focused on the case of Korea, which was previously classified as a non-Annex I country with no GHG reduction obligations under the Kyoto Protocol (2008–2012), but which now has responsibilities in terms of its Nationally Determined Contributions (NDCs), as determined by the Paris Agreement. Analysing Korean policy in this period of transition is anticipated to provide much insight for China and other emerging industrialised countries experiencing similar growth pathways, as they will also need to formulate responses.

Discussions have revealed that, on a practical level, the acceptance level of policy targets of industry is a key factor affecting progress and successful outcome for carbon pricing policies. Therefore, how companies respond to shifts in climate change policies, especially carbon pricing such as the carbon tax and GHG ETS, is an issue that has drawn much attention in the academic field of environmental economics. Nevertheless, few studies exist on this subject and there is only limited understanding of company perspectives and strategies related to carbon pricing. Previous researches have mainly focused on the question of how economic climate policies would affect Korean economy and industries. In this context, this study aims to gain insight into the perspectives of Korean companies, identify key factors and aspects in addressing improvements to related policies and systems, and ultimately to provide useful proposals for successful policy implementation and further practices. This analysis will have implications not only for emerging industrialised countries in Asia but also for Japanese companies with similar industrial structures, some of which are in competition.

Therefore, based on an understanding of carbon pricing theory, this study set out to overview the progress in carbon pricing policy in Korea, identify perspectives of Korean companies on carbon pricing in detail; to measure companies' policy understanding and its influence on policy acceptance and practice; to evaluate companies' affordability of energy cost increase due to carbon pricing; to analyse companies' policy preference to policy attributes of carbon tax and ETS; to explore companies' perspectives on the emission trading scheme introduction; and, to clarify barriers and determinant factors related to company investment in low carbon technology under the ETS. To do so this study was empirical and made use of data collected by questionnaire surveys targeting Korean companies, mainly in the energy intensive sectors.

This study is comprised of five chapters and several subsections. Chapter I provides an overview of the study, including research questions, research objectives and research framework. Chapter II explains the research methodology and originality of this study. Chapter III has two subsections, a literature review on carbon pricing and policy overview on the status of carbon pricing policy implementation and operation in Korea. Chapter IV provides a summary of the empirical studies, in five subsections, with each section comprising an introduction, methodology, results and discussion, conclusion and references. Lastly, chapter V wraps up the study.

1. RESEARCH QUESTION

The main research question in this dissertation is 'Why are companies so adverse to carbon pricing even though economic theory shows that it remains the most cost efficient way to reduce energy consumption and mitigate GHG emissions?' Based on this, some basic questions and detailed questions for empirical studies are listed as below.

The first three questions in carrying out this research were raised and formulated by investigating existing literature and policy overview. The following research questions were used for the empirical study.

1) What exactly is carbon pricing?'
2) What is the theory that supports carbon pricing in economics?'
3) What is the actual status of policy implementation?'
4) What is Korean companies' understanding and acceptance of carbon pricing and what are the determinants; and to what extent does understanding of policy lead to acceptance and actual carbon and energy management practices?
5) How can the affordability for companies in the target sectors regarding energy cost increases be estimated; and how can the external and internal determinant factors be identified to clarify the relationships between affordability levels and company characteristics?
6) What are the policy designs and attributes preferred by Korean companies in the design of carbon pricing policies, i.e., carbon tax and GHG ETS, and by what methodologies can we measure the preferences of Korean companies?
7) What are the opinions of Korean companies regarding the ETS scheme that the government

proposed? What are the determinants that affect differences in company viewpoints, in terms of organisation size, sector belongings and ownership?

8) One objective of carbon pricing policy is to promote low carbon technology investments. What are the impediments to companies making low-carbon technology investments? What policy solutions to the barriers do they advocate in the presence of climate change policies, and what would close the existing gap between government policies and the response of business?

2. RESEARCH OBJECTIVES

The overall purpose of the research is to grasp the perspective of Korean companies' carbon pricing policy based on the market mechanism, under a rapid shift in energy and climate change policy aimed at the green economy.

In particular, the following objectives are expected to be fulfilled through this study.

1) To uncover theories related to carbon pricing, through the literature review;

2) To overview the historical development, latest progress and future trends in carbon pricing policy;

3) To conduct empirical studies by implementing questionnaire surveys and analyse data based on the research questions indicated in the above section;

4) To modify existing models to measure willingness payment and choice preference by combining the factors with quantification and simulation possibility;

5) To propose policy recommendations and implications based on the study results.

3. RESEARCH FLOW AND COMPONENTS

This section provides an overview of the research flow and research content through the following Figure 1, which includes research questions, research topic and scope, research plan, research implementation and components and finalisation.

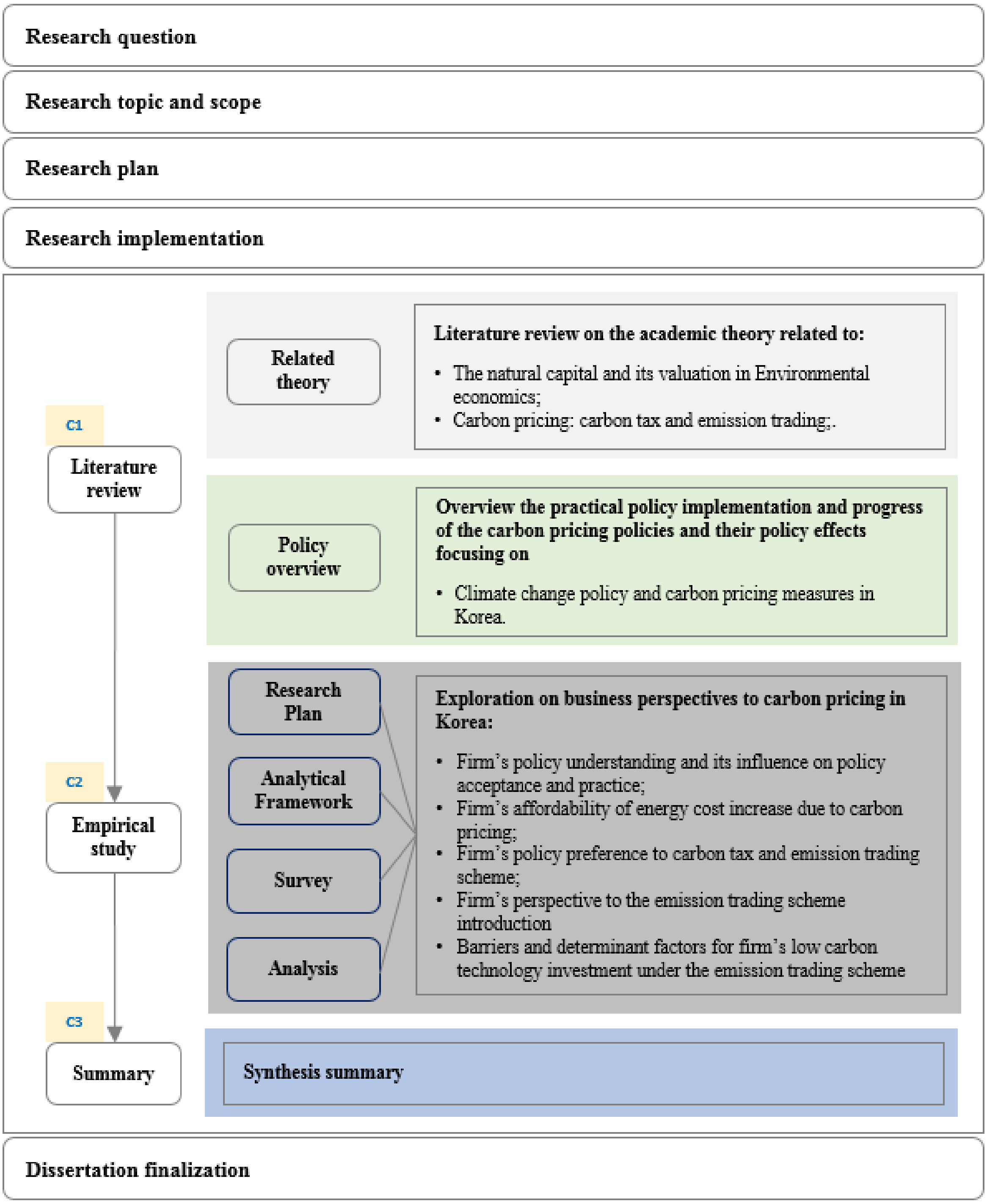

Figure 1 Research framework

Component 1: Literature review of the related theories and overview of the energy and climate change strategy and policies at the national level in Korea

A thorough policy overview was conducted into the history of carbon price policies in Korea as the target area as well as the latest progress made, and to understand trends in future development. In this step, a literature review, covering the valuation of ecosystem goods and services with the purpose of clarifying how natural capital is valued and produced, was carried out in parallel with a review of theories concerning carbon pricing, especially in ETS and carbon tax. The effect of carbon pricing policy on GHG mitigation was summarised through exemplifying the case of Europe, which has a longer history of carbon pricing policy than Korea.

Component 2: Empirical studies for the analysis of Korean companies' perspectives on carbon pricing policies

This section builds on the outputs of the overview work carried out in Component 1, which led to development of five sub-research plans for empirical study. The individual topics are:

1) Firm's policy understanding and its influence on policy acceptance and practice;
2) Firm's affordability of energy cost increase due to carbon pricing;
3) Firm's policy preference to policy attributes of carbon tax and ETS;
4) Firm's perspective on the emission trading scheme introduction;
5) Barriers and determinant factors for a firm's low carbon technology investment under the ETS.

For each empirical study, after deciding on the overall research plan, an analytical framework was developed based on the data analysis method, as described in subsections of Chapter IV. The questionnaire format was designed so as to measure the main objective of the study, and through analysing the data, research findings, policy implications, and recommendations were provided.

Component 3: Synthesis summary and dissertation finalisation

The main task of this part is to summarise the research findings and provide comprehensive policy options for Korea's carbon pricing policy that could facilitate, enable or otherwise bring about CO_2 reduction, investments in low carbon technologies, market activation, and further, a change in industrial paradigm, in order to direct the country on a green growth trajectory.

CHAPTER II: METHODOLOGY AND ORIGINALITY OF THIS STUDY

1. RESEARCH METHODOLOGIES AND DATA SOURCES

The research methodologies for this study may include,

1) Information collection on policy progress and literature review of carbon pricing

2) Questionnaire surveys for mainly energy intensive Korean companies for collecting raw data: The questionnaire formats were designed in accordance with the study objectives, as given in Appendix 1.

3) Interviews with related local government officials and experts in order to obtain an understanding of the status and trends of domestic policies, and interviews with related experts on the business side to obtain opinions and insights on the research results.

4) Statistical analysis and econometrics analysis of pre-defined models using sample data: For the empirical models for econometric analysis, regressions were constructed for measuring the study topics, as described in the sub-sections of Chapter IV indicating the study results of each topic.

5) Adaptation modified contingent valuation (CV) methods and choice modeling for quantitative estimation: In recent years, substantial progress has been made to improve the application of environmental valuation methodologies to ecosystem services. Table 1 indicates the various non-market methods that can be used for valuing ecosystem goods and services. These methods assume that analysis of the responses will provide an accurate measure of an individual's willingness to pay for the services. The modified evaluation methods are adopted, details of which are described in the sub-section of Chapter IV.

6) Presentations in workshops, seminars and domestic/international conferences for dissemination of research outputs and compiling of comments from scholars in related fields: Appendix 2 includes the list of workshops, seminars and domestic/international conferences where the research outputs were presented.

7) Desk work for the draft of journal papers and doctoral dissertation: Appendix 3 indicates the list of publications, in the form of journal articles or book chapters.

Table 1 Various non-market valuation methods applied to ecosystem services

Valuation method	Types of value estimated	Common types of applications	Ecosystem services valued
Travel cost	Direct use	Recreation	Maintenance of beneficial species, productive ecosystems and biodiversity
Averting behavior	Direct use	Environmental impacts on human health	Pollution control and detoxification
Hedonic price	Direct use and Indirect use	Environmental impacts on residential property and human morbidity and mortality	Storm protection; flood mitigation; maintenance of air quality
Production function	Indirect use	Commercial and recreational fishing; agricultural system; control of invasive species; watershed protection; damage costs avoided	Maintenance of beneficial species; maintenance of arable land and agricultural productivity; prevention of damage from erosion; groundwater recharge; drainage and natural irrigation; storm protection; flood mitigation
Replacement cost	Indirect use	Damage costs avoided; fresh water supply	Drainage and natural irrigation; storm protection; flood mitigation
Stated preference	Use and non-use	Recreation; environmental impacts on human health and residential property; damage costs avoided; existence and bequest values or preserving ecosystem	All of the above

Source: UNU-IHDP and UNEP (2012) which adapted the source from NRC (2005) table 4-2

2. ORIGINALITY OF THIS STUDY

In a recent article, Gill & Dolan (2015) conduct a review of the concept of originality in doctoral research and provide definitions of originality, some of which are quoted here to validate the originality of this study.

New Information and additional knowledge in a way that hasn't been done before**:** This study picks up on climate change policies, which are essential particularly in the current context. It traces the related policy progress and provides the latest policy status and design of carbon pricing in Korea (sub-chapter 2 in Chapter III). While related study is lacking in Korea, this study clarifies Korean companies' perspectives on the pricing of carbon emissions, which will contribute to close the existing gap between government policies and the response from business (Chapter IV).

Original techniques, observations, methods or results**:** This study (Chapter IV) is based on an empirical survey study targeting industries in Korea. An analytical framework was designed, based on which an original questionnaire survey was formulated”. Raw data were collected from the survey and analysed via methodologies used in environmental economics. The quantitative and qualitative analysis results obtained can be used to support the development of new climate change strategies using market mechanisms in Korea from a more comprehensive perspective that embraces the perspective of business, and thus generate significant impacts for the green economy of this country. The findings in this study realised through the empirical studies further have important implications in terms of policy for other countries seeking to introduce carbon pricing in response to climate change.

Adding to previously original work**:** Some parts of the empirical study, for example, sub-chapter 5 in Chapter IV, titled ‘*Korean companies’ understanding of carbon pricing and its influence on policy acceptance and practices*’, were modified or extended from existing studies in China. However, such studies contained several grey areas, which this study aimed at overcoming – specifically, in terms of substantiating the correlation between the level of policy understanding of a company and its carbon and energy practices.

CHAPTER III: LITERATURE REVIEW AND POLICY OVERVIEW

1. LITERATURE REVIEW

1.1 Putting a price on carbon

In the related literature, the term ‘capital’ crops up. Capital is defined as a stock yielding a flow of valuable goods or services into the future (Costanza and Daly, 1992). There are two types of human-made capital: ‘manufactured capital’ such as the factories, buildings, and other physical artifacts, and ‘human capital’ which is the stock stored in human beings in the form of education, skills, and knowledge.

These two correspond to the traditional economic factors of production of ‘capital’ and ‘labor’. Natural capital is the world's stock of natural resources from which humans derive a wide range of supply of goods or services. In the traditional economic analysis of the factors of production, natural capital would usually be classified as ‘land’ which has been regarded as free property and which incurs no opportunity cost in its use. However, at the start of the twentieth century natural capital became the limiting factor when we came to realise that human economic activities significantly reduce the capacity of natural capital and degrade its quality. Furthermore, as the productivity of human-made capital largely depends on non-renewable natural capital (Costanza and Daly, 1992), theorists argue that an additional intertemporal cost for extracting or harvesting natural resource existed (Hanley, 2013). Classical economists, for example Adam Smith, emphasised the efficient use of scarce natural resources (Hanley, 2013), and environmental and ecological economists have explicitly treated natural resources as an important form of capital that produces major contributions to human well-being (Pearce & Turner 1990) Present-day theories of natural resource economics reflect both early and modern viewpoints that explain the way people manage and use limited resources (Hanley, 2013). Thus, it is today widely agreed that poorly managed natural capital becomes not only an ecological liability, but a social and economic liability too.

Ultimately, nature is priceless, but this doesn’t imply valueless. While the valuation of natural capital is a challenge, many studies have sought to quantify the provisioning services of natural resources in financial terms. Throughout the entire ecosystem, human beings may actually utilise only a part of it, which is here referred to as the ecosystem of goods and services (e.g., food, fiber, fuel, fresh water). Early studies typically focused on calculating value based on the provisioning of such services or natural resources for which markets exist (Hanley, 2013).

Figure 2 indicates the concept of how human beings and natural capital interact, and what is to be considered in the pricing of the natural resources toward sustainable development. Some of the goods from natural resources are traded in the market at a certain price, which could be considered as deriving value. However, many important ecosystem goods and services usually exist in non-markets.

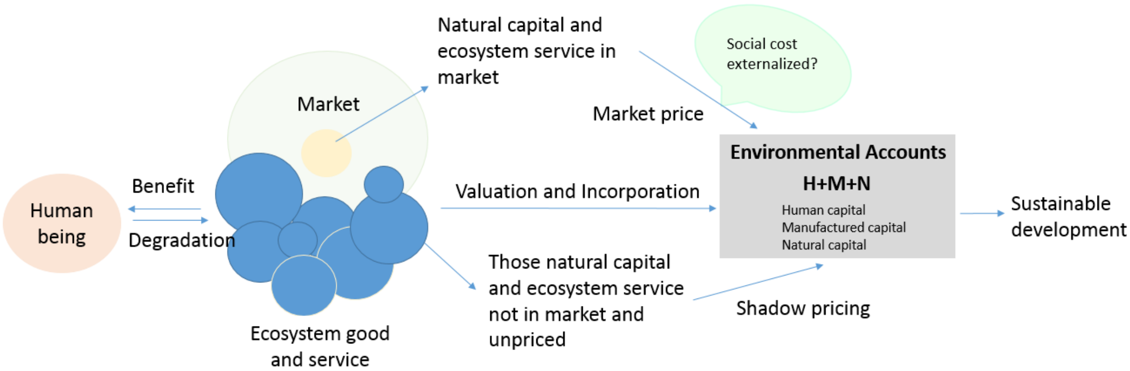

Figure 2 Shadow price of undesirable outputs (e.g., CO_2)

(Source: depicted by author)

From the late 1970s, the focus was expanded to those natural resources left unpriced by the market, for example stock pollutants such as carbon emissions and climate change, to examine the social inefficiencies. As carbon emissions lead to global warming, this degrades ecosystems services and also incurs considerable damage on humans as well as the quality of the environment. The economics of climate change requires the shadow price of carbon in the atmosphere to be discussed and fixed. Accordingly, the phrase “put a price on carbon” has become increasingly common and one of the key measures as discussions of how to address climate change move from concern to action.

The question raised is therefore how much should one unit of carbon cost in the market? Prior to this though, we may need to discuss how to approach price estimation. There are several pathways: one is to capture what are known as the external costs, so-called social cost, of carbon emissions. The social cost of CO_2 is a comprehensive estimate of climate change damages and includes changes in net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning (EPA website). However, it is difficult to obtain accurate information on social marginal costs, and even if it can be obtained, we still need to define what optimal emissions are and what the emission allowance is (Morotomi, 2000). In this respect, there are difficulties in calculating carbon price by use of social costs. One solution is to apply a price level to achieve a socially or politically agreed reduction level (Baumol and Oates 1988).

Several studies have quantitatively calculated the value of carbon with a certain mitigation target considering the social cost. World Bank (various years), Hamilton and Atkinson (1996), and Hamilton and Clemens (1999) estimated the deduction as the social cost of a country's CO_2 emissions. Notably, the World Bank (2010) used a value of 20 USD/t-C. Arrow et al. (2010) estimated the deduction to be the climate change damage in a particular country as a result of global emissions in a given year. Arrow et al. (2010) and Atkinson et al. (2010) arrived at a value of 50 USD/t-C. A study by Tol (2008) involved an extensive meta-survey of over 200 estimates and indicated a wide range, from -6.6 to 2,400 USD/t-C, which variation is due largely to differences in discount rates. Kwon and Heo (2010) suggested that a carbon tax equivalent to 36,545 KRW/t-CO_2 (about 31 USD/t-CO_2) would be required to achieve Korea's 2020 mitigation target. Calvin et al. (2012) compared the Copenhagen pledges to the results from 23 different models, all of which participated in the Asia Modeling Exercise (AME), and found that of the nine models reporting results for Korea, only two ever attain the pledged amount, with carbon prices of 30–50 USD/t-CO_2.

Meanwhile, several empirical studies to estimate the level of willingness payment of carbon pricing considered policy subjects. Empirical studies indicated affordable carbon pricing levels for industry in North East Asia, including China, Japan and Korea, by applying the valuation methods such as contingent valuation (Liu et al, 2014a, Suk et al., 2014). The estimation results are shown in Table 2.

Table 2 Willingness pay for carbon tax

(Unit: US$/$CO_2$)

Country	Sector	Carbon price
China	Iron & steel	6.8
	Cement	6.2
	Chemical	13.4
Korea	Iron & steel	3.3
	Cement	2.3
	Chemical	3.4
Japan	Food processing	6.6
	Chemical	10.3
	Iron & steel	4.1
	Electronics	7.8

Note) Exchange rate: 1,000 KRW = 0.96 USD, 100 JPY = 0.97 USD, 1 CNY = 0.16 USD in April, 2014
Source: Liu et al (2014a)

The calculations confirm that a similar range of carbon price (4–13 USD/t-CO_2) would be affordable for Japanese and Chinese companies, while Korea allows a carbon price of only about 2.3 to 3.4 USD/t-CO_2. The figure given by empirical evaluation of carbon price is generally less than that in the above model analysis.

Table 3 summarises the actual carbon prices that are currently being introduced in the world in the form of carbon tax or emission trading schemes.

Table 3 Prices in existing carbon pricing initiatives

(Prices on April 1, 2016, Unit: USD/tCO_2e)

Country	Carbon Tax	Country or region	ETS
Sweden	137	Tokyo and Saitama	31
Switzerland	88	Korea	16
Finland	62-66	California	13
Norway	53	Switzerland	9
Denmark	26	New Zealand	8
France	25	RGGI	6
Ireland	23	EU ETS	6
Slovenia	20	Beijing pilot	6
Iceland	9	Shenzhen pilot	6
Portugal	8	Hubei pilot	4
Latvia	4	Guangdong pilot	4
Mexico	3	Chongqing	2
Japan	3	Shanghai	<1
Estonia	2		
Poland	<1		

Source: listed by author based on the World Bank Group and Ecofys (2016)

Carbon prices between schemes significantly vary, from under 1 USD/tCO_2 in the Shanghai Emission Trading Scheme (ETS) up to 137 USD/tCO_2 in Sweden. Prices in most countries tend to be lower, clustering under 13 USD/tCO_2. Further, the prices given may also only indicate the threshold value required to reduce one unit of carbon in each market. However the variation is likely caused chiefly due to differences in stringency of regulations, small differences in scheme design and government intervention in each market.

1.2 Type of carbon pricing policy

Historically, regulatory instruments have been the basic mechanisms for enacting environmental policy throughout the industrialised world. Direct regulation involves the imposition of standards (or even bans) regarding emissions and discharges, product or process characteristics, etc., through licensing and monitoring. Legislation usually forms the basis for this form of control, and compliance is generally mandatory, with sanctions for non-compliance (Own, 2013).

More recently, the use of market-based economic instruments has emerged as a more flexible alternative to the conventional command-and-control regulatory approach to controlling emission of pollutants in market-based economies (Own, 2013). Such instruments can generally be divided (generically) into taxes and emission permits, although both categories comprise a large range of distinctly different forms of instruments in accordance with the ultimate intention of their application (Own, 2013). The advent of 'carbon pricing' represents an attempt to impose a cost on consumers that will limit such degradation (i.e., the deleterious impacts of climate change) to scientifically-determined 'acceptable' levels (Own, 2013). In theory, both instruments produce optimal results, but in practice they may yield significantly different outcomes. Table 4 below gives a comparison of strengths and weaknesses of ETS and carbon tax.

Table 4 Relative merits: taxes and tradable permits

	ETS	Carbon tax
Transparency	Specific emissions target that is intuitively easy to understand and facilitates direct control	Transparent and simple for domestic application
Operating (transaction) costs	Design of a new market and its infrastructure, thus incurring significant administrative and compliance costs. Requirement to ensure a competitive market in permits.	For many applications can use existing tax structure (e.g. excise duty on fuel), thus minimizing operating costs
Public acceptability	If permits are auctioned, revenue can be used to offset existing inefficient taxes or to compensate poorer sections of the community. Cost of permits represents another cost of production and, therefore, less visible than taxes.	Revenue can be used to offset existing inefficient taxes or to compensate poorer sections of the community, Politically unpopular, and demonized in many countries in the 1990s.
Dynamic efficiency	Encourages adopting of low-carbon technologies, but allocation criteria for new entrants may involve high set-up costs, particularly if permits are 'grandfathered'.	Encourages adoption of low-carbon technologies, but requires adjustment of tax rates as economy expands or contracts.
Revenue and distributional issues	If tradable permits are auctioned, then taxes and permits are equivalent in terms of revenue raising potential, and hence there is no difference in their distributional impacts. If a proportion (or all) of the permits are allocated to emitters free of charge, then revenue will fall correspondingly. Emitters would receive windfall gains.	
International harmonization	Quantitative caps permit transparency for international harmonization, ideally delivering a single carbon price	Difficult to impose globally and hidden subsidies could offset its impact

Source: (Owen, 2013)

The choice of the instrument depends on national and economic circumstances. There are also more indirect ways of more accurately pricing carbon, such as through fuel taxes, the removal of fossil fuel subsidies, and regulations that incorporate a "social cost of carbon". Greenhouse gas emissions can also be priced through payments for emission reductions. Private entities or sovereigns can purchase emission reductions to compensate for their own emissions (so-called offsets) or to support mitigation activities through results-based finance.

Forty countries and more than 20 cities, states and provinces have already attached a price to greenhouse gas emissions and use carbon pricing mechanisms, with more countries planning to implement them in the future. Together, the carbon pricing schemes now in place cover about half their emissions, which equates to about 13 percent of annual global greenhouse gas emissions (WB website).

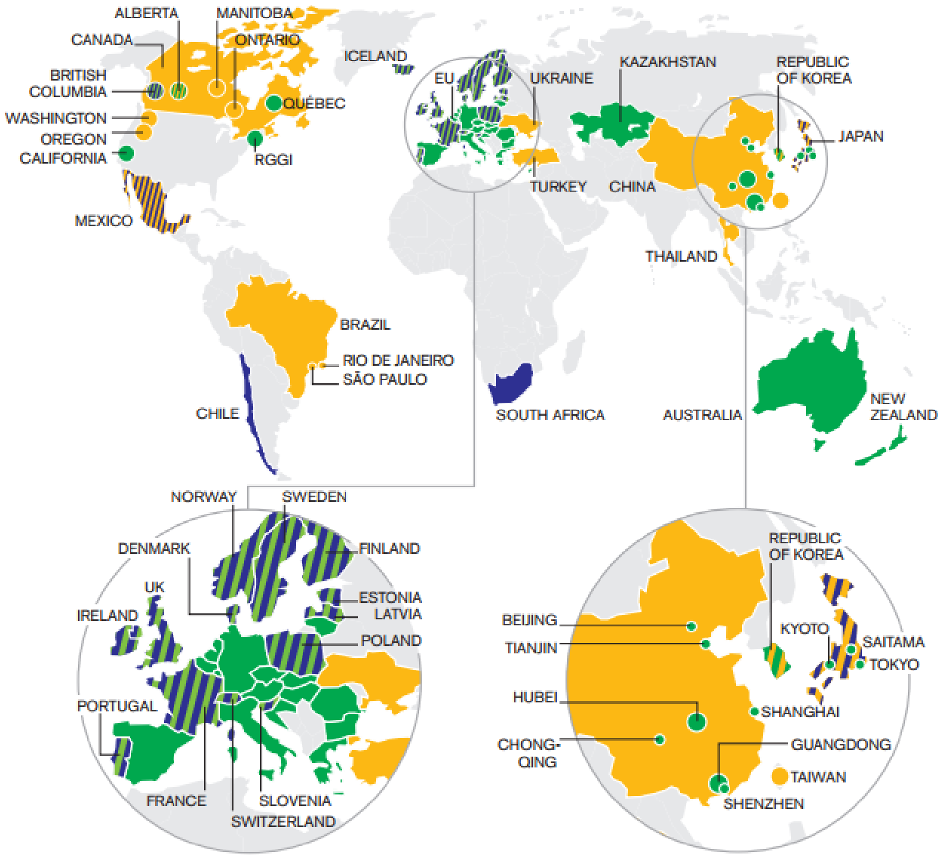

Figure 3 Summary map of existing, emerging and potential regional, national and subnational carbon pricing initiatives (ETS and tax)

(Source: adopted from World Bank website)

1.2.1 Carbon tax

A carbon tax directly sets a price on carbon by defining a tax rate on GHG emissions or on the carbon content of fossil fuels. The taxation approach requires the regulatory authority to set a pollution tax at a level that will ensure that a predetermined standard will be met (or, at least, not exceeded) through the normal operations of the marketplace

The proposal to impose taxes on pollution is far from new but suggested by the famous British economist Authur Ceil Pigou as a means of reducing London's famous fogs (or smog) last century. Pigou (1920) observed that pollution imposed uncovered costs on third parties that were not included in ordinary market transactions. His proposal was to tax pollution by means of a so-called externality tax in order to internalize within ordinary market transactions the damages caused by pollution, which later was rejuvenated as the core of the 'polluter pays principle'.

In the case of CO_2 emission the 'carbon tax' would be expressed in terms of tax rate per tonne of CO_2 emitted by the polluter. Figure 4 show that pollution reduction is measured on the horizontal axis and its associated cost and levels of taxation on the vertical axis.

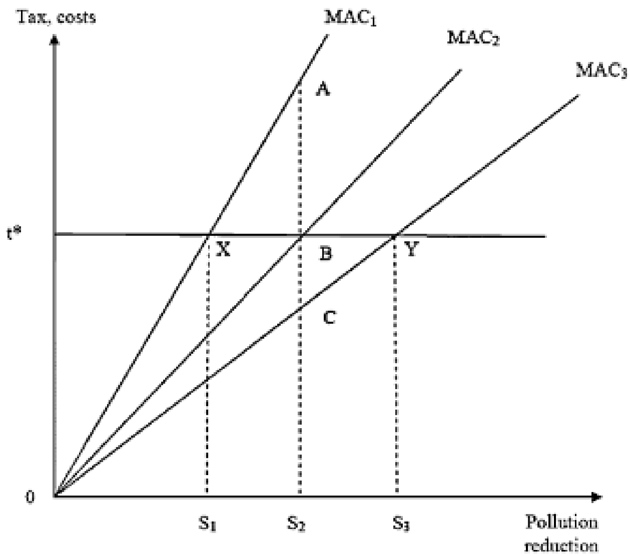

Figure 4 Taxes as a low-cost method of achieving a standard

Source: Owen (2013) adopting Pearce and Turner (1990)

MAC1, MAC2, and MAC3 are marginal abatement cost curves for three different plants producing the same product, with different technologies reflected by the different curves. The slope upwards from left to right indicating that the cost of the marginal unit of pollution abatement increases as the total required reduction increases. Clearly, Plant 3 has the lowest abatement costs and Plant 1 the highest. For simplicity assume that:

$$S_1+S_2+S_3=3S_2 \text{ and } S_1S_2=S_2S_3$$

One way of achieving a given standard of pollution abatement, say $3S_2$, is to instruct each plant to abate pollution by an amount $0S_2$. Under such circumstances, Plant 1 would go to point A, Plant 2 to point B, and Plant 3 to point C, thus achieving a total reduction of $3S_2$. However, clearly their costs of pollution are very different. By imposing a tax equal to t* the same total pollution abatement result can be achieved, but at lower overall cost of compliance. Plant 1 now goes to point X, Plant 2 point B, and Plant 3 to point Y. The overall desired level of pollution abatement has been achieved, with plants having the cheapest abatement options reducing more than those with higher cost options. Thus, to the right of S2, it is cheaper for Plant 1 to pay the tax rather than abate pollution, whereas for Plants 2 and 3 abatement remains cheaper (until points B and Y are passed, respectively). Now both standards and tax have achieved the same overall standard of 3S2. However, the total compliance cost differs. Under standards, the total compliance cost is $0AS_2+0BS_2+OCS_2$: whilst under taxation the total compliance cost is $0XS_1+0BS_2+0YS_3$. Subtracting the latter from the former gives $S_1XAS_2-S_2CYS_3$ which is always positive. Thus standards setting incurs greater total abatement costs than taxation to achieve the same standards.

1.2.2 Tradable permits

The emission trading system is one of the Kyoto mechanisms (flexible measures) stipulated in Article 17 of the Kyoto Protocol adopted at the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3). The Kyoto mechanism has been proposed as a new mechanism to reduce the cost of using market principles to achieve the reduction targets. The emission trading system currently operates 17 ETS globally and about 4,590 MT-CO_2 tons of greenhouse gas emissions are managed under the scheme in 2015. ETS will cover 9% of the global greenhouse gas emissions by 2016, and the figure will increase to 16% by 2017 as the Chinese system starts to operate (ICAP, 2016).

An ETS-sometimes referred to as a cap-and-trade system – caps the total level of greenhouse gas emissions and allows those industries with low emissions to sell their extra allowances to larger emitters. By creating supply and demand for emissions allowances, an ETS establishes a market price for greenhouse gas emissions. The cap helps ensure that the required emission reductions will take place to keep the emitters (in aggregate) within their pre-allocated carbon budget (WB website). A regulatory authority explicitly sets a target level of emissions covering all sources of emission in an industry, a region, or even a country. Permits are then auctioned or issued to each source according to its emissions at some agreed baseline date-a process referred to as 'grand fathering'. Sources are then free to trade the permits, which then command a market price. Sources with low (i.e. below the market price) abatement costs will have an incentive to sell permits and abate their emissions. Conversely, sources with unit abatement costs above the market price will have an incentive to purchase permits in the market. Assuming sources minimize their total production costs, the market for permits is competitive, it can be shown that the overall cost of achieving the emissions target will be minimized.

In theory, the trading of emission permits can be shown to be a least-cost economic instrument for meeting a specified level of reduction of CO_2. When the auction of allowance is 100%, carbon tax and ETS have same function in theory. The system of marketable emission permits allows the regulatory authority to determine the total quantity of emissions, but leaves the precise allocation of the source of such emissions to market forces. This is in marked contrast to the Pigouvian tax where a fee is levied which is equivalent to the marginal social damage of the emissions. The logic underlying a tradable permits scheme is illustrated in Figure 5.

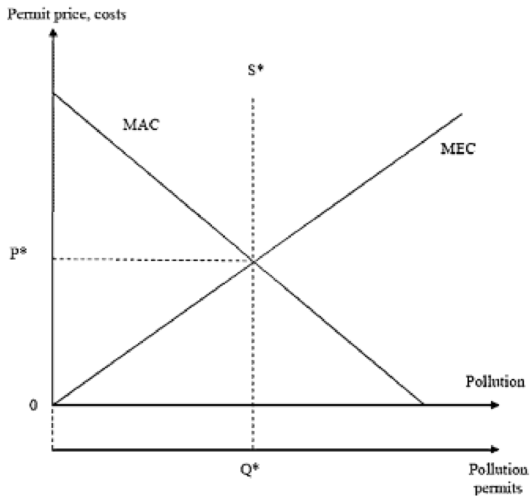

Figure 5 Tradable permits for optimal control of pollution

(Source: Adapted from Owen, 2013)

The aggregate marginal abatement cost (MAC) curve is the cost to the polluters and the number of pollution permits which, for simplicity, are assumed to be measured in a common unit. The horizontal axis measures the level of pollution and the number of pollution permits which, for simplicity, are assumed to be measured in a common unit. Thus one permit is required to permit production of one unit of pollution. Clearly, the optimal number of permits that the regulatory agency should issue to yield the socially optimal level of pollution is 0Q*, with a vertical permit supply function indicating that the issue is independent of price. Thus the equilibrium price of permits will be P*. However, 0Q* is clearly unknown, so in practice the regulator will inevitably set the number of permits at a level which corresponds to a sub-optimal position.

2. POLICY IMPLEMENTATION AND OPERATION OF CARBON PRICING IN KOREA[1]

2.1 Policy progress of carbon pricing in Korea

Korea was the world's seventh largest CO_2 emitter and placed sixth among Organization for Economic Co-operation and Development (OECD) countries in terms of emissions per capita in 2014 (IEA, 2016). In particular, its GHG emissions in 2010 stood at 136% the 1990 figure, placing it in third globally after China (256%) and India (179%) (IEA, 2016).

Despite being classified as a non-Annex I country without GHG reduction obligations under the Kyoto Protocol (2008–2012), Korea has actively responded to the international needs of climate change, set up the national mitigation target by 2020 under the 'Low Carbon Green Growth' national vision announced in 2008, and been establishing a domestic policy framework for promoting energy saving and GHG reduction. In addition, related law named 'Framework Act on Low Carbon Green Growth' was enacted in 2010, in which the GHG mitigation target and introduction of the measurement are stipulated. In 2015, Korea decided its 2030 target of reducing GHG emissions by 37 % from business-as-usual (BAU) levels.

To realize the national mitigation target, Korea's government has started considering the applications of market-based instruments (MBIs) to reduce GHG emissions. In enforcing these policies, the Korean government posits carbon pricing, particularly GHG ETS and carbon tax policy, as key measures to achieve cost effective domestic GHG reductions. In the following sub section, the policy progress and major issues of GHG ETS and carbon tax are provided.

2.2 Korea's Emissions Trading Scheme

2.2.1 Finalised Policy Design of K-ETS

This section provides a summary of the latest scheme design with reference to Suk (2015) and recently released governmental material: Ministry press releases, '2015 KRX Emissions Market Operations Report' report by Korea Exchange published January 2016 (KRX, 2016), amended 'Act on the allocation and trading of greenhouse gas emission (ETS Act)' and 'Enforcement Decree of the Framework Act on Low Carbon, Green Growth (Enforcement Decree of ETS Act)', June 2016.

The strategic action plan to create the institutional framework for a GHG reduction system incorporating ETS to promote a domestic carbon market first took shape through inclusion in the Fourth National Countermeasures on Climate Change in 2008. This led to introduction of a

[1] This chapter is based on the book chapter "Greenhouse Gases Emissions Trading and Carbon Tax Scheme in the Republic of Korea" in the book titled "Economic Instruments to Combat Climate Change in Asian Countries" published at the Wolters Kluwer in 2015.

preparatory ETS programme, named TMS, a mandatory regulation to limit energy consumption and GHG emissions of large energy-consuming entities and business sites, in 2011.

The scheme set out to establish a GHG emissions inventory and management procedures for the monitoring, reporting, and verification (MRV) of GHG emissions, paving the way for full-blown introduction of ETS in Korea. After the start of ETS it targeted companies with high energy intensities not meeting ETS criteria. In May 2012, the ETS bill, namely the 'Act on Allocation and Trading of Greenhouse Gases Emission Allowances' was approved by parliament and, after initial postponement due to heavy opposition from industry, domestic ETS entered into effect from January 2015.

ETS in Korea is a 'cap & trade' system in principle[2]. Six greenhouse gases, namely CO_2, N_2O, CH_4, PFCs, HFCs, and SF_6, are covered under the scheme and gasses generated by both direct and indirect means are targeted by ETS[3]. The commitment period is basically five years except for the first two phases, which are three-year periods of 2015–2018 and 2018–2020. The compliance period is one year during each commitment period. Entities and business sites belong to 23 sectors in five fields: power, public & waste, building, transportation, and industry, and comprise either entities emitting over 125,000 t-CO_2 or business sites emitting over 25,000 t-CO_2 annually on average during 2011–2013.In total, 572 were eligible to trade emissions during the compliance year of 2015, comprising 525 initially designed subjects, 44 facilities newly targeted in 2015 and three public financial institutes—Korea Development Bank, Industrial Bank of Korea and Korea Export Import Bank (KRX, 2016).

While a government estimate predicts national total GHG emissions will reach 776 Mt-CO_2 by 2020, realising the national GHG mitigation target of a 30% GHG emissions reduction compared to the BAU level will require Korea to cut emissions by 233 Mt-CO_2 by 2020, allowing the country to emit 543 Mt-CO_2 in total by 2020 (MOEK, 2014). Based on this the government published the 'National GHG Emission Allocation Plan' in 2014, which was revised to reflect the voice of industry, resulting in an aggregate emissions amount for the first phase (2015–2017) of approximately 1,687 billion t-CO_2, or 76.7% of the total emissions BAU by ETS target entities during the same period (around 2.2 billion t-CO_2). Of this, 1,598 billion t-CO_2 is allocated for the first phase and the remainder emissions (89 million t-CO_2) are allocated as a reserve for additional allocations due to unplanned establishment or expansion of facilities or market stabilisation (MOEK, 2014). The emissions cap drops by 2% for each compliance period of 2015, 2016 and 2017, i.e., individually around 574, 562 and 551 Mt-CO_2. The GHG emissions of regulated entities

2 Article 46 (2) of the Framework Act of 2010 (in Korean)
3 Article 2(9) of the Framework Act of 2010 (in Korean)

accounted for about 66% of the national total (MOEK, 2014).

Allocation was given 100% for free in the first phase (2015–2017) as the test period. In Phase II (2018–2020), 3% of the total emission allowances will be auctioned, rising to 10% in Phase III (2021–2025).

Banking of allowances to the next compliance year and the first year of the next commitment year is permitted, but not permitted between phases. Amounts to be banked are unrestricted and can be carried over on an annual basis to successive years, and allowances can be borrowed between compliance years within each implementation phase for up to 10% of emissions in each compliance year. Companies' emissions reduction activities are recognised as early action credits, and up to 3% of the total allowance will be additionally given. Regulated entities and business sites have been obliged to surrender allowances for each tonne of CO_2 they emit at the end of each reporting year, and are fined three times the average market price of credits to a maximum of 100,000 KRW/t-CO_2 (about 90 USD/t-CO_2; 1,000 KRW = 0.87 USD on April 15, 2016) for any shortfall in allowances in each compliance period.

The government amended the ETS Act and the Enforcement Decree of ETS Act on May 24 in 2016 to allow 20% of borrowing during the first implementation phase due to lack of emissions in the market. It also allows for additional allocation for the companies to submit an application for early reduction activities. Through a revision bill the government has largely reorganised how ETS is managed: the analogy of 'control tower' is given to the Office for Government Policy Coordination for overseeing climate change policy, and the MOSF estabilished a new division, the Climate Change Policy Division in the Future & Social Policy Bureau which is responsible for planning, coordinating, establishing of emission allocation as well as governing inter-ministry coordination for operating emissions trading market and market stabilisation measures, which were originally the responsibility of the Ministry of Environment (MOE) of Korea (MOSF Press, 2016).

The scheme deign, related article number in the 'ETS Act' and 'the Enforcement Decree of ETS Act' and details are given in Table 5.

Table 5 Summary of the final scheme design of Korea emissions trading scheme

Item	Article number in related law	Details	
Basic Plan of ETS (amended)	Article 4 of ETS Act, Article 2 of Enforcement Decree of ETS Act	To be established five-yearly by Minister of MOSF at least a year prior to the implementation period.	
National Allocation Plan	Article 5 of ETS Act, Article 3 of Enforcement Decree of ETS Act	To be completed at least six months before each implementation phase, by Minister of MOSF	
Phase and share of free allocation	Article 13 of Enforcement Decree of ETS Act	Phase	Free allocation
		Phase I: 2015–2017 Phase II: 2018–2020 Phase III: 2021–2025	100% 97% 90%
Target entities and business site	Article 8 of ETS Act	In total, 572 entities emitting over 125,000 t-CO_2 or business sites emitting over 25,000 t-CO_2 annually on average during 2011–2013.	
Allowance in the first phase	Article 12 of ETS Act	In total, 1.687 billion t-CO_2 in the first phase. For each year; 2015: 574 million t-CO_2, 2016: 562 million t-CO_2 2017: 551 million t-CO_2.	
Borrowing (amended)	Article 36 of Enforcement Decree of ETS Act	10% of emissions in each compliance year (20% in first implementation period)	
Banking	Article 28 of ETS Act	Banking of allowances to next compliance year and first year of next commitment year	
Offset	Article 38 of Enforcement Decree of ETS Act	10% of allocated allowances	
Early action (amended)	Article 19 of Enforcement Decree of ETS Act	Approved early actions shall be assigned additionally for second and third compliance year in first implementation period	
Penalty	Article 33 of ETS Act, Article 42 of Enforcement Decree of ETS Act	3x average market price of compliance year and max. KRW 100,000/t-CO_2 (about USD 90/t-CO_2)	
Criteria for carbon leakage industry for free allocation	Article 14 of Enforcement Decree of ETS Act	1) over 5% in carbon intensity and over 10% in trade intensity; or, 2) over 30% in carbon intensity; or, 3) over 30% in trade intensity.	
Linkage with international carbon market	Article 36 of ETS Act, Article 45 of Enforcement Decree of ETS Act	The government should endeavor to operate the domestic market in conjunction with international carbon market credits, and conduct research, studies and work related to technology development and international cooperation.	

Source: Author listed based on the ETS Act 2016 and the Enforcement Decree of ETS Act 2016

2.2.1 ETS operation and emissions trading results in early compliance years (2016-2016)[4]

Korea's emissions trading market was officially opened on 12 January 2015, with the Korea exchange (KRX) being appointed as the official exchange platform in the previous year. The trade units are *Korea Allowance Units (KAU)*; with 1 KAU equal to 1 tonne of CO_2. From April 6 in 2015, offset credits (*Korean Offset Credit (KOC))* were approved to be converted as *Korean Credit Units (KCU)*, which became tradable on the KRX. Thus both KAU and KCU can be transacted in the KRX and over the counter (OTC). OTC trading is a method of trading that does not take place in an organised exchange, and instead involves bilateral trading in permanent structures such as systematic internalisers and broker networks (Emissions-EUETS.com website).

The overall trading performance during the first compliance year of ETS was low. In total 1.24 Mt-CO_2 was traded, of which KAU comprised about 0.32 Mt-CO_2 and KCU 0.92 Mt-CO_2, which shows that the proportion of KCU transactions is three-fold greater than KAU. The total KAU allocated for 2015 was about 546 million, of which only 0.06% was actually traded. Given that the converted offset credit in 2015 was about 1.64 M KCU, 56% thereof was traded (KRX, 2016). Overall, less than 0.3% of the total allocation was traded in the market during the first compliance year of ETS. The OTC market was used predominantly, and of the total traded CO_2, 1.19 Mt-CO_2, or 96% was traded through bilateral OTC negotiation (KRX, 2016)—an experience similar to ET-ETS. In EU-ETS, the OTC platform was used during its early phase and still accounts for the virtual market, although the share of exchange emissions volume through organised exchanges such as the ECX and London exchange gradually increased (Ellerman, and Joskow, 2008). Based on interviews with companies participating in emissions trading in Korea, the main reason cited was that OTC is preferred due to its procedural convenience for large-volume transactions, while the maximum amount of registerable emissions on the KRX is limited to 5,000 t-CO_2. As shown in Figure 6, a large amount of emissions were traded via OTC. Another reason companies chose OTC was because it allows negotiation over price, when compared with the market price, and provides flexible contracts to which extra conditions can be added.

The price of KAU started at 8,640 KRW (about 7.5 USD) on the first day of trading in 2015, then rose to around 10,000 KRW soon after and remained stable throughout the year apart from a December high of 12,300 KRW (about 10.7 USD). The price of KCU was generally higher than KAU—and reached 9,600 KRW (about 8.3 USD) on the first day of listing and climbing gradually thereafter to 13,700 KRW (about 11.9 USD) in the last month of the compliance period. The price

[4] This part is cited from "The Korean emissions trading scheme: business perspectives on the early years of operations" published at the Journal of Climate Policy in 2017 by co-authors, Suk Sunhee, Lee Sang-youp, and Yu Shim Jeong.

fluctuations of KAU and KCU throughout the period are shown in Figure 6.

According to a KRX report (2016), it was revealed that the average trading signed price for KAU and KCU differed, in that the OTC price was higher than that of the KRX. Average KAU prices upon start of trading were 10,998 (about 9.6 USD) on the KRX and 12,073 KRW (about 10.5 USD) via OTC; for KCU, the same were 10,815 KRW (about 9.4 USD) and 12,637 (about 11.0 USD) KRW (KRX, 2016).

From January to March, KAU and KCU trading reached levels of 101,600 t-CO_2 and 602,978 t-CO_2, respectively, and in April alone was about 87,800 t-CO_2 and 320,000t-CO_2. During June, 1.66 million tonnes were traded (Lee, 2016). During this period, a total of 3.6 Mt-CO_2 was traded, a three-fold increase since the compliance year of 2015. Since January 2016 the price of carbon increased and hit 19,000 KRW (about 16.6 USD) per t-CO_2 in April 2016, for an 88% Year-on-Year increase over the price in the same month one year previous (10,100 KRW, about 8.8 USD) (Lee, 2016). However, this price does not always show the closing price of the transaction but is the 'sell' price set by the provider. During the interview we found some companies sometimes artificially inflated prices on the KRX to obtain profit therefrom, based on the fact that the OTC transaction price is index-linked with the KRX.

The total amount of KAU16 transactions for six months from July 1 to December 29 in 2016 totaled 1.26 Mt-CO_2, which is nearly four times that for 2015 (January to December)—0.32 Mt-CO_2. In this period, the price of KAU16 was 13, 000 KRW in July and rose to 19,300 KRW at the end of year, which is higher than the average trading price of KAU15 (10,998 KRW) in 2015. The price fluctuations and trading volume of KAU and KCU by quarter in 2015 and 2016 are shown in Figure 6.

According to a governmental analysis of emission statements submitted by ETS companies (523) up to June 2016, 407 companies out of 522 had reportedly met the emissions allowances allocated by the government (Cnews, 2016). Of the remaining, 115 contested the quota and were thus not included in the aggregate, 66 met the emission allowances, and 49 companies slightly exceeded the emission allowance basis. Among the industry and power sectors, of the total 402 companies under ETS, excluding the 78 companies raising complaints regarding allocations, 324 had completed the submission of verified emission credits meeting the emissions cap by June 30 (Lee, 2016). As of June 2016, despite initial concerns from businesses over allocated emission allowances being too low, 290 companies (55.6%) had allocations to spare, and most (227) of these banked their excess emissions to the next compliance year. Whereas companies that lacked in emissions (232, or 44.4%) amounted to 11 Mt-CO_2, and of these, 183 borrowed emissions from the next compliance year or purchased them on the market. Although the results may have been influenced by the economic recession, emissions allowances during the first year of ETS were over-allocated by about 17 M t-CO_2 overall (Hankokilbo, 2016). In terms of market stabilisation measures, the government increased the borrowing limit from 10% to 20% for the first compliance year, and released 90 million tonnes of additional emissions from market reserves (Kyunhhyang, 2016).

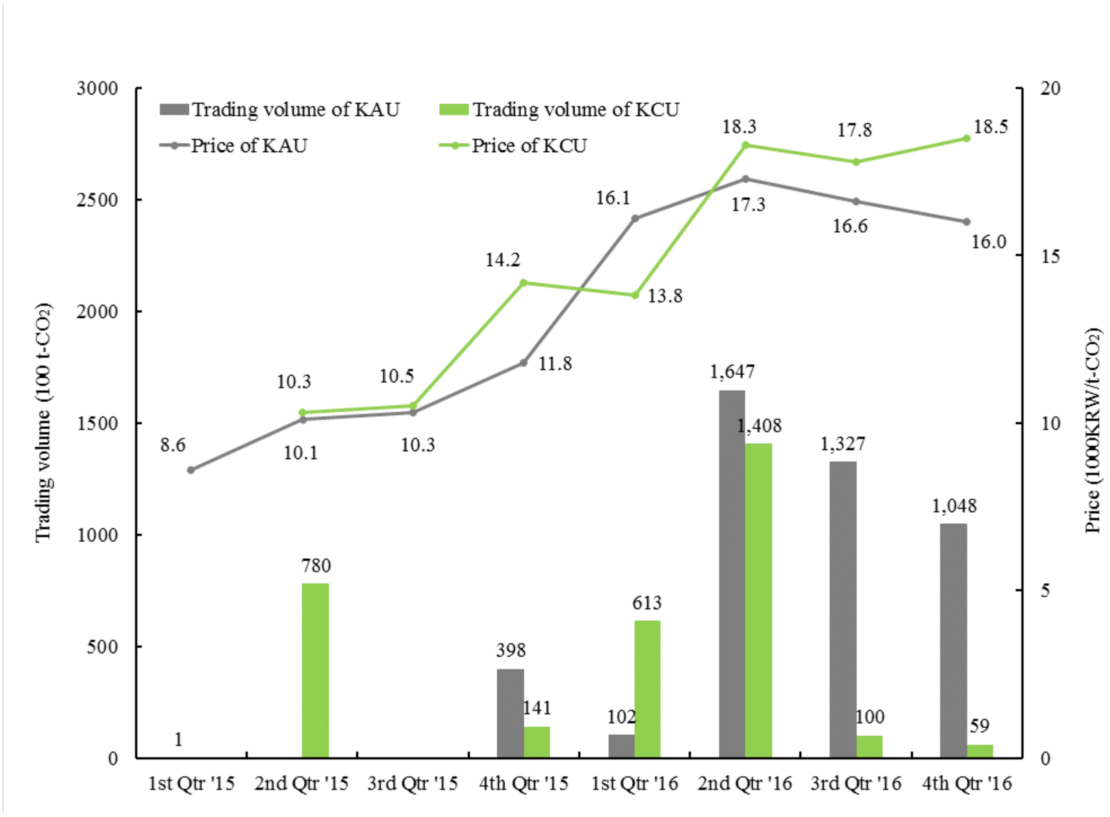

Figure 6 KAU15 price and trading volume during compliance year 2015 (12 January - 31 December) under the ETS

(Chart devised by author based on KRX data)

2.3 Deliberations on Carbon Tax Policy in Korea

2.3.1 Current Energy Taxation System

The existing energy price system was designed based on energy policies that prioritize price stability and domestic industry development over energy saving and environmental damage and is overly complex, as indicated in Table 7. Several taxes, including the transportation-energy-environment tax, individual consumption tax, education tax, local motor fuel tax, value-added tax (VAT) and tariff, and various charges are applied to energy resources. This system has been criticized as not truly reflecting the social cost of climate change in energy prices (Kim and Kim, 2010).

The transportation-energy-environment tax[5] is an energy-environment related tax imposed on the consumption of gasoline and diesel on a per-litre basis. Originally introduced in 1993 as a transportation tax, it was designed to fund public transportation infrastructure such as roads and railways, with the revenue thereafter going to the 'Transportation Facilities Special Account'. The tax assumed its current appellation in 2007 and is scheduled to be abolished by 2015.[6]

2.3.2 History of and Deliberations on Carbon Tax Policy

After the signing of the UNFCCC in the early 1990s, the MOE studied adopting and modifying the carbon tax policy that had been introduced in Europe. Much research covered the adverse impacts of a carbon tax on domestic industries; however, the necessity of its introduction in the near future in response to strengthened global environmental regulations was widely agreed on (KEEI, 1993a, 1996, and 1997). KEEI analyzed the economic impact and policy challenges in implementing a carbon tax, and concluded economic loss would be greater if it was not introduced (KEEI, 1993b). The introduction of a carbon tax by reforming the energy taxation system has been considered from 2000 in Korea. The Presidential Commission on Sustainable Development suggested integrating various charges on water, air pollution, and waste into an environmental tax under the 'Plan of Green Taxation Reform for Sustainable Development' (Yonhap News, 1999). KEEI recommended reforming the current tax system and applying an energy tax and carbon tax to energy sources based on fuel type and carbon content. In 2001, the government announced a plan to reorganize the energy price system into one adjusted for relative price ratio between energy sources and increase prices gradually over the subsequent six years from July 2001. The prices for gasoline, diesel, LPG, kerosene and B-C oil are to be respectively set in the proportions of 100:75:60:55:23, as indicated in Table 6 (Yonhap News, 2000). The reform omits any carbon tax and only covers the traffic and transport sectors. Discussions on the introduction of a carbon tax that includes non-transportation sectors in the near further are emerging (Seoul Economic News, 2005).

Table 6 Relative Energy Price Ratio

(Price: KRW)

Year	Gasoline	Diesel	LPG for Transportation	Kerosene	B-C Oil
1999	100 (1279)	47 (604)	26 (337)	40 (517)	22 (276)
2001	100	52 (663)	32 (409)	43 (548)	-
2006	100	75 (959)	60 (767)	55 (703)	23 (298)

Source: (Yonhap New,1999)

5. Transportation-energy-environment tax law, Law number of 11690 of 1993 (last amended 23 March 2013) (in Korean).
6. Annex (2) of the Transportation-energy-environment tax law of 1993 (in Korean).

In 2003, President Noh Moo-hyun (2003–2007) supported the introduction of an environmental tax on fossil fuels during his term (HankookIbo, 2003). MOE under the Noh's government proposed a draft Framework Act of Climate Change that incorporated a carbon tax proposal. Industrial lobbying (KCCI, 2004), however, stalled the introduction of a carbon tax and further strategies and plans were excluded from the third Comprehensive Plan on Countermeasures to Climate Change (2005–2007), which addressed statistical system preparation for the GHG inventory (MOEK, 2005).

Table 7 Taxes and Charges in the Energy Price as of 2012 in Korea

		Gasoline	Kerosene	Diesel	Heavy Oil	LPG		LNG	Briquette	Electricity		Heat
						Profane	Butane			Household	Night	
		KRW/L	KRW/L	KRW/L	KRW/L	(KRW/Kg)		KRW/m^3	KRW/Kg	(KRW/kWh)		KRW/10000Kcal
Tariff	Basic rate	Crude oil 3%, petroleum product 5%				3%		3%	-	-	-	-
	Quota	Crude oil 3%, petroleum product 5%				Product 0%		2%	-	-	-	-
Individual Consumption	Basic rate	-	90	-	17	20	252	60	-	-	-	-
	Elasticity	-	90	-	17	20	275	60	-	-		
Transportation-Energy-Environment Tax	Basic rate	475	-	337	-	-	-	-	-	-		
	Elasticity	529	-	375	-	-	-	-	-	-		
Education Tax		79.35	13.5	55.25	2.55	-	41.25	-	-	-		
Local Motor Fuel Tax		137.54	-	97.5	-	-	-	-	-	-		
Value-Added Tax (VAT)		164	107	149	93	118	157	110	-	12	6	73
Import surcharge		16	16	16	16	-	-	24.2	-	-		
Quality Inspection Charge		0.47	0.47	0.47	0.47	0.0027	0.027	-	-	-		
Safety Control Charge		-	-	-	-	4.5	4.5	4.9	-	-		
Sale Charge		(36)	-	-	-	-	62.28	-	-	-		
Electric Power Industry Foundation Fund		-	-	-	-	-	-	-	-	4.44	2.14	
Sum	Price	926.36	226.97	694.22	129.02	142.53	540.06	199.1	-	16.44	8.14	73
	%	51.30%	20.20%	42.20%	12.70%	11%	29.50%	16.40%	-	12%	12.30%	8.43%
Retail Price (July 2012)		1,804	1,122	1,642	1,019	1,300	1,834	1,214	391	167	66	866

Source: KEPCO, 2014

After the enactment of the Kyoto Protocol from February 2005, it was widely understood that Korea would be classified into the group with obligations for GHG reduction in the protocol's second commitment period (post-2013) and that preparations therefor should begin. In 2006, MOSF announced a long-term tax reform plan that embraced a carbon tax introduction from 2008 in the form of a tax supplementary to the transportation tax and a special consumption tax (Special Committee for Tax Reform, 2005). In December 2007, Noh's government confirmed the Forth Comprehensive Plan on Countermeasures to Climate Change (2008–2012). The plan involved a total reduction of 72Mt-CO_2 by 2012, which included 1.8Mt-CO_2 via industrial voluntary reduction activities, and establishment of a Framework Act of Climate Change (tentative name) by 2009, which outlines the introduction of a carbon tax via replacement of the current transportation-energy-environmental tax (Money Today News, 2007).

However, the succeeding president, President Lee, conducted an overhaul of all GHG reduction policies and revised the Fourth plan established under the former government. As mentioned earlier, Lee's government transformed the energy efficiency policies from voluntary agreements (VAs) to NAs centered on ETS, and placed emphasis on ETS system construction in view of participation in the international carbon market (Seoul News, 2008). Plans to introduce a carbon tax were once more shelved. Meanwhile, Lee's government initiated a three-year project spanning 2008–2010 to explore energy tax reform and discussed scenarios for introduction of a carbon tax in Korea. The project was mainly conducted by the KIPF, and a report issued therefrom suggested a scenario in which a carbon tax would be introduced in 2013 and replace the extant transportation-energy-environment tax, with lower tax rates applying in the early stage (nearly KRW 4,000/t-CO_2) in light of policy acceptance and minimizing negative impacts (Kim and Kim, 2010).

Policymakers are becoming increasingly involved in the carbon tax debate. During the latest presidential election of 2012, major political parties, i.e., the Saenuri Party as the ruling party and the Minjoo Party as the leading opposite Democratic Party, examined a transition from the current transportation-energy-environment tax to a carbon tax (Korea Times, 2012). A minor opposition party, the Progressive Justice Party, also pledged to introduce a carbon tax as part of its manifesto in the presidential election campaign (Tax Daily, 2012).

In 2013, the Progressive Justice Party submitted two proposals on carbon tax introduction to the National Assembly: 'Carbon Tax' and 'Climate Justice Tax'. The taxes were to be levied on the carbon content of various energy sources, with rates calculated based on a 2008 KIPF study analyzing EU-ETS carbon pricing (25 Euro/t-CO_2, equivalent to KRW 31,328/t-CO_2). It is worth noting that environmental taxes on polluting activities can offer additional benefits, i.e. the so-called 'double dividend', entailing improvements in the environment and economic efficiency by the use of environmental tax revenues to reduce other taxes, such as income tax. However, while both proposals mentioned above do not do away with income or corporation tax (as they were already decreased in the early stages of Lee's government from 2008), they differ in the target energies for taxation and tax accounts for the utilization of tax revenues. Details are provided in Table 8, which also compares them in scope with the extant energy taxes (Park, 2015), (Shim, 2013). Table 9 compares the tax rates.

Table 8 Comparison of Carbon Tax and Climate Justice Tax Proposals

Item	Existing Energy Taxation*	Carbon Tax**	Climate Justice Tax***
Date of bill proposed	-	July 10, 2013	June 28, 2013
Date of proposed start of tax	-	January 1, 2016 (Annex: Article 1)	January 1, 2014 (Annex: Article 1)
Account	Special account for social infrastructure	General account	Special account for climate change
Target energy sources	Gasoline, Diesel, Kerosene, B-C oil, Butane, Profane, LNG	In addition to those under energy taxation, Jet fuel, Naphtha, Nuclear fuel (Article 2)	In addition to those under energy taxation, Briquette, Anthracite, Electricity (Article 2)
Tax payer	Consumer	Energy and fossil fuel supplier (Article 3)	Energy and fossil fuel supplier (Article 3)
Tax rate	-	10% of 2008KIPF proposal (Article 2)	10–30% of 2008KIPF proposal (Article 2)
Expected total tax revenue	Approx. KRW 22 trillion	Approx. 4.5 KRW trillion during 2016~2021	Annual approx. KRW 5.0 trillion for the initial period
Revenue recycle	For prevention of environmental pollution and building/maintenance of transportation infrastructure	For sustainable development and climate change mitigation /adaptation policies, renewable energy technologies development, and energy welfare	For CO_2 reduction, energy transformation from nuclear power, energy welfare and green growth for industry

Source: *(Kim and Kim, 2010), **(Shim, 2013), ***(Park, 2015)

The Carbon Tax is intended to be levied on coal and electricity on top of existing energy taxes, and incurs a tax rate of KRW 3,000/t-CO_2 (about USD 2.6/t-CO_2, around 10% of the tax rate initially proposed by KIPF) in initial years, which would then be ramped up. The tax payers are energy and fossil fuel suppliers. The total estimated income from the carbon tax would be between KRW 0.96 and KRW 1.2 trillion annually, with revenues entering the special account for use according to sustainable development and climate change policies (Shim, 2013). The tax was assumed to enter into effect on January 1, 2016. Kim (2013) evaluated the effect of this bill by extrapolating 2009 input-output data and indicated a maximum mitigation rate of 3.59% in GHG emissions from the base scenario with no carbon tax levied (Kim and Kim, 2010).

The Climate Justice Tax proposal includes a nuclear fuel tax on nuclear power plants, with tax rates of KRW 2.5–7.5/kWh initially and rising to KRW 25/kWh to prevent nuclear power plants from being relatively cheaper than the other energies levied. This equates to a tax rate of around KRW 3,000–9,000/t-CO_2, which is 10%–30% of the earlier KIPF proposal. Different rates apply to different energy sources – a lower tax rate on anthracite and kerosene for heating and a higher rate for coal and nuclear power. The bill estimated a total revenue of KRW 5.3 trillion per year in the first period. This proposal addressed the recycling of revenue under the special account for climate change policies and energy transformation from nuclear power (Park, 2015).

Table 9 A Comparison of Tax Rates of Different Proposals

Energy Type	Unit	Energy Taxation* (VAT Excluded)	KIPF Proposal*	Carbon Tax**	Climate Justice Tax***
Gasoline	(KRW/L)	745.0	67.5	6.7	8
Diesel	(KRW/L)	528.0	82.4	8.2	11
Kerosene	(KRW/L)	104.0	77.7	7.8	0
B-C oil	(KRWL)	20.0	95.5	9.5	19
Butane	(KRW/L)	185.0	53.2	5.3	10
Profane	(KRW/Kg)	20.0	92.0	9.2	15
LNG	(KRW/m^3)	60.0	71.0	8.8	5
Briquette	(KRW/Kg)	-	33.7	3.3	15
Anthracite	(KRW/Kg)	-	-	5.8	0
Electricity	(KRW/kWh)	-	-	1.4	-
Jet fuel	(KRW/L)	-	-	-	15
Naphtha	(KRW/L)	-	-	-	14
Nuclear fuel	(KRW/kWh)	-	-	-	12

Sources: * (Kim and Kim,2010), ** (Shim, 2013), *** (Park, 2015)

These two tax proposals are, however, still held up in the National Assembly, and carbon pricing policy progress has been dominated by ETS in recent years in Korea.[7] Deliberation on carbon tax will likely resurface before the transportation-energy-environment tax ends, at the close of 2015.

2.3.3 Carbon Tax on Vehicles

In 2010, MOE proposed a carbon tax on vehicles (the 'low carbon car incentive scheme'[8]) as one of GHG emission reduction measures affecting the automotive-transport sector. The carbon

7. National Assembly pending status: available at: http://likms.assembly.go.kr/bill/jsp/BillDetail.jsp?bill_id=PRC_V1T3N0C6I2M8T1D7I3C0S1D3F9D0W0.
8. Article 76 (7 and 8) of the Clean Air Conservation Act, Act number of 12248of 1990 (last amended 14 January 2014) (in Korean).

tax system is designed to subsidies consumers purchasing cars with low carbon emissions, and conversely, tax those purchasing cars with high emissions. Of the total MOE budget for 2013 (6.2 trillion), KRW 151.5 billion was allocated for this scheme (MOEK press, 2012), which the MOE estimated would yield a CO_2 saving of 1.6 million tonnes by 2020 if implemented. In August 2012, an amendment to the 'Clean Air Conservation Act'[9] containing an outline of the low carbon car incentive scheme was passed by the National Assembly and approved for promulgation from July 2013. However, it met heavy resistance from domestic carmakers, which resulted in the implementation period being delayed until January 2015 (MOEK press, 2013). According to the Korea Economic Research Institute (KERI), based on a price comparison of domestic and imported cars, those buying imported cars will be less burdened (KERI, 2014). The taxes imposed on vehicles are projected to total KRW 2.4 trillion by 2020, 83% of which would come from domestic car sales (JoongAng, 2014). Most of the gasoline-fueled, low-mileage cars are domestically produced, while high-mileage hybrid cars are imported, primarily from Germany and Japan, which would be disadvantageous for domestic car makers under the scheme. In the end, the government has since further delayed the above implementation by over five years to the end of 2020 out of fear of overburdening Korean industry if launched concurrently with the carbon trading scheme.

9. Clean Air Conservation Act of 1990 (in Korean).

CHAPTER IV: EMPIRICAL STUDIES AND RESUTLS

1. KOREAN COMAPANIES' UNDERSTANDING OF CARBON PRICING AND ITS INFLUENCE ON POLICY ACCEPTANCE AND PRACTICES[10]

[Abstract]

In response to climate change, Korea is attempting to shift the paradigm of energy and climate change policies by introducing carbon pricing based on market mechanisms. While policy adoption is proceeding at a rapid pace, the introduction of carbon pricing has been faced with great opposition from industry.

This study measures to what extent Korean companies understand and accept carbon pricing, using data from a questionnaire survey covering energy consuming companies in 2012, when discussions between the government and such companies about the introduction of a domestic emission trading system were active. It further identifies how preparations and practices for carbon and energy management of companies correlate with their policy understanding and acceptance.

The analysis results show that the surveyed companies indicate moderate understanding of, as well as resistance to carbon pricing policies, while appreciating the economic incentives and accepting the mandatory regulations in this phase. Companies' understanding is more related to characteristics, i.e., sector, size, etc. than external pressures. This study found that the extent to which companies understand policy is the essential factor in their policy acceptance and related practices. In particular, understanding of carbon policy significantly influences their managerial practices and voluntary activities for carbon and energy practices.

This study reveals the level of understanding and acceptance of carbon pricing, as well as the status of carbon and energy practices of Korean companies in the early phase of introduction of carbon pricing. It also further substantiates the correlation between the level of policy understanding of a company and its carbon and energy practices – something that all countries seeking to introduce carbon pricing in response to climate change should consider prior to policy actually being implemented; in other words, enhancing the understanding of major policy subjects of the new instrument is a key policy strategy that should be elaborated as it will lead to better performance of companies and smoother policy implementation.

Key words: Carbon pricing, industry, policy understanding, policy acceptability, Korea

[10] This part is cited from "Korean companies' understanding of carbon pricing and its influence on policy acceptance and practice" submitted to the Journal of Environmental and Resource Economics Review on 21 June, 2017 and the first review has been done.

1.1 Introduction

The Republic of Korea (hereinafter referred to as Korea) was the world's seventh largest CO_2 emitter in 2014 and placed sixth among the Organisation for Economic Co-operation and Development (OECD) countries in terms of emissions per capita. In particular, its greenhouse gas (GHG) emissions in 2010 stood at 136% of the 1990 figure, placing it third globally after China (256%) and India (179%) (IEA, 2016). In response to climate change, Korea embodied climate change policies by positing carbon pricing, such as carbon tax and GHG emission trading scheme (ETS), as a key measure in the fourth National Countermeasures on Climate Change established in 2008. Whilst its energy and climate policies had mainly been based on voluntary approaches, through strong governmental support, a domestic ETS was initiated in 2015. Further, starting in 2020, a low carbon car incentive scheme, or so-called 'vehicle carbon tax', will go into effect (MOEK, 2014).

The principal appeal or inherent advantage of using prices to induce carbon abatement is that this encourages emission reductions where they are cheapest, both in the sense of using the cheapest options currently available and steering innovation and investment towards lower-carbon technologies. By using carbon pricing, the Korean government expects to achieve its GHG mitigation target in a cost effective way and bring about a paradigm shift in domestic industry toward sustainable economic development. The government also puts a premium on the utilisation of carbon pricing as a way of providing incentives for companies to reduce GHG emissions.

However, the government's intentions and expectations on carbon pricing have been met with heavy resistance from domestic industry, which has delayed or watered down the proposals – domestic ETS was revised twice and the low carbon car incentive scheme, initially due to start in 2013, was pushed back to 2015 and then again to 2020. Industry mainly argued that the weight of the restrictions will mean the aforementioned inherent advantages of market-based policies will not be realised, and that industrial competitiveness will be weakened due to lack of sufficient readiness (FKI, 2015a).

Given the accountability of industry regarding energy consumption and GHG emissions in Korea, acceptance of policy and related practices on the part of companies is essential for successful policy implementation and goal realisation. Therefore, the response of companies to policy shifts in climate change using market mechanisms is an issue that has drawn much attention in the academic field of environmental economics. World literature has identified and discussed a variety of determining factors that both stimulate and hinder companies' proactive environmental management and strategy (González-Benito and González-Benito, 2006). Nevertheless, clarification is lacking as to why companies do not welcome carbon pricing, which is thought to be more advantageous than existing regulations, as has been emphasised by governments.

Usually, in order to draw up business strategies and practices in response to new governmental policy, companies first need to undergo a procedure of recognition, understanding and acceptance of such policy. When it comes to carbon pricing, however, a clear and thorough understanding of such policy is even more critical since companies need to proactively apply their collective business acumen to take full advantage of any available incentives by trading as a respected player in the carbon market. In Korea, discussions surrounding the introduction of carbon pricing and its actual introduction came about very suddenly, which means any given company may have lacked the necessary time for full comprehension and for preparing the requisite systems. Some studies have covered this lack of ability to deal with sudden shifts in policy (Suk et al., 2013, Hong, 2010), and from a certain perspective it could be considered natural that in the absence of full understanding of such policies, companies would perceive carbon pricing as a mere regulatory measure and react to such in knee-jerk fashion.

To be able to grasp the level of perception of policies among companies and how such affects their performance is a key factor in and prerequisite to addressing improvements to the related policies and system, and eventually to successful policy implementation and further practices. Previous studies measured awareness and acceptability of market-based instruments among companies in China and Japan (Liu et al., 2013a, Liu et al., 2014b). However, such studies contained several grey areas – such as precisely how a company's understanding of policy actually affects its behavior, when based on the premise that company awareness did not necessarily influence their policy acceptance. Consequently, the decision to measure them individually was taken.

Therefore, by expanding on the previous studies, this study sets as a premise that companies with better understanding of carbon pricing may adopt corresponding strategies via their policy acceptance. In other words, a company's acceptance and behavior may reflect their understanding, or further still, the choices it makes in response to internal and external stimuli. In this context, the purpose of this paper is to reveal the levels of understanding and acceptance of carbon pricing of Korean companies, and clarify how they are related with pre-classified determinants. It also aims to identify to what extent a company's understanding of policy leads to its acceptance and actual carbon and energy practices. This paper is organised as follows. Section 2 provides an overview on the Korean climate change policies targeted in this study. Section 3 explains the research method and analytical framework for regression analysis, and outlines the questionnaire survey and samples used in the study. Section 4 discusses the statistical results of companies' understanding and acceptability of carbon pricing, and the status of companies' carbon and energy performance, and the regression results of analyses of determinant factors. Lastly, section 5 concludes the study.

1.2 Literature review and related policy overview

1.2.1 Literature review on the determinants of companies' energy saving and GHG mitigation

This section provides a literature review on the factors affecting the companies' behavior of existing energy management. Strategic corporate responses to environmental challenges do not seem to be the primary domain of corporate management (Aggarwal and Dow, 2012). Companies feel 'Going green' is an activity requiring extra-effort and keen managerial focus (Kock et al., 2012). However global warming and the associated increase in the requirements posed to companies brings about that, to deal with growing competitiveness and, simultaneously, to stand out on the turbulent market, a lot of them implement the concepts underlying not only the economic context of company activity but also company responsibility for the condition of natural environment (Romanowska 2004).

The green business literature usually makes a distinction between companies that are compliance-driven, and merely aim to meet legal requirements, and those that adopt more proactive environmental strategies (Schot and Fischer, 1993). For the proactive environmental management and strategy, the international literature indicates a variety of determinant factors both stimulating and hindering. The measure of a sincere environmental proactivity should not only be based on the external but also on an analysis of the environmental transformations accomplished in the operations and production system. Carrion-Flores and Innes (2010) confirmed tightened pollution targets induce environmental innovation which is an important driver of pollutant reductions. The level of energy prices affects low-carbon technology investment decisions of energy-consuming industries. (Suk, 2016).

Aggarwal and Dow (2012) revealed institutional ownership and board entrenchment seem to significantly influence climate change and environmental impact mitigation policies of large firms. Brunnermeier S. and Cohen M (2003) found the determinants of environmental innovation of US manufacturing that are increases in pollution abatement expenditures and international competitive. Quazi et al. (2001) claim that the top management concern for the natural environment strongly discriminates between companies that have adopted the ISO14001 standard and companies that have not. Similarly, De Brio et al. (2001) find that the higher the commitment of managers and their awareness of the advantages, disadvantages and tools of environmental management, the higher the formal importance they give to this question within the organization. Buysse and Verbeke (2003) evaluates the relationship between the level of reactiveness of environmental strategies and the importance to stakeholders using survey data from Beligian firms and found that companies adopting an environmental leadership strategy clearly view as critical a broader range of stakeholders. Cole et al. (2007) found that foreign ownership per se does not influence fuel use or total energy use but is found to increase electricity use, perhaps the cleanest form of energy used.

Meanwhile, the relationship between stakeholder pressures and environmental strategy tends to vary with size of companies (Darnall et al., 2010). Large European companies have established management systems and processes necessary to respond to regulations and reduce GHG emissions (Sullivan, 2009); meanwhile, small, finance-constrained companies are more susceptible to economic incentives than their larger and financially less-constrained counterparts (Skuras et al., 2006). González-Benito and González-Benito (2006) reviewed determinant factors of environmental proactivity and found that managerial attitude and motivations, and strategic attitude have been considered as relevant for the selection of environmental strategies.

1.2.2 Climate change policies and measures in Korea

Korea has promoted energy and climate change policies through various policy instruments, including market based instrument (MBIs), command and control regulations (C&Cs) and voluntary approaches (VOAs). Among them, representative policies are listed in the survey in order to comprehend the degree of a company's understanding and acceptance. For the MBIs, six existing incentive-based MBIs and two carbon pricing MBIs (ETS and carbon tax) are included. For the C&Cs and VOAs, three main policies for each are selected.

The descriptions and abbreviations of policies in this survey are listed in Table 10.

Table 10 Descriptions and abbreviations of policies covered in this survey

Category	Description	Abbreviation
Command and control (C&Cs)	GHG-energy target management system	C&C01
	Energy use reporting system	C&C02
	Energy audit requirement	C&C03
Voluntary approaches (VOAs)	Voluntary agreement on energy saving	VOA01
	Training for energy managers	VOA02
	Green company designation	VOA03
Market-based instruments (MBIs)	Subsidies for maintenance, improvement and replacement of energy saving facilities	MBI01
	Soft loan for investment in energy saving facilities	MBI02
	Soft loan for installing high-efficiency production facilities and equipment	MBI03
	Grant for high energy-efficiency products	MBI04
	Soft loan for energy saving companies (ESCO) projects	MBI05
	Tax reduction for investment in energy-saving facilities	MBI06
	Carbon tax	MBI07
	GHG emission trading scheme	MBI08

Command and control regulations (C&Cs)

C&C01 is a GHG-energy target management system (TMS), started in 2011, and which controls large energy consumers by capping their GHG emissions and energy consumption. TMS is the preparation system for GHG ETS introduction. C&C02 (Energy use reporting system) is a mandatory requirement for companies and buildings consuming over 2,000 toe (tonnes of oil equivalent) annually to report their annual energy consumption, energy savings, investments in facilities and production to the government. C&C03 (Energy audit requirement) requires business sites to assess their energy consumption status and saving potentials and make plans for improving energy efficiency by receiving consulting services.

Voluntary approaches (VOAs)

In 1998, the Voluntary Agreement (VA) system (VOA01) was adopted based on the 'Energy Use Rationalisation Act' to accelerate companies' voluntary energy saving activities. The system initially targeted business entities with an annual energy use of 5,000 toe or more, but has since reduced this figure to 2,000 toe to broaden the number of industries targeted. The government provides training courses (VOA02) targeting energy managers within companies to provide them with information on energy efficiency improvements, climate change conventions and renewable energy, and so on. Green Company Designation (VOA03) is a system that certifies a company that radically reduces its pollutants, resource use or energy consumption for environmental improvement as a "Green Company".

Market-based instruments (MBIs)

The Korean government provides financial support for companies investing in energy saving facilities to cover a portion of project costs in the form of a subsidy, grant, or long-term, low-interest loan under the funding system of energy use rationalisation. The scale of the government's budget is about 350 billion KRW per year, and this amount is trending down. Under this scheme a company seeking project funding submits an application to Korea Energy Management Corporation (KEMCO). Categories of projects eligible for financial support in the form of soft loans are as follows: Energy saving companies (ESCO); investment projects (MBI05); approx. six categories of projects (covering energy-saving facility replacement, insulation renewal/maintenance, IT-based energy saving, new/renewable energy facilities, GHG reduction installations, and miscellaneous energy efficiency improvements); Energy-saving facility installation projects, for example, energy management system (EnMS), heat cogeneration facilities, compressors, etc. (MBI02, Soft loan for investment in energy saving facilities); and, Manufacturing facility installation projects of small and medium-sized enterprises (SMEs) for products with the highest efficiency ratings (MBI03, Soft loan for installing facilities and equipment for high-efficiency production). Companies designated under the TMS can apply for the MBI01 (Subsidies for TMS companies for maintenance, improvement and replacement of energy saving facilities) for introducing or replacement of energy saving facilities. MBI04 (Grant for high energy-efficiency products) is a grant for companies installing high energy-efficiency equipment and products, e.g., LEDs, inverters, transformers and freezers. MBI06 (Tax reduction for investment in energy-saving facilities) is a preferential tax policy to promote business competitiveness through energy saving by providing a 10% corporate income tax deduction in accordance with level of energy saving achieved by a company. As for carbon pricing, carbon tax and GHG ETS are included in this study. It should be noted that at the time of the survey (25 January to 10 February 2012), while other MBIs (MBI01-06) had already been introduced, carbon pricing had not. For the carbon tax (MBI07), Korea Institute of Public Finance (KIPF) proposed a low tax rate (approx. 3 USD/CO_2-t) for the initial stage with a tax revenue equating to 2% of Korea's GDP in 2010 (Kim and Kim, 2010), which became the basis of the carbon tax proposals in Parliament in 2012. MBI08 is the GHG ETS, and at the time of the survey, introduction of ETS in Korea was a heavily debated topic. Since then, in May 2012 the Korean National Assembly approved the 'Greenhouse Gases Emissions Allocation and Trading Act', which led to the formal introduction of domestic ETS from 2015.

1.3 Research Method and Materials

1.3.1 Analytical Framework

Expanding previous study of Suk (2013), the analytical framework of this study is developed based on the institutional theory and shown in Figure 7.

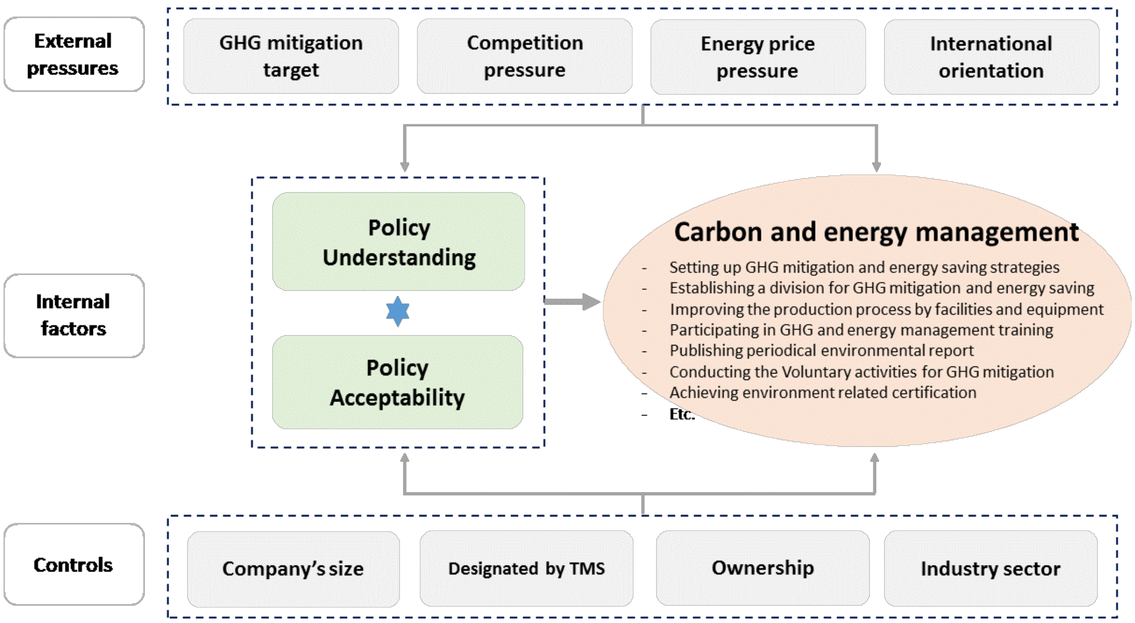

Figure 7 Analytical Framework

Instigating a shift in business strategies and practices may not be realised ahead of broad-based awareness and understanding on the part of companies of such new policies or social norms. Based on this precept, a company's acceptance of certain policies would naturally be determined according to how they impact on its comparative competitiveness, either experienced or perceived. In other words, preceding a company's understanding and acceptance of the need to implement environmental management is the need for an institutional behavioural transformation within the industry at large. Although the former does not automatically follow as a consequence of the latter, it may factor in to a certain extent. Or in other words, the practices of carbon and energy management may be determined by whether or not a company understands and accepts the related policy.

The 'policy understanding' mentioned above refers to how companies comprehend the contents of the target policy. 'Policy acceptability' is defined as the quality of being acceptable in this study. Both are used as the internal factors in the analytical framework.

Meanwhile, the external factors and company characteristics that may be associated with a company's CEPs are selected and included in the framework – regulation, competition pressure, energy price and international orientation – which are classified as external pressures. External governance pressures through regulation can have a significant influence on a company's strategies and actions in terms of adoption of various carbon and energy practices (Sullivan and Gouldson, 2016). In this study, the GHG mitigation target is considered as an external pressure to compel companies to take action. The GHG mitigation goals for iron & steel, petrochemical and cement industries set by the government are respectively 6.5%, 7.5% and 8.5%, compared with BAU levels, which are together designed to realise a national GHG mitigation target of 30% from the BAU scenario by 2020 compared with 2005 levels. There is some truth to the belief that market competition works as a driver pushing companies to obtain strategic information (De Groot et al., 2001). Prindle (2010) documented the rising price of energy as a principal driver for improving the energy efficiency of companies, and Suk et al. (2016) looked at what affected decisions to invest in low-carbon technology of energy-consuming industries. The energy and environment-related standards, certification, technical regulations and non-tariff barriers are becoming increasingly intensified at global and intergovernmental levels in response to climate change, which implies there is a relationship between a company's environmental strategies and its level of exports. Given that Korea's economic growth relies heavily on international trade, businesses need to take heed of such trends and act accordingly. In this sense, international orientation functions as an external push for companies to actively acquire relevant information on policy and technology.

Company size, sector belongings, ownership type and so on are the structural variables that appear to influence the implementation of environmental practices. Therefore, as control variables, company size, sector belongings, ownership type and involvement status of GHG/energy target management (TMS) are used to identify differences in policy understanding and acceptability as well as carbon and energy practices. Company size is an important variable and influences environment management and response to climate change policy in the areas of energy-saving and GHG mitigation. TMS is a mandatory scheme targeting companies with high energy consumptions and GHG emissions, which are required to set GHG and energy reduction goals and be subject to monitoring, reporting, and verification. Following Porter and Van der Linde's (1995) argument that environmental regulation of an industry can boost its competitiveness through accelerated innovation, strengthened GHG mitigation caps under the TMS will drive companies to collect related information and respond to such measures.

1.3.2 Econometric Approach

1.3.2.1 Valuation of the variables

The abbreviation, description and valuation of the variables are listed in Table 11.

A five-point scale was applied to evaluate three of the four external pressures, SECTORTARGET, COMPETITION and EN_PRICE, with '5' = very high; '4' = relatively high; '3' = moderate; '2' = relatively low; and '1' = very low. The main market of the product, EXPORT, is used as the proxy of a company's international orientation, in which products for the local market are appended with the value '0' and export-oriented companies, '1'.

Table 11 Abbreviation, description and valuation of the variables

Abbreviation		Description	Valuation					
			0	1	2	3	4	5
External	SECTORTARGET	GHG mitigation target by sector						
	COMPETITION	Competition degree of the company's sales market						
	EXPORT	Main market of the products						
	EN_PRICE	Perception of domestic energy price levels						
Intern	UNDERSTANDING	Company's understanding of MBIs						
	ACCEPTABILITY	Company's acceptability of MBIs						
Control	SIZE	Company's size						
	SECTOR	Industrial sector belongings of the company						
	OWNERSHIP	Ownership status						
	TMS	TMS involvement						

A similar approach was used for the internal factors, UNDERSTANDING and ACCEPTABILITY as regards policy understanding, with '5' = 'very clear'; '4' = 'clear'; '3' = 'moderate understanding'; '2' = 'don't know well'; and, '1' = 'completely unknown'. The scales for the policy acceptability are: '5' = fully acceptable; '4' = relatively acceptable; '3' = moderate acceptance; '2' = hardly acceptable; and, '1' = completely unacceptable.

Company size, SIZE, is classified into small, medium, large-medium and large, individually named SMALL, MEDIUM, LMEDIUM and LARGE. Company sector belongings, SECTOR, have three types: iron & steel, cement and petrochemicals, presented as STEEL, CEMENT and CHEMICAL. Ownership consists of two types, domestically private and foreign-funded, abbreviated as DOMESTIC and FOREIGN. The status of TMS involvement is indicated as 'TMS' for TMS target companies and 'non-TMS' for the others.

1.3.2.2 Empirical models for econometric analysis

The regression capturing the relationships between the company's policy understanding, UNDERSTANDING, and the classified determinants can be constructed as Eq. (1), where ε represents the error term and β_0 is the constant.

$$\begin{aligned} &UNDERSTANDING \\ &= \beta_0 + \beta_1 SECTORTARGET + \beta_2 COMPETITION + \beta_3 EXPORT + \beta_4 EN\_PRICE + \beta_5 SIZE \\ &\quad + \beta_6 SECTOR + \beta_7 OWNERSHIP + \beta_8 TMS + \varepsilon \end{aligned} \tag{1}$$

The regression identifying the relationships between the company's policy acceptability, ACCEPTABILITY, and the classified variables can be established as Eq. (2), where ζ represents the error term and λ_0 is the constant.

$$\begin{aligned} &ACCEPTABILITY \\ &= \lambda_0 + \lambda_1 UNDERSTANDING + \lambda_2 SECTORTARGET + \lambda_3 COMPETITION + \lambda_4 EXPORT \\ &\quad + \lambda_5 EN\_PRICE + \lambda_6 SIZE + \lambda_7 SECTOR + \lambda_8 OWNERSHIP + \lambda_9 TMS + \xi \end{aligned} \tag{2}$$

The regression estimating the relationships among variables, internal factors, external pressures, and control with the companies' activities for CEP, can be constructed as Eq. (3), where η represents the error term and α_0 is the constant.

$$\begin{aligned} &CEP \\ &= \alpha_0 + \alpha_1 UNDERSTANDING + \alpha_2 ACCEPTABILITY + \alpha_3 SECTORTARGET + \alpha_4 COMPETITION \\ &+ \alpha_5 EXPORT + \alpha_6 EN\_PRICE + \alpha_7 SIZE + \alpha_8 SECTOR + \alpha_9 OWNERSHIP + \alpha_{10} TMS + \eta \end{aligned}$$

(3)

Ordered logistic regression was employed in this study since ordinal dependent variables are used.

1.3.3 Outline of Questionnaire Survey and Samples

A survey was implemented targeting three energy-intensive sectors – iron & steel, cement and petrochemicals – as they are major CO_2 emitters and accounted for over 75% of emissions from the manufacturing industry in Korea (MOEK press, 2011). A questionnaire was designed based on the main objectives of this study and consisted of four major components: general information of company; the status of energy consumption and CO_2 emissions; understanding and acceptance degree of various policy tools; and status of CEP.

Data was collected by a faxed/emailed questionnaire survey sent to 205 companies in the cement, iron & steel and petrochemical sectors from 25 January to 10 February 2012. Of the above, 130 were targets of TMS, with non-TMS accounting for the remainder. The questionnaire was directed at environmental and energy managers at mid-management level. Responses from 58 TMS target entities were collected and confirmed valid, which included 34 petrochemical, 14 iron & steel and 10 cement companies, or 43.6%, 41.2% and 55.6% of the total TMS target entities in each sector, respectively. Therefore, the respondents of this survey may be taken as representative of half the TMS targets in the three energy-intensive sectors. The distribution of the samples by company characteristics is summarised in Table 12.

Table 12 Distribution of usable respondents by sector, size and TMS involvement status

Company characteristics		Number of samples				Number in total (Percentage)
		Small	Medium	Large medium	Large	
Number in total (Percentage)		2 (3.2)	27 (43.5)	20 (32.2)	13 (21.0)	62 (100.0)
Sector	Cement	2	6	2	1	11 (17.7)
	Iron & Steel	-	8	5	3	16 (25.8)
	Petrochemical	-	13	13	9	35 (56.5)
TMS	TMS	2	26	17	13	58 (93.5)
	Non-TMS	-	1	3	-	4 (6.5)

The respondents from cement, iron & steel and petrochemical sectors individually account for 17.7%, 25.8% and 56.5 % of the total. According to the company size classification criteria of Korea’s ‘Minor Enterprises Act’, which is based on number of employees only, 27 were medium-sized companies having staffs of 50–300, 2 were small companies with less than 50, and 13 were large companies with over 1,000. The remaining 20 were large medium-sized companies between large and medium-size ones.

1.4 Results and Discussion

1.4.1 Company’s understanding of MBIs and the determinant factors

1.4.1.1 Statistics of company understanding of MBIs

The companies were requested to indicate their understanding of the eight MBIs listed in Table 13. The integrity of measuring this was tested by Cronbach’s alpha, which gave an overall figure of 0.88 for all answers, and is over the 0.70 criteria recommended by Nunnally and Bernstein (1994), thus confirming the reliability of the survey data construct. The statistics of company understanding of MBIs are shown in Table 13.

Table 13 Statistics of company understanding of MBIs (N=62)

MBI items		Mean	Std. Dev.	Min.	Max.
MBI01	Subsidies for TMS target companies' investment in maintenance, improvement and replacement of GHG mitigation and energy saving facilities	3.21	1.01	1	5
MBI02	Soft loan for investment in GHG mitigation and energy saving facilities	3.03	0.99	1	5
MBI03	Soft loan and grant for installing high-efficiency production facilities and equipment	3.11	0.94	1	5
MBI04	Grant for high energy-efficiency products (i.e., LED, inverter, transformer and freezer)	3.31	0.86	1	5
MBI05	Soft loan for GHG mitigation and energy saving company (ESCO) projects	3.60	0.95	1	5
MBI06	Tax reduction for investment in GHG mitigation and energy saving facilities	3.27	1.03	1	5
MBI07	Carbon tax	2.93	0.83	1	5
MBI08	GHG emission trading scheme	3.31	0.74	2	5

Companies in Korea show moderate understanding of the pre-listed MBIs in general, which is consistent with the result of an empirical study covering Korea in 2010 (Suk et al. 2013) and similar to the result in China (Liu et al., 2013a), while Japanese companies were confirmed to have low awareness of market-based instruments (Liu et al., 2014b). Comparatively, the respondents have a better understanding of MBI05 (Soft loan for ESCO projects), with a mean of 3.60, which mirrors the success of Korea's government-supported ESCO project. The following policies that have relatively higher company understanding are MBI04 (Grant for high energy efficiency equipment, i.e., LED, transformer and freezer, etc.) and MBI08 (GHG ETS), with the same mean of 3.31. At the time this survey was being undertaken, GHG ETS introduction from 2013 was in the public spotlight, thus energy-intensive companies would have had elevated awareness of such. As ETS was mainly focused on as regards carbon pricing, and the carbon tax was under discussion mainly within the government and academic domains, it is understandable for MBI07 (Carbon tax) to obtain a relatively low score for understanding.

1.4.1.2 Factor analysis of MBI items

An exploratory factor analysis was conducted on the level of understanding of the eight MBIs to cluster them into their different dimensions. Two principal component factors were extracted (Table 14). The item of 'understanding' of MBI is abbreviated as UNDERSTAND_MBIs.

UNDERSTAND_MBI01 to UNDERSTAND_MBI06 are highly associated with factor 1. UNDERSTAND_MBI07 to UNDERSTAND_MBI08 are related with factor 2. To assess the appropriateness of factor analysis, the Kaiser Meyer-Olkin (KMO) test was used. Table 14 is a matrix of rotated components and KMO values. The overall KMO value is 0.76, which indicates moderate data suitability for factor analysis to proceed.

Table 14 Rotated component matrix of factor analysis and KMO values

UNDSTAND_MBIs	Factor		KMO value
	1	2	
UNDSTAND_MBI01	0.790	-0.069	0.823
UNDSTAND_MBI02	0.886	-0.232	0.762
UNDSTAND_MBI03	0.869	-0.219	0.866
UNDSTAND_MBI04	0.783	-0.238	0.871
UNDSTAND_MBI05	0.522	-0.022	0.683
UNDSTAND_MBI06	0.746	0.108	0.736
UNDSTAND_MBI07	0.521	0.630	0.618
UNDSTAND_MBI08	0.348	0.686	0.578

Based on the result of factor analysis, two sets of UNDERSTAND_MBI constructs may be defined. MBI items 01 to 06 are incentives such as soft loans, grants and tax benefits for investment in energy saving facilities, while MBI07 and MBI08 are carbon tax and GHG ETS. These UNDERSTAND_MBIs are thus classified into the two categories shown in Table 15.

Table 15 Definition and valuation of the sub-category of ACCEPTMBI items

Abbreviation	Description of the sub-category	Valuation
UNDSTAND_MBIs_IN	Companies' understanding on the incentive MBIs	Sum of scores of UNDSTAND_MBI 01 to 06
UNDSTAND_MBIs_CP	Companies' understanding on the carbon pricing	Sum of scores of UNDSTAND _TMBI07 and 08

UNDERSTAND_MBI_ALL, the variables representing the involvement of sub-categories of UNDERSTAND_MBI_IN and UNDERSTAND_MBI_CP, are used as dependent variables for the multivariate regressions to observe their respective relationships with the predicting determinants.

1.4.1.3 Multivariate analysis with company policy understanding of MBIs as dependent variables

Econometric regressions were performed to identify the determinant factors of a company's understanding of MBIs by equation (1). As this 'understanding' is an ordinal measurement, it was rational to choose the ordered logistic model. Results of multivariate regressions of UNDERSTAND_MBI_ALL and UNDERSTAND_MBI_IN listed in Table 16 are statistically significant and are thus discussed here.

Company sector belongings, size and TMS targets are associated with their understanding of

MBI_ALL, while there is no significant relationship between external factors and a company's understanding of MBIs.

The petrochemical sector indicated higher understanding of MBI_ALL, and MBI_IN than other sectors. Medium-sized companies are aware of overall MBIs, particularly MBI_IN, which sheds light on the current trend in policy for funding energy-use rationalisation projects and increased budgetary allocation for SMEs, in order to accelerate energy-saving facility installation in SMEs. An additional finding is that the TMS-targeted companies show a negative relationship with understanding of overall MBIs as well as incentive instruments, which is backed up by previous research by the authors showing few TMS companies applied for the loan (Suk et al., 2013). This may be due to the low amounts of finance available for large companies, the main targets of TMS. Overall, this implies that the government should adopt an approach that considers company characteristics if it intends to increase policy understanding on the part of companies.

Table 16 Multivariate regression results with understanding of MBIs as dependent variables

Independent variables and controls		Dependent variables: UNDSTAND_MBI		
		MBI_ALL	**MBI_IN**	**MBI_CP**
External Pressure	SECTORTARGET	-0.353	-0.353	0.388
	COMPETITION	0.002	0.002	0.496
	EXPORT	-0.462	-0.462	-0.985 [c]
	EN_PRICE	0.075	0.075	-0.304
Company's characteristics as control	CEMENT	-0.241	-0.241	-0.524
	CHEMICAL	**1.143 [b]**	**1.143 [c]**	1.032 [c]
	FOREIGN	-0.657	-0.657	0.272
	SMALL	1.218	1.218	1.292
	MEDIUM	**2.165 [a]**	**2.165 [a]**	0.744
	L-MEDIUM	0.556	0.556	0.850
	TMS	**-1.620 [c]**	**-1.620 [c]**	-1.167
Number of obs		62	62	62
LR chi2(11)		**19.67 [c]**	**19.67 [c]**	12.3
Pseudo R2		0.058	0.058	0.060

a significant at 1% level
b significant at 5% level
c significant at 10% level

1.4.2 Company Acceptability of Climate Change Policies and the Determinant Factors

1.4.2.1 Statistics of company acceptability of climate change policies

In this survey we asked the companies to indicate the level of subjective acceptance degree of policy measures including MBIs, C&Cs and VOAs, as listed in Table 10, to find statistical differences. The reliability of valuation results was checked via Cronbach's alpha, which produced a score of 0.80, thus confirming the data construct was valid (Nunnally and Bernstein, 1994). The average scores are depicted in Figure 8.

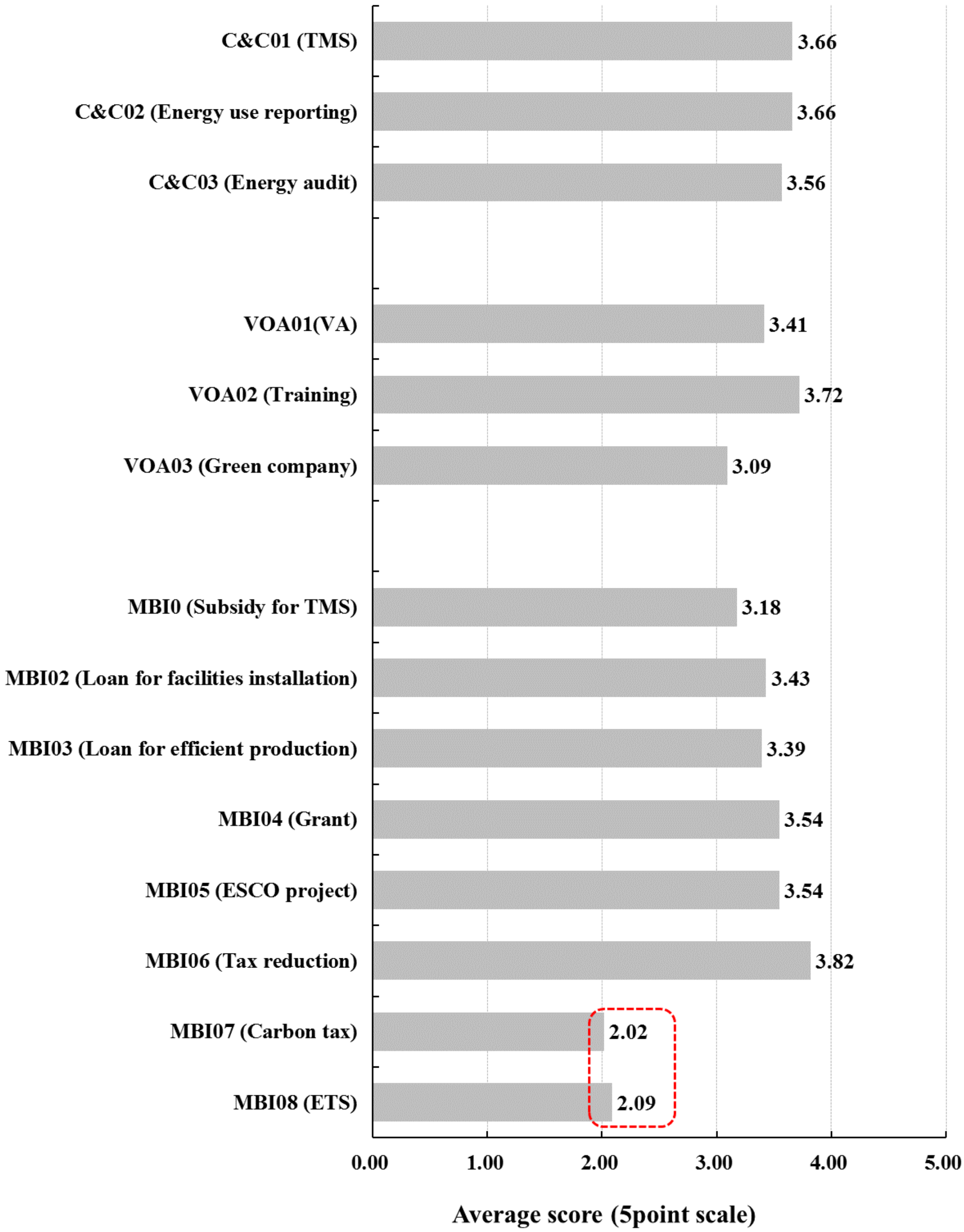

Figure 8 Company's acceptability of GHG mitigation and energy saving measures

Intuitively guessable, economic incentives are preferable and presented relatively higher scores, in particular MBI06 (Tax reduction for investment in energy-saving facilities), with a mean of 3.82. MBI02 (Soft loan for investment in energy saving facilities), MBI03 (Soft loan for installing high-efficiency production facilities and equipment), MBI04 (Grant for high energy-efficiency products, i.e., LEDs, inverters, transformers and freezers) and MBI05 (Soft loan for ESCO projects) received similar means of around 3.40–3.50. The survey confirms that voluntary approaches are appreciated by the companies. VOA02 (Training for energy managers) achieved a high mean of 3.72, indicating the need for technical support for Korean companies. VOA01 (Voluntary agreement for energy saving) obtained a mean of 3.41. The samples indicate good acceptability to certain regulative tools, such as C&C01 (GHG/energy target management system) to C&C03 (Energy audit requirement), with similar means of around 3.56–3.66. From this it can be inferred that Korean companies as a whole exhibit broad acceptance of the need for and utility of governmental intervention in industrial GHG mitigation and energy saving (Klok et al., 2006).

However, it was obvious that carbon pricing policies, carbon tax (MBI07) and GHG ETS (MBI08), are resisted by companies in Korea, as both presented the lowest score of around 2.00 (see red box in graph).

1.4.2.2 Factor Analysis of MBI Items

As with 4.1.2, factor analysis of the eight items of MBI acceptability was performed to cluster them into their different dimensions, abbreviated as ACCEPT_MBIs. The overall KMO value is 0.65, indicating moderate suitability of the data for factor analysis. The results are shown in Table 17.

Table 17 Rotated component matrix of factor analysis and KMO values

ACCEPT_MBIs	Factor		KMO value
	1	2	
ACCEPT_MBI01	0.696	-0.018	0.849
ACCEPT_MBI02	0.811	-0.085	0.712
ACCEPT_MBI03	0.873	0.072	0.661
ACCEPT_MBI04	0.726	0.003	0.881
ACCEPT_MBI05	0.412	0.122	0.717
ACCEPT_MBI06	0.367	-0.010	0.725
ACCEPT_MBI07	-0.035	0.939	0.390
ACCEPT_MBI08	0.036	0.947	0.390

Based on this factor analysis, two sets of ACCEPT_MBI constructs are defined: ACCEPT_MBI_IN and ACCEPT_MBI_CP. ACCEPT_MBI_ALL, and two sub-categories are used as dependent variables for the multivariate regressions to observe how they are related with the pre-listed factors.

Table 18 Definition and valuation of the sub-category of ACCEPTMBI items

Abbreviation	Description of the sub-category	Valuation
ACCEPT_MBIs _IN	Companies' acceptability on the subsidy MBIs	Sum of scores of ACCEPT_MBI 01 to 06
ACCEPT_MBIs _CP	Companies' acceptability on the carbon pricing	Sum of scores of ACCEPT_MBI07 and 08

1.4.2.3 Multivariate analysis with company acceptability of MBIs as dependent variables

Multivariate regressions were performed using equation (2) to identify whether the company's acceptability of MBIs varies due to the variables, including policy understanding as an internal factor, external pressures and the company's characteristics. The ordered logistic model was applied and the regression results are listed in Table 19. Regression results of all dependent variables are statistically significant and are thus discussed here.

This analysis confirms that a company's acceptability of economic instruments including loans, subsidies and carbon pricing is significantly and positively correlated to their understanding of such policies. The sectoral target negatively influences a company's MBI acceptance, especially carbon pricing, in that companies that feel highly pressured due to GHG mitigation targets show less acceptance towards MBIs all and carbon pricing. Accordingly, acceptability of MBIs varies across sectors. Compared with iron & steel and petrochemical sectors, cement companies are relatively more highly pressured by the sectoral GHG mitigation target, and are more likely to accept incentive instruments. It can be seen that the petrochemical industry is more likely to embrace carbon policies compared to other industries, which may be because this industry has the largest energy saving potential in Korea (KEMCO, 2010). This result is consistent with the answer for another question in the survey, in which respondents were requested to evaluate the sectoral GHG mitigation target related to their industry. For petrochemical companies, 20% view the mitigation target of their sector as appropriate, which shows they are relatively more credible as a target for GHG reductions than other sectors.

TMS participating companies resisted carbon pricing. As described earlier, TMS targets the large energy-consuming entities in Korea that are to be covered by ETS and that are therefore opposed to ETS introduction. The sticking point is the presence of what they call a 'double burden', or the burden of the present system coupled with that of carbon pricing. There was no significant relationship between size, ownership and other external pressures with policy acceptability.

Table 19 Multivariate regression results with acceptability of MBIs as dependent variables

Independent variables and controls			Dependent variables: ACCEPT_MBI		
			MBI_ALL	MBI_IN	MBI_CP
Internal factor		UNDSTAND_ALL	**1.519** ^{a}		
		UNDSTAND_IN		**1.665** ^{a}	
		UNDSTAND_CP			**1.084** ^{b}
External Pressure		SECTORTARGET	**-0.683** ^{c}	-0.391	**-1.223** ^{a}
		COMPETITION	-0.370	-0.323	0.199
		EN_PRICE	0.255	0.246	0.213
		EXPORT	0.251	0.539	-0.426
Company's characteristics as control	Sector	CEMENT	-	**1.774** ^{b}	-
		STEEL	-1.180	-	0.756
		CHEMICAL	-0.445	0.545	**1.615** ^{c}
	Ownership	DOMESTIC	-	0.746	0.602
		FOREIGN	-0.535	-	-
	Size	MEDIUM	1.239	2.077	-2.207
		L-MEDIUM	0.773	1.711	-2.216
		LARGE	0.610	1.510	-2.357
	TMS		-0.536	0.668	**-2.438** ^{b}
Number of obs.			62	62	62
LR chi2(12)			**31.85** ^{a}	**37.68** ^{a}	**30.77** ^{a}
Pseudo R2			0.088	0.108	0.141

a significant at 1% level
b significant at 5% level
c significant at 10% level

1.4.3 Companies' CEM and its Relationship with Policy Understanding and Acceptability

1.4.3.1 Status of companies' CEM

Ten CEPs are given in Table 20, and companies were requested to indicate to what extent they practiced them.

Companies' practices to cope with Korean carbon pricing policy deviate little from conventional energy saving and environmental management. Overall, the most practiced activity is CEP07 (Participate in GHG-related and energy management training organised by the government), with a percentage of 85.2%. As for carbon management, 72.1% of companies had made efforts to improve production processes by installing energy-saving facilities and equipment (CEP08), and 65.6% had obtained ISO 14001 Certification as part of their carbon and energy management (CEP05). CEP09 (Participate in the Voluntary Agreement) follows at 57.4%. The proportion of VA is relatively low, considering the fact that energy saving activities were mainly carried out through voluntary agreements, probably due to the change in designation of large, energy-consuming companies as target companies under the TMS – meaning their energy saving activities were not counted as VA.

Table 20 Status of company's carbon and energy practices (N=62)

No.	Carbon and energy management	%
CEM01	Set up GHG mitigation and energy saving strategies	50.8
CEM02	Strengthen the network between companies in the same sector to exchange information of GHG mitigation and energy-efficient technologies, etc.	24.6
CEM03	Publish periodical environmental reports containing information of GHG emissions and energy consumption, e.g., Sustainable development report, carbon report, etc.	16.4
CEM04	Introduced Green accounting system	4.9
CEM05	Obtained ISO 14001 Certification in Environmental Management	65.6
CEM06	Achieved Green company certification	21.3
CEM07	Participate in carbon and energy management training organised by the government	85.2
CEM08	Improve the production process by installing GHG mitigation and energy saving facilities and equipment	72.1
CEM09	Participate in the Voluntary Agreement (VA)	57.4
CEM10	Establish a specific division for carbon and energy management	32.8

However, in general, there is little evidence demonstrating that carbon management takes place within Korean industry at large. One sure way to tell if companies are responding to climate change is whether they have set up specific goals or strategies for GHG mitigation or energy saving strategies. Overall, half of the companies answered that they have implemented GHG mitigation and energy-saving strategies (CEP01). In order to tell whether a company has established environmental management, this is manifested by the presence of environment departments or appointment of managers in charge of environmental issues (Del Brio et al. 2001). Of the Korean companies, only a third had established specific divisions for carbon and energy management (CEP10). They also exhibited low interest in Green company certification (CEP06), as only 20% were certified as such. As the demand for high quality environmental reports is mounting, an increasing number of firms publish information on the environmental impact of their activities, and such function is handled by environmental management systems in most companies (OECD Secretariat and EIRIS). However, with the exception of several large, well-known companies, few regularly report on environmental and carbon performance – only a small percentage of the surveyed companies had published environmental reports (CEP03, 16.4%).

With the object of measuring the cost and impact of implementing environment-related activities from the perspective of companies, in 2006 the Ministry of Environment published green accounting guidelines and encouraged companies to adopt them. The uptake was very low, however, as the related score for recognition and execution of Green accounting (CEP04) is at the insignificant level (4.9%).

1.4.3.2 Factor analysis of climate change policy practice items

CEPs were grouped into different dimensions via exploratory factor analysis. Four principal component factors were extracted: factor 1 was highly associated with all of CEP01–03, CEP07, and CEP08; factors 2, 3, and 4 are highly associated with CEP04, CEP05 and CEP06, respectively. Thus CEPs was classified into four categories, as defined in Table 21. The overall KMO value is 0.64, which indicates moderate suitability of the data for factor analysis to proceed.

Table 21 Rotated component matrix of factor analysis and KMO values

CEMs	Factor				KMO value
	1	2	3	4	
CEM01	0.490	-0.065	0.065	0.008	0.689
CEM02	0.531	-0.048	0.001	-0.275	0.593
CEM03	0.700	0.032	-0.098	0.115	0.698
CEM04	0.293	0.325	0.025	0.209	0.638
CEM05	0.470	0.324	0.052	-0.178	0.784
CEM06	0.170	0.475	0.058	0.059	0.674
CEM07	0.145	0.020	0.050	0.398	0.357
CEM08	0.060	0.432	-0.177	-0.029	0.472
CEM09	0.152	-0.056	0.493	0.015	0.411
CEM10	0.680	0.228	0.311	0.045	0.678

The CEP items highly associated with factor 1 are managerial practice for environmental management of the companies. CEP04 (Green account system) and CEP06 (Green company certification) (factor 2), are relatively new and proactive managerial practices for carbon management.

Table 22 Definition and valuation of the CEP sub-categories

Abbreviation	Description of the sub-category	Valuation
CEM_MP	Managerial practice	Sum of scores of CEM01 to CEM03, CEM05, CEM08, and CEM10
CEM_NMP	New managerial practice	Score of CEM04 and CEM06
CEM_ EDU	Educational practice	Score of CEM07
CEM_VA	Voluntary Agreement	Score of CEM09

Others were individually defined into two: educational practice and Voluntary Agreement, CEP07 and 09. Further, the overall level of CEP_ALL, i.e., the variables representing the involvement of the above CEP sub-categories, are also used as dependent variables for the multivariate regressions to observe how they are respectively related to the predictive factors.

1.4.3.3 Multivariate regression results of CEMs as dependent variables

CEP_ALL and 4 sub-categories, CEP_MP, CEP_NMP, CEP_EDU and CEP_VA defined are used as dependent variables for the multivariate regression to observe their respective relationships with the predetermined factors. As the independent variables, internal factors of company policy understanding and acceptability for MBIs are included, which are separated into incentive-based MBIs and carbon pricing to identify whether a company's CEPs are associated with understanding and acceptability for different MBIs. Ordered probit regressions were then performed, which were found to be statistically significant, thus the results are described here.

The present study confirmed that companies' understanding of policy is one of the key factors stimulating the implementation of carbon and energy practices, as had been presumed at the outset of this study. Company understanding of the carbon policy significantly influenced the CEPs, especially managerial practice and voluntary activities, although acceptability is not necessary related. Government regulations are one of the key drivers for resource allocation in various environmental management domains (Buysse and Verbeke, 2003). However, this study showed that the companies' CEPs are not particularly associated with pressures derived from sectoral mitigation targets.

Meanwhile, as has been confirmed by several studies, competition is an essential external pressure driving companies to conduct CEPs, which indicates that companies are sensitive to the climate change response performance of their business competitors, i.e., that they may face an overall loss of competitive advantage if proactive environmental management becomes common practice among its rivals (Garrod, 1997). Voluntary activities are positively associated with a company's energy price pressure, which confirms that energy price is a driver for improving energy efficiency of companies (Prindle, 2010, Suk et al. 2016). The status of CEPs differs according to company characteristics, i.e., the belonging sector, size and ownership (Gonzalez-Benito & Gonzalez-Benito, 2006). The petrochemical industry, as confirmed in another part of this study, is positively involved in the CEPs. Further, foreign-owned companies were found to be more active in engaging in carbon management than domestic ones in Korea, probably because multinational companies tend to shape their environmental policies based on the most stringent requirements prevailing in the relevant countries in which they compete (Magreta, 1997). The level of CEPs in companies is determined by the size of the company, which agrees with the results found in world literature (University of Cambridge, 2015).

Table 23 Multivariate regression results with CEPs as dependent variables

Independent variables and controls			Dependent variables: CEMs		
			CEM_ALL	CEM_MP	CEM_VA
Internal factor	UNDSTAND_IN		**0.562^{b}**	0.351	-0.466
	ACCEPT_IN		**0.630^{a}**	**0.776^{a}**	**0.818^{b}**
	UNDSTAND_CP		**0.647^{a}**	**0.699^{a}**	**0.700^{b}**
	ACCEPT_CP		0.084	-0.006	-0.053
External pressure	SECTORTARGET		-0.299	-0.102	-0.046
	COMPETITION		**0.678^{b}**	**0.574^{c}**	0.146
	EN_PRICE		0.222	0.041	**0.551^{b}**
	EXPORT		0.420	0.280	0.782
Company's characteristics as control	Sector	STEEL	0.676	0.774	-0.584
		CHEMICAL	**1.278^{b}**	**1.069^{b}**	0.134
	Ownership	FOREIGN	0.780	**1.166^{b}**	-0.936
	Size	SMALL	-10.858	-11.354	-10.374
		MEDIUM	**-1.211^{a}**	**-1.173^{a}**	0.530
		L-MEDIUM	**-1.499^{a}**	**-1.227^{a}**	-0.482
	TMS		0.522	-0.040	-0.345
Number of obs			62	62	62
LR chi2(15)			**70.95^{a}**	**61.53^{a}**	**23.33^{c}**
Pseudo R2			0.280	0.296	0.275

a significant at 1% level
b significant at 5% level
c significant at 10% level

1.5 Conclusions

The increasing reliance of energy and climate change policy on market mechanisms under the present climate change policy has required companies to shift their strategy focus from voluntary, or regulation-driven management approaches, to innovative carbon management. In terms of the GHG responsibilities of energy-intensive sectors in Korea, it is their carbon and energy practices that are important in addressing current climate change and environment problems.

This study aimed to contribute to this body of knowledge by measuring the extent of understanding of policy and acceptance of carbon pricing, on the part of businesses, in the early phase of introduction of carbon pricing and by linking such awareness or acceptance with company performances. Carbon pricing policies are still highly resisted by the sampled Korean companies, especially those within the sector with high GHG mitigation targets or those targeted by TMS. However, this study revealed that company understanding of carbon pricing is essential for their policy acceptance, as well as to proceed with aspects of actual management, even though policy acceptance itself does not necessarily lead to implementation. In other words, even if the policy is not favorable, understanding of the policy enhances the company's response. The companies are more open to incentive policies as they expressed higher understanding of them and agree with the utility of certain regulative requirements for industrial climate change performance. This study observed divergences in the way different sectors perceive and accept carbon pricing as well as in how they incorporate their understanding in their carbon management. It also confirmed that their behaviors are likely more influenced by the internal aspects than external pressures, although they are concerned about rivals.

The results of this study underlined the importance of increasing the level of policy understanding among companies, particularly with regards to characteristics of companies, and this has important implications in terms of policy not only for Korea’s government but also that of other countries planning to introduce market mechanisms related to climate change. Nevertheless, this study is subject to the following shortcomings, which could be addressed through further study. This study used self-reporting questionnaires to gather data, in which companies made subjective assessments of their policy understanding and acceptability, which introduces the potential for bias in interpreting the scale. In this study, a company's carbon management and practices are not defined but mainly focused on energy and GHG reduction activities included in existing energy and environmental management. However, in order to carry out the carbon management necessary for participating in the carbon market in which carbon credits are traded under the ETS, companies may need to adopt more proactive strategies that are clearly discernable from those of existing environmental management, which are regarded as a form of social responsibility. In this respect, future research will need to clarify exactly at what stage Korean companies are presently at in terms of carbon management

2. AFFORDABILITY OF ENERGY COST INCREASES FOR KOREAN COMPANIES DUE TO MARKET-BASED CLIMATE POLICIES: A SURVEY STUDY BY SECTOR[11]

[Abstract]

This paper estimates the affordability of energy cost increases for energy-intensive companies due to the introduction of market-based climate policies in Korea. Data were collected from 62 respondents from iron & steel, cement and petrochemical industries, over 90% of which are under control of the 'Target Management Scheme', an ongoing mandatory system limiting the GHG emissions of large energy-consuming entities. The affordable energy cost increase was estimated using the multiple-bounded discrete choice (MBDC) format, results of which show that a mean energy cost increase of 2.6% is acceptable for all the entities sampled. Companies from the three sectors had similar affordability, with an average acceptable energy cost increase of 2.5–2.8%. The affordable policy-induced energy cost increases equate to carbon prices of 2,500–4,000 KRW/t-CO_2 (about 2.3–3.5 USD/t-CO_2) for the companies surveyed. Econometric analysis confirmed a strong correlation between energy price level and company ownership with cost affordability. With a view to developing carbon tax policy and a domestic GHG emissions trading scheme in Korea, this research provides a basis, from an industrial perspective, for carbon pricing.

Key words: Affordability, energy cost, multiple-bounded discrete choice, company, Korea

[11] This chapter is based on the journal article "Affordability of Energy Cost Increases for Korean Companies due to Market-Based Climate Policies: A Survey Study by Sector" published at the Journal of Cleaner Production published in 2014 by co-authors, Suk Sunhee, Liu Xianbing, Lee Sang-youp, Go Seokjin and Sudo Kinichi.

2.1 Introduction

Korea is committed to being one of the leading low-carbon green growth hubs in Asia, and pledged in 2009 to reduce its GHG emissions by 30% from the BAU scenario by 2020 compared with 2005 levels under the new national vision of the ‘Low Carbon Green Growth’ announced in 2008 (PCGG, 2009). In order to realise this target, regulatory measures such as the TMS were launched, and since 2011 have limited the emissions of large energy-consuming entities (PCGG, 2010). TMS covers 471 business sites, with GHG emissions accounting for about 60% of the country’s total in 2007 (MOE, 2010). Korea’s government has also considered the use of MBIs, particularly GHG ETS and carbon tax policy, to reduce GHG emissions.

GHG ETS allows target entities to trade their GHG emissions permits. Theoretically, those who can reduce emissions most cheaply will do so, achieving reductions at the lowest cost to society (Montgomery, 1972). As the first large-scale GHG trading programme, Europe launched EU-ETS in 2005, which covered 11,400 installations in the initial phase (2005–2007). Allowances were allocated on the basis of historical emission levels of the target entities and member countries could auction up to 5% of their allowances, and any excess emissions incurred a penalty of 40 Euro/t-CO_2. During the second phase (2008–2012), EU-ETS was extended from its 27 EU members to 30 countries by the inclusion of Iceland, Liechtenstein and Norway. Fully-free emissions allowances for the power sector ended and the maximum allowance auction rate was raised to 10% from 5%. The third phase of EU-ETS is from 2013 to 2020, the goal of which is a 21% emissions reduction by programme target sectors from 2005 levels. A progressive move towards auctioning of allowances will further enhance the effectiveness of this scheme (Guo et al., 2011).

EU-ETS has since inspired other countries, including Korea, to consider cap and trade schemes of their own. Discussions on introducing domestic GHG ETS in Korea were started under the ‘Framework Act on Low Carbon Green Growth’ passed in 2010. Several studies analysed the economic effects and impacts of GHG ETS on Korean industry and concluded that this scheme would be more cost-effective (reduce costs by 44–68%) compared to mandatory regulations for achieving the 2020 national reduction target (PCGG, 2011; Kim, 2010a; Lee, 2009).

The latest version of Korea’s GHG ETS bill, approved on 2 May 2012 and due to enter force on 1 January 2015, is aimed at the largest energy-consuming or GHG-emitting entities heading the list of TMS targets. The legislation provides for allowances to be allocated fully for free in the first phase (2015–2017), at 95–97% for the second phase (2018–2020) and at 90% for the third phase (2021–2025). It also allows the government to intervene in the market to stabilise credit prices. For companies failing to achieve their GHG reduction targets penalties will be levied at less than triple the average market price of carbon credits (PCGG, 2012).

A direct tax on the carbon content of fossil fuels (carbon tax) has also been reviewed in Korea as a possible measure to mitigate GHG in recent years. During 2008 to 2010, KIPF studied green fiscal reform by addressing the negative externalities of the existing taxation system, and proposed a carbon tax policy to start in 2013, with a tax rate of 25 Euro/t-CO_2 and tax revenue equaling 1% of Korean GDP, to replace the transportation-energy-environment tax slated to end in 2012 (Kim et al., 2008). According to its 2009 report estimation, energy prices would hike by 4.10%, 37.90%, 4.39% and 6.05% respectively for oil, coal, gas and electricity due to this proposed carbon tax. KIPF later revised this proposal and recommended initial tax rates of 1/8 the above levels to make the policy more acceptable and to minimise negative economic impact (Kim and Kim 2010). A recent proposal further reduces the above figure to 1/10 the original rate, and to start in 2016—equivalent to around 3,000 KRW/t-CO_2 (about 2.7 USD/t-CO_2) (Shim, 2013). Kim (2013) extrapolated the policy effect of this carbon tax bill using 2009 input-output data into a maximum mitigation rate of 3.59% for GHG emissions**.**

In the context of recent developments in policy, an earlier survey conducted by the authors found that small and medium-sized enterprises (SMEs) of Korea tend to practice institutional and managerial energy saving activities, which incur relatively lower costs and efforts, rather than carry out research and development of energy efficient products. This is assumed to be because strategic cooperation with external business partners is absent, i.e., not factored into the business cycles for such SMEs, implying that Korean SMEs are still at an early stage in responding to governmental climate and energy saving countermeasures (Suk et al., 2013). In reality, there exists strong resistance from industry in Korea for the introduction of carbon pricing policies, including GHG ETS and carbon taxing (Liu et al., 2011; 2012b). Based on the general consensus that Korea’s economy is export-oriented and dominated by energy-intensive industries, the industrial sector is thus highly sensitive to any potential loss of international competitiveness that may result from increased energy costs due to carbon pricing policies. Further, Korea fails to see why it alone needs to change, considering other major economies such as the U.S. and Japan have shelved their GHG ETS plans, and the general lack of real progress in climate negotiations at the global level (Liu et al., 2012b).

Discussions revealed that, on a practical level, the acceptance level of policy targets for industry is a key factor affecting progress and a successful outcome for carbon pricing policies. Previous researches have mainly focused on the question of how economic climate policies would affect Korean industries (Kang et al., 2011; Kim et al., 2010; Kim, 2009a; Kim, 2009b; Kim et al., 2008)—few studies have actually tested the affordability of energy cost increases due to the introduction of MBIs from the perspective of individual companies in Korea. To overcome this policy practice gap this research estimates the affordability of Korean companies for energy cost increases based on a phase-in of market-based climate policies. Three energy-intensive sectors—

iron & steel, cement and petrochemical industries—were selected as survey targets, since they were major CO_2 emitters and accounted for over 75% of emissions from the manufacturing industry in 2007 (MOEK, 2011a), as detailed in section 2.

Two topics are discussed in this paper. One is how the affordability for companies in the target sectors regarding energy cost increases can be estimated; the other is how the external and internal determinant factors can be identified, to clarify the relationships between affordability levels and company characteristics. The remainder of this paper is structured as follows. Section 2 gives an overview of the three target sectors in terms of their overall status and energy efficiency; section 3 explains the methodology, including the models for estimating affordability of companies on energy cost increases by multiple-bounded discrete choice (MBDC) data, the analytical frame identifying the determinants of the estimated affordability and an outline of the questionnaire survey, and section 4 discusses the results of affordability estimations and econometric analysis. Section 5 concludes the research findings.

2.2 Overview of the Three Target Sectors

Korea's robust economic growth over the past half-century has chiefly been achieved through energy-intensive manufacturing industries—in particular, iron & steel, petrochemicals and cement (Kim et al., 2011). Exports of Korean energy-intensive industries amounted to 75.0 billion USD in 2007, 20.2% of the country's total of the same year (Park and Kim, 2009). Specifically, exports from the iron & steel industry increased from 4.2 billion USD in 1990 to 25 billion USD in 2010, for a share of 6.0% of total exports (source: http://www.kosa.or.kr). As a major product of the petrochemical industry, ethylene production ranked fifth in the world with a global share of 5.5% in 2007, and exports in 2009 amounted to 27.4 billion USD, accounting for 6.5% of total exports in the same year (source: http://kpia.or.kr/index.html). Korea currently has 10 cement companies, which produce about 6.2 million tons of cement per year, exported to the U.S., Japan and Africa (source: http://www.cement.or.kr).

In terms of energy use, the manufacturing industry consumed more than 55% of the country's total energy in 2008 (Kim et al., 2011). In comparison with the energy consumption (of energy-intensive industries in terms of total energy use) in OECD countries as a whole over the period 1997–2006, which dropped from 23% to 22%, that of Korea increased from 32% to 38% over the same period (Park and Kim, 2009). The three sectors in this study are major energy-consuming industries in Korea. In 2009, Korea's petrochemicals industry used 50.904 million toe of energy; of this, 83.1% was non-energy oil and second was electricity, with a share of 6.8% (KEEI, 2011). Bituminous coal is the largest energy source for the iron & steel industry. Of the total 19.35 million toe of energy used by this sector in 2009, 75% was bituminous coal. Shares of electricity, city gas and oil were 15.6%, 7.5% and 1.8% individually. As in the iron & steel industry, energy use in the cement sector is dominated by bituminous coal; in 2010, cement consumed 3.966 million toe of energy overall, of which bituminous coal had a share of 71.7% and electricity accounted for 27.8% (KEEI, 2011). During 1990–1997, energy efficiency in the three target sectors improved steadily: at an annual rate of 3% for petrochemicals, 1% for iron & steel and 0.9% for cement; however, this encouraging trend ended after the Asian financial crisis in 1997 (Park and Kim, 2009).

The three sectors under review are major emitters of CO_2 in Korea due to their heavy use of fossil fuels. Of the total 233 million tonnes of CO_2 emissions from the manufacturing industry in 2007, petrochemicals emitted 50.7 million, with a share of 21.7%. Iron & steel and cement emitted 86.0 and 42.2 million, with respective shares of 36.9% and 18.1%. Overall, these three sectors accounted for more than 75% of CO_2 emissions from the manufacturing industry in 2007 (MOE, 2011a). Based on an MOE (2011b) estimate that BAU emissions from the petrochemicals sector would reach 63.47 million tonnes of CO_2 by 2020, this represents an increase of 25% from 2007. Accordingly, the BAU emissions of iron & steel and cement industries will be 121.35 and 41.48 million tonnes of CO_2 by 2020, an increase of 41.1% and a slight decrease of 1.7% from the 2007 levels, respectively. Aiming to realise the country's 30% mitigation goal, the sectors of petrochemicals, iron & steel and cement are therefore required to reduce their emissions by 7.5%, 6.5% and 8.5% compared with the projected BAU levels by 2020.

2.3 Methodology

2.3.1 Estimating affordability of energy cost increases for companies

2.3.1.1 Multiple-bounded discrete choice questionnaire

Contingent valuation (CV) is a survey-based economic technique and a stated preference model for placing a monetary value on a good. This approach is the only valuation technique capable of measuring non-use values and is well suited for public goods and non-market private goods. One problem in applying this method, however, is that it may present respondents with goods they are unfamiliar with and choices they would not normally face. The CV method has been widely used to estimate an individual's willingness-to-pay (WTP) for environmental improvements or willingness-to-accept (WTA) the compensation of ecological damage and pollution. Wang (1997) argued that uncertainty would be inherent in public valuations of commodities or services, i.e., that a distribution rather than a single number will result. The uncertainty of the CV method can be dealt with using two strategies. One is to lengthen the dimensions of bidding prices to narrow down the actual interval of respondent valuations by increased information quantity. The other is to request respondents express the quality of their choices concerning the proposed price levels (Wang and He, 2010). Double-bounded dichotomous choice (DC) (Cameron and Quiggin, 1994) and payment card questionnaires (Ryan et al., 2004) are typical examples of the first strategy, which reveal the superiority of increasing the information quantity by multiple bidding propositions. As an example of the second approach, Li and Mattsson (1995) asked respondents to value their confidence in the CV answers and used this information to measure the preference uncertainty.

As a developed method for CV estimation, the 'return potential' format, used by sociologists to measure the strength of social norms, was adapted for the MBDC questionnaire (Welsh and Bishop, 1993). The MBDC format is a two-dimensional matrix, in which one dimension delineates different levels of the commodity and the other elicits preference intensity. This approach contains elements of both the payment card and DC approaches widely used in CV research. Like the PC format, however, respondents are presented with an ordered sequence of thresholds, but rather than circling a single value or interval, the respondent is given a 'polychotomous choice' option, a format that allows respondents to vote on a wide range of referendums and express voting certainty for each. Therefore, the MBDC technique reinforces the quantity and quality of data to better approach real values.

Inspired by the research of Wang and He (2010) on the public's WTP, an MBDC questionnaire was applied in this survey to estimate affordability of individual companies for energy cost increases due to the introduction of economic climate policies. Referring to Welsh and Poe (1998), the questions and format prepared for the surveyed companies and an example response from a cement company are shown in Figure 9.

Q: Direct rise of energy prices and/or government's levying of energy tax or carbon tax in energy production and conversion sector will bring a rise in energy prices and therefore increase the company's energy costs. We would like to know your company's opinion on the possible rise of energy costs due to above factors. Please evaluate and make your choice according to the willingness level of your company to accept the optional increasing rates of energy costs.

Rise rate of energy cost (%)	Your choice				
	Too low; Very easy to accept	Not high; Accept	Moderate; Moderately accept	High; Reject	Too high; Strongly reject
0.1	✓	☐	☐	☐	☐
0.5	✓	☐	☐	☐	☐
1.0	☐	✓	☐	☐	☐
3.0	☐	✓	☐	☐	☐
5.0	☐	☐	✓	☐	☐
7.0	☐	☐	✓	☐	☐
10.0	☐	☐	☐	✓	☐
20.0	☐	☐	☐	✓	☐
30.0	☐	☐	☐	☐	✓
50.0	☐	☐	☐	☐	✓

Figure 9 A question and example response of MBDC format in this study.

The companies are presented with an ordered and ascending sequence of energy cost increase thresholds and multi-choice options, 'easily acceptable', 'acceptable', 'barely acceptable', 'rejection' and 'strong rejection'. Although it collects more information from each respondent, the MBDC approach is more difficult to implement than traditional survey approaches, as witnessed by the presence of some awkward responses, such as incomplete answers, in our survey.

2.3.1.2 Estimation models for affordability for companies

Various models have been proposed for the likelihood matrix data gathered by the MBDC questionnaire. The most prominent are those developed by Welsh and Poe (1998) and Alberini et al. (2003). Welsh and Poe (1998) employed information from the MBDC technique and conducted WTP analysis based on the multiple-bounded maximum likelihood interval modeling approach and found that their multi-bounded questions with 13 bids (14 intervals) could reduce the confidence bounds around estimates of WTP by over 60% relative to a single-bounded question with the same bid design. However, this model is straightforward and has an underlying assumption that all respondents share the same valuation distribution; but, the analysis actually makes full use of only one dimension of the information enrichment from the MBDC panel—the discrete choice of bid price levels. Alberini et al. (2003) extended the random valuation threshold model via a log-likelihood function to enable retaining all the response categories reflecting the different preference certainties of each respondent. This extended random valuation model permits the threshold to be individualised and offers the possibility to measure the degree of uncertainty of each individual. The disadvantage of this approach, however, is that estimation incorrectly treats the same individual's responses across the alternative bid values as independent (Vossler and Poe, 2005).

This study applied the two-stage estimation approach proposed by Wang and He (2010). The subjective verbal likelihoods presented by the respondents are encoded into numerical data for estimations. Taking the affordable cost increase rate of a company *i* as V_i, which is a random variable with a cumulative distribution function F(r), the mean value of V_i is μ_i and the standard variance is σ_i. The cost affordability model can be written as,

$$V_i = \mu_i + \varepsilon_i \qquad (1)$$

where ε_i is a random term with a mean of zero. Given an energy cost increase rate of r_{ij}, the probability for the company to accept this rate will be,

$$P_{ij} = \Pr(V_i \rangle r_{ij}) = 1 - F(r_{ij}) \qquad (2)$$

Once P_{ij}, the probability for the individual company *i* to agree with the increase rate r_{ij}, is known by assigning numerical values to the verbal MBDC answers, equation (2) can be estimated for each company. The estimation model can be written as,

$$P_{ij} = 1 - F(r_{ij}) + \lambda_i \qquad (3)$$

where λ_i is an error term with a mean of zero and a standard variance of δ_i, and P_{ij} is the dependent variable with values between 0 to 1, which can be achieved from the uncertainty answer given by the company *i* at the rate of r_{ij}. Assuming a specific function for $F(r_{ij})$, such as a normal accumulative distribution function with a mean of μ_i and a standard variance of σ_i, equation (3) becomes,

$$P_{ij} = 1 - \Phi\left(\frac{r_{ij} - \mu_i}{\sigma_i}\right) + \lambda_i \qquad (4)$$

At the first stage, μ_i and σ_i can be estimated for each company using equation (4). After obtaining each company's mean affordability and the standard variance, a multivariate regression model can be constructed as the second step to analyse the factors determining the affordability. For instance, linear models can be expressed as,

$$\mu_i = \beta_0 + \beta X_i + \varepsilon \qquad (5)$$

where X_i is a vector of determinant factors including the company's specific characteristics, β is a vector of coefficients to be estimated and ε is the random error.

As described in Wang and He (2010), this two-stage approach may provide a less biased estimation of the mean values and the variances of valuation distributions of individual companies since no econometric models are introduced at the first stage. The linear modeling results at the second stage can be easily compared with the results of the other CV approaches. The only bias that could be introduced comes from the WTP distribution assumption, which was confirmed as not being serious in Wang and Whittington (2005).

2.3.2 Econometric analysis of the determinants of affordability for companies

2.3.2.1 Analytical framework and the determinants

In this study, we carried out an econometric analysis to identify the relationships between the estimated affordability of energy cost increases of companies with the determinant factors, including company characteristics. The analytical framework is depicted in Figure 10. The determinant factors are described in detail in the following paragraphs.

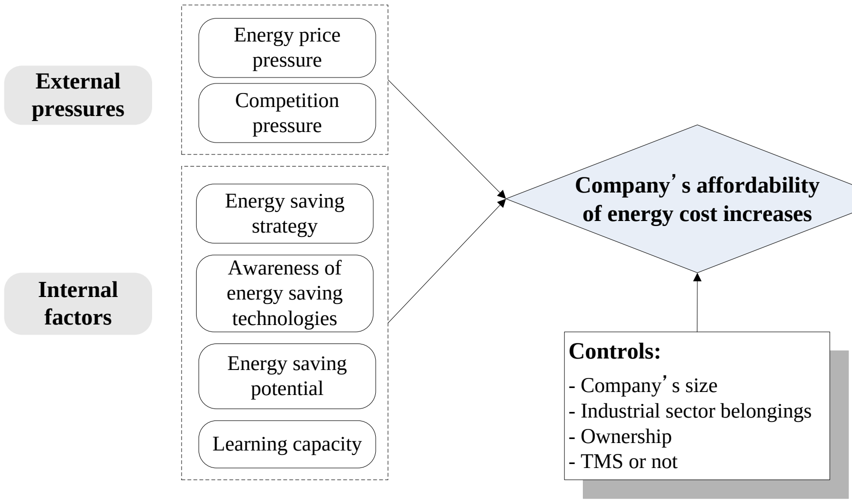

Figure 10 Analytical framework for econometric analysis.

The determinants of affordability of companies on energy cost increases are classified into external pressures and internal factors. Two external pressures were defined. One is the energy price pressure felt by companies—if a company felt energy prices to be already high, it would be hard for it to accept additional increases in energy costs. The other external pressure is the strength of market competition—a company would be reluctant to take on an additional cost burden to avoid the loss of competitiveness if competition in the sector was fierce.

Four internal factors were classified accordingly. One is the energy saving strategy of companies, indicating willingness to improve energy management. It is understandable that a company would more easily afford an energy cost increase if it were motivated to increase energy efficiency. The second is company awareness of energy saving technologies, both existing and new. Being aware of technological alternatives would enable a company to more accurately evaluate the measures dealing with business risks due to energy cost increases. Energy saving potential is categorised as the third internal factor. Companies with higher energy saving potential can more flexibly alleviate the energy cost burden by self-reduction efforts. The last internal factor is a company's learning capacity. A company's energy efficiency is a kind of environmental performance, which is dynamic and related to the company's learning capacity (Hart, 1995). Raising the level of individual skills can help transform the skills of the organisation as a whole, but the learning process itself largely depends on interrelations among individuals and groups within the organisation (Lozano, 2008), and various factors influence the learning dynamic, such as manager integration power, external linkages and codification of experience (Chen et al., 2009). To simplify this analysis, the educational level of employees is used as a proxy for this factor as it is the basis of a company's learning capacity.

Regarding company characteristics, size, industrial sector and ownership were selected. The involvement status of TMS was added as another control for this analysis. As energy-intensive sectors are naturally more sensitive to changes in energy costs, proposals for carbon pricing policies often provide relief measures for energy-intensive sectors to overcome the resistance anticipated from such sectors (Liu et al., 2011).

2.3.2.2 Valuation of the variables

The dependent variable for the econometric analysis is the estimated mean of affordability for companies in equation (4). The abbreviations, descriptions and valuations of determinant factors as independent variables and company characteristics as controls are listed in Table 24.

Table 24 Abbreviations, descriptions and valuations of independent variables and controls

Category	Abbreviation	Description	Valuation					
			0	1	2	3	4	5
External pressures	ENPRICE	Perception of domestic energy price levels						
	COMPETITION	Competition degree of the company's sales market						
Internal factors	ENSTRATEGY	Status of energy saving target setting						
	EXISTINGTECH	Company's awareness of existing energy saving technologies						
	NEWTECH	Company's awareness of new energy saving technologies						
	SAVPOTENTIAL	Level of energy saving potential of the company						
	AVGEDU	Average education level of the company's employees						
Controls	SIZE	Organisational size						
	SECTOR	Industrial sector to which the company belongs						
	OWNERSHIP	Company's ownership status						
	TMS	Status of TMS involvement						

A five-point scale was applied to evaluate the two external pressures, ENPRICE and COMPETITION, and company awareness of energy saving technologies, EXISTINGTECH and NEWTECH, with '1' = very low; '2' = relatively low; '3' = moderate; '4' = relatively high; and, '5' = very high. A four-level point was applied to the level of energy saving potential, SAVPOTENTIAL, with '1' = further energy saving very difficult; '2' = limited potential; '3' = relatively large potential; and, '4' = very high potential. The status of energy saving target setting was used to represent a company's energy management strategy, ENSTRATEGY. A five-level classification was applied, with '5' referring to a company having clear annual and internally decomposed energy saving targets; '4' as one having a specific annual target; '3' as one having a short- to medium-term target of 3 to 5 years; '2' as one having only a rough target in the long run, and '1' as one having no quantitative targets. The average educational level of employees, AVGEDU, was used to indicate the company's learning capacity. Five categories were used, with '1' = the rate of employees with educations of college and above being less than 10%; '2' = 10–20%; '3' = 20–30%; '4' = 30–50%; and, '5' = over 50%.

For the controls, company size is classified into four types: small, medium-sized, large-medium and large, which are respectively abbreviated as SMALL, MEDIUM, LMEDIUM and LARGE. Company sector is categorised into three types: iron & steel, cement, and chemicals, named STEEL, CEMENT and CHEMICAL. Ownership consists of two types, domestically private and foreign-funded, abbreviated as DOMPRIVATE and FOREIGN, respectively. The respondents are sorted into TMS target or non-TMS.

2.3.2.3 Econometric model

The regression model capturing the relationship between the company's mean affordability, abbreviated as *MEANAFFORD*, and the identified variables can be developed from equation (5) and written as equation (6), where ε is the error term and β_0 is the constant.

$$\begin{aligned} MEANAFFORD = \beta_0 + \beta_1 ENPRICE + \beta_2 COMPETITION + \beta_3 ENSTRATEGY \\ + \beta_4 EXISTINGTECH + \beta_5 NEWTECH + \beta_6 SAVPOTENTIAL \\ + \beta_7 AVGEDU + \beta_8 SIZE + \beta_9 SECTOR + \beta_{10} OWNERSHIP + \beta_{11} TMS + \varepsilon \end{aligned} \quad (6)$$

2.3.3 Outline of the survey and samples

Based on an understanding of the situation in Korea, a questionnaire was designed with the main objective of measuring the affordability of companies for energy cost increases due to the introduction of MBIs and identifying the corresponding determinants. The questionnaire consisted of four major components: company general information; company energy use and management status; the acceptability degrees to various rates of energy cost increases due to economic climate policies; and, the external pressures felt by the company and the company's internal factors. The questionnaire format is attached in Appendix 1.

Data were collected by the questionnaire survey from January 25 to February 10, 2012. Questionnaires was sent via fax and email to a total of 205 companies—137 targeted by TMS and 68 non-TMS—intended to be filled out by environmental and energy managers. Of these, answers received from 62 companies were collected and confirmed to be valid. The distribution of the usable samples by company characteristics is summarised in Table 25.

The respondents from cement, iron & steel and chemical sectors individually account for 17.7%, 25.8% and 56.5 % of the total. According to the classification criteria of the 'Minor Enterprises Act' of Korea based on number of employees only, 27 were medium-sized companies having a staff of 50–300, two were small companies with a staff of less than 50, and 13 were large companies with a staff of over 1,000. The remaining 20 were large medium-sized, i.e., between large and medium-size companies. Of the total 62 samples, 58 respondents were TMS targets.

Table 25 Distribution of usable respondents by company characteristics

Company characteristics		Number of samples				Number in total (Percentage)
		Small	Medium	Large Medium	Large	
Number in total (Percentage)		**2** **(3.2)**	**27** **(43.5)**	**20** **(32.2)**	**13** **(21.0)**	62 (100.0)
Sector	Cement	2	6	2	1	11 (17.7)
	Steel	-	8	5	3	16 (25.8)
	Petrochemicals	-	13	13	9	35 (56.5)
TMS	TMS	2	26	17	13	58 (93.5)
	Non-TMS	-	1	3	-	4 (6.5)

2.4 Results and discussions

2.4.1 Energy use status of the samples

The surveyed companies were requested to elaborate on the types of energies and their corresponding rates in total energy use. The energy use structure of the samples overall and by sector is statistically summarised in Figure 11.

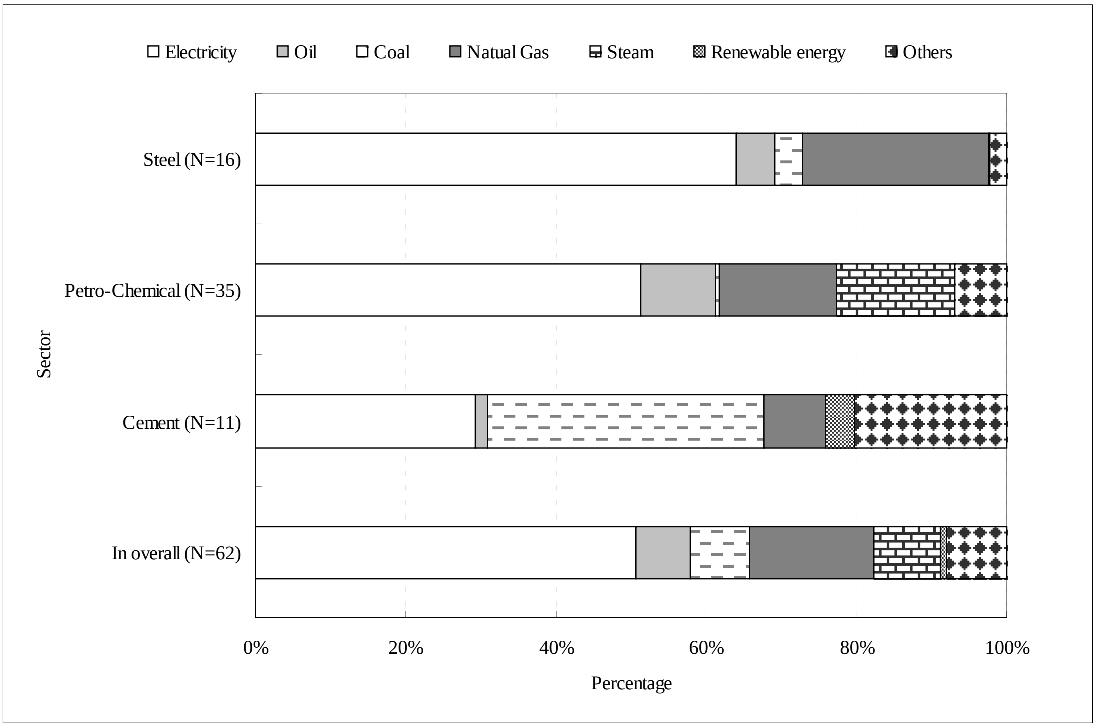

Figure 11 Energy use structure of the samples by sector

The results confirm that electricity is the largest energy source for the surveyed companies as a whole, with an average share of 51% of total energy use; natural gas is second-largest and accounts for 17% of total energy use; and third is steam with a share of about 9%. Oil and coal share around 7% each, and renewables account for less 1% as a minor source. The remaining 8% is others, including LNG and Petro cokes. Regarding the energy use structures of the three target sectors, several differences were found. Iron & steel and chemicals use electricity mostly, with a share of 64% and 51% respectively. The rate of electricity used by the surveyed cement companies is less than 30%. Coal is a major energy source for cement companies, accounting for about 37% of total energy use, while this rate is less than 5% for the chemical and steel sectors. Steel companies in the survey use natural gas as the second largest energy source, accounting for about 25%. Natural gas and steam are used at the same rate of 15.5% as the second largest energy source for the chemical companies.

Figure 12 shows the distribution of energy cost shares in total sales of the samples by sector. Rather than units of physical quantity, this rate represents energy intensity as an energy value. Overall, the samples have an even distribution of energy cost rates up to 20%. Nearly 30% of companies have an energy cost rate of 5–10%; companies with energy cost rates of less 5% and 10–20% individually have a similar share of around 25%. The remaining 16% of samples have an energy cost rate of 20–50%. The surveyed cement companies indicate high rates of energy costs in sales; around 55% have an energy cost rate of 20–50%, 9% of them have costs of over 50% of sales for energy use, and 27% answered their energy cost rates range from 10–20%. The remaining 9% have energy costs of 5–10% in total sales. For the chemical sector, almost 90% of the surveyed companies have an energy cost rate below 20%. The companies with energy cost rates of less 5%, 5–10% and 10–20% individually account for 31%, 37% and 23% of the total samples from this sector. Another 6% have energy cost rates of 20–50%. As in the chemical sector, most steel companies have energy cost rates below 20%. About 30% of steel companies have a rate of below 5% and 10–20%, respectively; 25% of them have an energy cost rate of 5–10%. The remaining 12.5% have an energy cost rate of 20–50%.

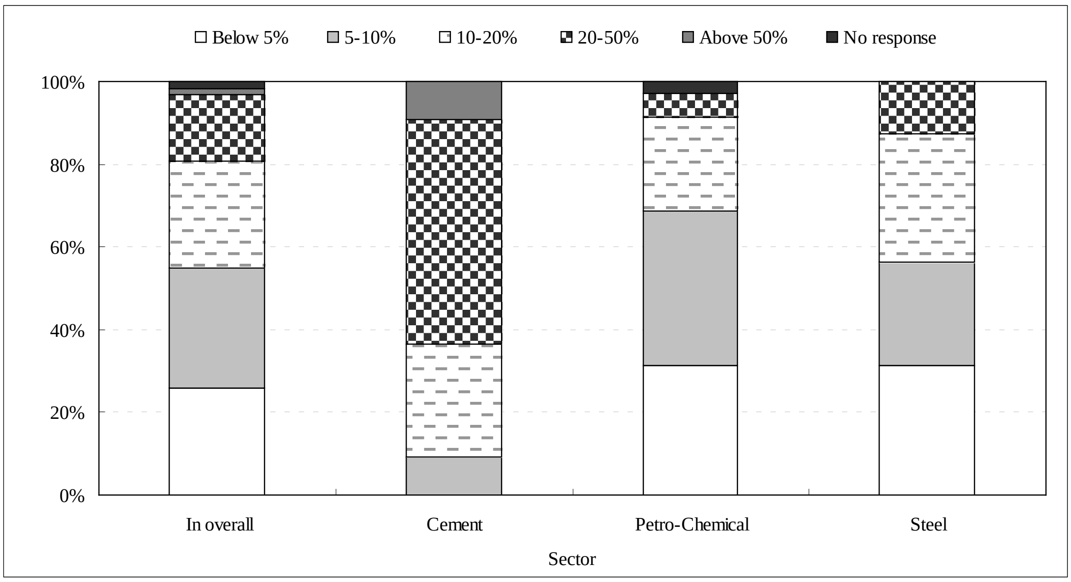

Figure 12 Distribution of energy cost shares in total sales by sector

2.4.2 Affordability of energy cost increases for companies

The affordability of energy cost increases for companies was monitored by the MBDC format as shown in Figure 13, which shows ten thresholds of energy cost increase. The reliability of this measurement was tested using Cronbach's alpha, which produced a result for all the samples of 0.9075. This figure is above 0.70, the criteria recommended by Nunnally and Bernstein (1994), and thus confirmed the reliability of the survey data construct.

2.4.2.1 Statistics of cost affordability of the samples overall

Table 26 lists the statistics of affordability of all the valid respondents to each energy cost increase rate presented in the MBDC format. A total of 36 companies fully circled the format and their answers were used for the statistics. At the lowest energy cost increase option of 0.1%, 22.2% of companies indicated this increase to be very low and easily acceptable. Another 55.6% of respondents expressed that it is no problem for them to afford this increase. The remaining 22.2% selected 'barely acceptable' for this increase rate. In summary, all the respondents could afford this increase. The share of companies with acceptance degrees of barely acceptable and beyond dropped to 94.4% at the increase rate of 0.5%, 80.6% at the rate of 1.0%, and 30.5% at the rate of 3.0%. The rates of companies with affordability degrees of 'barely acceptable' and over continue to decrease with growing energy cost increases. More than 91.6% of the companies viewed an increase of 10.0% to be high and answered with rejection or strong rejection. Energy cost increase rates of 20% and over are rejected or strongly rejected by all the surveyed companies.

Table 26 Statistics of affordability responses of all the samples (N=36)

Energy Cost Increase Rate (%)	Strong Rejection (%)	Rejection (%)	Barely Acceptable (%)	Acceptable (%)	Easily Acceptable (%)	Total (%)
0.1	0.0	0.0	22.2	55.6	22.2	100.0
0.5	0.0	5.6	25.0	63.9	5.6	100.0
1.0	8.3	11.1	61.1	16.7	2.8	100.0
3.0	25.0	44.4	19.4	8.3	2.8	100.0
5.0	41.7	41.7	8.3	8.3	0.0	100.0
7.0	72.2	16.7	11.1	0.0	0.0	100.0
10.0	83.3	8.3	8.3	0.0	0.0	100.0
20.0	86.1	13.9	0.0	0.0	0.0	100.0
30.0	88.9	11.1	0.0	0.0	0.0	100.0
50.0	91.7	8.3	0.0	0.0	0.0	100.0

Figure 13 depicts the results of aggregated data listed in table 24 and the simulation curves. Two groups of data, easily acceptable and acceptable, and barely acceptable and the beyond, are shown in the figure because they are meaningful for observing the rough range of energy cost increase rates acceptable of the sampled companies. A cumulative normal distribution model was applied for the regressions with the aggregative shares of the samples as a dependent variable and the energy cost rates as an independent variable. The R squared for regressions of the two sets of data is 0.9565 and 0.9721, respectively, indicating a good fit between the observed data and regression curves. Affordability on the part of 50% of the samples corresponds to energy cost increase rates of 0.6% and 2.3% on the two curves. The mean of energy cost increase rates affordable for the samples may be between 0.6% and 2.3%.

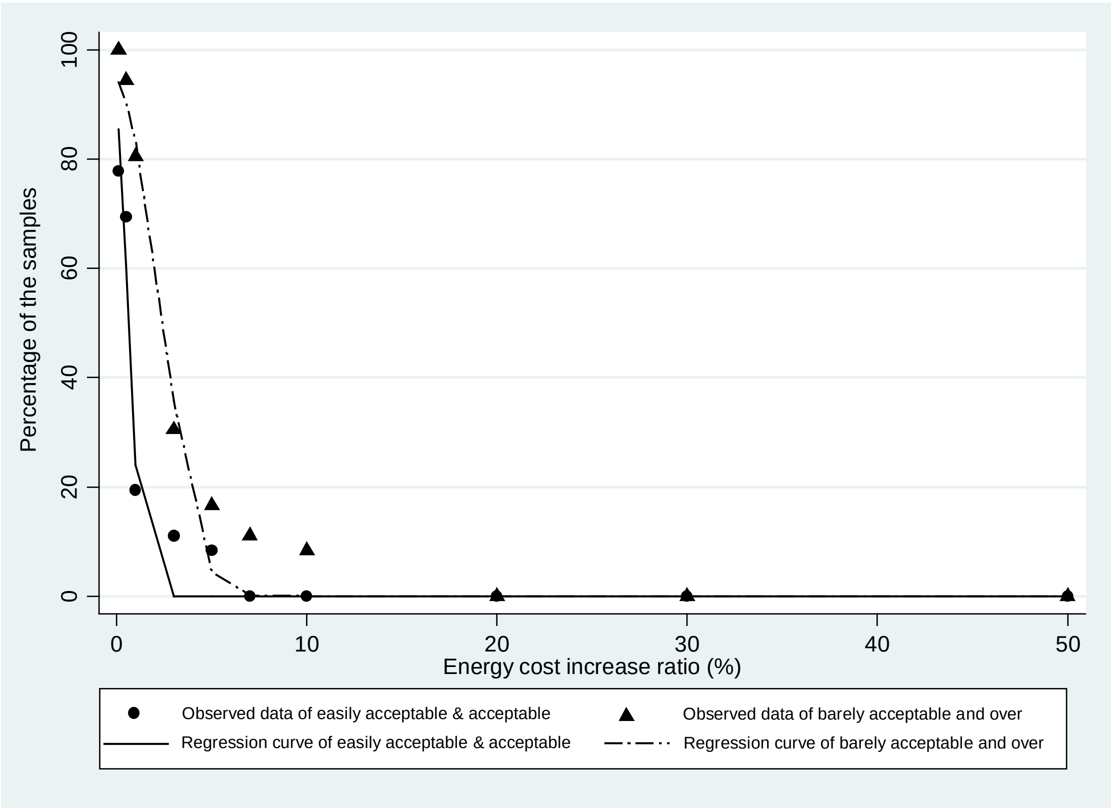

Figure 13 Affordability of energy cost increases of all the samples (N=36)

2.4.2.2 Statistical summary of the affordability for iron & steel companies

Table 27 lists the statistics of affordability for samples from the iron & steel industry. At the lowest rate of 0.1%, 36.4% of respondents indicated the increase to be too low and easily acceptable, and 45.5% of the companies thought it was unproblematic to accept this increase. Another 18.2% selected ‘barely acceptable’ for this increase rate. Therefore, all the respondents could accept this rate. The share of samples with selections of barely acceptable and beyond dropped to 90.9% when energy cost increased by a rate of 1.0%. This number drastically fell to 18.2% at the rate of 3.0%, and 9.1% at the rate of 7.0%. Less than 10% of the companies thought they would accept an increase rate of 10.0%. All the surveyed companies rejected the energy cost increase rate of 20% and over.

Table 27 Statistics of affordability responses of iron & steel companies (N=11)

Energy Cost Increase Rate (%)	Strong Rejection (%)	Rejection (%)	Barely Acceptable (%)	Acceptable (%)	Easily Acceptable (%)	Total (%)
0.1	0.0	0.0	18.2	45.5	36.4	100.0
0.5	0.0	0.0	18.2	81.8	0.0	100.0
1.0	0.0	9.1	81.8	9.1	0.0	100.0
3.0	27.3	54.5	9.1	9.1	0.0	100.0
5.0	54.5	27.3	9.1	9.1	0.0	100.0
7.0	72.7	18.2	9.1	0.0	0.0	100.0
10.0	81.8	9.1	9.1	0.0	0.0	100.0
20.0	81.8	18.2	0.0	0.0	0.0	100.0
30.0	81.8	18.2	0.0	0.0	0.0	100.0
50.0	81.8	18.2	0.0	0.0	0.0	100.0

Figure 14 presents the aggregation results of observed data listed in Table 27 and the regression curves thereof. The R squared for the regressions of two sets of data is 0.9523 and 0.9708, respectively, confirming that the simulations are appropriate. The affordability of 50% corresponds to an energy cost increase rate of 0.7% and 2.2% on the two curves. This shows a similar affordability range for the iron & steel sector compared with that of all the samples.

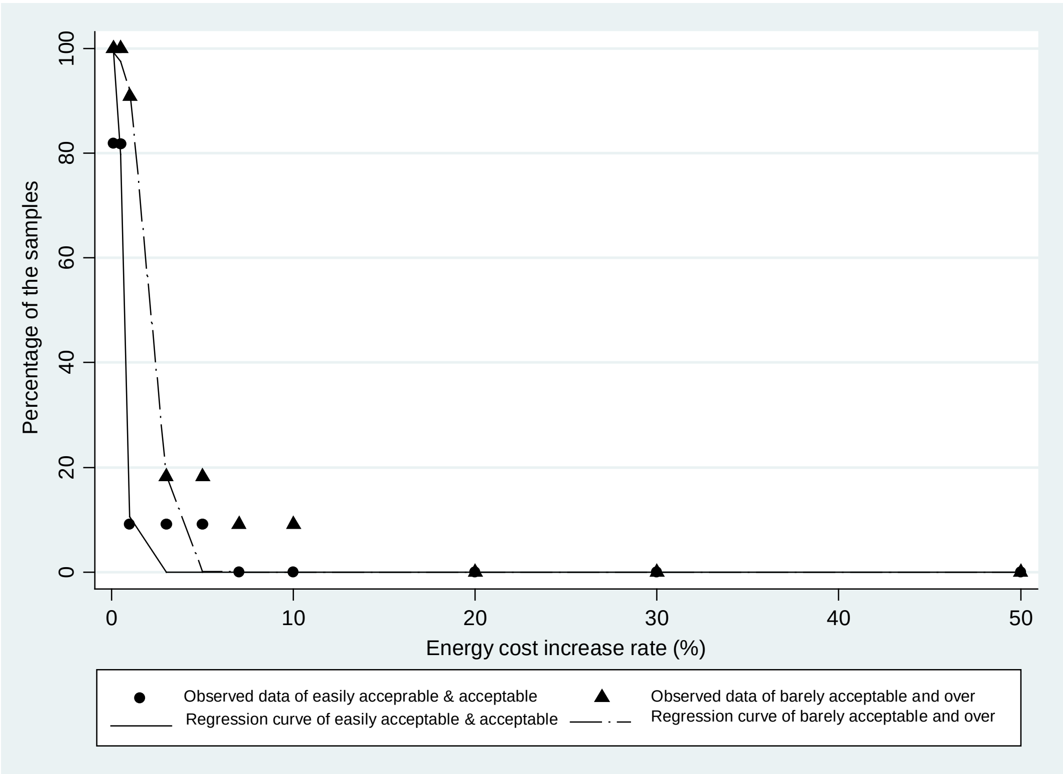

Figure 14 Affordability of energy cost increases for the iron & steel industry (N=11)

2.4.2.3 Statistical summary of the affordability for chemical companies

Table 28 shows the statistics of affordability for samples from the chemical industry to energy cost increases. The number of usable respondents in this sector is 20. At the lowest rate of 0.1%, 15.0% of the respondents indicated the increase to be too low and easily acceptable and 65.0% of the companies indicated it to be no problem for them to afford the increase. Another 20.0% selected 'barely acceptable' for this increase rate. This result confirms full acceptance of the respondents to this rate. The share of the samples with selections of barely acceptable and beyond dropped to 75.0% at the increase rate of 1.0%, and 35.0% at the rates of 3.0%. The affordability continues to decrease as the energy cost increase rates are raised. Five percent of the chemical companies believed that they would barely accept an increase rate of 10.0%. All of the chemical companies viewed an increase of 20.0% and over to be high and selected the answer of rejection and strong rejection.

Table 28 Statistics of affordability responses of chemical companies (N=20)

Energy Cost Increase Rate (%)	Strong Rejection (%)	Rejection (%)	Barely Acceptable (%)	Acceptable (%)	Easily Acceptable (%)	Total (%)
0.1	0.0	0.0	20.0	65.0	15.0	100.0
0.5	0.0	5.0	30.0	55.0	10.0	100.0
1.0	10.0	15.0	50.0	20.0	5.0	100.0
3.0	20.0	45.0	25.0	5.0	5.0	100.0
5.0	35.0	50.0	5.0	10.0	0.0	100.0
7.0	70.0	20.0	10.0	0.0	0.0	100.0
10.0	85.0	10.0	5.0	0.0	0.0	100.0
20.0	90.0	10.0	0.0	0.0	0.0	100.0
30.0	90.0	10.0	0.0	0.0	0.0	100.0
50.0	95.0	5.0	0.0	0.0	0.0	100.0

Figure 15 presents the aggregation results of observed data listed in Table 28 and the regression curves thereof in the same way. The R squared for the two regressions is 0.9700 and 0.9775, respectively, indicating the suitability of simulations. The affordability of 50% corresponds to an energy cost increase rate of 0.7% and 2.5% respectively on the two curves, which is almost same as that of all the samples and the iron & steel sector.

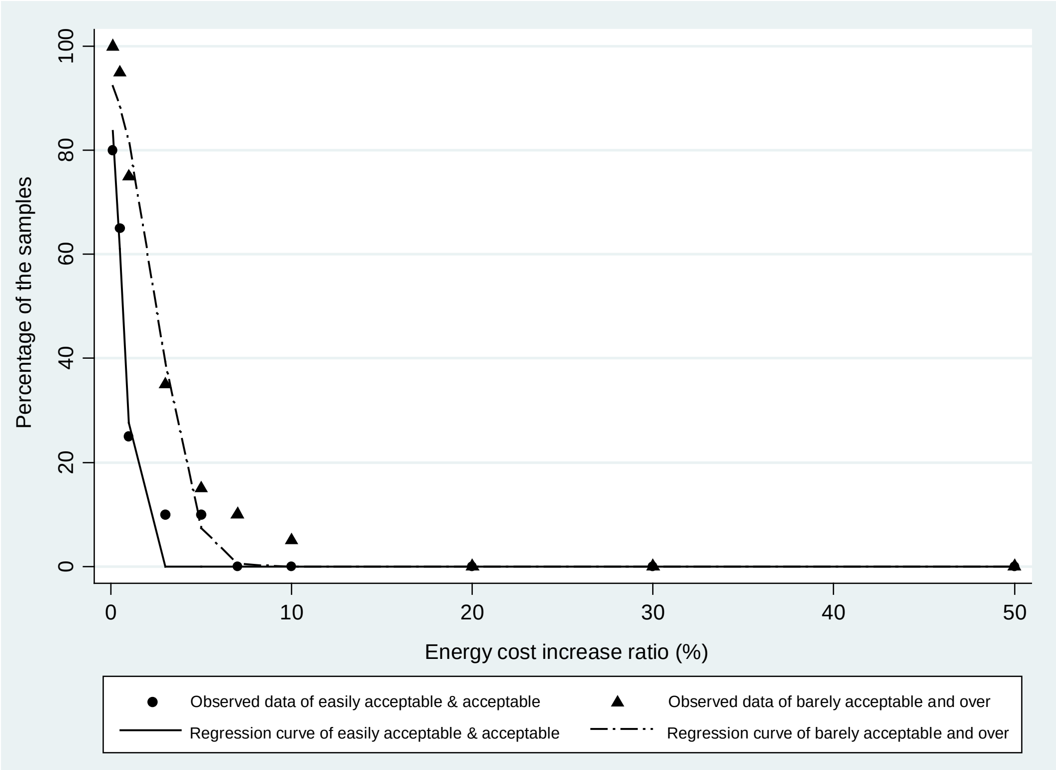

Figure 15 Affordability of energy cost increases for the chemical industry (N=20)

2.4.3 Estimation results of cost affordability for individual companies

The mean and standard variance of affordability of individual companies for energy cost increases were estimated using equation (4). As discussed earlier, numerical likelihood values of affording energy cost increase rates need to be assigned to the verbal expressions in MBDC format. In this study, a 'strong rejection' was given a probability value of 0.1% since a value of zero would generate infinity in the model estimation. A simple 'rejection' was given a value of 25%, 'barely acceptable' 50% and 'acceptable' 75%. An 'easily acceptable' was presented a value of 99.9% to avoid infinity in the calculation. Table 29 lists the mean values and percentiles of all the samples and the respondents from the three target industries.

The mean of energy cost increase rates affordable for all the surveyed companies is 2.6%, which drops near the range of affordability, 0.6% to 2.3%, preliminarily observed from Figure 13. The sample's standard deviation is 3.9%. The medium value of affordability for the companies on energy cost increases is 1.6%. The mean of energy cost increase rates affordable for chemical companies is 2.6% and the mean for steel companies is 2.5%. The medium values of energy cost increase affordability for companies of chemical and steel sectors are the same at 1.6%, which is almost the same as that of all the samples. The mean and medium value of energy cost increase affordability for the cement sector is 2.8% and 1.8%. In comparison with a similar study conducted in China (Liu et al., 2013b), which indicates that a mean of 8.8% in energy cost increase would be acceptable for all the sampled Chinese companies, the affordability of Korean companies is much lower. This may be attributed to the perception of Korean companies in their limited energy saving potential, particularly for the energy-intensive industries targeted in this survey.

Table 29 Distribution of estimated individual company's cost affordability

Variable	Percentile	Centile (%)	95% Conf. Interval (%)	
Panel A: All the samples (N=36)				
Mean of μ: **2.6%** The std. dev. of μ: 3.9%	10	0.4	0.1	0.5
	30	0.7	0.5	1.4
	50	**1.6**	0.9	2.3
	70	2.6	1.7	3.6
	90	9.2	2.8	13.2
Panel B: Samples from iron & steel sector (N=11)				
Mean of μ: **2.5%** The std. dev. of μ: 3.8%	10	0.5	0.5	1.0
	30	0.9	0.5	1.6
	50	**1.6**	0.6	2.4
	70	1.8	1.4	12.7
	90	11.4	1.7	13.3
Panel C: Samples from cement sector (N=5)				
Mean of μ: **2.8%** The std. dev. of μ: 4.3%	10	0.1	0.1	1.5
	30	4.1	0.1	3.9
	50	1.8	0.1	8.8
	70	3.9	4.1	8.8
	90	8.8	20.2	8.8
Panel D: Samples from chemical sector (N=20)				
Mean of μ: **2.6%** The std. dev. of μ: 3.8 %	10	0.3	0.1	0.6
	30	0.7	0.4	1.6
	50	**1.6**	0.7	2.7
	70	2.7	1.5	6.7
	90	9.6	2.7	11.3

*: Lower (upper) confidence limit held at minimum (maximum) of sample.

2.4.4 Statistics of the determinant factors and controls

Table 30 summarises the statistics of determinants as independent variables in Equation (6). The surveyed companies presented moderate scores to ENPRICE (The level of domestic energy prices), with an average of 3.27. COMPETITION achieved a high mean of 4.31. This indicates that the surveyed companies felt strong pressures from market competitors in the same sector. An average score of 3.27 given to ENSTRATEGY implies that companies have moderate motivation to set targets for energy saving. The understanding of companies on energy saving technologies, existing and new, is not optimistic, as EXISTINGTECH and NEWTECH achieved means of 2.89 and 3.05, respectively. A mean of 1.89 for the variable of SAVPOTENTIAL reveals that the surveyed companies are using manufacturing technologies at a domestically advanced level and have limited potential for further improvement in energy efficiency. A mean of 2.43 for AVGEDU indicates that the company employee education level is not so high. Around 30% of the sampled companies have a share of 50% of employees with college level and above education.

Table 30 Statistical summary of the determinant factors

Variable	Obs.	Mean	Std. dev.	Min.	Max.
ENPRICE	62	3.27	0.70	1	5
COMPETITION	62	4.31	0.83	3	5
ENSTRATEGY	62	3.27	1.44	1	5
EXISTINGTECH	62	2.89	0.96	1	5
NEWTECH	62	3.05	0.77	2	5
SAVPOTENTIAL	61	1.89	0.63	1	4
AVGEDU	62	2.43	0.69	1	5

Regarding the characteristics of companies, the distribution of samples by sector and size has been described in section 4. The rates of samples with an ownership of domestically private and foreign-funded are 88.7% and 11.3%, respectively.

2.4.5 Correlation matrix and bi-variable results

Pair-wise correlation was calculated to explore the relationships between the estimated cost affordability, *MEANAFFORD*, and the independent variables. The correlation matrix is shown in Table 31.

Table 31 Correlation matrix of estimated affordability and the determinants

	MEAN	ENP.	COM.	ENS.	EXI.	NEW.	SAV.	AVG.
MEANAFFORD	1.000							
ENPRICE	-0.106	1.000						
COMPETITION	0.026	-0.101	1.000					
ENSTRATEGY	-0.081	0.099	0.080	1.000				
EXISTINGTECH	-0.029	-0.131	0.187	0.106	1.000			
NEWTECH	-0.213	-0.230[c]	-0.152	0.257[b]	0.437[a]	1.000		
SAVPOTENTIAL	0.034	-0.359[a]	-0.088	0.019	-0.051	0.048	1.000	
AVGEDU	-0.294[c]	-0.114	0.004	0.072	0.050	0.026	-0.141	1.000

[a]: Significant at 1% level; [b]: Significant at 5% level; [c]: Significant at 10%.

There is no indication for an unacceptable level of multi-collinearity between these variables as the highest correlation coefficient is 0.437 for NEWTECH (Awareness of new energy saving technologies) and EXISTINGTECH (Awareness of existing energy saving technologies). Harmful levels of multi-collinearity are expected not to occur until the correlation coefficient reaches ±0.8 or ±0.9 (Farrar and Glauber, 1967). The correlation result indicates that AVGEDU

(Average education level of the company's employees) is significantly but negatively associated with MEANAFFORD at *P*<0.1. The other variables have no significant correlations with the estimated MEANAFFORD.

2.4.6 Multivariate regression results of the estimated affordability

Table 32 presents the results of econometric analysis of the estimated affordability of the companies using equation (6). This analysis tests the validity and quality of the affordability estimations for individual companies since the estimated results track underlying economic factors and intuitive comprehension. In practice, econometric analysis can check the ordering effects of matrix design in the MBDC approach. As a referendum method, there may be an anchoring effect of the cost presentation sequence in the MBDC format. Considering the difficulty in requesting cooperation from companies, the questionnaire in this survey only used an identical matrix starting at the lowest cost increase rate, with all the other rate options ascending. Therefore, anchoring effects cannot be tested in this analysis.

Table 32 Multivariate regression results of cost affordability for companies

Independent variables and controls		**Coefficients with mean affordability as the dependent**		
		Model 1	**Model 2**	**Model 3**
ENPRICE		-0.003	-0.009	-0.013*
COMPETITION		-0.001	-0.009	-0.011
ENSTRATEGY			0.001	0.001
EXISTINGTECH			0.002	0.004
NEWTECH			-0.015	-0.017
SAVPOTENTIAL			-0.003	-0.010
AVGEDU			-0.009*	-0.008
SIZE	MEDIUM			0.009
	LMEDIUM			0.019
	LARGE			0.015
SECTOR	CEMENT			-0.013
	CHEMICAL			-0.009
OWNERSHIP	FOREIGN			0.033*
TMS				0.026
Obs.		36	35	35
R Squared		0.011	0.192	0.349

* Significant at 10%.

The robustness of the analysis results was tested by repeating the regression with gradual introduction of the independent variables and controls. Three models were adopted: Model 1 only imports external pressures as independent variables, Model 2 adds the internal factors and Model 3 includes all the independent variables and controls. There are no obvious changes of the determinants that have significant relationships with the estimated affordability. It is indicated that energy price level and ownership are significantly associated with affordability. Compared with domestically private companies, foreign-funded ones have relatively higher affordability for energy cost increases. If a company feels energy prices are already high, it would be more difficult for such company to afford additional energy price increases resulting from the pricing of carbon emissions. All other determinant factors and controls, including the company sector and size, reveal no significant effect on the estimated cost affordability.

2.4.7 Carbon price affordability for the companies by sector

According to carbon tax policy, costs are ascribed to CO_2 emissions based on a specific carbon tax rate, and the price of CO_2 emissions under GHG ETS is determined by supply and demand of emissions credits in the carbon market. Energy cost increases that a company or sector can afford on average, *MEANAFFORD*, equates to the affordable price of carbon in response to the introduction of carbon pricing policies, the relationship of which can be expressed as equation (7), where *i* means the energy type.

$$\begin{aligned} MEANAFFORD &= \frac{\sum_i Emission\ factor_i \times Use\ amount_i \times Affordable\ carbon\ price}{\sum_i Energy\ price_i \times Use\ amount_i} \\ &= \frac{\sum_i Emission\ factor_i \times Energy\ ratio_i \times Affordable\ carbon\ price}{\sum_i Energy\ price_i \times Energy\ ratio_i} \end{aligned} \tag{7}$$

To arrive at an affordable price for carbon for the respondents, equation (7) can be incorporated into the following equation (8), which uses the mean of affordable rates of energy cost increases, *MEANAFFORD*, and the surveyed rates of energy uses of the companies by type.

$$Affordable\ carbon\ price = MEANAFFORD \times \frac{\sum_i Energy\ price_i \times Energy\ ratio_i}{\sum_i Emission\ factor_i \times Energy\ ratio_i} \tag{8}$$

The data sources and calculation results are listed in Table 33. An underlying assumption for this calculation is that price increases of the secondary energies (including electricity and steam) due to the introduction of climate economic policies are fully passed on to the final energy users.

Table 33 Estimations of affordable carbon prices by sector

Energy type	Energy use rates (%)			Current energy price[*1]	Emission factor [*3]
	Iron & steel	Cement	Chemical		
Electricity	64.0	29.3	51.3	73.69 KRW/KWh	1.428t-C/toe[*4]
Coal	3.6	36.9	0.5	113,138 KRW/t	1.059 t-C/ toe
Fuel oil	5.2	1.6	10.0	612,352 KRW/t	0.875 t-C/ toe
Gas	24.8	8.2	15.5	552 KRW/m^3	0.637 t-C/ toe
Steam	0.2	0	15.7	30,000 KRW/t [*2]	0.3231t-C/ toe
MEANAFFORD	2.5%	2.8%	2.6%		
Affordable carbon price KRW(USD)/t-CO_2	3,770 (3.3)	2,600 (2.3)	3,950 (3.5)		

Data sources: [*1] IEA (2010); [*2] International Internet Journal; [*3] IPCC (1996); [*4] Kim (2006).
As of August 2013, exchange rate was: KRW1,000 = USD0.9

The calculation results indicate that a carbon price of 2,500 to 4,000 KRW/t-CO_2 (about 2.3 to 3.5 USD/t-CO_2) would be acceptable for the surveyed companies in Korea. These figures are much lower than the price level affordable for Chinese companies (which range from 6 to 12 USD/t-CO_2) (Liu et al., 2013b). In comparison with the carbon tax policies actually practiced in Europe—20 Euro/t-CO_2 in 2010 for Finland (the first country to introduce the tax) and approx. 13 Euro/t-CO_2 for Denmark (since 2002)—the carbon price affordable for Korean companies is thus comparatively low. However, blanket agreement between the EU member states has not been reached and the current European Commission (EC) proposal is 4–30 Euro/t-CO_2 (SBS News, 2013).

There exists a large gap between the present cost affordability of Korean companies and the carbon price identified by macro-economic modeling for realizing the country's GHG mitigation target over the medium term. Kwon and Heo (2010) suggested that a carbon tax equivalent to 36,545 KRW/t-CO_2 (about 31 USD/t-CO_2) would be required to achieve Korea's 2020 mitigation target. Calvin et al. (2012) compared the Copenhagen pledges to the results from 23 different models, all of which participated in the Asia Modeling Exercise (AME), and found that of the nine models reporting results for Korea only two ever attain the pledged amount, with carbon prices of 30–50 USD/t-CO_2. Nevertheless, a recent KIPF report recommends that the carbon tax should be introduced in Korea at a lower rate initially, bearing in mind the short-term negative impact on industrial competitiveness and acceptance at the company level (Kim and Kim, 2010). Kim and Kim (2010) thus suggested a carbon tax rate at the level of 1/8 that of KIPF's first proposal which was 25 EURO/t-CO_2, equivalent to 31,328 KRW/t-CO_2 and 28.2 USD/t-CO_2 (Kim et al., 2008). Therefore, the estimated carbon price affordable for companies in this survey is at a level comparable with the tax rate proposed by KIPF, which confirms that KIPF's latest carbon tax proposal, in terms of the tax rate, would be acceptable for the Korean companies surveyed.

2.5 Conclusions

This study extended application of the MBDC technique to estimate the affordability of Korean companies in energy-intensive industries for energy cost increases due to possible introduction of market-based climate policies. The results indicate that a mean energy cost increase of 2.6% is acceptable for the respondents as a whole. Further, this affordability is relatively consistent across the three sectors, with the range of acceptable energy cost increases being 2.5–2.8%. Econometric analysis confirms the current energy price level and company ownership as the determinants significantly affecting the cost affordability of the companies. The calculations of the affordable carbon prices for companies may be referred for the development of carbon tax policy and the establishment of a domestic GHG ETS in Korea. In contrast with policy practices in Europe, progress in the pricing of carbon emissions is laggard in major Asian economies, including Japan, China and Korea (Liu et al., 2011). This analysis shows the limited cost affordability of Korean companies, confirming that introducing effective carbon pricing policies in this country is highly difficult. In practice, levying of taxes on carbon emissions for companies in Korea would thus need be introduced gradually and start with low rates, as practiced for Japan's environmental tax which started October 2012 (Liu et al., 2011). As described earlier, domestic GHG ETS for Korea will be formally launched at the beginning of 2015; however, this scheme would not exert a real economic burden on the target entities since the allowances will be allocated fully for free in the initial phase and the rates by auction will be very limited in the following two phases. Therefore, Korea will have to rely on regulatory measures, e.g., TMS, to achieve its GHG mitigation target in the medium term. Nevertheless, such modification of the policy mix, which permits more leeway for economic measures, is a step in the right direction towards reducing GHG emissions in a cost-effective way. Korea's government intends to continue enhancing the awareness of and support from industry for carbon pricing policies, so that introduction thereof may be implemented smoothly.

This research does suffer several shortcomings, as follows. The survey relied on self-reporting by companies, only a very limited number of samples of which were gathered for the analysis. Companies were particularly reluctant to provide internal quantitative data, and less than 60% of the samples provided full answers for the MBDC format. This small sample size may lead to bias in the estimations and thus limit the general scope of applicability based on the research findings. Further studies would close these gaps by expanding the surveys in sample scale and number of sectors, as companies in less energy-intensive industries may respond to climate policies differently; such research efforts may facilitate a more comprehensive understanding of the level of business acceptability of policy costs in Korea. In addition, the real policy acceptance of companies needs to be jointly determined by the costs and non-economic aspects, such as the complexity, transparency and flexibility of the policies. Subsequent research should also account for perspectives from the side of the companies themselves as regards these factors. All such empirical input would help in the formulation of effective and equitable climate policies for Korea.

3. A SURVEY ANALYSIS OF COMPANY PERSPECTIVE TO THE GHG EMISSIONS TRADING SCHEME IN KOREA[12]

[Abstract]

This study discussed two topics; one is to monitor the opinions of Korean companies to various aspects of GHG ETS, and other is to identify the difference in companies' viewpoints due to their characteristics in organizational size, sector and ownership. This analysis was carried out in a qualitative manner using the 66 data collected by a questionnaire survey to energy-intensive cement, iron and steel and petro-chemical industries.

This study observed that most of the surveyed companies are still opposed to the introduction of GHG ETS although the introduction schedule has been decided by the government. Company size and sector significantly determine their evaluation of negative aspects of GHG ETS. It clarifies the difficulties and expectations of the industry for GHG ETS. A meaningful finding form this survey is that the companies would make internal efforts in energy saving and GHG mitigation and invest in energy efficient technologies rather than simply transfer the policy burden to their clients. This study suggests that Korean government shall make efforts to meet companies' expectation to overcome the barriers, for examples, the coordination of GHG ETS with ongoing policies, declaration of the method for emission allowance allocation, clarification of responsibilities of authorities in charge, and capacity building are the priorities.

With a view to introduction of a domestic GHG ETS in Korea, this research provides a basis for better understanding of an industrial perspective, which may be referred for the discussion and development of the GHG ETS.

Key words: companies, emission trading scheme, Korea

[12] This chapter is based on the book chapter "A Survey Analysis of Company Perspective to the GHG Emissions Trading Scheme in the Republic of Korea" in the book titled "Environmental Taxation and Green Fiscal Reform: Theory and Impact" published at the Edward Elgar in 2014.

3.1 Introduction

Korea announced in November 2009 to reduce its GHG emissions by 30% from the BAU scenario by 2020. Korean industry used 61.6% of the country's total energy in 2011, making it a key target of climate policies (KEMCO, 2013). The enactment of the 'Basic Act on Low Carbon Green Growth' in 2010 established a legal ground for the practice of MBIs, i.e., GHG ETS and carbon tax, etc. Korea adopted the mandatory TMS in 2011 for large energy-consuming entities. The TMS paves the way for the introduction of GHG ETS in Korea. Accordingly, a bill of quasi-mandatory GHG ETS was approved in May 2012 and determined to launch the domestic GHG ETS at the beginning of 2015. More recently, a bill of carbon tax was also proposed, suggesting the introduction of this policy from 2016.

GHG ETS holds theoretical advantage in cost efficiency and shall be effective for GHG mitigation referring to the experience of EU-ETS as the largest example of emissions trading in operation, encompassing over 11,500 installations across 30 countries and covering approximately 40% of total EU emissions. This scheme has led to emissions reductions of 40 - 80 Mt-CO_2 per year, sharing about 2-4% of the total capped emissions. This amount is much bigger than the impact of most other individual policy instruments. According to the studies investigating the impact of the EU-ETS based on managerial interviews at firms, EU ETS has captured attentions of decision-makers and brought some impact on the innovation and investment of low carbon technology (Laing et al., 2013). However, businesses in Korea indicate less acceptability to carbon pricing policies and show limited affordability of costs originated from the introduction of MBIs (Suk et al., 2014; Suk, 2017). Our previous survey confirmed the marginal function of the government in enhancing Korean company's energy saving and GHG mitigation practices (Suk et al., 2013). The resistance from industry was identified as the largest barrier for the introduction of GHG ETS in Korea. In practice, the acceptance level of companies, as the major policy targets, is a key factor determining the actual progress and success of climate policies. It is necessary to understand viewpoints of businesses to the policies in advance. However, few studies have been conducted at the individual company level in Korea under the emerging process of carbon pricing policies.

Aiming to bridge the existing gap, a questionnaire survey to Korean companies was arranged to clarify their perspective to GHG ETS. Two topics are discussed in this chapter. One is to monitor the opinions of Korean companies to various aspects of GHG ETS. The other is to identify the difference in company's viewpoints due to their characteristics in organizational size, sector belongings and ownership. Three sectors, iron & steel, cement, and petro-chemical industries, were targeted since they are energy-intensive and significant for realizing the country's overall goal of GHG mitigation.

This chapter is set up as follows. Section 2 describes the progress of GHG ETS in Korea and the debate for the introduction of this scheme. Section 3 outlines the questionnaire survey and the samples. Section 4 discusses the survey analysis results. Lastly, section 5 concludes this survey study.

3.2 The progress of GHG ETS in Korea

3.2.1 GHG ETS proposals and bill of Korea

The preliminary proposal of GHG ETS was firstly formulated in November 2010, suggesting its introduction in 2013 with three phases. The first phase would start from 2013 and end in 2015. Two following phases would run for five years for each from 2016. In this proposal, 10% of the total allowances would be allocated by auction and the remaining 90% for free in the initial phase, with the auction proportions increased thereafter. The penalty for non-compliance emissions is less than five times the average market price of credits. This preliminary proposal received strong opposition from industry. As a result, the proposal was revised and its stringency was watered down in terms of starting time, the allocation of emissions allowances and the level of penalty, etc. The starting time was postponed to 1 January 2015 and 95% allowances would be allocated for free in the initial period. The penalty was decreased to less than three times the average market price and as up to 100,000 KRW/t-CO_2 (About 90 USD/t-CO_2). The updated proposal called for an 'Allocation Committee', led by the MOSF, for determining the method of allowances allocation for each field and maintaining the stability of carbon market. This proposal indicated one likely option for targeting the largest energy consumers or GHG emitters heading the list of TMS targets. Allowances transfer is allowable between different compliance periods.

This revised proposal was submitted to the parliament in April 2011. After slight revisions, the GHG ETS bill, namely the 'Act on Allocation and Trading of Greenhouse Gas Emissions Allowances', was finally approved by the parliament in May 2012. Later, the 'Presidential Decree', officially approved on 13 November 2012, clarified the commencement of GHG ETS since the beginning of 2015 and specified the management rules. Responsibility for operation lies within the MOE of Korea. The entities emitting over 125,000t-CO_2 and business sites emitting over 25,000t-CO_2 annually shall participate obligatorily. The legislation provides for allowances to be allocated fully for free in the first phase (2015–2017), at 95–97% for the second phase (2018–2020) and at 90% for the third phase (2021–2025). Banking within and between compliance periods, and borrowing within compliance period are allowed. Six years later, domestic and foreign individuals or corporations can join as parties for the transaction. The carbon leakage sectors will be given 100% free allocation. Early action for GHG reductions will be recognized. MOEK established the 'Emissions Trading Task Force' to prepare for the detailed allocation method for emissions allowances.

3.2.2 The debate for the introduction of GHG ETS in Korea

Cost effectiveness is viewed as the key merit for Korea to introduce GHG ETS. The evaluations of several core research institutes in Korea did indicate that GHG ETS would be more cost effective than the mandatory regulations, like TMS, and could save the cost by 44% to 68% for achieving the country's GHG mitigation target of 2020 (PCGG press, 2011; Kim and Kim, 2010; Lee, 2009). On the other hand, Korea Energy Management Cooperation (KEMCO) estimated that the additional production cost would be 5.6 trillion KRW (About 943 million USD) for main industries if 10% of the allowances were allocated by auction. Similarly, several studies revealed the additional production cost increase of overall sectors in difference allowance scenarios of the ETS introduction (Kim, 2009c; Lee, 2010a; Han et al., 2010, Steel & Steel, 2011; Cho, 2011). Referring to the estimation results above, the industry argued that GHG ETS would obviously weaken the industrial competitiveness due to the increase of production costs, and increase burden to the Korean economy as a whole.

Korean industry also emphasized that early action of Korea would bring significantly adverse impact to its competitiveness in international markets, considering the laggard policy movement of major competing economies, e.g., the U.S., China and Japan, in the pricing of carbon emissions. Korean companies pointed out that this policy effort of Korea would not have virtual contribution to the mitigation overall, given that GHG emissions of Korea only account for 1.7 % of global total. The other concerns of industry include the stability of carbon credit prices and the sufficient number of participants for the market to operate smoothly. Actually, the number of business sites emitting GHG emissions over 25,000t-CO_2 in 2007 was only 704 in Korea, with emissions sharing 78% of the total from manufacturing sector. The top 25 business sites contributed to 40% of the emissions of manufacturing industry (except for the power sector). The total participants by the business sites in Korea would be no more than 600. If counted by entities, the number of GHG ETS targets would be much less. High concentration of GHG emissions emitters and small number of GHG ETS targets may cause low credit liquidity and instability of carbon prices.

Affirming the usefulness of governmental requirements in mandatory (Suk et al., 2017), Korean companies assert that the existing regulations are sufficiently strong and effective considering the introduction of the GHG ETS. They strongly appeal their good performance to abide by the regulations and insist on their limited potential for energy efficiency improvement and GHG mitigation. In fact, petro-chemical, cement, and iron & steel sectors have achieved comparative level in energy efficiency with Japan and Germany (IEA, 2007). The companies thus argued that GHG ETS with high stringency would discourage their investments since they have to purchase additional credits for the increased production.

3.3 The questionnaire survey and the samples

Based on the understanding of Korean situation, a questionnaire was developed with main objectives of estimating the affordability of companies on carbon prices and measuring their perspective to GHG ETS. Major components of the format include company general information;

company’s energy use and management status; the acceptability level to various energy cost increases due to carbon pricing policies; and, company’s opinions of GHG ETS. This chapter summarizes the part of company’s perspective of GHG ETS.

The survey was carried out from 25 January to 10 February 2012. Questionnaires were sent via fax and email to 205 companies including 137 TMS target companies and 68 non-TMS, intending to be filled out by environmental and energy managers. Valid answers from 62 companies were collected and used for this analysis. The distribution of the samples by company characteristics is summarized in Table 34.

Table 34 Distribution of respondents by company’s characteristics

Company’s characteristics		**Number of samples**				**Number (Percentage)**
		Small	**Medium**	**Large Medium**	**Large**	
Sector	Cement	2	6	2	1	11 (17.7)
	Steel	-	8	5	3	16 (25.8)
	Petro-chemical	-	13	13	9	35 (56.5)
Number (Percentage)		2 (3.2)	27 (43.5)	20 (32.2)	13 (21.0)	62 (100.0)
TMS target or not	TMS	2	26	17	13	58 (93.5)
	Non-TMS	-	1	3	-	4 (6.5)
Number (Percentage)		2 (3.2)	27 (43.5)	20 (32.2)	13 (21.0)	62 (100.0)

The respondents from cement, iron & steel and petro-chemical sectors individually account for 17.7%, 25.8% and 56.5 % of the total. Twenty seven are medium-sized companies having 50 -300 staffs, 2 are small companies with staff number less than 50, and 13 are large companies with employees over 1,000. The remaining 20 are large medium-sized between large and medium-sized companies. Of the total 62 samples, 58 are TMS target companies.

Overall, the surveyed companies are large energy consumers and heavy carbon emitters. Around 95% of them used more than 2,000 toe of energy in 2010. The samples consuming more than 100,000 toe in 2010 account for 35.5% of the total. Most respondents (92%) emit over 25,000t-CO_2 annually. The companies with emissions less than 5,000t-CO_2 only share 4.8%. The other companies answered that their annual CO_2 emissions are between 5,000 to 15,000t-CO_2. The companies were requested to check their potential for energy saving. A majority of them evaluated that there remains limited energy saving potential. Even 40% of iron & steel companies selected almost no further potential. Only 3% of the samples in petro-chemical sector admit that they have very high potentials.

3.4 Results and discussions

3.4.1 Company's evaluations of merits of GHG ETS

The companies were asked to evaluate the advantages of GHG ETS to be implemented in Korea. A five-point scale was applied, with 5 = 'very appropriate', 4 = 'appropriate', 3 = 'somewhat appropriate', 2 = 'not appropriate', 1 = 'not appropriate at all'. The average scores for the six merits listed in the questionnaire are shown in Table 35.

Table 35 Company's evaluations of merits of GHG ETS

Item	Merits	Mean of scores			
		Overall (N=62)	Chemical (N=35)	Cement (N=11)	Steel (N=16)
MERIT01	ETS is an effective measure to mitigate GHG emissions	3.08	3.40	2.55	2.75
MERIT02	ETS is cost-effective compared with regulative policies	2.86	2.83	2.64	3.06
MERIT03	There would be an advantage to be better involved in international carbon market if introduced earlier	2.40	2.63	2.00	2.19
MERIT04	It is a global policy trend to introduce ETS	2.45	2.66	2.09	2.25
MERIT05	Compared with TMS, ETS has a possibly positive effect in generating economic revenues	2.08	2.23	1.82	1.94
MERIT06	Introducing ETS may generate the opportunities for new business and employment	2.50	2.69	2.09	2.38

The companies evaluated the advantages of GHG ETS at low degrees and almost all the merit items achieved a mean under 3.00. The samples moderately recognize GHG ETS as an effective measure for GHG mitigation, with a mean of 3.08 for MERIT01. Although Korean government expects to make use of the advantage of GHG ETS in cost efficiency, the businesses seem not to agree with this, with the mean for MERIT02 being 2.86. The companies do not believe that GHG ETS could generate economic revenues at current stage and present MERIT05 the lowest mean of 2.08. This result confirms the negative attitude of Korean companies to the introduction of GHG ETS in Korea.

Econometric regressions were performed for identifying the difference in company's evaluations of GHG ETS merits due to their various characteristics. As the dependent variables, the evaluations of GHG ETS merits, MERIT01 to MERIT06, are in an ordinal measurement. Ordered logistic model is a rational choice for this analysis (Greene, 1997). Company size, sector belongings, ownership, TMS involvement and its international orientation are selected as the independent variables. The company size, SIZE, is classified into small, medium, medium-large and large, individually named as SMALL, MEDIUM, MLARGE and LARGE. Sector belongings, SECTOR, have three categories: iron & steel, cement, and chemical, which are presented as STEEL, CEMENT and CHEMICAL. The ownership consists of two types, domestically private and foreign-funded, DOMESTIC and FOREIGN. The status of TMS involvement is indicated as TMS for the targets and non-TMS for the others. The main market of the products, EXPORT, is used as the proxy of a company's international orientation. Companies with products for the domestic market are presented a value of '0' and '1' is for the export-oriented companies. The regression coefficients are listed in Table 36

Table 36 Regression results of company's evaluations of merits of GHG ETS

Independent variables		Dependent variables					
		MERIT01	**MERIT02**	**MERIT03**	**MERIT04**	**MERIT05**	**MERIT06**
SECTOR	STEEL	0.389	0.583	0.151	0.741	0.448	0.540
	CHEMICAL	**1.262[a]**	0.361	0.629	**1.274[a]**	0.898[c]	**0.912[b]**
SIZE	MEDIUM	-0.862	-1.291	0.577	**-1.546[c]**	-0.522	-0.812
	MLARGE	-0.407	-0.980	1.182	-1.419	-0.537	-0.594
	LARGE	-0.806	-1.325	0.918	**-1.759[b]**	-0.740	-1.305
DOMESTIC		0.301	-0.647	-0.076	0.358	0.007	0.282
TMS		-0.566	-0.217	-0.774	**-1.238[b]**	-1.426[b]	**-1.70[a]**
EXPORT		-0.178	-0.051	-0.128	-0.543	-0.126	0.208
Obs.		62	62	62	62	62	62
LR chi		**16.08[b]**	5.57	12.23	**15.42[c]**	10.16	**17.84[b]**
Pseudo R^2		0.098	0.030	0.073	0.089	0.067	0.100

[a] Significant at 1%; [b] Significant at 5%; [c] Significant at 10%.

The regression results of MERIT01, MERIT04 and MERIT06 are statistically significant. Compared with cement companies, the samples from petro-chemical industry gave more positive assessment to all these three merits of GHG ETS. Company size is significantly but negatively associated with the evaluations of MERIT04. It is less likely for the companies with medium size and above to view GHG ETS as a global policy trend than the small ones. Similarly, TMS targets more negatively evaluate MERIT04 and MERIT06 in comparison with the non-TMS companies. This result is consistent with intuitive perception. The companies with higher energy intensities, larger size and covered by TMS are more likely included by GHG ETS and have negative attitudes to the merits of this policy.

3.4.2 Company's evaluations of negative aspects of GHG ETS

In order to find out to what extent Korean businesses are concerned about the negative issues of GHG ETS, the samples were requested to evaluate 10 items of disadvantages pre-listed in the questionnaire. A five-point scale was applied, with 5 being 'highly concern' and 1 meaning 'no concern at all'. The statistics are presented in Table 37.

Table 37 Company's evaluations of negative aspects of GHG ETS

Item	Negative aspects	Mean of the scores			
		Overall (N=62)	Chemical (N=35)	Cement (N=11)	Steel (N=16)
NEG01	Premature implementation and loss of business competitiveness	4.52	4.40	4.91	4.50
NEG02	Unclearness of the detailed operation scheme including emission allowance allocation method, etc.	4.39	4.17	4.73	4.63
NEG03	Unclearness of the detailed measure to avoid the possible double burdens with TMS	4.29	4.20	4.18	4.56
NEG04	Ambiguity of the contribution of ETS to national GHG reductions	4.02	3.89	4.00	4.31
NEG05	Company's lack of capacity to cope with the implementation of ETS	4.00	3.86	4.18	4.19
NEG06	Insufficient liquidity of carbon market due to the limited credit volume in total	3.98	3.71	4.27	4.38
NEG07	Instability of carbon price and the speculative trading	4.05	3.94	4.36	4.06
NEG08	Carbon leakage problem	3.97	3.89	4.27	3.94
NEG09	Foreign companies hesitate to invest in Korea and the problem of domestic deindustrialization	4.16	4.00	4.55	4.25
NEG10	Ambiguity of the competent authorities and their responsibilities in implementing ETS	3.98	3.83	4.00	4.31

The companies revealed high concerns about the negative aspect of GHG ETS and all the items achieved a mean of nearly 4.00 and over. Among which, NEG01 is presented the highest mean of 4.52. This implies that the companies commonly and most worry about the loss of business competitiveness due to the production cost increase if GHG ETS is phased in earlier in Korea than major competition countries. The uncleanness of the detailed operation scheme, e.g., method for emissions allowance allocation (NEG02), was ranked the second, with a mean of 4.39. The surveyed companies also concern about other ambiguous issues of GHG ETS, including the expected contribution of this policy for GHG mitigation of the country (NEG04), the relationship between GHG ETS and the mandatory TMS (NEG03), market liquidity (NEG06), carbon price stability (NEG07) and the unclear responsibilities of related authorities for the policy implementation (NEG10). This requires Korean government to further clear these aspects for achieving the understanding and support from the industry.

Ordered logistic analyses were carried out with company's evaluations of disadvantages of GHG ETS, NEG01 to NEG10, as the dependent variables, and the company's characteristics as independents. The regression coefficients, as listed in Table 38, indicate that the results of NEG02, NEG06, NEG07 and NEG10 are statistically significant.

Table 38 Regression results of company's evaluations of negative aspects of GHG ETS

Independent variables		**Dependent variables**									
		NEG01	**NEG02**	**NEG03**	**NEG04**	**NEG05**	**NEG06**	**NEG07**	**NEG08**	**NEG09**	**NEG10**
SECTOR	STEEL	-1.358	-1.076	0.440	0.423	-0.131	-0.446	**-0.937[c]**	-0.833[c]	-0.756	0.641
	CHEMICAL	-1.534	**-1.958[a]**	-0.150	-0.206	-0.676	**-1.522[a]**	**-1.209[b]**	-0.946[b]	-1.236[b]	0.002
SIZE	MEDIUM	-4.604	**2.177[b]**	0.485	1.061	0.417	**2.582[a]**	**1.716[c]**	1.434	1.110	0.823
	MLARGE	-4.852	**2.277[b]**	0.311	0.610	0.382	**2.712[a]**	**1.781[c]**	1.150	0.699	0.201
	LARGE	-4.631	**2.466[b]**	0.801	1.070	0.905	**3.217[a]**	**2.467[b]**	2.059[b]	1.059	1.078
DOMESTIC		-0.234	-0.236	-0.430	-0.556	-0.023	-0.365	-0.552	-0.343	-0.568	**-1.056[b]**
TMS		1.050	0.990	-0.122	0.182	0.810	**1.377[b]**	0.903	-0.216	-0.637	-0.976
EXPORT		0.060	-0.139	-0.392	-0.416	-0.086	-0.358	-0.089	0.078	0.445	-0.879
Obs.		62	62	62	62	62	62	62	62	62	62
LR chi		11.96	**17.37[b]**	6.55	10.73	7.59	**25.82[a]**	**14.48[c]**	10.27	11.87	**20.06[b]**
Pseudo R^2		0.110	0.146	0.052	0.079	0.057	0.175	0.106	0.077	0.087	0.138

[a] Significant at 1%; [b] Significant at 5%; [c] Significant at 10%.

Company size and sector belongings significantly determine their evaluation of negative aspects of GHG ETS. Specifically, it is less likely for chemical companies to concern about these three negative points of GHG ETS compared with the cement industry. Steel companies concern less on carbon price stability (NEG07) than their counterparts from the cement sector. In comparison with small companies, the samples of the other size categories more likely emphasize NEG02, NEG06 and NEG07. Additionally, foreign-funded companies tend to make clear the competent authorities and their responsibilities in implementing GHG ETS (NEG10) than the ones with domestic ownership. TMS targets more address NEG06 than the non-TMS ones.

3.4.3 Company's preparations for GHG ETS

The companies were asked to check the activities they have practiced or plan to do for the preparation of GHG ETS. Table 39 lists the percentages of samples with answer of 'YES' overall and by sector. It is encouraging that most companies (93.5%) have established the internal inventory of GHG emissions, which is verified by a third party. This is because most sampled companies are targeted by the TMS launched in 2011 and TMS requires the target entities to establish their inventories of GHG emissions. Companies have made some preparations for GHG ETS by institutional arrangement. Nearly 40% of them established a specific division for TMS and GHG ETS. Around 1/3 of the samples actively participate in the pilots of TMS or GHG ETS for accumulating policy practice experiences. Nevertheless, the companies have not started to act by self-implementation and this activity only achieved a participation ratio of 4.8%. The samples did not consider about achieving carbon credits by the offsetting programs, which obtained the lowest participation ratio of 3.2%. It is meaningful that the companies do not believe the moving of production to areas with loose regulations as an option and less than 5% of the samples ticked this choice.

Table 39 Company's preparations for GHG ETS

No.	Preparation activities	Percentage with 'YES' (%)			
		Overall (N=62)	Cement (N=11)	Steel (N=16)	Chemical (N=35)
1	Establish a specific division for TMS and ETS	38.7	48.6	27.3	25.0
2	Sign the MOU with government for the self-implementation of ETS within the group company	4.8	8.6	0.0	0.0
3	Establish the company's inventory of GHG emissions and verified by a third party	93.5	94.3	90.9	93.8
4	Participate in the pilot project of ETS or TMS	33.9	48.6	27.3	6.3
5	Develop the offset program for achieving carbon credits	3.2	2.9	0.0	6.3
6	Plan to move the factory abroad with loose carbon regulations	4.8	5.7	0.0	6.3
7	Hire or outsource external professionals or company for necessary preparations	21.0	22.9	0.0	31.3

3.4.4 Company's behavioral changes in response to GHG ETS

The company's energy costs would increase while introducing GHG ETS. Aiming to understand the possible responses of companies to this policy, we requested the samples to check the possibility to take alternative actions. A five-point scale was applied with the meanings: '5' = very possible; '4' = relatively possible; '3' = moderate possibility; '2' = low possibility; and '1' = completely impossible. The statistics are listed in Table 40.

The companies would avoid the reactive behaviors, including to reduce production; move production to the areas with loose policy; close production facilities; and, to take no reaction by accepting the loss. These four choices were presented average scores under 2.70. In contrast, the companies prefer to internal efforts in energy saving to relieve the policy's negative impacts. Practicing managerial energy-saving activities is the most possible choice, with the highest mean of 3.82. To invest in energy efficient technologies, self-investment in R&D and use less carbon-intensive energies are preferable options with relatively higher possibilities. Besides capping emissions, another key objective of the GHG ETS is to drive innovations in low-carbon technologies, incentivize additional investments in low carbon assets and reduce investment in carbon-intensive products and processes. The companies would not like to simply transfer the policy economic burden to their clients. The option of raising product prices for cost shifting achieved a moderate mean of 2.84. De Groot et al. (2001) suggested that Dutch companies would more possibly charge the customers with additional costs given an energy tax increase. The different finding of this survey may be attributed to the strict competition faced by Korean companies. In this sense, our survey, to a certain degree, confirmed the effectiveness of GHG ETS in enhancing Korean company's efforts in energy saving and GHG mitigation.

Table 40 Company's behavioral changes in response to GHG ETS

No.	Optional actions	Mean of scores			
		Overall (N=62)	Chemical (N=35)	Cement (N=11)	Steel (N=16)
1	Strengthen internal management and save energy through management measures	3.82	3.89	3.73	3.75
2	Invest in more advanced energy-saving technologies and equipments	3.58	3.71	3.45	3.38
3	Self-investment in research and develop of new energy-saving technologies and equipments	2.84	2.97	2.36	2.88
4	Try to use low carbon energies, adjust the company's energy use structure	2.90	3.09	2.09	3.06
5	Adjust product structure for reducing energy intensity per product	3.31	3.46	2.82	3.31
6	Raise the product price to transfer the increased costs	3.15	3.00	3.18	3.44
7	Increase production amount to reduce the energy cost in average	2.84	3.00	2.45	2.75
8	Reduce productions to alleviate market pressure due to cost increase	2.11	2.09	2.27	2.06
9	Relocate part or all the company to areas with relatively loose policies	2.32	2.43	2.18	2.19
10	Stop the production and business due to cost pressures	2.03	2.03	2.73	1.56
11	No specific reaction by accepting the loss due to cost increase	2.68	2.57	2.73	2.88

3.4.5 The barriers for companies to implement GHG ETS

The companies were asked the difficulties they may encounter for the implementation of GHG ETS. Table 41 lists the percentages of samples confirming the barriers pre-listed in the survey document.

It is obvious that companies feel pressures from the introduction of GHG ETS due to the limited reduction potential, with the highest ratio of 80.6%. As mentioned earlier, energy intensities of the three target sectors have been improved dramatically in the past (Park and Kim, 2009). The energy efficiency of the most energy-intensive petro-chemical and steel sectors in Korea has generally outpaced their counterparts in other countries (IEA, 2009a). The barriers with relatively high ratios of 'YES' answers are 'lack of information for the analysis of future carbon market' (64.5%) and 'lack of specialists on energy management and reduction potential identification' (61.3%). Less companies confirmed the 'budget shortage' (38.7%) and 'lack of awareness of top management' (33.9%) as the difficulties to implement GHG ETS.

Table 41 Barriers of companies for the implementation of GHG ETS

No.	Barriers	Percentage with 'YES' (%)			
		Overall (N=62)	Chemical (N=35)	Cement (N=11)	Steel (N=16)
1	Lack of information for the analysis of future carbon market	64.5	74.3	45.5	56.3
2	Lack of technology	50.0	51.4	45.5	50.0
3	Limited reduction potential	80.6	80.0	90.9	75.0
4	Lack of specialists on energy management and reduction potential identification	61.3	54.3	81.8	62.5
5	Budget shortages	38.7	48.6	45.5	12.5
6	Lack of effective incentive and support policies at national level	50.0	48.6	54.5	50.0
7	Lack of awareness at top management level	33.9	45.7	18.2	18.8

3.4.6 Company's expectations to GHG ETS

In the survey, companies were allowed to show their expectations for the implementation of GHG ETS. The result is shown in Table 42.

Table 42 Company's expectations to GHG ETS

No.	Expectations	Percentage with 'YES' (%)			
		Overall (N=62)	Chemical (N=35)	Cement (N=11)	Steel (N=16)
1	To coordinate with existing regulations such as Energy Audit and TMS	75.8	68.6	81.8	87.5
2	To clarify the competent ministries and their specific roles	54.5	54.3	54.5	56.3
3	To provide related information	37.1	37.1	36.4	37.5
4	To conduct training programmes to improve the understanding of the latest policy progress	56.5	68.6	27.3	50.0
5	To appropriately appreciate the early actions for GHG reduction such as KCER and Energy Audit	58.1	48.6	72.7	68.8
6	To diversify the offset credits	12.9	5.7	18.2	25.0
7	To clarify the allowance allocation method in earlier	72.6	80.0	63.6	62.5
8	To expand incentives policies (tax reduction, subsidies, etc.)	74.2	77.1	90.9	56.3
9	To alleviate penalties on the excessive carbon emissions	74.2	80.0	90.9	50.0

Similarly as the evaluation results of disadvantages of GHG ETS, the samples highly expect that GHG ETS could well coordinate with existing regulations, like Energy Audit and TMS (With a ticked ratio of 75.8%). 72.6% of the samples wish the government to clarify the allowance allocation method in earlier. The companies are reluctant to take much economic burden from GHG ETS. Nearly 3/4 of them hope to alleviate the burdens either by reducing the penalties for the excessive emissions or by expanding the incentives in forms of tax reduction and subsidies, etc. More than half of the samples (58.1%) expect the government to appropriately appreciate the early actions for GHG reductions. Training programs are viewed necessary for the companies to improve their understanding of the latest policy progress and 56.5% of the samples expressed this expectation.

3.5 Conclusions

This study summarized the perspective of Korean companies to GHG ETS to be formally launched since 2015 in Korea. The analysis was carried out in a qualitative manner using the data collected by a questionnaire survey to energy-intensive petro-chemical, cement and iron & steel industries.

The results indicated that the companies do not appreciate the merits of GHG ETS, whereas, strongly concern about its negative aspects. This confirms that Korean companies are still reluctant to the introduction of GHG ETS even the starting time has been determined. Most of companies under TMS established the inventory for GHG emissions, which provides a necessary basis for the actual implementation of GHG ETS. A meaningful finding from this survey is that the companies would make internal efforts in energy saving and GHG mitigation and invest in energy efficient technologies rather than simply transfer the policy burden to their clients. This result confirms the effectiveness of GHG ETS for enhancing company's carbon performance in Korea. Our survey also clarified the difficulties and expectations of the industry for GHG ETS. Korean government shall make efforts to meet these expectations for the companies to overcome the barriers. Specifically, the coordination of GHG ETS with ongoing policies, declaration of the method for emissions allowance allocation, clarification of responsibilities of authorities in charge and capacity building are the priorities. These efforts may increase the understanding and support from the industry for smooth implementation of GHG ETS in Korea.

The current bill of GHG ETS of Korea is friendly for companies in order to minimize their resistance to the adoption of this policy. On another hand, it is essential to have an adaptation period with ease rule for the arrangement of relevant institutional infrastructure and to test the scheme operation at the early stage of the policy introduction. As confirmed by the interview-based studies to the companies under EU-ETS, the effectiveness of this scheme is dependent on its strictness. The stringency of GHG ETS of Korea should be strengthened in later phases for achieving the policy goals in carbon mitigation and low carbon technology investment as desired.

4. AN ANALYSIS OF COMPANY'S PREFERENCES TO CARBON TAX POLICY AND GHG EMISSIONS TRADING SCHEMES IN KOREA

[Abstract]

This paper presents a choice experiment analysis of Korean companies on their preferences to the alternatives of carbon tax policy and GHG ETS. A total of 150 samples were collected. Various modeling exercises confirm that the companies favor a carbon tax characterized as low tax rate, with tax relief measures either to energy-intensive industries or to energy-efficient companies, and using the tax revenues as specific funds for climate change. Later introduction of carbon tax significantly increase the company's preference to this policy. For GHG ETS, around half of the samples prefer to the grandfathering method in cap setting rather than the benchmarking approach. To increase the auction ratio for the allocation of emissions allowances would significantly reduce the company's preference to GHG ETS. Regarding the penalty to emissions exceeding the allowances, a fine of three times market prices of carbon credits would significantly reduce the company's choice preference. Carbon intensity is a more preferable criterion than trade intensity for the surveyed companies in determining the sectors with carbon leakage risk. The results of this study indicate certain principles for the design of carbon tax policy and GHG ETS from the viewpoint of Korean businesses.

Key words: Choice experiment, Carbon pricing, Korea

4.1 Introduction

In recent years, discussions are emerging in the applications of MBIs, particularly carbon tax policy and GHG ETS, for energy saving and the mitigation of GHG emissions in Korea.

The introduction of carbon tax has been considered from 2000 in Korea since the current energy prices and taxation system were criticized for not properly reflecting the social cost of environmental damage. There were many discussions and debates on this policy among the core government institutes with relevance, including the Congress, the MOSF, KIPF, and the Citizens' Coalition for Economic Justice (CCEJ). MOSF initiated a 3-year project during 2008 to 2010 to explore energy tax reform and discuss the scenarios for the introduction of a carbon tax in Korea. This project was mainly conducted by KIPF. According to KIPF reports, carbon tax should be introduced separately at low rates without cutting down the existing taxes at early stages, considering that income tax and corporation tax have been deducted after the launch of Lee's government (2008-2012) (Kim et al, 2009). At the beginning, the KIPF report suggested the introduction of carbon tax from 2013 to replace the existing transportation-energy-environment tax, which was scheduled to end in 2012. Although the transportation-energy-environment tax has been extended to 2015, there is increased attention of policy makers on the introduction of carbon tax. During the latest presidential election in 2012, major political parties (i.e., Saenuri party as the ruling party and Minjoo party as the leading opposition) examined the transition of existing transportation-energy-environment tax to carbon tax. Progressive Justice Party, another minor opposition, promised the introduction of carbon tax in its pledge for presidential election. More recently, Progressive Justice Party proposed a bill of carbon tax, suggesting the introduction of this policy from 2016. To certain degree, the key government institutes of Korea have recognized the needs for the introduction of carbon tax. The question is how to bridge the different opinions of various stakeholders on this policy.

In Korea, discussions on the adoption of a domestic GHG ETS started under the 'Framework Act on Low Carbon Green Growth', which passed in 2010. A preliminary GHG ETS proposal was formulated in November 2010, suggesting the introduction of GHG ETS in Korea from 2013 in three phases. By that time, several studies analyzing the economic effects of GHG ETS and its impact on Korean industries were reported. Some researches indicated that GHG ETS would be more cost-effective than the mandatory regulations, like the TMS, and could save the cost by 44% to 68% for achieving the national GHG reduction target of 2020 (e.g., PCGG press, 2011; Kim, , 2010a; Lee, 2009). Kim (2009c) argued that Korea's industrial competitiveness in the world might be weakened due to this policy. The price increase of all sectors would be 1.38% in average. Particularly, the price increases of metal products, electricity, gas, tap water, non-metallic products would be higher at around 2.4%. Kim (2010b) suggests the adoption of differentiated methods in the allocation of emissions allowances for different sectors to secure industrial competitiveness of the country.

In spite of the advantage of GHG ETS in economic efficiency confirmed by previous studies, the preliminary proposal of GHG ETS of Korea received strong opposition from the industry. The second version of GHG ETS proposal reflected opinions of the industry and was submitted to the parliament in April 2011. It was finally approved by the lawmakers in May 2012. According to this bill, the domestic GHG ETS will formally start from 1 January 2015 in Korea. Nevertheless, the discussions of specific aspects of Korean GHG ETS are not finished and the Korean government is still consulting actively with the industry. Considering the continuous lobby of the industry, the stringency of this policy may be further watered down in forms of the extension of starting time and the provision of allowances for international offsets.

Our earlier study also revealed that carbon tax and GHG ETS are much less preferable for Korean companies than the other types of energy saving and GHG mitigation policies. Although the resistance from the industry was identified as the largest barrier for the actual implementation of carbon tax and GHG ETS, quite few studies were arranged at the company level for understanding their viewpoint of the pricing of carbon emissions. Aiming to close this research gap, we carried out a choice experiment to Korean companies for measuring their preferences to various alternatives of carbon tax and GHG ETS. This paper is structured as follows. Section 2 explains the models analyzing the policy choice datasets collected in this survey. Section 3 details the experiment design individually for carbon tax and GHG ETS, including the selection of policy attributes, classification of the attribute levels and the choice set examples. Section 4 outlines the questionnaire survey and the distribution of samples. Section 5 summarizes the analysis results by various models. Section 6 finally concludes this survey analysis.

4.2 The model used in this study

The analysis model of discrete choices originates from the random utility theory. The basic assumption in the random utility modeling is that decision makers tend to maximize the utility for their choices. For this analysis, we applied similar models in Shen and Saijo (2009), which identified the influence of energy efficiency labeling to purchasing preferences of Chinese consumers. The model details are specified as follows.

The utility of a policy alternative for an individual company (*U*) can be modeled as the sum of a deterministic component (*V*) and a random error term (ε). Specifically, the company *q*'s utility of policy alternative *i* can be expressed as:

$$U_{iq} = V_{iq} + \varepsilon_{iq} \qquad (1)$$

The probability that the company *q* chooses policy alternative *i* from a particular set *J* that comprises *j* alternatives can be written as:

$$P_{iq} = P(U_{iq} > U_{jq}; \forall\ j(\neq i) \in J) \qquad (2)$$

For converting the random utility model into a choice model, certain assumption is required on the joint distribution of the vector of random error terms. Assuming the random error terms to follow the distribution of type I extreme value and be independently and identically distributed (IID) across alternatives and observations, the multinomial logit (MNL) model is obtained. In the MNL model, the choice probability in Equation (2) is expressed as:

$$P_{iq} = \exp(\mu V_{iq}) / \sum_{j=1}^{J} \exp(\mu V_{jq}) \qquad (3)$$

Further assuming that the deterministic component of utility is linear and additive in parameters, the probability in Equation (3) can be expressed as:

$$P_{iq} = \exp(\mu \beta^{'} X_{iq}) / \sum_{j=1}^{J} \exp(\mu \beta^{'} X_{jq}) \qquad (4)$$

Where μ represents a scale parameter that determines the scale of the utilities, which is typically normalized to 1.0 in the MNL model. X_{iq} is the vector of explanatory variables of V_{iq}, usually including alternative specific constants (ASCs), the attributes of alternative *i* and the characteristics of the individual company q, and $\beta^{'}$ is the parameter vector associated with X_{iq}.

The heterogeneity among individual companies is extremely difficult to examine by the MNL model (Shen, 2006). This shortage may be relaxed by adding the interaction terms between individual specific characteristics and various choices. This requires a priori selection of key characteristics and attributes, and could only involve a limited selection of specific variables (Boxall and Adamowicz, 2002). Another way is to estimate by applying the latent class (LC) model. The LC model assumes that the surveyed samples consist of a number of latent classes (*S*). The unobserved heterogeneity can be captured by the classes through estimating a different parameter vector in corresponding utility function. Formally, the choice probability of individual company *q* of class *s* is expressed as:

$$P_{iq|s} = \exp(\mu_s \beta_s^{'} X_{iq}) / \sum_{j=1}^{J} \exp(\mu_s \beta_s^{'} X_{jq}) \quad s = 1,\ldots,S \qquad \text{bbbb} \qquad (5)$$

Where μ_s and $\beta_s^{'}$ are class-specific scale and utility parameters, respectively. According to Boxall and Adamowicz (2002), the probability of company *q* in class s (H_{qs}) is expressed as:

$$H_{qs} = \exp(\alpha \lambda_s^{'} Z_q) / \sum_{s=1}^{S} \exp(\alpha \lambda_s^{'} Z_q) \qquad (6)$$

Where α is a scale factor normally normalized to 1.0, $\lambda_s^{'}$ is the parameter vector in class *s*, and Z_q denotes a set of characteristics determining the classification probability. Combining conditional choice equation (5) and membership classification equation (6), the unconditional probability of choosing alternative *i* is given as:

$$\begin{aligned} P_{iq} &= \sum_{s=1}^{S} P_{iq|s} H_{qs} \\ &= \sum_{s=1}^{S} [\exp(\mu_s \beta_s^{'} X_{iq}) / \sum_{j=1}^{J} \exp(\mu_s \beta_s^{'} X_{jq})] \times [\exp(\alpha \lambda_s^{'} Z_q) / \sum_{s=1}^{S} \exp(\alpha \lambda_s^{'} Z_q)] \end{aligned} \qquad (7)$$

In equation (7), when we set μ_s and α equal to one, the parameter vector $\beta_s^{'}$ and $\lambda_s^{'}$ can be simultaneously estimated by maximum likelihood method for explaining choice preference.

The LC model can not be estimated unless the number of classes (*S*) in equation (7) is given. *S* is discrete but maximum likelihood estimation theory requires that the parameter space to be continuous and estimates to be in the interior of the space (Swait, 2007). The central issue in performing the LC model is how to determine *S*. The existing literature recommends a number of information criteria to determine *S* (Shen, 2006; Swait, 2007). Four measures, based on the log likelihood at convergence with *s* classes, sample size and number of parameters, are used to determine *S* in this analysis. They are:

Akaike Information Criterion: $AIC = -2(\log L_s^{*} - K_s)$ (8)

Bozdogan Akaike Information Criterion: $AIC3 = -2\log L_s^{*} + 3K_s$ (9)

Bayesian Information Criterion: $BIC = -\log L_s^* + (K_s \log N)/2$ (10)

Hannan-Quinn Information Criterion: $HQIC = -2\log L_s^* + K_s \log\log N$ (11)

Where $\log L_s^*$ is the log likelihood at convergence with *s* classes, K_s is the number of parameters in the model with s classes, and N is the sample size.

Another approach to account for the individual heterogeneity is Random Parameter Logit (RPL) or Mixed Logit (ML) model (Greene and Hensher, 2003). In this approach, each company has its own set of scale and utility parameters. The RPL/ML model may be viewed as the case that each company is an individual class, which is indeed the LC model with N classes (N is the sample size). Compared with the RPL model, there are two major advantages of the LC model. One is that the LC approach is semi-parametric and does not require any specific assumption about the distributions of parameters across individuals (Greene and Hensher, 2003). The other is that the LC model provides the probabilities in each class. Although each respondent is assumed to belong to one class, there is uncertainty about the class membership of respondents.

4.3 Experiment design in this survey

4.3.1 Definition of the policy attributes and levels

4.3.1.1 Attributes and levels for carbon tax policy

We selected four major aspects as the attributes to be taken into account for the introduction of carbon tax in Korea. They are tax rate, tax relief measures, use of tax revenues and starting time. Table 43 lists the levels of these policy attributes.

Table 43 Attributes and their levels of carbon tax policy in this study

Attributes	Levels of attributes
Tax rate (KRW/t-CO_2)	1) 1,000; 2) 2,000; 3) 3,000; 4) 5,000
Tax relief measures	1) No relief; 2) Preferential treatment to energy-intensive companies; 3) Preferential treatment to companies actively reducing emissions to a certain level
Use of tax revenues	1) General budget; 2) Specific fund for energy saving and climate change; 3) To reduce company’s other taxes
Starting time	1) Since 2015; 2) Since 2021

Tax rate

Tax rate is presented with four levels, 1,000, 2,000, 3,000 and 5,000 KRW/t-CO_2 in sequence. These figures are decided by the overview of available literature analyzing of the impacts of carbon taxes at macro-economy level and our own estimations of carbon prices affordable for Korean companies.

In 2008, KIPF firstly suggested a carbon tax proposal with tax rates at 34-96 KRW/l for fossil fuels, which are calculated according to the carbon price of the EU-ETS (25 €/t-CO_2, an equivalent of 31,328 KRW/t-CO_2) (Kim et al., 2008). The expected tax revenue would be 8.5-9.1 trillion KRW (USD7.38-7.91 billion) per year based on 2007 emissions of Korea, which is about 1% of the country's GDP. In the later report of KIPF, considering the policy acceptance and to minimize the policy impact, much lower tax rate at the early stage was suggested, at 1/8 level of the initial proposal (Nearly 4,000 KRW/t-CO_2) (Kim and Kim, 2010).

Kwon and Heo (2010) showed that a carbon tax equivalent to 36,545 KRW/t-CO_2 (about 31 USD/t-CO_2) must be imposed for the realization of national mid-term GHG mitigation goal. At the business level, we conducted an empirical survey measuring the carbon prices affordable for Korean companies. The survey targeted the companies from three energy-intensive sectors, including iron & steel, cement and chemical industries.

The estimations show that a carbon price at around 2,500 KRW/t-CO_2 would be acceptable for all the sampled 62 companies in average. A sensitivity analysis reveals that at a carbon price as high as 3,500 KRW/t-CO_2, the acceptance share of companies would decrease to one quarter. Almost all the samples strongly reject or reject a price of 5,000 KRW/t-CO_2. The estimations by sector generate similar conclusions. The affordable carbon prices for the companies range at 2,500-4,000 KRW/t-CO_2 (Suk et al., 2014).

As mentioned earlier, a carbon tax bill was proposed by the Progressive Justice Party of Korea recently. According to this proposal, the taxes would be imposed in addition to current energy taxes. Anthracite coal would be taxed at 5.8 KRW per kilogram, while bituminous coal would be taxed at 3.3 KRW per kilogram, and electricity at 1.4 KRW per kWh (Shim, 2013). These rates are at 1/10 level of the KIPF proposal in 2008, an equivalent of around 3,000 KRW/t-CO_2. If the bill was passed, it would enact since 2016.

We may infer that a low tax rate, e.g., 1,000 KRW/t-CO_2, would be possible for starting the carbon tax in Korea. This rate may be then increased to 2,000 to 3,000 KRW/t-CO_2 after a few years since the first initiation of carbon tax. A tax rate of 5,000 KRW/t-CO_2 is already high for companies to accept at current phase. Therefore, we defined four levels for tax rate, respectively at 1,000, 2,000, 3,000, and 5,000 KRW/t-CO_2.

Tax relief measures

KIPF's study addressed tax relief measures for energy-intensive industries with high concern of international competitiveness due to introduction of carbon tax. One is to provide tax reduction for some energy-intensive industries that would be significantly influenced by this policy. The other measure is to provide preferential tax treatment for the companies in consideration of their performances under the pilot GHG ETS or voluntary agreements for energy saving and carbon mitigation (Kim and Kim, 2010). In this survey, we assume three options for carbon tax relief measures. One is no relief treatment for all the tax payers. The second is to provide preferential treatment to energy-intensive companies. The last is to provide preferential tax treatment to companies actively reducing their CO_2 emissions to a certain level.

Use of tax revenues

There are two options for the utilization of carbon tax revenues. One is to use the revenues as general budget. The other is to use carbon tax revenues as a specific fund, either for the countermeasures of climate change or to cut down the other taxes. Korea's energy-related tax was used to support transportation sector as an objective tax. KIPF report of 2010 suggested that the revenue of carbon tax should be recycled for the countermeasures of climate change, such as renewable energy and R&D for the improvement of energy efficiency or the development of clean technologies. It also suggested that carbon tax revenue needs to be used as incentives for energy-intensive and export-oriented sectors to make ease their tax burden and protect international competitiveness (Kim and Kim, 2010). Accordingly, three options are defined for this attribute, to use the tax revenues as general budget; or as specific fund for energy saving and climate change; or to reduce the company's other taxes.

Starting time

There have been discussions on the starting time of carbon tax in Korea. KIPF suggested the implementation of this policy from 2013 to replace the transportation-energy-environment tax to be ended in 2012 in the report of 2010 (Kim and Kim, 2010). However, the transportation-energy-environment tax has been extended to 2015. The bill of carbon tax, proposed recently, suggested the starting time to be from 2016. We defined two categories for the starting time of carbon tax in Korea. One is since 2015 and the other is since 2021. The year of 2015 is selected as one option considering the time necessary for the discussions and approval of the policy. Hong (2011) indicated that the simultaneous introduction of GHG ETS and carbon tax in 2015 would bring significant saving of mitigation cost, approximate 30% to 50% than the implementation of only either one. An additional reason is that 2015 is the initial year for the implementation of GHG ETS in Korea. The emissions allowances will be allocated fully for free for the beginning phase of GHG ETS. Starting carbon tax since 2015 may exert certain economic pressure as early as possible for the emitters. To launch carbon tax later from 2021 may give companies more time to learn about this tax and make necessary preparation.

4.3.1.2 Attributes and levels for GHG ETS

The design and institutional arrangement of GHG ETS has a decisive impact on the cost-effectiveness of this policy (Woerdman and van der Gaast, 2001). The design aspects of a GHG ETS include transaction costs, spatial and temporal dimension mechanisms, initial allocations of emission allowances, monitoring, enforcement and so on (Antes et al., 2008). In this survey, we defined four attributes for the choice experiment of GHG ETS. They are cap setting method, allocation of allowances, the penalty and criteria for carbon leakage industry. The levels for these attributes are listed in Table 44

Table 44 Attributes and their levels of GHG ETS in this study

Attributes	Levels of attributes
Cap setting	1) Based on the company's historical emissions; 2) Based on the sector's advanced emission levels; 3) Differentiated measures for the existing and new established companies
Allowance allocation	1) All for free; 2) 5% auction, the rest for free; 3) 10% auction, the rest for free; 4) 30% auction, the rest for free
Penalty	1) A fine the same of market price of carbon emissions; 2) 3 times of market price; 3) 5 times of market price
Criteria for carbon leakage industry	1) Carbon intensity; 2) Trade intensity

Cap setting

GHG ETS has to be developed on the basis of emission caps. The cap setting based on the historical emissions of companies is relatively easy for the policy operation. However, this method is probably unfair to the companies that have taken efforts in carbon mitigation earlier. Comparatively, the benchmarking approach is complicated since different industries, production processes and products have different emission intensities and thus require various standards for cap setting. In current bill of GHG ETS in Korea, both grandfathering and benchmarking are considered to calculate the emissions permit for the companies. In this experiment, we defined three options in cap setting, either based on the historical emissions (grandfathering), or based on the sector's advanced emission levels (benchmarking), or applying a hybrid approach to differentiate the existing sources and new entrants.

Allocation of emissions allowances

The first phase of GHG ETS of Korea will be from 2015 to 2017, with the first compliance date falling in 2016. The second phase will be from 2018 to 2020 and the third phase from 2021 to 2025. During the first phase, liable entities will be allocated all the emissions permits for free. Demand for the credits will be only needed for the entities whose emissions exceed their allocated allowances. The free allocation ratio will drop to 97% during the second phase and below 90% in the third phase. In this survey, four ratios for the allowances allocation are provided for the companies: all for free; 3% auction and the rest 97% for free allocation; 10% auction and 90% for free; and, 30% auction and the rest 70% for free.

Penalty

The penalty mechanism is essential for the operation of a GHG ETS and the realization of policy target. The penalty has two forms. One is compensation for the allowance deficit and the other is the fine. The compensation could be the same amount or several times of the allowance deficit of the past compliance period. In the preliminary proposal of GHG ETS of Korea, the penalty for the non-compliance emissions was proposed to be less than five-times of average market price of the credits. This received strong opposition from the industry. In the final proposal, three times of the average market price and a maximum of 100,000 KRW/t-CO_2 ($90/t-$CO_2$) will be fined to the entities failing to submit sufficient allowances in each compliance period. We defined three levels of fines as penalty measures of GHG ETS in Korea. They are: the same level as the market price, 3 times of the market price and 5 times of the market prices of CO_2 credits.

Criteria for carbon leakage industry

Carbon leakage occurs when there is an increase in GHG emissions in one country as the result of a reduction by a second country with a strict climate policy. According to IEA (2008), a particular country or region could be weakened in the international competitiveness due to the emissions reduction policy, resulting in relocation of energy-intensive production in less constrained regions. In 2009, the European Commission firstly granted free allowances to around 60% of industrial sectors under the EU ETS. The rules and procedures to decide whether a sector is deemed to be exposed to carbon leakage based on two indicators. One is the additional production costs defined as the sum of direct and indirect carbon costs divided by the Gross Value Added of a sector. The other is trade intensity of a sector with countries that are not part of the EU ETS, defined as the ratio between the total value of exports to third countries plus the value of imports from third countries and the total market size for the industry (annual turnover plus total imports from third countries).

Four criteria were given and if a sector qualified for one of these, it would obtain free allocation of allowances: 1) the additional production costs > 5% and the trade intensity > 10%; 2) the additional production costs > 30%; 3) the trade intensity > 30%; and, 4) for sectors that would not qualify one of the above situations, a provision has been made for more detailed analysis at a more disaggregated level and/or a qualitative assessment if trade intensities and/or increase in production costs were close to the thresholds, in which the required investments, market characteristics and profit margins would flourish as alternative indicators (De Bruyn et al., 2013).

In the bill of GHG ETS of Korea, certain key emissions-intensive trade-exposed industries are to be exempted from the reduction in free allocations for at least the second phase. The company with high tendency of carbon leakage may be defined by two criteria, either by its carbon intensity or by its trade intensity. The candidates for full free allowances allocation are businesses that belong to industries: 1) over 5% in carbon intensity and over 10% in trade intensity; or, 2) over 30% in carbon intensity; or, 3) over 30% in trade intensity.

Lee (2010b) analyzed the trade intensity and carbon intensity of the sectors deemed to be exposed to carbon leakage in Korea. The heavy carbon intensity sector includes cement industry, while iron & steel sector shows high trade intensity. Two criteria, carbon intensity and trade intensity, are thus proposed as options to determine the carbon leakage industry in this survey.

4.3.2 The design of choice sets for this experiment

In this study, the efficient design is performed to maximize a chosen optimality criterion based on the pre-specified model (e.g., MNL model). Various efficiency criteria have been proposed, such as D, A or G-efficiency. The D-optimal approach become the most widely used measure of efficiency because of its insensitivity to the magnitude of the scale of parameters (Street et al., 2005). This approach may extract the maximum amount of information from the respondents subject to the number of attributes, attribute levels and the other characteristics of the survey (Carlsson and Martinsson, 2003). The D-efficiency is given as:

$$D - efficiency = [|\Omega|^{1/K}]^{-1} \qquad (12)$$

Where K is the number of parameters, Ω is the covariance matrix of a vector of parameters.

As the result of running the D-optimal design by Design Expert 8.0 (Stat-Ease, Inc.), 12 choice sets were created for carbon tax policy and another 12 choice sets for GHG ETS. Considering the complexity for the companies to check their preferable options, these choice sets were randomly divided into two versions. Each version of the questionnaire consists of 6 choice sets for carbon tax and 6 choice sets for GHG ETS. The sampled companies were requested to select more preferable policy profile in each set and answer the other questions related to their companies. An example choice set for carbon tax is presented in Table 45.

Table 45 An example of choice set for carbon tax policy

Policy attribute	**Option A01**	**Option B01**
Tax rate (KRW/t-CO_2)	2,000	5,000
Tax relief measure	No relief measure	Preferential treatment to energy-intensive companies
Use of tax revenues	General budget	Specific fund for energy saving and climate change
Starting time	Since 2015	Since 2021
Please tick the one you prefer	□	□

Similarly, a choice set example for GHG ETS is listed in Table 46.

Table 46 An example of choice set for GHG ETS

Policy attribute	Option A01	Option B01
Cap setting	Based on the company's historical emissions	Based on the historical emissions for the existing companies, and the sector advanced emission levels for the new entrants
Allowance allocation	3% auction, the rest for free	All for free
Penalty	A fine of 3 times of the market price	A fine of 5 times of the market price
Criteria for carbon leakage industry	Carbon intensity	Trade intensity
Please tick the one you prefer	□	□

4.4 Outline of the survey and statistics of the samples

4.4.1 The questionnaire format and survey arrangement

The data were collected by a survey during December 2012 to January 2013. A questionnaire was developed to measure the choice preferences of Korean companies to carbon tax and GHG ETS, and to identify their viewpoint of financial subsidy policy for industrial energy saving. The format consists of four major components. They are background of the company; the company's ideas about the economic incentives for energy saving; the choice preferences of companies to carbon tax; and, the choice preferences of companies to GHG ETS. This paper presents the analysis of company's choice preferences to carbon tax policy and GHG ETS. See the Questionnaire format 2 in Appendix 1.

It is difficult to request the company's top managers to answer the questionnaire referring to our previous experiences of conducting similar surveys to the companies in Korea. We thus targeted the company's energy or environmental managers at the middle level. These people are responsible for the company's energy management in practice and shall be very clear about the policy impacts on energy cost changes of their companies. In explaining the survey objective and requirements, we ask the energy or environmental managers to answer the questions on behalf of their companies and consult with the other related staffs like financial managers in necessary. Their answers represent the situation and choices of their companies.

At the beginning, we carried out experimental survey to companies to test the feasibility of answering the questions. The finalized format was sent to the companies either by mail or by email. The key energy-consuming companies under control of the TMS are selected. The questionnaires were sent to 230 companies, in which, 150 responded and were confirmed to be useful for this analysis.

4.4.2 Distribution of the samples

The distribution of samples by size and sector is listed in Table 47.

Table 47 Distribution of the respondents by size and sector

Sector	Size				Number in total (Percentage)
	Small	Medium	Medium-large	Large	
Iron & steel	1	13	8	4	26 (17.3)
Cement	6	4	3	1	14 (9.3)
Chemical	3	23	13	13	52 (34.7)
Paper making	3	27	6	0	36 (24.0)
electronics	0	1	12	9	22 (14.7)
Number in total (Percentage)	13 (8.7)	68 (45.3)	42 (28.0)	27 (18.0)	150 (100.0)

The samples from iron & steel, cement, chemical, paper-making and electronics industry individually account for 17.3%, 9.3%, 34.7%, 24.0% and 14.7% of the total. Among the total 150 samples, 13 are small companies, 27 are large ones. The remaining 110 are medium-large or medium-sized. The ratio of small, medium, medium-large and large companies in total is respectively 8.7%, 45.3%, 28.0% and 18.0%. By the ownership, 110 companies are domestically private, accounting for 73.3% of the total. The number of foreign-funded companies (Fully foreign-funded and joint-ventures) is 40, with a share of 26.7%.

4.5 Results and discussions

4.5.1 Characteristics of the samples

4.5.1.1 Energy consumption and CO_2 emissions of the samples

The companies were requested to check the range of their energy consumptions in 2010. A total of 145 companies answered this question. The result, as shown in Figure 16, indicates that 98% of the respondents consumed more than 2,000 toe of energy in 2010. The samples using more than 100,000 toe account for 20.7% of the total. According to Kim (2009d), only the top 2.2% of SMEs consumed more than 2,000 toe in 2009 and 85% of the rest SMEs used less than 200 toe. This implies that the respondents in this survey represent the largest energy-consuming SMEs in Korea.

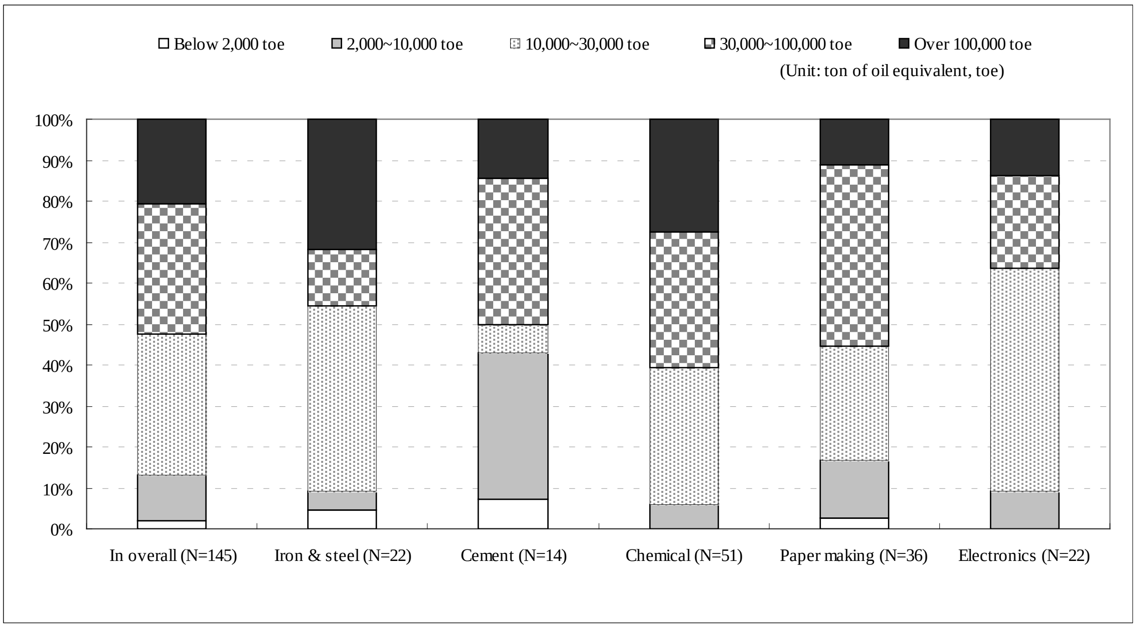

Figure 16 Energy consumptions of the samples by sector

The surveyed companies were also requested to elaborate the types of energies and the corresponding ratios in total energy use. All the respondents provided answers. The energy use structure of the samples in overall and by sector is summarized in Figure 17.

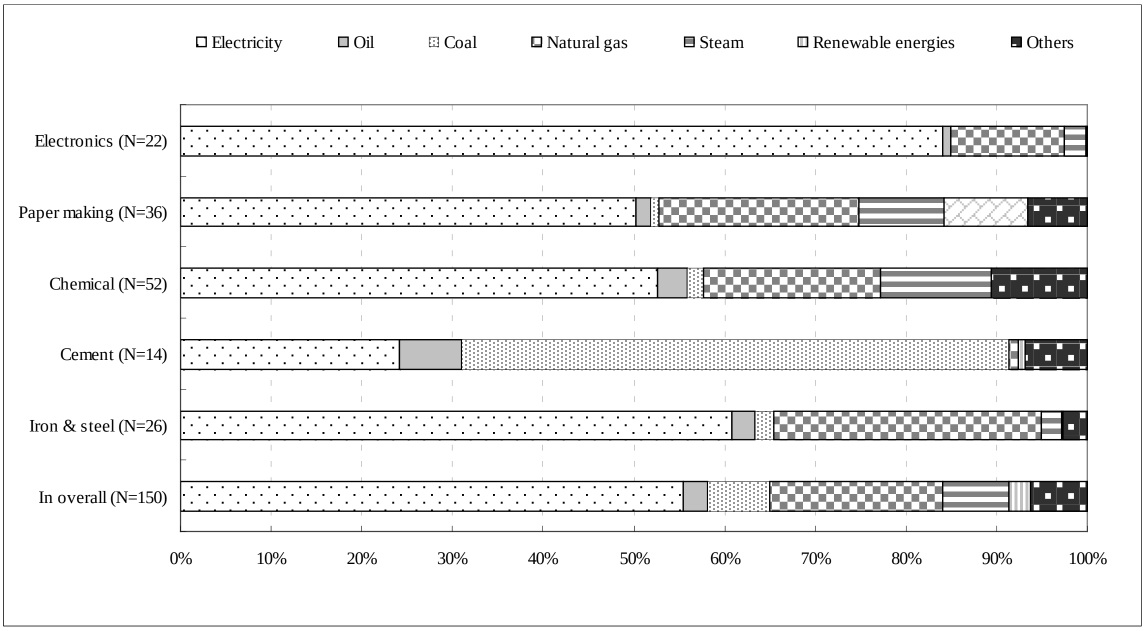

Figure 17 Energy use structures of the samples by sector

Electricity is the largest energy source for the surveyed companies as a whole, with a share of 55.4% of total energy use. Natural gas is the second and accounts for 19.1%. The third one is steam with a share of 7.3%. Oil and coal together share around 9%. Renewable energies account for 2.3% as a minor. The remaining 6.3% is the others including LNG, Petro cokes and so on. There is some difference between energy use structures of the five sectors. More than half of energy used by iron & steel, chemical, paper-making and electronic industry is electricity, with a share of 60.8%, 52.7%, 50.2% and 84.0%, respectively. The ratio of electricity is less than 25% for cement companies. Instead, coal is the major energy source for cement companies, accounting for about 60.4% of total, while this ratio is less than 2% for the other sectors.

Figure 18 shows the distribution of samples by shares of energy costs in total sales. Overall, the surveyed companies indicate relatively low ratios of energy costs in the sales, revealing the low energy intensities of the samples overall. 24.7% of them have an energy cost ratio under 5%. The majority of companies (around 47%) have an energy cost ratio of 5-10%. The companies with energy cost ratios of 20-30%, 30-50% and over 50% individually have a share of 4.1%, 1.4%, and 1.4%. Among the sectors, nearly 70% of iron & steel companies have an energy cost ratio of 5-10%. The cement companies exhibits high energy intensity. Only 15.4% of cement companies have an energy cost ratio below 10%. Nearly 40% of them have an energy cost ratio of 10-20%, and 45% has energy cost ratios of over 20%. The surveyed chemical companies also have a relatively low energy cost ratios, with 66.0% of them having a ratio of below 10%. No companies in chemical sector have an energy cost ratio over 30%. 61.1% of the samples from paper industry have an energy cost ratio of 5-10%. The share of electronic companies with energy cost ratio of less than 5% is more than 80%, indicating the lowest energy intensity of this sector compared with the other industries in this survey.

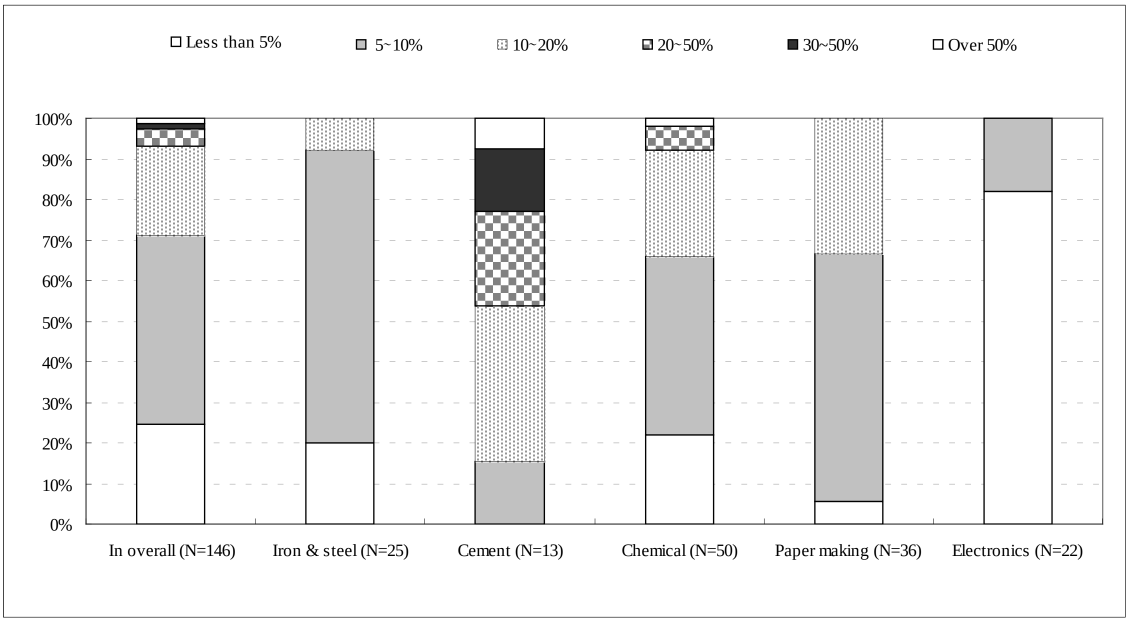

Figure 18 Energy cost ratios in total sales of the samples by sector

The surveyed companies were asked to indicate the range of their CO_2 emissions in 2011. As depicted in Figure 19, the samples are large CO_2 emitter. Most of them (90.0%) emitted over 25,000t-CO_2 in 2011. The companies with less than 5,000t-CO_2 only accounts for 0.7%. The remaining companies answered that their CO_2 emissions are in the range of 5,000-25,000t-CO_2.

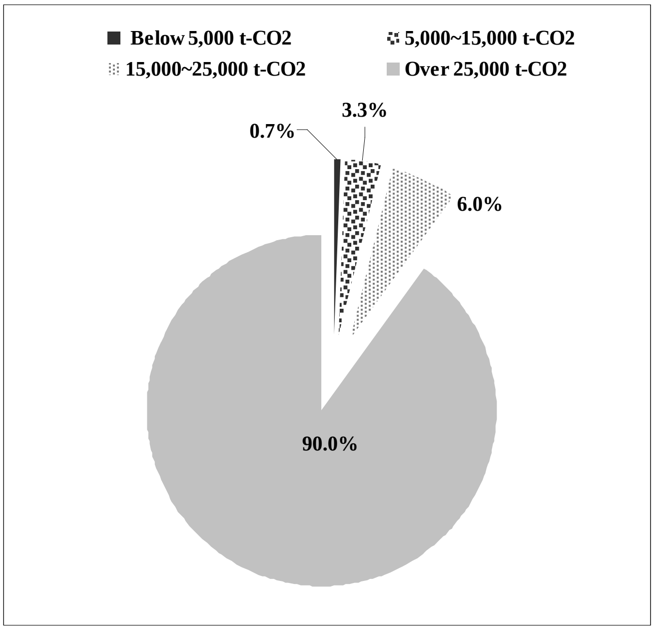

Figure 19 The range of CO_2 emissions of the samples in 2011 (N=150)

4.5.1.2 Energy saving management of the samples

The companies feel high pressures from energy costs. 84.7% of the samples selected the evaluation of high for current energy prices. Among which, 18% view energy prices to be very high. The samples, with the answers of low and very low, only account for 15.3% of the total. The companies feel high pressures from the market competition. 58.7% of the surveyed companies felt very fierce competition and another 30.0% selected the fierce competition. Only 6.7% of them view the competition to be moderate.

The surveyed companies indicate good performance in internal energy monitoring and statistics. As shown in Figure 20, among the 150 companies, less than 5% of them admitted that they have not yet established the measurement and statistics system for internal energy use, 76% have established system for statistics of comprehensive energy use. Around 63% have specific departments and staffs for energy management and have a perfect system for internal energy measurement and statistics.

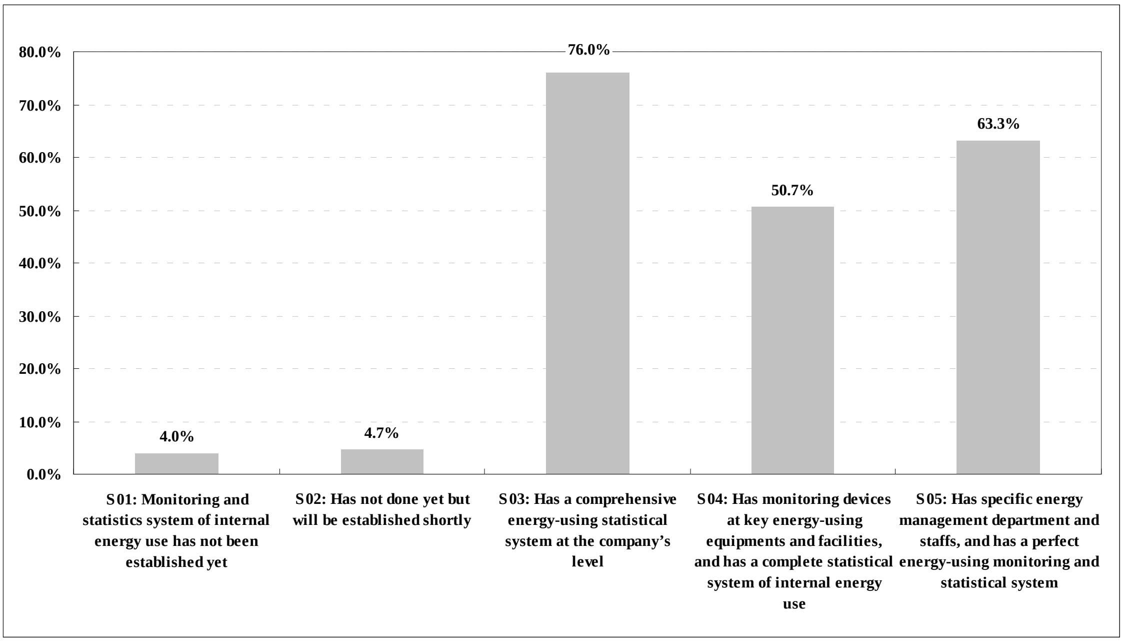

Figure 20 The status of samples in the monitoring and statistics of internal energy use (N=150)

We requested the companies to check their technology level and the potential for further energy saving. As indicated in Figure 21, 48.7% of the samples confirmed that their production technologies are at the domestic average level. 24.0% view their technology levels to be domestically advanced. Another 20.0% answered that their production technologies are at the level of internationally advanced.

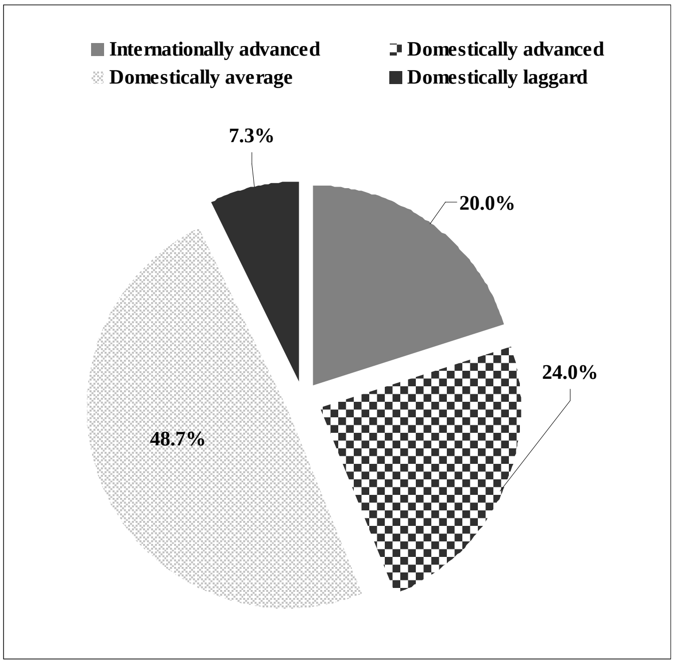

Figure 21 Company's evaluation of their production technology level (N=150)

Regarding energy saving potential, as shown in Figure 22, nearly 65% of the companies evaluated that there remains limited potential. 22% selected almost no potential. Only 12.7% of the samples admit that they have relatively large energy saving potentials.

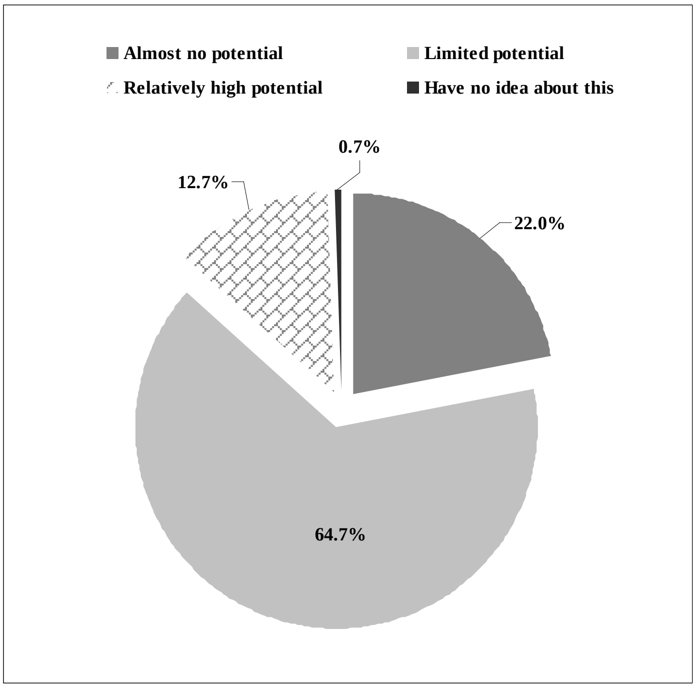

Figure 22 Company's evaluations of their potential for energy saving (N=150)

4.5.2 The determination of number of latent classes

The measures of AIC, AIC3, BIC and HQIC were applied to determine the number of latent classes in this study. The regressions with various numbers of classes (1, 2, 3 and 4 classes) were attempted and the statistics are listed as in Table 48.

Table 48 Information criterions for different number of latent classes

Classes	#Par	Log-likelihood	AIC	AIC3	BIC	HQIC
A: Choices of carbon tax policy						
1	6	-501.62	1015.2	1021.2	1044.1	1026.3
2	13	-475.08	976.2	989.2	1038.6	1000.0
3	20	-463.08	966.2	986.2	1062.2	1002.9
4	27	-457.88	969.8	996.8	1099.4	1019.3
B: Choices of GHG ETS						
1	6	-565.85	1143.7	1150.7	1172.5	1154.7
2	13	-541.19	1108.4	1121.4	1170.8	1132.2
3	20	-520.98	1082.0	1102.0	1178.0	1118.7
4	27	-517.26	1088.5	1115.5	1218.2	1138.0

The log likelihood values (Column 3) at convergence reveal that the greater the number of classes was, the better the LC model would fit, especially in the cases from 1 to 2 class models for the choices of carbon tax and from 2 to 3 class models for GHG ETS. This is because log likelihood values normally increase in magnitude when there are more parameters estimated. For the choice dataset of carbon tax, the result indicates that the minimum values of BIC and HQIC (Columns 6 and 7) have clear relevance to the 2-class model, suggesting that the 2-class model is optimal by these two information criteria. The reductions of AIC and AIC3 (Column 4 and 5) are very small from 2-class to 3-class, confirming the negligible improvement between these two cases. We decided to select 2-class in the estimation for the choices of carbon tax by the LC model. For the choices of GHG ETS, the minimum values of the four information criteria (Column 4 to 7) are all associated with the 3-class model. Therefore, 3-class was determined for the regression of GHG ETS dataset by the LC model.

4.5.3 Characteristics of the class members

Results of class memberships for the 2-class and 3-class LC models respectively analyzing the choice datasets of carbon tax and GHG ETS are reported in Table 49.

Table 49 Relationship between class memberships and the company characteristics

	Variable	A: Choices of carbon tax		B: Choices of GHG ETS		
		Class 1	Class 2	Class 1	Class 2	Class 3
	Constant	-1.663 (1.350)	0	-0.184 (1.539)	-2.781 (2.218)	0
SIZE	LARGE	0.114 (1.256)	0	-0.177 (1.389)	3.720** (1.884)	0
	MLARGE	1.791 (1.185)	0	0.712 (1.386)	3.057* (1.796)	0
	MEDIUM	0.832 (1.046)	0	-0.234 (1.237)	0.755 (1.804)	0
SECTOR	STEEL	0.791 (0.952)	0	0.652 (1.155)	-0.223 (1.417)	0
	CEMENT	2.474* (1.303)	0	34.561 (0.158D+08)	35.916 (0.158 D+08)	0
	CHEMICAL	1.614* (0.868)	0	0.796 (1.037)	-0.081 (1.340)	0
	PAPER	0.730 (1.014)	0	1.578 (1.250)	2.639* (1.497)	0

Note: The data in the parentheses are standard errors. * and ** denote that the parameter is significant at 10% and 5% level, respectively.

The latent classes of the respondents are classified by the company size and sector belongings. The company size is categorized into four types, small, medium-sized, medium-large and large ones, which are represented by ‘SMALL’, ‘MEDIUM’, ‘MLARGE’ and ‘LARGE’, respectively. The sector belongings are divided into five categories, iron & steel, cement, chemical, paper and electronics, individually abbreviated as ‘STEEL’, ‘CEMENT’, ‘CHEMICAL’, ‘PAPER’ and ‘ELECTRONICS’. The parameters of the second class for carbon tax and the third class for GHG ETS in Columns 4 and 7 are set to 0 due to their normalization in the estimations. The parameters of the other classes shall be explained as being relative to these benchmark classes. As the result, for the analysis of carbon tax, the samples from cement and chemical sectors are more likely to be in class 1 than the electronic companies. For the regression of GHG ETS, the members of class 2 may be characterized as the large and medium large-sized companies from paper industry.

4.5.4 Results of the empirical analyses with various models

NLOGIT 5.0, the latest version of a package specific for discrete choice modeling in LIMDEP (Econometric Software, Inc.), was used to analyze the datasets in this survey. The estimation results of the 2-class LC model for the choices of carbon tax and the 3-class LC model for the choices of GHG ETS are listed in Table 50 and Table 51, respectively. For the comparison, the estimation results by the MNL model and RPL model are also provided in these two Tables. For applying the RPL model, we assumed that tax rate and allocation ratio of the allowances by auction are normally distributed across the respondents respectively in the choices of carbon tax and GHG ETS, and held the parameters of all the other policy attributes fixed. As a whole impression of the MNL, RPL and LC estimates, the goodness of fit measures was significantly improved in applying the LC approach compared with the MNL and RPL models (Pseudo R squared were largely increased when using the LC model in Table 50 and Table 51). The analysis results of the choice datasets of carbon tax and GHG ETS are explained as follows.

4.5.4.1 Analysis results of choice dataset of carbon tax policy

As shown in Table 50, the possibility of the respondents in class 1 is 57.2% and the possibility of the samples categorized as class 2 is 42.8% in the LC model. There reveals obvious difference between the two classes of companies in their choice preference to carbon tax due to the influences of various attributes.

The analysis results for class 1 respondents in the LC model are similar as the estimations by the MNL and RPL models. The level of tax rate significantly but negatively determines the company's choice preference to carbon tax policy. This is consistent with the intuitive recognition that higher tax rate would bring heavier cost for energy uses of companies and thus increase their resistance to this policy. Significant and positive relationships between tax relief measures and the respondent's policy preferences were confirmed in this analysis. This implies that allowing the preferential tax treatments would increase the acceptability of companies to carbon tax, by cutting down the taxes either for energy-intensive industries (RELIEF-B) or to the companies with energy efficiency improvement to certain level (RELIEF-C). The utilization of carbon tax revenues has significant influence to the company's preference to this policy. The respondents view that to use the revenues as specific fund for climate change (REVENUE-B) is more preferable than to use it as general budget (REVENUE-A). However, the utilization of carbon tax revenues to reduce the company's other taxes (REVENUE-C) does not differentiate their preference of this policy. The starting time is significant in determining the company's choice preference to carbon tax. The result indicates that to postpone the introduction time of carbon tax from 2015 to 2021 would significantly increase the company's preference. In summary, the analysis results confirms that a carbon tax policy characterized as lower tax rate, with tax relief measures for energy-intensive or energy-efficient industries, to utilize the tax revenues specific for climate change, and to be introduced later would be more preferable from the perspective of surveyed companies.

Table 50 Estimation results for the choices of carbon tax policy

Attribute	**MNL**	**RPL**	**LC**	
			Class 1	**Class 2**
TAXRATE	-0.00045***	-0.00056***	-0.00114***	-0.00017
RELIEF-B	0.419**	0.570***	1.800***	0.394
RELIEF-C	0.518**	0.592***	1.393**	0.423
REVENUE-B	0.296*	0.360**	1.348**	-0.081
REVENUE-C	-0.140	-0.101	-0.243	0.013
TIME	-1.038***	-1.058***	-2.635***	-0.031
Class probability			0.572	0.428
Log-likelihood	-501.62	-498.76	-470.35	
Pseudo R squared	0.169	0.201	0.246	
Obs.	900	900	900	

Notes: 1) The standard errors are not reported to save space.
2) *, ** and *** denote that the parameter is significant at 10%, 5% and 1% level, respectively.

4.5.4.2 Analysis results of choice dataset of GHG ETS

The estimations of the choice dataset of GHG ETS by the MNL, RPL and 3-class LC models are listed in Table 51. In the LC model analysis, almost half of the respondents are classified into class 1, with a class possibility of 49.0%. The remaining 28.3% and 22.6% of samples belong to class 2 and class 3, respectively.

The similar as the results of MNL and RPL analysis, the companies in class 2 and 3 in the LC model prefer the grandfathering method in cap setting (CAP-A) rather than the method of benchmarking (CAP-B). The samples in class 1 indicate the contrary preference between these two methods (CAP-A and CAP-B). For the cap setting by a hybrid approach (CAP-C), the companies in class 2 and 3 show the contrast preferences in comparison with CAP-A. Nevertheless, the significant relationship between CAP-C and the company's choice preference of GHG ETS could not be found in the MNL and RPL model analyses.

Table 51 Estimation results for the choices of GHG ETS

Attribute	MNL	RPL	LC		
			Class 1	Class 2	Class 3
CAP-B	-0.440***	-0.440***	1.009***	-2.857***	-2.541***
CAP-C	-0.041	-0.041	0.340	-3.646***	3.337**
ALLOCATION	-4.844***	-4.846***	-7.957***	-4.293**	-12.301***
PENALTY-B	-0.622***	-0.622***	-1.071***	-0.607	-1.483**
PENALTY-C	-0.119	-0.119	-0.073	-0.866	-0.551
LEAKAGE	0.484***	0.484***	0.938***	0.844	1.861***
Class probability			0.490	0.283	0.226
Log-likelihood	-565.85	-565.84		-505.74	
Pseudo R squared	0.080	0.093		0.189	
Obs.	900	900		900	

Notes: 1) The standard errors are not reported to save space.
2) *, ** and *** denote that the parameter is significant at 10%, 5% and 1% level, respectively.

The allocation of carbon emissions allowances is an essential aspect for GHG ETS. To allocate the allowances by auctions would bring costs for carbon emissions of the companies and thus would be resisted by the policy target companies. In this analysis, the significant but negative relationship between the variable of ALLOCATION and the company's choice preference of GHG ETS was clearly indicated in all the three models. This confirms the perceived intuition that increasing auction ratio for the allowance allocation significantly reduces the company's preference of GHG ETS. With class 2 in the LC model as an exemption, a penalty with 3 times of credit prices (PENALTY-B) significantly decreases the sample's choices of GHG ETS. A penalty with 5 times of market prices of carbon credits (PENALTY-C) indicates no significant relationship with company's choices of GHG ETS. This implies that a penalty as high as 3 times of market prices of carbon credits is strict enough at present for ensuring the sampled Korean companies not to exceed their allocated allowances under GHG ETS. In addition, the criterion for carbon leakage industry is significant in influencing the company's choices of GHG ETS. The respondents favor the use of carbon intensity as the criteria, which shall be given preferential treatments under GHG ETS.

4.5.5 Relationships between various attributes of the policy

An advantage of CE method is its ability to quantitatively estimate willingness-to-pay (WTP) of the respondents by introducing a price attribute. In this study, the tax rate and the auction ratio for allocating carbon allowances may be regarded as this kind of attributes for carbon tax and GHG ETS, respectively. To illustrate how the companies evaluate the other policy attributes in comparison with the monetary value, WTP values for the two policies are presented in Table 52.

The WTP may be viewed as the tradeoff between the target attribute and the price attribute in determining the company's policy preferences. The WTP values do vary across different policy attributes. For carbon tax policy, the WTP values of RELIEF-B, RELIEF-C, REVENUE-B and TIME are all statistically significant. Setting tax relief measures for energy-intensive companies (RELIEF-B) equals to a decrease of 1,804 KRW/t-CO_2 of tax rate in influencing the company's choice preference to carbon tax. Similarly, the effect of changing from the utilization of carbon tax revenues as general budget (REVENUE-A) to the specific fund for climate change (REVENUE-B) is the same as a decrease of tax rate of 678 KRW/t-CO_2. Regarding the starting time, the surveyed companies would have equal choice preference to a carbon tax introduced since 2015 with the policy alternative to be phased in 2021 but with the tax rate increased by 1,665 KRW/t-CO_2.

Table 52 Willingness-to-pay (WTP) indicating relationships between policy attributes

A: Choices of carbon tax policy				B: Choices of GHG ETS			
Attribute	**WTP (KRW/t-CO_2)**	**95% Confidence Interval (KRW/t-CO_2)**		**Attribute**	**WTP (%)**	**95% Confidence Interval (%)**	
RELIEF-B	-1804	-1851	-1758	CAP-B	16.2	11.5	20.9
RELIEF-C	-1607	-1688	-1526	CAP-C	12.9	6.6	19.3
REVENUE-B	-678	-785	-571	PENALTY-B	13.3	13.2	13.4
REVENUE-C	125	107	144	PENALTY-C	6.8	5.6	8.0
TIME	1665	1528	1803	LEAKAGE	-14.7	-15.1	-14.2

Notes: The tax rate is used as the denominator for the choices of carbon tax policy in this estimation. For the choices of GHG ETS, the allocation rate by auction is used as the denominator.

For GHG ETS, the WTP values of CAP-B, PENALTY-B and LEAKAGE are statistically significant. For cap setting, applying the benchmarking approach (CAP-B) rather than CAP-A is similar as an increase of auction ratio by 16.2% in influencing the company's choices of GHG ETS. An increase of 14.7% in auction ratio for carbon allowances allocation would be the same as change in the criteria from trade intensity to carbon intensity in determining the carbon leakage industry.

4.6 Conclusions

This paper summarizes a choice experiment to Korean companies for measuring their choice preferences to two representative carbon pricing tools, carbon tax and GHG ETS. The analyses by various models identified the policy attributes significantly determining the company's choices of policy alternatives. For carbon tax policy, lower tax rate, allowing relief measures to energy-intensive or energy-efficient companies, to use the tax revenues specific for energy saving and climate change and later introduction would increase the company's preference to this policy. For GHG ETS, different categories of companies have different preference in cap setting methods.

Around half of the samples companies prefer the cap setting on the basis of historical emissions. Another half favors the approach of benchmarking. Lower ratio of auction for allowances allocation is more preferable for the companies. To set a penalty of 3 times of prices of carbon credits is strict enough for ensuring the samples not exceeding their allocated emissions limit. For the definition of industries with carbon leakage risks, carbon intensity is a more favorable option than trade-intensity.

The findings of this analysis provide meaningful implications for the discussions and development of carbon pricing policies in Korea, especially from the perspective of industry. With carbon tax as an example, the discussions so far and our estimations of carbon prices affordable for Korean companies earlier indicate that to introduce a carbon tax at 2,000-3,000 KRW/t-CO_2 would be feasible for Korea currently. However, TMS, as a regulative policy, was just introduced since 2011 to limit carbon emissions of large energy-consuming entities. A formal and domestic GHG ETS has been determined to launch since the beginning of 2015. Under this context of related policy progress, Korean government may take more time to consider whether to introduce carbon tax and how to coordinate the relationship between various policies. The result of this analysis reveals that if the introduction time of carbon tax was delayed until 2021, the tax rate could start from 4,000-5,000 KRW/t-CO_2 by then.

There remain certain shortcomings to overcome by further research in the near future. Considering the large amount of choice sets generated in the experiment design, the questionnaire was divided into two versions. The number of samples and observations for each version of choice sets is equal but limited. We purposely target the energy-intensive companies from iron & steel, cement and chemical industries. The final datasets also includes some samples from the other sectors. The numbers of samples for the two versions of choice sets are not perfectly equal by the company's characteristics. The gap in data collection may generate certain bias in the analysis results.

5. A SURVEY ON THE IMPEDIMENTS TO LOW CARBON TECHNOLOGY INVESTMENT OF THE PETROCHEMICAL INDUSTRY IN KOREA[13]

[Abstract]

Responding to the climate change, Korea has been establishing a domestic policy framework for promoting energy saving and greenhouse gases reduction, with the expansion of low carbon technologies for industry as a key area.

This paper analyzes investment barriers for low carbon technology investment and suggests supportive policies based on a survey to petrochemical companies in Korea. A total of 35 samples were collected. Among which, 32 companies are targeted by the Korean domestic ETS and represent 63% of the total CO_2 emissions of all petrochemical companies under this scheme. The analysis result indicates that low carbon technology introduction is not a priority for the sampled companies. Besides the lack of financial support, there exist other impediments to low carbon technology investment, e.g., lower investment priority, economic loss during new technology replacement, technology uncertainty and less pressure on energy prices. In addition, technology payback period acceptable for companies was estimated by the multi-bounded discrete choice method. The acceptable payback period on the part of half samples ranges from 2.4 to 3.6 years. The relatively high preference to short-term profitability of low-carbon technologies may hinder the companies to make the investment decision. Financial support and information dissemination for low carbon technologies may be useful to facilitate company's investment in low carbon technologies. Carbon pricing policies, such as ETS, is agreed to be supportive by providing the price signal for the investment.

This analysis enhances the understating of Korean company's perception on low carbon technology investment and provides meaningful policy implications for the development and improvement of related policies.

Key words: Investment barrier, low carbon technology, petrochemical industry, Korea

[13] This chapter is based on the journal article " A survey on impediments to implementing in low carbon technologies of the petrochemical industry in Korea" published at the Journal of Cleaner Production published in 2016 by co-authors, Suk Sunhee, Lee Sang-youp, Jeong Yushim.

5.1 Introduction

Korea, as the world's seventh largest CO_2 emitter in 2012 (Source: USEIA website), has responded to the international needs of climate change and been establishing a domestic policy framework for promoting energy saving and GHG reduction. The government set the national GHG mitigation target in 2009 and issued the 'National GHG Emission Reduction Roadmap' in 2014. The government strengthened the energy efficiency policy for industry and firstly depicted a roadmap in the first 'National Energy Plan (2008-2030)' to gradually transform from voluntary agreements (VAs) to NAs. Out of the NAs, the TMS and domestic ETS are addressed as key measures for climate change policies. In enforcing these policies, the Korean government posits the expansion of low carbon technologies (LCTs)[14] and equipment for management of energy saving and GHG mitigation.

Looking in this direction, to create new drivers for green growth, the government has announced a list of 27 key technologies with a focus on Research and Development (R&D) investment areas (Lee at el., 2015). The Korean government, thus, prioritizes them for support and investment. These technologies can be divided into energy-efficient technologies, renewable energy and pollution abatement technologies. To facilitate the development of technologies, the government invested approximately 2% of the country's GDP in 2015 (around USD 23 billion) (Kim, 2014). As sectoral action in promoting the above measures, the government proposed the fuel alternative, efficiency improvement of common equipment, GHG emissions reduction from the process, and cogeneration and waste heat recovery technologies as major reduction means (Joint ministries, 2014).

When energy saving and GHG mitigation policy is introduced, a question that arises is primarily associated with how companies react regarding their choices of investment in LCTs and equipment to enhance energy and GHG management. Studies have found that cost-effective energy saving measures, such as the introduction of energy efficient technology, have not been undertaken as expected (Rohdin et al., 2007). A detailed review of literature on the determinants of companies' investment in energy efficiency has been done in Suk et al. (2013). In this previous study in Korea, we found that the green strategies of small and medium-sized enterprises (SMEs) in response to energy and climate change policies were still at an early stage. They do focus largely on the practices related to institutional and managerial energy saving activities, requiring relatively lower costs and efforts (Suk et al., 2013). Resisting the introduction of domestic ETS, Korean businesses argued whether emerging and newly introduced climate change policies would be effective in reducing CO_2 emissions and triggering companies to really invest in LCTs (OhmyNews, 2014).

[14] LCTs in this study is defined as the energy efficiency technologies to be applied in the production process.

Exploring the barriers that influence to companies' adaptation of LCTs, this study implemented a survey targeting the Korean petrochemical industry mainly due to the large responsibility of this sector for the national GHG emissions**.** Korea's petrochemical industry was the world fourth largest based on ethylene capacity in 2012 (KPIA, 2013). Korea exported 45.9 billion USD worth of petrochemicals in 2012, which represented 8.4% of the country's total exports in the same year (KPIA, 2013). The total energy consumption of the Korean petrochemical industry in 2013 was 60,122 thousand toe, the largest portion, accounting for 48.1% among manufacturing sectors. This was a large increase from the share of 30.4% in 1990 (KEMCO, 2015a). BAU emissions from the petrochemical sector were estimated to reach 59.6 Mt-CO_2 by 2020. In the 'National GHG Mitigation Roadmap', the reduction rate required for the petrochemical industry is 7.5% which allows 55.1 Mt-CO_2 emissions by 2020. Among the reduction amount, the government expects to cut about 1.59 Mt-CO_2 through efficiency improvements in common equipment (driers, electric motors, boilers) (Joint ministries, 2014).The total energy and environment-related investment in the Korean petrochemical sector in 2013 amounted to KRW135 billion, which is equal to 2.5% of this sector's total investment in plants and equipment (KRW 5,382 billion). Meanwhile, investment in this sector is the most abundant, with 37% in facility expansion, followed by 29% and 17% for new products production and maintenance, respectively in 2013 (KPIA, 2013). During 2011 to 2013, the ratio of investment in other parts has largely changed, for example, the investment ratio for new product production has changed from 9% ('11) to 29% ('13), for R&D from 3% ('11) to 7% ('13), and for automation and labor saving from 5% ('11) to 1% ('13). Whereas, investment related to energy and environment has maintained at a stable level less than 3%, 2.3% ('11), 2.9% ('12) and 2.5% ('13), (KPIA, 2013).

Under the prompt policy transition to the green economy in Korea, the skeptical attitude from industries and their stagnated investment in energy saving and GHG mitigation by technological measures are the motivation for this survey. Actually, there is only few studies and limited understanding on the perspective of companies' LCTs introduction and investment in Korea. Thus it is necessary to explore the questions like how companies evaluate the LCTs investment barriers pre-defined, what policy solutions to the barriers they advocate in the presence of climate change policies, what would close the existing gap between government policies and the response of business. Particularly, this study uses the data collected by a questionnaire survey for looking into three aspects for petrochemical companies in Korea: their acceptable payback period; technology investment barriers; and related supportive policies for them to invest in LCTs.

The remainder of this paper is structured as follows. Section 2 explains the research method, including models for estimating investment possibility of companies on LCTs applying the multi-bounded discrete choice (MBDC) data and an analytical framework for regression analysis. The questionnaire survey and samples used in this study are also outlined in this part. Section 3 shows the status of energy consumption and GHG emissions of the samples. In Section 4, discussions focus on the results of the statistical analysis. Section 5 presents the estimations results of investment possibility under various payback periods and regression analysis of investment barriers and supportive policies. Section 6 summarizes the research findings.

5.2 Research method and materials

In order to estimate a company's investment possibility depending on the technology payback period, the MBDC format was used. The statistical analysis and econometric regression were conducted to identify the barriers and related supportive policies for the investment in LCTs. The methods are explained followed the outlining of the materials.

5.2.1 Outline of the survey and samples

A questionnaire was designed with the main objective to identify the status of the introduction and investment of LCTs, and to identify the corresponding determinants, such as payback periods, barriers and supportive policies. The questionnaire format consists of four major components: general information of the company and the company's energy use and GHG mitigation, and energy and GHG management status; the company's energy saving and GHG mitigation activities; the status of LCTs introduction and the possibility of LCTs investment; and company evaluation on the relevant policies and barriers for LCTs investment. The question list is attached in the Questionnaire format 3, Appendix 1.

The data were collected by a questionnaire survey from February to March in 2015. The questionnaire was sent via fax and email to a total of 134 petrochemical companies, including all the 84 companies designated for the domestic ETS. Another 11 companies are under the TMS, and the remaining 39 are non-ETS and non-TMS petrochemical companies. Environmental and energy managers in the companies were targeted in the survey. The distribution of the usable samples according to company characteristics is summarized in Table 53.

According to the classification criteria of the 'Minor Enterprises Act' of Korea taking into account the number of employees only, nine are large companies with more than 1,000 employees. Eighteen belong to the group of medium-sized companies, having more than 50 but fewer than 300 staffs. There are only two small companies, with fewer than 50 staffs. The remaining six are large-medium companies, intermediate between large and medium-size companies.

Among 35 samples, 32 respondents are the ETS target companies in 2015, accounting for 38% of the total petrochemical companies under the ETS. Their CO_2 emissions in 2013 accounted for 63% of the total emissions from all ETS-targeted petrochemical companies.

Most surveyed companies, 85.7% of the total, have been designated once by the TMS in the period of 2012~2014. Fourteen companies have participated in TMS or ETS pilot projects conducted either by the MOE or the Ministry of Trade, Industry and Energy (MOTIE). A total of 37% of respondents indicate their main market is in overseas and they export their products.

Table 53 Distribution of usable respondents by company characteristics

Company characteristics	Number in total (%)	Number of samples by size			
		Small	Medium	Large-medium	Large
Number in total (% of total)	35 (100.0)	2 (5.7)	18 (51.4)	6 (17.1)	9 (25.7)
ETS Targeted (% of total)	32 (91.4)	0	17	6	9
Participated_TMS (% of total)	30 (85.7)	2	14	5	9
Participated_Pilot (% of total)	14 (40.0)	0	6	3	5
Export (% of total)	13 (37.1)	0	5	3	5

5.2.2 Method measuring the possibility for companies to invest in technologies

The MBDC format allows respondents to vote on a wide range of referendums and express voting certainty for each referendum and therefore reinforces the quantity and quality of data (Liu et al., 2013b). It has been utilized to estimate a company's affordability level of energy increasing due to the introduction of a market-based instruments. Considering the advantage of this method, an MBDC questionnaire was applied in this survey to measure the possibility of companies to invest in LCTs with different profitability. The question and format prepared for this survey and an example response from a company is shown in Table 54. A total of 15 thresholds for the payback period are listed for the companies to show their possibility in making an investment decision. The companies are provided with multiple choice options, including 'very high', 'high', 'moderate', 'low' and 'very low' possibility.

Given a payback period threshold of PB_{ij}, the probability for a company to invest in the technology will be

$$P_{ij} = \Pr(V_i > PB_{ij}) = 1 - F(PB_{ij}) \qquad (1)$$

Once P_{ij}, the probability for company *i* to invest under the payback period PB_{ij}, is known by assigning numerical values to the verbal MBDC answers, equation (1) can be estimated for each company. Assuming a specific function for $F(PB_{ij})$, such as a normal accumulative distribution with a mean of μ_i, and a standard variance of σ_i, the estimation model can be written as:

$$P\text{ij} = 1 - \Phi\left(\frac{PB_{ij} - \mu_i}{\sigma_i}\right) + \lambda_i \qquad (2)$$

Where, P_{ij} is the probability for company *i* to decide to invest; PB_{ij} is the threshold of technology payback period; μ_i and σ_i is the mean and standard variance of the distribution; λ_i is an error term. Stata 10 was applied for this estimation.

Table 54 The question and an example response of the MBDC format

<table>
<tr><td colspan="6"><u>Question:</u> The adoption of energy-saving low-carbon technologies can reduce energy use and GHG emissions of companies. Accordingly, the cost of energy and GHG emissions of companies can be reduced. The initial investments and operation expenditures of energy-saving low-carbon technologies may be recouped within a certain period. The payback period of different technologies may be different due to various initial investments, operational costs, energy-saving potentials and life spans, etc. We would like to know your company opinion on the decision to invest in such technologies with different payback period. Please tick the level of possibility of your company deciding to invest in the technologies under various payback periods.</td></tr>
<tr><td rowspan="2">Payback period (Years)</td><td colspan="5">The possibility of your company making an investment decision</td></tr>
<tr><td>Very high</td><td>High</td><td>Moderate</td><td>Low</td><td>Very low</td></tr>
<tr><td>0.25 (3 Months)</td><td>√</td><td>□</td><td>□</td><td>□</td><td>□</td></tr>
<tr><td>0.5 (Half a year)</td><td>√</td><td>□</td><td>□</td><td>□</td><td>□</td></tr>
<tr><td>1.0</td><td>□</td><td>√</td><td>□</td><td>□</td><td>□</td></tr>
<tr><td>1.5</td><td>□</td><td>√</td><td>□</td><td>□</td><td>□</td></tr>
<tr><td>2.0</td><td>□</td><td>□</td><td>√</td><td>□</td><td>□</td></tr>
<tr><td>2.5</td><td>□</td><td>□</td><td>√</td><td>□</td><td>□</td></tr>
<tr><td>3.0</td><td>□</td><td>□</td><td>□</td><td>√</td><td>□</td></tr>
<tr><td>3.5</td><td>□</td><td>□</td><td>□</td><td>√</td><td>□</td></tr>
<tr><td>4.0</td><td>□</td><td>□</td><td>□</td><td>□</td><td>√</td></tr>
<tr><td>5.0</td><td>□</td><td>□</td><td>□</td><td>□</td><td>√</td></tr>
<tr><td>6.0</td><td>□</td><td>□</td><td>□</td><td>□</td><td>√</td></tr>
<tr><td>7.0</td><td>□</td><td>□</td><td>□</td><td>□</td><td>√</td></tr>
<tr><td>8.0</td><td>□</td><td>□</td><td>□</td><td>□</td><td>√</td></tr>
<tr><td>9.0</td><td>□</td><td>□</td><td>□</td><td>□</td><td>√</td></tr>
<tr><td>10.0</td><td>□</td><td>□</td><td>□</td><td>□</td><td>√</td></tr>
</table>

5.2.3 Econometric analysis

The analytical framework and model for econometric analysis are described in following sub-sections.

5.2.3.1 Analytical framework

In this study, we carried out an econometric analysis to measure the respective relationship between company evaluated payback periods, investment barriers and relevant supportive policies for LCTs introduction with the determinant factors. The analytical framework is depicted in Figure 23. The determinant factors are described as follows. We classified the determinants into external pressures, internal factors and controls. Four external pressures were defined, regulation, competition, energy price and international orientation, which are deemed to influence company perspective on LCTs investment and their evaluation of relevant government policies. In our previous study conducted in 2011 in Korea, the external coercive, government regulation, indicated no significant influence on a company's energy-saving activities (Suk et al., 2013). In this study, we assume that the ETS target is one of the external conditions affecting technology adoption although it has just started. A previous survey in China found that it is useful for business competitors to exert pressure to encourage the company to save energy, including collecting information on energy-saving policies and technologies (Liu et al., 2012a). Companies from energy-intensive industries are more sensitive to energy prices due to their higher reliance on energy use. Companies with higher export ratios may more concerned about climate change policy which will have a long-term impact on their competitiveness in the international market.

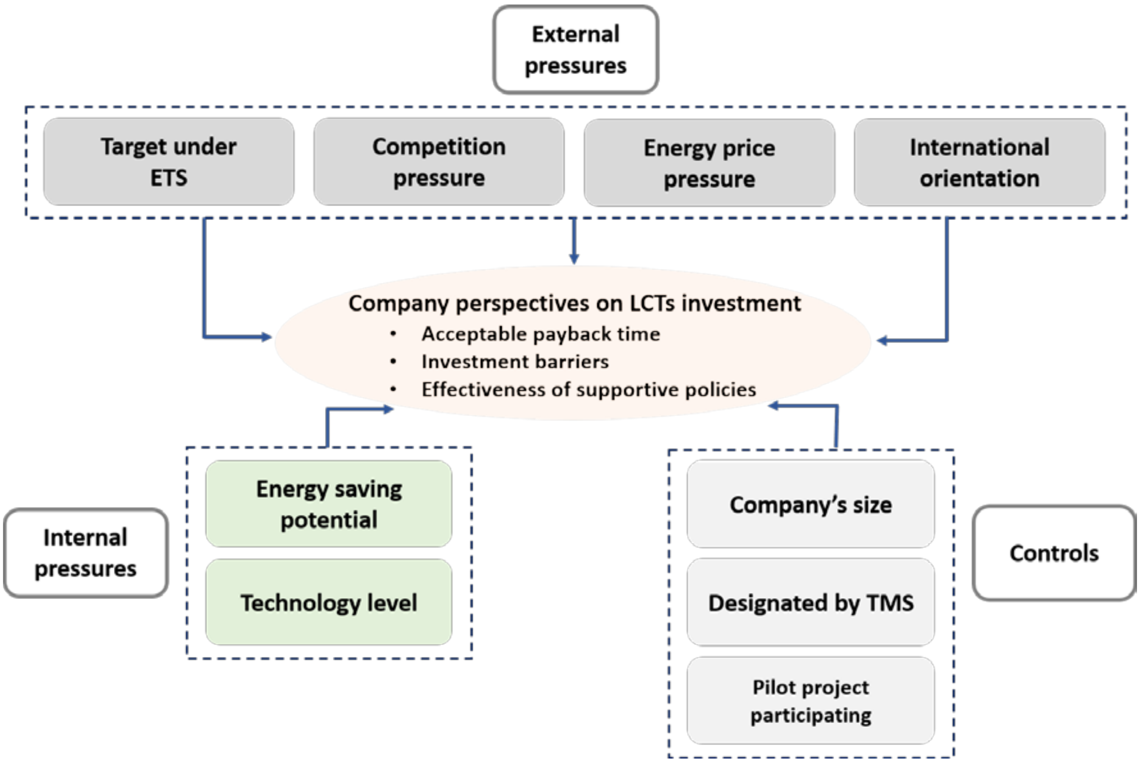

Figure 23 Analytical framework for econometric analysis

Two internal factors were classified, energy-saving potential and technology level of the company. They may indicate the company efforts in self-reduction and are closely related to the consideration of LCTs investment and evaluation of relevant supportive policies for companies. Regarding the company's characteristics, the size, experience of participating in pilot projects for TMS or ETS, and an experience of TMS designated entities during 2012~2014 were set as controls for this analysis.

As indicated in Table 55, a five-point scale was applied to evaluate the variable of COMPETITION and ENPRICE, with '1' = very low; '2' = relatively low; '3' = moderate; '4' = relatively high; and, '5' = very high. For EXPORT, companies with products for the domestic market are designated a value of '0', with '1' designated for export-oriented companies. The respondents are sorted into ETS target or not. TECHLEVEL is divided into four levels, '1' = domestically laggard; '2' = domestically average; '3' = domestically advanced; '4' = internationally advanced. Companies indicated the SAVPOTENTIAL of technologies they hold as being four levels, with '1' = no potential; '2' = limited potential; '3' = high potential; '4' = very high potential. For the TECHLEVEL and SAVPOTENTIAL, the answer of 'have no idea' was counted as '0'.

For the controls, company size is classified into four types: small, medium-sized, large-medium and large, which are respectively abbreviated as SMALL, MEDIUM, LMEDIUM and LARGE. Companies with experience of participating in pilot projects of TMS or ETS are given a score of ‘1’. The history of whether the company was designated by TMS target during 2012~2014 is presented a value of ‘1’. Stata 10 was used for statistical analysis in this study.

Table 55 Abbreviation, description and valuation of independent variables and controls

Category	Abbreviation	Description	Valuation					
			0	1	2	3	4	5
External pressures	ETS	Involvement status of ETS						
	EXPORT	Company’s international orientation						
	ENPRICE	Perception of domestic energy price levels						
	COMPETITION	Competition degree of the company’s sales market						
Internal Factors	SAVPONTEINTIAL	The level of energy saving potential of the company						
	TECHLEVEL	The level of technology held by company						
Controls	SIZE	Company’s size						
	PILOT	Participant in pilot projects						
	TMS	Designated in TMS						

5.2.3.2 Econometric Model

The regression model capturing the functional relationship between the company’s mean evaluation of dependent variables and the classified independent variables and controls can be constructed and written as equation (3), where ε is the error term and β_0 is the constant.

$$\begin{aligned} MEAN &= \beta_0 + \beta_1 ETS + \beta_2 EXPORT + \beta_3 COMPETTION \\ &+ \beta_4 ENPRICE + \beta_5 SAVPOTENTIAL + \beta_6 TECHLEVEL \\ &+ \beta_7 SIZE + \beta_8 PILOT + \beta_9 TMS + \varepsilon \end{aligned} \quad (3)$$

As dependent variables, the mean of acceptable payback period, evaluations of pre-listed barriers and related policies for stimulating LCT expansion are used for the regressions. The multivariate regression and the ordered logistic regression were employed for the regression analysis of the payback time, and the analysis of barrier and supportive policies, respectively considering the characteristics of the dependent variables.

5.3 Energy consumption and CO_2 emissions of the samples

In order to understand the status of energy consumption and CO_2 emission of samples, the companies were requested to show their energy consumption amounts and CO_2 emissions in 2013. Since more than 90% of the samples are ETS targeted companies, most of them are heavy energy consumers, as shown in Figure 24. Companies using more than 10,000 toe accounts for 81% of the total sample. Around 16% of the samples used even more than 100,000 toe. According to

KEMCO (2015a), 43% of petrochemical companies in Korea consumed less than 5,000 toe and 38% used over 10,000 toe in 2014. Among which only 8% consumed over 100,000 toe. Kim (2009d) reported that only the top 2.2% of SMEs in Korea consumed more than 2,000 toe and 85% of the remaining SMEs used even less than 200 toe in 2009. It implies that the respondents of this survey represent the heavy energy-consuming companies in the petrochemical industry in Korea.

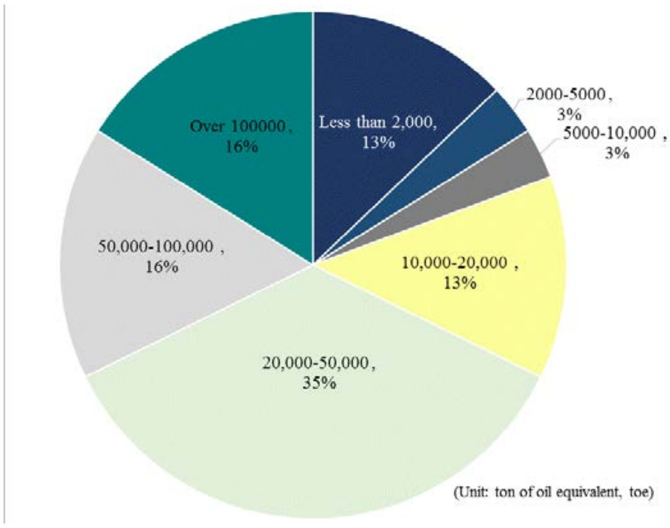

Figure 24 Distribution of the samples by the energy use in 2013 (N=31)

The surveyed companies indicated the range of their energy consumption costs in relation to total sales in 2013. As summarized in Table 56, 85% of the samples have a range of either less than 5% or 5~15%. Companies that spend more than 30% of total revenue for energy costs account for 11%. The remaining 4% has a range of 15~30%.

Table 56 Sample distribution by energy expenditure to total sales in 2013

Range	Less than 5%	5~15%	15~30%	Over 30%
Percentage of the samples (%)	41	44	4	11

The emissions criteria to be targeted by the ETS are for entities emitting over 125,000 t-CO_2 or for business sites emitting over 25,000 t-CO_2 annually on average during 2011–2013. As our survey targeted business sites, it is a natural result that over 90% of surveyed companies emitted more than 25,000t-CO_2 in 2013. However, as shown in Figure 25, the samples CO_2 emissions are far larger than the criteria. The companies with emissions in the range of 25,000~50, 000 t-CO_2 and 50,000~125,000 accounted for 12.9% and 32.3% of the total, respectively. The number of companies responding that their CO_2 emissions are even more than 125,000t-CO_2 makes up half of the total. In addition, 16% of the samples emitted over 1,000,000 t-CO_2 in 2013.

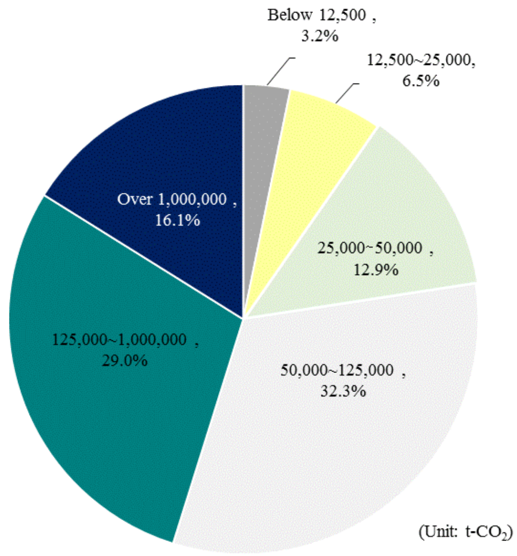

Figure 25 Distribution of samples by CO_2 emissions in 2013 (N=31)

5.4 Statistical analysis results

This section shows statistical analysis results of the company's energy saving and GHG mitigation practices, firms' possessed technology level and their CO_2 mitigation potential, the ratio of investment for energy-saving and CO_2 mitigation in that for overall production process improvement and the statistics of independent variables

5.4.1 Company's energy-saving and CO_2 mitigation practices

Five areas – (1) introduction of low carbon energy, (2) introduction of LCTs and equipment in the production process, (3) improvement of transportation of raw materials, (4) development of environmental friendly new products, and (5) promotion of energy saving activities in the office – were listed and companies were asked to evaluate the relative energy-saving potential on a five-point scale with 5 being 'very high' and 1 meaning 'no potential' and to indicate the area in which they are actually focused for saving energy on a five-point scale with 5 being 'most focused' and 1 meaning 'no practice'.

As shown in Figure 26, the energy-saving potential and status of actual energy-saving activities for each area that a company evaluated are low or moderate. Companies indicated a relatively high energy-saving potential in the office and practically they are active in practice in this area. This result is consistent with our previous study measuring the status of energy-saving activities of Korean energy-intensive companies in 2010 (Suk et al., 2013). On the other hand, companies felt there was moderate energy-saving potential in introducing LCTs and devices in the production process, with a score of 2.97. However, companies gave the highest value as their actual practice area. Companies marked the lowest score for development of environmentally-friendly production as their actual energy-saving practice. It may be because 85% of the samples produce raw material and intermediary goods. Overall, there was no significant difference between the areas having energy-saving potential and those with energy-saving activities in practice.

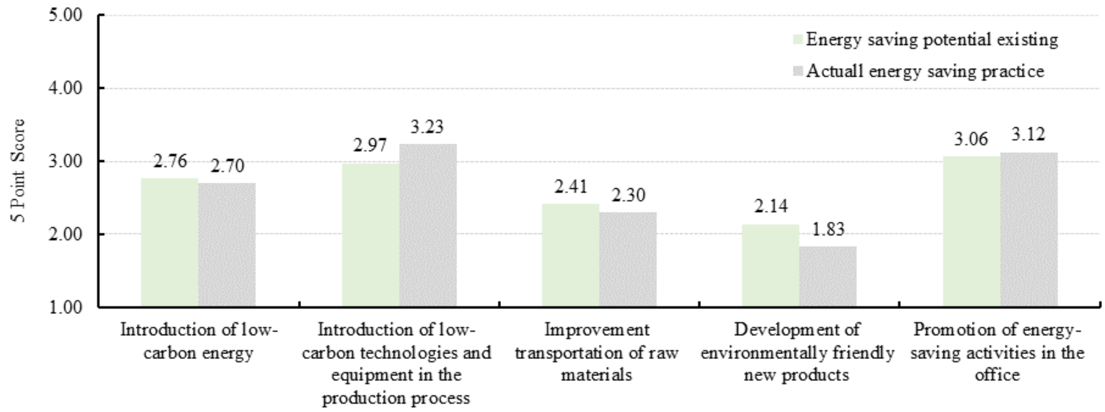

Figure 26 Evaluation result of energy-saving potential and actual practice by area

5.4.2 Company’s technology level and further energy-saving potential

We asked companies to check their technology level and the potential for further energy-saving. As indicated in Table 57, 42.9% of the samples confirmed that their production technologies are at the domestic average level. 11.4% viewed their technology levels to be domestically advanced. Another 20.0% responded that their production technologies are at the internationally advanced level. One-fourth of the sample was not aware of the level of technology they currently possess. Regarding energy-saving potential, none of the companies assessed their technology energy-saving potential to be very high. However, nearly 66% of the companies evaluated that there is still limited potential. Just 8.9% selected no potential. Only 5.7% of the samples admit that they have relatively large energy-saving potential. This is consistent with the fact that Korean industry insists that energy efficiency for petrochemicals is already higher than other industrialized countries, and accordingly their energy reduction capacity is limited (FKI, 2015b). This sector has undertaken several major initiatives to improve its energy efficiency in response to the government policies, for example, voluntary action improving existing processes and dissemination of high-efficiency devices. As a result, this sector achieved remarkable energy efficiency levels in the World (FKI, 2015b). The average energy intensity of domestic petrochemical industry’ core facilities (i.e. Naphtha cracking center processes) is 67% of the world average, while the average of Asia, Europe, South America and North America is 85%, 97%, 104% and 112% of the world average, respectively (KEMCO, 2012). IEA (2009b) analyzed energy-saving potential with best practice technology (BPT) and found negative improvement potential for the chemical and petrochemical sector in Korea, which implies that the existing processes are on average more efficient than BPT.

Companies with an answer of no idea of their energy-saving potential make up about 20% of the total. In Korea, according to the ‘Regulation on Energy Audit’, the companies consuming more than 2,000 toe annually, including fuel, heat and electric power, have a duty to undergo an energy audit. Through the energy audit, a company should find the opportunities for energy saving and the ways to improve energy efficiency. Therefore, companies that do not understand the level of technology and energy-saving potential are probably those enterprises with annual energy use less than 2000 toe, about 13% of respondents in this survey. Even excluding them, there are still some companies that do not know the level of their technologies and energy saving potentials. With a more detailed analysis, we confirmed that all these companies are SMEs. Korea’s energy-saving policies have mainly targeted large companies in the past and some SMEs might not seriously concern their energy management even targeted by TMS and ETS. Given that the number and proportion of SMEs as the target of TMS and ETS are increasing, it is necessary for the government to develop and implement measures specifically for promoting energy-saving and CO_2 mitigation in SMEs, e.g., through enhancing energy audit requirements and ensuring the audit results to be effectively applied for their energy management improvement.

Table 57 Company’s evaluation of production technology level and energy-saving potential

Current technology level (N=35)		Energy-saving potential (N=35)	
Internationally advanced	20.0%	Very high	0.0%
Domestically advanced	11.4%	High	5.7%
Domestically average	42.9%	Limited	65.7%
Domestically lagging	0.0%	No potential	8.6%
Have no idea	25.7%	Have no idea	20.0%

5.4.3 Status of companies’ investment in LCTs

The sample distribution by ratio of investment for energy-saving and CO_2 reduction in that for production process improvement is depicted in a pie graph in Figure 27. Over 60% of companies invest less than 5% of investment in the production process for energy-saving and CO_2 reduction. However, this is still higher than the average investment ratio, which was 2.5% for the energy and environment-related investment by petrochemical industry in 2013 (KPIA, 2013). Around 16% of companies put more than 20% of their total investment capital into environmental related investment.

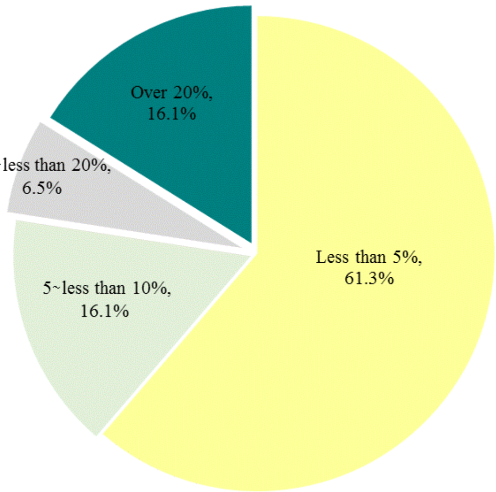

Figure 27 Sample distribution by ratio of investment for energy-saving and CO_2 mitigation in that for production process improvement (N=31)

On the question of business plan for expansion or introduction of facilities within how many years, more than half of the samples replied within 3 years. If within five years, 86% of the samples appeared to have a plan for the facility expansion or introduction of plants, as shown in Figure 28.

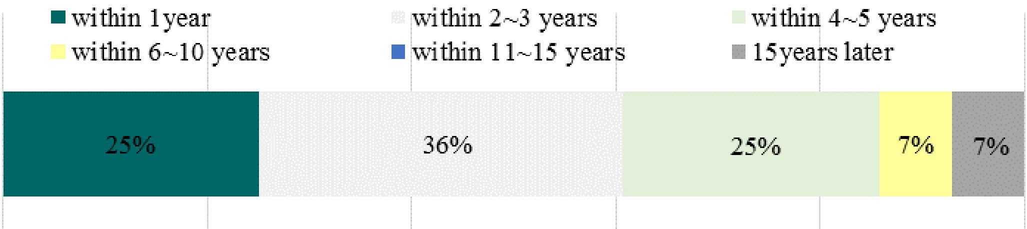

Figure 28 Sample distribution by the years with investment plan (N=31)

5.4.4 Statistics of the independent variables

Table 58 summarizes the statistics of independent variables. The skewness and kurtosis values were listed to show the shape of the distribution of scores achieved by theses variables. The variables' skewness ranges between -1.466 and 0.485, with the absolute values less than 3 and their kurtosis ranges from 1.88 to 2.45 with the absolute values less than 10. This confirms that the skewness and kurtosis of the adopted variables are not significant (Kline, 1998).

The external factor of 'COMPETITION' achieved a high score. In order to maintain competitiveness, company energy-saving activities are largely determined by the energy performances of major business competitors in the same sector. Companies felt high pressure from current energy prices, and the quantitative control of 'ENPIRCE' obtained a mean of 3.73. As described in Section 5.2, the sampled companies evaluated their technology level and energy-saving potential moderately or less, with the variable of ‘TECHLEVEL’ and ‘SAVPONTEINTIAL’ being presented a mean of 3.00 and 2.57, respectively. The variable of ‘ETS’, ‘TMS, ‘PILOT’, ‘SIZE’ and ’EXPORT’ are summarized in Section 3.1.

Table 58 Statistical summary of independent variables and the quantitative control

Variable	Obs.	Mean	Std. Dev.	Min.	Max.	Skewness coefficient	Kurtosis coefficient
ENPRICE	31	3.73	0.58	3	5	-1.40	1.88
COMPETITION	35	4.11	0.68	3	5	0.49	2.45
TECHLEVEL	35	3.00	1.41	1	5	0.00	2.32
SAVPONTEINTIAL	35	2.57	0.88	1	4	-1.47	2.06

5.5 Results of company’s acceptable payback period and evaluations of barriers and supportive policies

5.5.1 Payback time acceptable for LCTs investment

The payback period of a given technology is usually the most important criteria for companies to determine whether or not to undertake the investment. This Section show the analysis of the payback period that companies could accept for the LCTs investment. In addition, the result of econometric regressions identifies the differences in selections of companies for payback periods due to internal and external factors and their characteristics.

5.5.1.1 Statistics of acceptable payback period of the samples

Companies were asked to indicate one of the five degrees of investment possibility for LCTs projects from a total of 15 thresholds of payback period. Table 59 lists the statistics for the investment possibility of all valid respondents to each payback year presented in the MBDC format. A total of 30 companies made proper circle on the question format and their answers are used for the statistics. A total of 90% of companies indicated that the shortest payback period of 3 months was very highly acceptable for them. Another 7% of respondents also expressed high possibility to accept this payback period for energy-saving projects. Another 3% selected ‘moderate’ for this option. In summary, 97% of respondent would invest in energy-saving projects with this payback period. The share of the companies which indicated investment potential to a moderate degree and lower increased to 50% if the payback period was 2.5 year, 67% if it was 3 years, and 100% if it was 3.5 years. The ratios of companies indicating an investment possibility of combining ‘low’ and ‘very low’ continue to decrease as the payback period increased. More than half of the companies viewed a payback period of over 3.5 years to be long and rejected this response. Almost 90% of the surveyed companies may strongly reject investing in energy-saving projects with payback periods of 5 years and over.

Table 59 Statistics of company's investment possibility for LCTs (N=30)

Payback time	Very low (%)	Low (%)	Moderate (%)	High (%)	Very high (%)	Total (%)
0.25 (3 Months)	0	0	3	7	**90**	100
0.5 (Half a year)	0	0	3	10	**87**	100
1	0	3	0	33	**63**	100
1.5	0	3	7	**67**	23	100
2	0	7	30	**57**	7	100
2.5	10	13	27	**47**	3	100
3	10	17	**40**	33	0	100
3.5	27	30	**43**	0	0	100
4	30	30	**40**	0	0	100
5	37	**47**	17	0	0	100
6	**57**	43	0	0	0	100
7	**63**	37	0	0	0	100
8	**83**	17	0	0	0	100
9	**87**	13	0	0	0	100
10	**87**	13	0	0	0	100

Figure 29 depicts the results of aggregated data listed in Table 59 and the simulation curves. Two groups of data – high and very high possibility, and moderate and above – are shown in the figure because they are meaningful for observing the rough range of payback periods that a company would consider for investment. A cumulative normal distribution model was applied to the regressions with the aggregative share of the samples as dependent variable and the payback period as independent variable. As shown in Figure 29, the R squared for the regressions of two sets of data is 0.9971 and 0.9942 respectively, indicating a good fit between the observed data and regressions curves. The range of the payback period on the part of 50% of the samples corresponds to 2.4 to 3.6 years. 90% of companies strongly rejected to invest the technologies with a payback period of over 4.9 years. This result is similar to that of our previous survey indicating 63% of the Korean petrochemical companies accepted a payback period of less than two years (Suk et al., 2013). According to KEMCO (2015b), the average payback period for energy efficiency projects under the 'Energy Audit Program' was 1.8 years during from 2007 to 2014. Another survey in Hyogo Prefecture in Japan indicates that around 30% of the samples expect a payback period of less than three years and 41.4% of them request to recover the investment between 3 to 5 years (Liu et al., 2014b). UK companies show similar payback period as Japanese companies, with an average of 3-5 years (Martin et al., 2012). This implies that Korean companies desired relatively short-term profitability on LCTs investments, which can be a hindering factor in their investment determination.

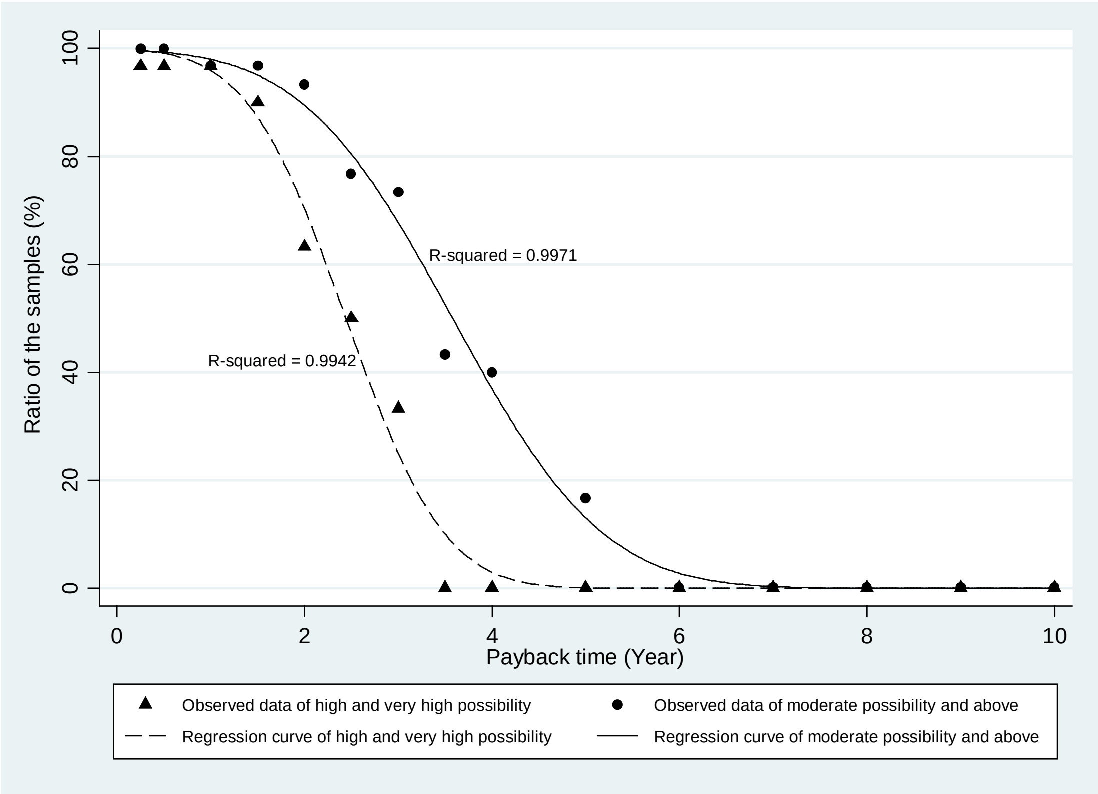

Figure 29 Simulation of companies' acceptable payback time for LCTs project (N=30)

The average payback period of the company is 3.3, 3.7, 3.0 and 2.6 years for large, large-medium, medium and small companies, respectively. This shows that SMEs want slightly faster recovery period for LCTs investments than that of their bigger counterparts.

5.5.1.2 Estimation of Payback Time for Individual Companies to Invest

The mean and standard variance of payback periods for individual companies investing in LCTs were estimate by equation (1). Numerical likelihood values of the investment were assigned to the verbal expression in MBDC format. A 'very low' answer was given a probability of 0.1% as a value of zero would generate infinity in the estimation. A response of 'low' possibility was given a value of 25%, 'moderate' 50% and 'high' 75%. A 'very high' answer was presented a value of 99.9% for the same reason to avoid calculation infinity.

Table 60 lists the mean and percentiles of payback periods for the samples when making investment decisions. As the result, the mean payback period for the surveyed companies to decide the investment is 3.2 years, which falls within the range of a payback period between 2.4 to 3.6 years, preliminarily observed in Figure 29. The sample's standard variance of technology payback period is 1.9 years and the medium value for the companies is 3.2 years.

Table 60 Distribution of estimated payback period for individual companies (N=29)

Variable	Percentile	Centile	95% Confidence Interval	
Mean of payback period: 3.3 years The std. dev. of payback period: 1.8 years	10	1.8	1.5	2.4
	20	2.3	1.8	2.8
	30	2.6	2.1	3.1
	40	3.0	2.4	3.4
	50	3.2	2.6	3.6
	60	3.5	3.0	3.8
	70	3.7	3.2	4.2
	80	3.9	3.6	4.9
	90	4.9	3.8	4.9

5.5.1.3 Multivariate regression result with acceptable payback period as the dependent variable

The robustness of the results was tested by repeating the regression with certain variables omitted. Five models were adopted. In Model 01, 02 and 03, the external, internal and control variables are tested individually. Model 04 includes all the variables except for the companies' size. Model 05 adds the size. The regression coefficients, as listed in Table 61, indicate that there is no obvious significant relationship between the independent variables and the payback period in the results of Model 01, 02 and 03. In the Model 04 and 05, three significant factors (export, pilot, and company size) are identified as indicated in shade. In the Model 04, a meaningful finding is that companies with experience of pilot projects can bear a relatively long-term on LCTs investment for cost recovery. According to the result of Model 05, export companies are negatively associated with payback periods, which indicates that these companies prefer more prompt capital return when investing in LCTs.

Table 61 Multivariate regression result with payback period as the dependent variable

	Variables	Model 01	Model 02	Model 03	Model 04	Model 05
External	ETS	0.342			2.009	2.430
	EXPORT	-0.448			-0.580	-0.836[c]
	ENPRICE	-0.213			0.185	0.404
	COMPETITION	-0.275			-0.507	-0.273
Internal	TECHLEVEL		0.193		0.006	-0.184
	SAVPONTEINTIAL		-0.210		-0.385	-0.304
Control	PILOT			0.453	0.851[c]	0.757
	TMS			-0.987	-1.178	-2.040
	LARGE			0.429		4.140[c]
	LMEDIUM			0.879		4.563[b]
	MEDIUM			0.086		3.430
	SMALL			(dropped)		3.981[c]
Obs.		25	29	29	25	25
R-Sq		0.139	0.069	0.216	0.390	0.536

a significant at 1% level
b significant at 5% level
c significant at 10% level

5.5.2 Barriers for company's implementation or investment in LCTs

Barriers are a set of issues that lead to decision makers in the company not making an investment. They are pre-listed in the questionnaire and companies were asked to score the degree of influence of each barrier to a company investment in LCTs on a five-point scale with 5 being 'very influential' and 1 meaning 'no influence'. There were 14 barriers listed and the results are presented in Table 62.

Overall, the average score for each barrier is between 2.1~3.5, revealing a low to moderate evaluation of the samples. Five barriers were scored over 3.0, including BARRIER 01 (company needs to invest in other more important projects); BARRIER 05 (company's lack of internal budget); BARRIER 06 (difficult to get external financing); BARRIER 07 (uncertainty in quality and reliability of new technologies and equipment); and, BARRIER 12 (economic losses due to the production suspending during the new equipment replacement).

Investment in LCTs is still not a priority for companies, as being seen from BARRIER 01 which had the highest score of 3.5. It is said that it usually takes at least one month to replace and install new equipment, and Korean companies highly concerned about their business loss during this period (BARRIER 12). As discussed in several studies (e.g., Jalone and Lehtonen, 2011), uncertainty of the quality and reliability of new technologies is one hindrance to companies in determining investment (BARRIER 07). We confirmed during interviews with persons from energy-intensive sectors in Korea that it would be essential for provide companies information on energy and CO_2 performance of the new technology and equipment, and an analysis of the market trends.

Companies are constrained by their limited internal budget (BARRIER 05) and difficulties to obtain external financing (BARRIER 06) for their investment for LCTs. IEA suggests putting complementary financial policies in place that promote energy efficient investment for industry in their updated 25 energy efficiency policy recommendations (IEA, 2011). Korean government has a funding system for energy use rationalization projects. Under this system, a total of KRW 500 billion has been assigned for the installation of energy-saving facilities, such as waste heat recovery, power generation, replacing old boilers, and high-efficiency LED lighting, in a form of long-term and low-interest loans (source from KEMCO website).

However, several previous survey studies mainly targeting SMEs showed that only a small number of surveyed companies from energy intensive sectors received preferential long-term loans and other financial incentives, i.e., tax incentives and energy-saving rewards (Suk et al, 2013). This is consistent with the low score of BARRIER 09 (averaged at 2.1). It seems that Korean companies prefer to rely on their own budget or private funding for LCTs investment.

Table 62 Evaluation of barriers of companies for the investment in LCTs

Abbreviation	Description of barriers	No. of Samples	Influence degree*
BARRIER 01	Company needs to invest in other more important projects	34	**3.5**
BARRIER 02	Energy costs and efficiency improvement in corporate management are not priorities	34	2.7
BARRIER 03	Existing technologies and equipment are highly efficient	34	2.5
BARRIER 04	Company's internal management factors make it difficult to implement energy-saving projects	34	2.5
BARRIER 05	Company's lack of internal budget	34	**3.5**
BARRIER 06	Difficult to get external financing	34	**3.1**
BARRIER 07	Uncertainty in quality and reliability of new technologies and equipment	33	**3.4**
BARRIER 08	The price of the technologies and equipment may decrease soon	34	2.2
BARRIER 09	Rely on financial subsidies on energy saving from the government	33	2.1
BARRIER 10	Pay the mild fines of TMS or ETS rather than to invest huge money for energy efficiency in the early stage	34	2.1
BARRIER 11	Lack of support at the national level (E.g., lack of tax incentives)	34	2.9
BARRIER 12	Economic losses due to the production suspending during the new equipment replacement	34	**3.4**
BARRIER 13	Lack of awareness at top management level	34	2.5
BARRIER 14	There is no significant economic benefits to introduce high-efficiency devices due to the affordable electricity prices	34	2.5

* Mean of the scores measured by a five-point scale.

The influence degree of listed barriers are used as dependent variables for the regressions to observe their respective relationship with the pre-listed factors. An attempt was made to group the 14 barriers into different dimensions using an exploratory factor analysis. However, no distinctive groups emerged. Therefore, all barriers were used as individual dependent variables. Table 63 indicates the regression coefficients. Results showed a significant association was shaded.

BARRIER 01 (Company needs to invest in other more important projects) seems to have more influence for companies with less competition, larger saving potential, and those as ETS target. It confirms that improving energy efficiency are not priority issues in their management (BARRIER 02) for companies under less energy price pressure. It is natural that BARRIER 03 (Existing technologies and equipment are highly efficient) is positively and significantly correlated with the companies who evaluated that their technologies have limited energy saving potential, and that energy prices are high. Former TMS-targeted companies, businesses under high competition pressure, and companies that target the domestic market may choose to pay fines or penalties for non-compliance of energy saving and GHG mitigation rather than investing in LCTs considering the weight of economic gains and losses (BARRIER 10). Companies under TMS, and enterprises focusing on the domestic market may think that there is no major economic advantage to introducing high-efficiency equipment since the current electricity price is low (BARRIER 14). Including the above results, it is noteworthy that the reasons to hesitate introducing LCTs for TMS designated companies are associated with BARRIER 07 (Uncertainty in quality and reliability of new technologies and equipment), BARRIER 10 (Pay the mild fines of TMS or ETS rather than to invest huge money for energy efficiency in the early stage) and BARRIER 14 (Rely on financial subsidies on energy saving from the government), considering they are major targets in the present enrolment policies. This shows that the size of the companies does not have a decisive influence on technology implementation and investment, except for large enterprises that show a significant relationship with BARRIER 11 (Lack of support at the national level). Large-sized companies urge stable and long-term supports, e.g., lower electricity price, rather than the one-time financial subsidies (Liu and Suk, 2014).

Table 63 Ordered logistic regression result with BARRIERs as the dependent variable

	Variables	BARRIER 01	BARRIER 02	BARRIER 03	BARRIER 04	BARRIER 05	BARRIER 06	BARRIER 07	BARRIER 08	BARRIER 09	BARRIER 10	BARRIER 11	BARRIER 12	BARRIER 13	BARRIER 14
External	ETS	3.453^{c}	-1.969	-2.422	0.438	1.052	0.997	1.308	2.598	-1.801	3.397	0.623	1.232	-1.417	1.630
	EXPORT	1.054	0.494	-0.807	-2.747	0.416	-0.589	-0.795	0.096	-1.033	-2.194^{b}	-1.240	-1.088	-1.326	-1.963^{b}
	ENPRICE	0.340	-1.881^{b}	0.521^{b}	2.338	1.183	0.621	-0.603	0.820	-0.554	0.253	0.119	0.959	1.042	0.641
	COMPETITION	-1.257^{c}	-0.452	0.025	2.138	1.264	0.126	0.847	0.724	-0.148	1.619^{c}	0.970	0.953	1.637	1.041
Internal	TECHLEVEL	-0.564	-0.485	1.085	-0.208	0.634	-0.387	-0.353	-0.566	-0.217	-0.040	-0.579	-0.027	-0.054	0.359
	SAVPONTEINTIAL	1.024^{c}	0.906^{c}	-1.034^{c}	-0.103	-0.043	0.628	-0.154	0.281	1.015	-0.456	0.637	-0.353	-1.273	-0.710
Control	LARGE	1.773	2.185	-1.530	25.219	23.555	22.647	1.259	-1.752	21.736	-1.069	3.684^{c}	2.055	21.517	0.364
	LMEDIUM	1.891	1.723	-2.749	28.587	25.790	23.733	3.375	1.740	22.581	0.458	2.603	1.939	23.078	1.049
	MEDIUM	-0.174	1.885	-2.290	23.359	24.852	22.774	1.850	-0.241	21.010	-0.376	1.324	1.104	22.228	-0.516
	TMS	1.769	-1.865	0.647	3.137	3.399	1.181	2.537^{b}	0.957	0.631	4.646^{b}	1.267	1.130	3.042	3.622^{b}
	PILOT	0.164	-1.500	0.549	-1.641	-1.258	-0.558	0.134	0.788	-0.558	-0.286	-1.000	1.187	-0.311	-1.469
Obs.		29	29	29	29	29	29	28	29	28	29	29	29	29	29
LR chi2(11)		21.72^{b}	14.54	14.54	30.56^{a}	24.55^{a}	12.03	11.49	15.68	10.63	13.67	12.24	11.12	19.62^{c}	15.65
Pseudo R2		0.2949	0.1695	0.1695	0.3662	0.2833	0.1436	0.1455	0.2206	0.1568	0.1804	0.1412	0.1273	0.2297	0.186

a significant at 1% level
b significant at 5% level
c significant at 10% level

5.5.3 Company's evaluation of supportive policies

In order to find out to what extent the Korean petrochemical industry evaluates the effectiveness of government measures for promoting the application and diffusion of LCTs, companies were requested to give a score for the listed policies. A five-point scale was applied, with 5 being 'very effective' and 1 meaning 'no effect'. The statistics are presented in Table 64.

The sampled companies presented low to moderate scores overall for the listed policies. Financial support is expected to be useful for encouraging a company's investment in LCTs, with a score of 3.3. The financial support to encourage the deployment of new technologies will be needed to help create the market until they achieve a large enough market penetration and to become cost-competitive when technologies are immature and require higher up-front cost initially (IEA, 2009b). As discussed above, the current financial program provided by the government has not been widely utilized by energy-intensive companies even though it is their preference. There may be several reasons. For example, the scale of the loans may be too small to attract companies. Alternatively, the procedure may be complex making it difficult for companies to access. Surprisingly, there is a lack of domestic action on this, such as a system-wide review, performance analysis, or improvement in operations.

Surveyed companies gave a relatively high score to set up a system to disseminate new technology information. The behavioral theory of companies confirmed that information is required to make the most appropriate decisions (Cyert and March, 1963). In practice, an information barrier was identified as a major obstacle restricting companies from adopting energy efficiency technologies (Kostas et al., 2011). In our individual interview with persons from energy-intensive sectors, including petrochemical, cement, and iron & steel industries, they emphasized the needs and importance of collecting information on new technologies. It was also pointed out that most of LCTs currently listed by the government, which are used to estimate the projected CO_2 emissions amount and reduction targets, are those that have been already introduced or the ones that are less likely to be applied to domestic companies under the current situation.

The surveyed companies agreed that intensive economic instruments, such as ETS, are effective for stimulating company's energy saving and GHG mitigation investment, although they strongly opposed their implementation. Through carbon pricing policy, the external costs of energy and CO_2 emissions may be internalized into energy prices, and the price signal will incentivize managerial strategy and LCTs investment by companies. Although the remainder of the policies received a score of less than 3.0, the difference is not large from the above policies.

Table 64 Statistics of effectiveness of supportive measures for LCTs investment

Abbreviation	Description of supportive measures	Obs.	Mean	Std. Dev.	Min.	Max.
SUPPORT 01	Introduction of economic instruments, such as emissions trading policy	34	**3.1**	0.89	1	5
SUPPORT 02	Incentives for eco-friendly products (tax incentives, purchasing expansion of public agencies, etc.)	34	2.8	0.73	2	4
SUPPORT 03	Financial support to energy-saving facilities or energy-saving technology projects	33	**3.3**	0.95	1	5
SUPPORT 04	System for the dissemination of new technology information	33	**3.0**	0.90	1	4
SUPPORT 05	Investment in green technology related R&D	33	2.9	0.93	1	4
SUPPORT 06	Infrastructure building for joint facilities or green partnerships	33	2.9	0.88	1	5

As the dependent variables, SUPPORT 01~06 are in ordinal measurements, ordered logistic regressions were performed. The analysis results are listed in Table 65, which indicates the associated factors influencing a company’s evaluation of whether or not current policies are supportive for LCT investment.

The ETS (SUPPORT 01) and technology level have a negative relationship, which implies that companies with a high level of technology may not appreciate ETS as an effective incentive for LCT expansion. In comparison with the small companies, large-medium companies more significantly evaluated the usefulness of SUPPORT 03 (Financial supporting to the energy saving facilities or energy saving technologies project). This is probably since both SMEs and large-medium companies are usually lack of financial resources and need the subsidies from the government. Whereas, the current funding system for energy use rationalization projects solely focuses on SMEs for accelerating their installation of energy-saving facilities. This may make the large-medium companies, which cannot enjoy this policy currently, more appreciate the usefulness of government subsidies. It should be noted that building a system to support technology information dissemination (SUPPORT 04) is positively significant for those companies possessing a high level of technology. Companies without experience of TMS or related pilot projects but that have high energy-saving potential, which are the SMEs, more welcome R&D investment from the government (SUPPORT 05). The total amount of investment for green technology R&D in 2012 accounted for 17.1% of the total R&D investment, which was increased from 15.7% in 2009 (Source from GTC website). The energy price pressure is negatively related to SUPPORT 03 (Financial support to energy-saving facilities or energy-saving technology projects), 04 (System for the dissemination of new technologies information) and 05 (Investment in green technology related R&D).

Table 65 Ordered logistic regression results with SUPPORTs as dependent variables

	Variables	SUPPORT 01	SUPPORT 02	SUPPORT 03	SUPPORT 04	SUPPORT 05	SUPPORT 06
External	ETS	-0.072	1.732	-0.318	-1.192	-1.049	-1.486
	EXPORT	-0.660	-1.259	-0.884	-0.584	0.753	-0.407
	ENPRICE	-0.337	-2.465	-2.302[b]	-2.162[b]	-2.777[b]	-0.783
	COMPETITION	0.798	3.190	1.031	0.949	1.480[b]	0.717
Internal	TECHLEVEL	-0.752[c]	-0.070	0.307	0.819[c]	0.748	-0.115
	SAVPONTEINTIAL	1.107	1.010	1.107[c]	0.796	1.080[c]	0.549
Control	LARGE	1.883	18.603	3.055	-0.795	0.863	1.793
	LMEDIUM	1.268	20.891	4.856[c]	0.020	0.748	2.195
	MEDIUM	-1.070	17.937	2.733	-1.320	0.306	1.020
	TMS	1.954	3.555	-0.064	-2.367[c]	-2.897[b]	-0.421
	PILOT	0.155	-2.823	-1.766[c]	-2.039	-2.041[c]	0.094
Obs.		29	29	29	29	29	29
LR chi2(10)		16.02	23.87[b]	19.91[b]	15.92	19.8[b]	7.56
Pseudo R^2		0.211	0.391	0.253	0.218	0.269	0.101

a significant at 1% level
b significant at 5% level
c significant at 10% level

5.6 Conclusions

Under the climate change policy transition pursuing low carbon green growth in recent decade, the Korean government has newly implemented industry target measures, such as the TMS and ETS, and emphasized innovation and dissemination of LCTs as a major measure for greening industry.

However, investment in LCTs seems not a priority for companies in their management strategic. Several barriers are identified in this study. It reveals that budget constraints, economic loss during new technology replacement and uncertainty of technologies are hindering LCTs investment by companies. Meanwhile, using the MBDC format, the payback period Korean petrochemical companies prefer for the LCTs investment is estimated. As the result, the companies tend to accept relatively shorter payback time for the LCTs to invest. If the payback period for an LCT project was over 5 years, almost all the sampled companies would likely to reject it. Half of the surveyed petrochemical companies accept a payback period up to 3.6 years. This preference for short-term profitability of LCTs may limit them to make an investment decision. The quantitative analysis of the payback time may assist the government to design appropriate and evidence-based funding schemes aimed at the deployment of LCTs in the related industry (Kennedy et al., 2016).

There exist correlations between energy price and company energy saving performance, particularly energy price is associated with a company's decision in the priority for its management, and its evaluation of the economic advantage of high-efficiency equipment. It is a meaningful evidence for the argument that the current low energy price, i.e., electricity price for industry, inhibits the company decisions for LCTs investment. Some companies tend to pay low-level fines for TMS or ETS rather than respond to the government policies, which would bring more benefit to them. The result of this study has significant policy implications regarding the necessity of enhancing the current system and institutions of climate change measures to encourage green investment of the industry.

Complementary policies to support industrial LCTs investment are obviously needed. For instance, an information platform to provide the latest technology information and accessible finance would be important and useful. Incentives of market-based instruments, such as the GHG ETS, would be effective for stimulating expansion of LCTs.

Overall, this study enhanced understanding of companies' perception of the barriers of LCTs investment and generated meaningful implications for clarifying the focus for further improvement in government policy and institutions.

A major scientific added-value of this study is the application of the method of multi-bounded discrete choice (MBDC) for measuring the company's investment possibility to LCTs with different payback periods. Using the result of this analysis, the effect of carbon pricing policies in increasing technology investment possibility may be observed since these policies usually enhance the profitability of LCTs. This makes it possible to depict the diffusion trend of LCTs under various policy conditions and assists in the prospective policy assessment.

Nevertheless, it has several shortcomings. Firstly, the analysis relies on company's self-reporting data. Due to the reluctance of companies to cooperate, only a small number of usable samples could be gathered. The limited sampling may cause a certain bias for generalizing the results in a wider scope. This survey concentrated on companies from the petrochemical sector, which is energy-intensive. Future studies shall extend to the other industries because companies from different sectors may have quite different opinions. Following research effort could further clarify the successful policy conditions for promoting the expansion of LCTs in Korea.

CHAPTER V: CONCLUSION AND SYNTHESIS SUMMARY

As climate change becomes a major social concern, it is being discussed as a holistic issue in all its aspects, from political, to social, environment and economic. International society agreed to introduce market mechanisms as a measure to encourage international efforts in such a way as to minimise the social cost of carbon abatement from an economics standpoint. However, on the national level, the experience was that introducing actual policy faces huge hurdles, mainly due to resistance from industry.

This study took as its starting point the question of why businesses in general do not welcome carbon pricing, in spite of the advantages it offers over existing regulations, as has been emphasised by national governments. The case of Korea was focused on as an example of first implementation of domestic ETS in this region. Analysing the corporate view of Korea's carbon pricing policy at the point of policy switchover provides significant insight into the likely response of firms in China and other emerging industrialised countries in the transition period under the Paris Agreement. This study adopted an empirical approach to analyse the company response to carbon price policy and carbon reduction behavior, which is important, as it assumes most of the products produced by companies are the main sources of carbon dioxide emissions in other sectors. The study findings and implications are meaningful not just for emerging industrialised countries in Asia but also for Japan.

For the empirical studies, analytical frameworks were designed according to the purpose of each study. Questionnaire surveys targeting the energy intensive sectors, mainly petrochemical, cement, steel & iron in Korea were implemented, and the collected raw data was analysed quantitatively or qualitatively using model tools to reveal several meaningful findings. The results of each study are summarised as below.

Overall, Korean companies do not appreciate the merits of GHG ETS and were reluctant to participate in the carbon market of GHG ETS, and were also strongly concerned about its negative aspects, such as degraded industrial competitiveness. As a result, although transactions increased by year, actual liquidity of the carbon market overall remained stagnant, resulting in only a negligible amount of emissions traded through intermittent transactions in the early phase. In the current phase it was found that carbon pricing is consistently highly resisted by the sampled Korean companies. Accordingly, the affordability of energy cost increases for energy-intensive companies in Korea due to the introduction of carbon pricing is limited, equating to carbon prices of 2,500–4,000 KRW/t-CO_2 (about 2.3–3.5 USD/t-CO_2), which is lower than the level of companies in China and Japan. However, it is noteworthy that company’s understanding of carbon pricing is essential for policy acceptance, as well as to proceed with aspects of actual management, even though policy acceptance itself does not necessarily lead to implementation. In other words, even if the policy is not favorable, understanding of the policy enhances the company's response.

Considering a key objective of ETS is to impact decision making regarding low-carbon technologies, one encouraging finding is that carbon pricing policies such as ETS was evaluated by companies to be supportive since they provide the price signal for investment, while several barriers hindering low carbon technology (“LCT”) investment by companies still exist – such as budgetary constraints, financial loss during new technology replacement and uncertainty over technologies Especially, it was found that Korean companies tend to demand relatively short payback times for investments in LCT, implying such investments are expected to return high profits.

This study identified several key issues to be addressed by the government and companies for improving carbon pricing policy and operating the carbon market. Institutional improvements are needed by the government in order to improve the decision-making capacity of companies in trading. As is commonly pointed out, the key issue to be addressed in the emission trading system is for the government to clear up any policy uncertainty, due to recent changes in the related ministries (June 2016), while concurrently promoting carbon-oriented management to companies so that they can make longer-term decisions in innovation. On the other hand, the companies themselves also need to take action. Korean companies’ preparation for ETS is in the early stage and companies do not consider the asset value of carbon allowances in optimising their management of GHG under market mechanisms. Instead, they view the cap implicit in their allowance allotment as a mere matter of compliance. Lack of familiarity with market-based instruments for pollutant reductions is one of the main reasons behind deactivation of K-ETS. They urgently need to adopt a systematic and analytic approach to respond to the new carbon pricing policy. Further, ETS participating companies need to plan for the long term, estimate and develop their own position on carbon and as well as examine all the abatement measures available to maximise cost-effective emissions reductions under the marginal cost condition. As was revealed by our study, providing information on the carbon market and financial supports would be beneficial to companies.

This study provides the latest comprehensive information and historical assessment in accordance with political trends regarding the introduction of carbon tax and ETS, and clarifies the need for a better understanding of the perspective of industry as a point of reference for discussions and development of carbon pricing in Korea. It also derives several policy implications and suggestions useful in determining appropriate and effective directions for policy. In particular, the quantitative results may be used as a referendum in discussions of carbon pricing policy and price level from the perspective of individual companies. Thus, it will serve as a helpful reference for policy experts in government as well as academia and related stakeholders at the international level concerned with Korea’s carbon pricing policies.

Nevertheless, this study has several shortcomings and limitations. The survey relies on the company’s self-reporting for data collection. Further, although the respondents may represent energy intensive industries, the limited number of samples may result in bias or generalisation leading to a distorted picture of Korea’s industry in general. It is thus important to keep track of behavioral changes in industry in response to ETS as this will provide a better understanding of their perspective, which will assist in improving the scheme towards realisation of its goal.

As topics for further study and to overcome any shortcomings in this study, the below are suggested.

It is required to address how to define a company's carbon oriented management. As companies have taken measures to rationalise energy use and minimise pollutants through energy and environmental management, this has contributed to cost reduction and mitigated the environmental burden. The term ‘carbon management’ in this study refers to energy saving and GHG reduction activities which come under the category of existing energy and environmental management. “However, going forward, what the term ‘carbon-oriented management’ will come to refer to is the implementation of business strategies that utilise a company’s carbon assets, as well as linking the economic (monetary) value with potentially radical activities. To do so, companies need to prepare in-house systems and analyse carbon prices with an eye to market participation. In other words, a more proactive management strategy than that governing the present form of energy and environmental management is needed. Therefore, as further study, it is necessary to define carbon oriented-management as differentiated from energy and environmental management, as well as to categorise its development stages and related activities, and based on such categorisation, to diagnose the status of Korean companies’ carbon-oriented management and identify the factors determining companies’ proactive response. This study will further contribute to formulating carbon-oriented management guidelines intended to assist companies in countries planning to implement carbon pricing policy.

As another topic for future study, how carbon markets can be linked between China, Korea, China and Japan also needs to be explored, since one important aspect of the Paris Agreement is the degree to which this new agreement can help facilitate the growth and integration of carbon markets. Accordingly, there is increasing interest in linking these systems, both directly and indirectly via connections to emissions-reduction-credit systems – the largest of which is the Clean Development Mechanism (CDM) under the Kyoto Protocol. In this respect, policy dialog has already been initiated between the three countries of China, Japan and Korea, to discuss the possibility of linking carbon markets from 2016 (Would Bank, 2016), and the next five years will likely see realisation of carbon markets and climate change strategies in each of these three countries as well as throughout the region. This linkage is highly significant, argues a report from the Asia Society Policy Institute (ASPI), as it would greatly reduce GHG emissions in Northeast Asia (ASPI, 2016). However, despite growing interest in and policy progress on carbon market linkage, research related thereto is limited, both in scope and quantity. Therefore, based on a thorough understanding of how carbon pricing systems operate in each country, it will be necessary to study how the systems can be linked, as well as what the resulting ripple effects thereof will be on the economy and environment, from a macroeconomic perspective.

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APPEDICES

APPENDIX 1: QUESTIONNAIR FORMATS
APPENDIX 2: LIST OF PUBLICATION

APPENDIX 1: QUESTIONNAIR FORMATS

Questionnaire format 1

Topic: Companies' perspectives and response to the economic policies for energy saving and carbon mitigation

Survey target: Environmental and energy managers of 205 companies including 137 TMS target companies and 68 non-TMS at Cement, steel and iron, petrochemical sectors in Korea

Period survey implementation: 25 January to 10 February 2012

Valid answers: 62 companies

Output: Chapter IV-1, IV-2 and IV-3

Question list

1. Company's general information

Ownership status	□ State-owned □ Domestically private □ Foreign-funded □ Join-venture □ Others (Please specify:)
Your company's size	□ Large □ Medium-sized □ Small
Size of parent company in case	□ Large □ Medium-sized □ Small
Industrial sector	□ Iron & Steel □ Cement □ Petro-chemical
TMS involvement status	□ Involved □ Non-involved
The number of employees	___________ Persons
Annual turnover in 2010	___________ Won
Registered capital	___________ Won
Main market	□ Mainly export (export rate: _______%) □ Mainly domestic
Main products	□ Raw materials □ Intermediary goods □ Final consumption goods

2. Please assign the ratio of employees with education level of college and above in your company:

   □ Below 10% □ 10~20% □ 20~30% □ 30~50% □ Over 50%

3. Please assign the average education level of top managers in your company:

   □ Senior high school and below □ Junior college

   □ Undergraduate degree □ Graduate degree and above

4. How would you evaluate the degree of market competition your company is facing?

   □ Very high □ High □ Moderate □ Limited □ Very limited

5. Please indicate the geographical distribution of your company's major competitors:

   □ Mainly within the country

   □ Almost half and half within and outside of the country

□ Mainly abroad in developed countries and regions

□ Mainly abroad in developing countries and regions

6. Please assign the total amount of your company's annual energy consumption (Unit: ton of oil equivalent, toe):

□ Below 2,000 □ 2,000~10,000 □ 10,000~30,000

□ 30,000~100,000 □ Over 100,000

7. Please assign the amount of your company's annual CO_2 emissions (Unit: t-CO_2):

□ Below 5,000 □ 5,000~15,000 □ 15,000~25,000 □ Over 25,000

8. Please indicate the types of energies consumed by your company and their rough ratios of the total energy use in average in the past 3 years:

□ Electricity (Ratio: _______) □ Coal (Ratio: _______) □ Oil (Ratio: _______)

□ Natural gas (Ratio: ________) □ Steam (Ratio: ________)

□ Renewable energies (Ratio: ________) □ Others (Please specify:____________)

9. Please indicate the ratio of your company's energy cost in total sales revenue in 2010:

□ Below 5% □ 5~10% □ 10~20% □ 20~50% □ Over 50%

10. How would you evaluate the current energy price levels (Evaluation criteria for reference are: 5 = 'very high', 4 = 'high', 3 = 'moderate', 2 = 'low', 1 = 'very low')?

Energy types	Evaluation				
In overall	□ 5	□ 4	□ 3	□ 2	□ 1
Electricity	□ 5	□ 4	□ 3	□ 2	□ 1
Oil	□ 5	□ 4	□ 3	□ 2	□ 1
Coal	□ 5	□ 4	□ 3	□ 2	□ 1
Natural gases	□ 5	□ 4	□ 3	□ 2	□ 1
Steam	□ 5	□ 4	□ 3	□ 2	□ 1
Renewable energies	□ 5	□ 4	□ 3	□ 2	□ 1

11. Korea government recently announced the decomposed national GHG reduction targets by sectors. The reduction targets of iron & steel, petro-chemical and cement industries are respectively 6.5%, 7.5%, and 8.5% compared with BAU cases by 2020. How would you evaluate the specific target of the industry to which your company belongs?

□ Too strict □ Strict □ Moderate □ Low □ Too low

12. How would you evaluate the impact of the sectoral GHG reduction target and plan in medium term on your business?

□ Positive □ No any □ Negative □ Have no idea yet

13. Which of the following may describe the situation of your company in setting up the target of energy-saving and carbon mitigation? (Multi-selection is allowable)

□ Has no specifically quantitative target

□ Has specific target for 10 years or even longer time

□ Has specific target for 3 to 5 years in short term

□ Has clear annual targets

□ Has clear annual targets and decomposed targets of internal divisions

14. Please indicate the energy-saving and carbon mitigation activities listed below that your company has practiced (Multi-selection is allowable)

Business strategy	□	Set up the company's environmental and energy saving strategies
	□	Strengthen the network between companies in the same sector to exchange information of energy-efficient technologies, etc.
	□	Publish periodical environmental report containing information of energy consumption and GHG emissions, e.g., Sustainable development report, carbon report, etc.
	□	Implement environment accouting (Green accout)[15]
	□	Achieve ISO14001 certification
	□	Awarded as 'Green Company'
Education and training	□	Develop training programs within the company
	□	Participate in GHG-related and energy management training organized by the governments
Process Improvement	□	Improve the production process by installing the energy-saving facilities and equipment
	□	Purchase eco-friendly raw materials and/or intermediary goods
Voluntary reduction	□	Participate in the VA[16]
	□	Participate in the KVER[17]
Improvement of organizational management	□	Implement GSCM[18]
	□	Establish a specific division for energy management
Product innovation	□	Develop eco-friendly products
	□	Develop Eco-labeling products (authorized by MOE)
	□	Be certified GR[19]
Others	(Please specify:)	

15. How about your company's current situation regarding the monitoring and statistics management of internal energy use and carbon emissions? (Multi-selection is allowable)

□ Monitoring and statistics system of internal energy use has not been established yet

□ Has not done yet but will be established shortly

□ Has a comprehensive energy-using statistical system at the company's level

□ Has monitoring devices at key energy-using equipment and facilities, and has a complete statistical system of internal energy use

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[15] Environment account (Green account): While the usual business accounting contains company's sales and financial status, environment account (also known as Green account) is to specify the environment-related expenses in financial statement.

[16] Voluntary Agreement (VA): A completely voluntary agreement for energy saving and GHG emission reduction singed by the industry with the government.

[17] Korea Voluntary Emission Reduction (KVER): A domestically voluntary emission reduction program, started from 2005 in order to promote firm's GHG mitigation efforts. From 2007, Korea government started to purchase the credit of KVER as one of incentive policies.

[18] Green Supply Chain Management (GSCM): To manage the supply chain for satisfying the relevant regulations, in particular for a better business performance in environmental aspect.

[19] Good Recycled Product (GR): A certification system approved by the government for environmentally-friendly recycled products.

□ Has specific energy management department and staffs, and has a perfect energy-using monitoring and statistical system

16. Please indicate the production technology level and the potential for energy saving and carbon reduction of your company:

The production technology level	The potential for energy saving and carbon reduction
□ Internationally advanced	□ Almost no potential
□ Domestically advanced	□ Limited potential
□ Domestically average	□ Relatively high potential
□ Domestically laggard	□ Very high potential
	□ Have no idea about this

17. Please indicate how much your company knows about the energy saving and carbon reduction technologies that have been adopted by the other companies in the same sector:

□ Knows very well □ Knows well □ Knows some □ Knows a little
□ Knows nothing

18. Please indicate how much your company knows about the energy saving and carbon reduction technologies that are still new and have not been adopted in your industry:

□ Knows very well □ Knows well □ Knows some □ Knows a little
□ Knows nothing

19. If grants or preferential loans were provided for equipment funding, would your company be willing to invest in replacing the old facilities for improving energy efficiency and reducing carbon emissions?

□ Strongly consider □ Consider □ Possible □ Less possible □ Impossible

20. The factors listed below may affect your company's decisions in adding new investments and adopting new technologies and equipments for energy saving. Please rate the influence levels of these factors. (Evaluation criteria for reference are: 5 = 'very strong', 4 = 'strong', 3 = 'moderate', 2 = 'little ', 1 = 'no influence at all'):

No.	Factors	Score				
1	Company needs to invest in other more important projects	5□	4□	3□	2□	1□
2	Energy cost of the company is not important and no emphasis has been given to energy efficiencies	5□	4□	3□	2□	1□
3	The existing technologies and equipment are highly efficient	5□	4□	3□	2□	1□
4	Company's internal management factors make it difficult to implement energy-saving projects	5□	4□	3□	2□	1□
5	Company's lack of internal budget	5□	4□	3□	2□	1□
6	Difficult to get external financing	5□	4□	3□	2□	1□
7	Lack of supporting at the national level (E.g., lack of tax incentives and so on)	5□	4□	3□	2□	1□
8	Uncertainty in quality and reliability of new technologies and equipment	5□	4□	3□	2□	1□
9	The price of the technologies and equipment may decrease soon	5□	4□	3□	2□	1□
10	Rely on financial subsidies on energy saving from the government	5□	4□	3□	2□	1□

11	The technology to be invested in may not satisfy the government's new requirements	5□	4□	3□	2□	1□
12	Pay the mild fines of TMS or ETS rather than to invest huge money for energy efficiency in the early stage	5□	4□	3□	2□	1□
13	Economic losses due to the production suspending during the new equipment replacement	5□	4□	3□	2□	1□
14	Lack of awareness at top management level	5□	4□	3□	2□	1□

21. Investment in energy-saving and carbon reduction projects can improve energy efficiency and save energy costs. The company may reclaim the initial investment within a certain period. Which of the payback times below is acceptable to your company?

□ Within 6 months □ Within 1 year □ Within 2 years □ Within 3 years

□ Within 5 years □ Within 10 years □ No specific expectation and requirement

22. The table below lists the policies on energy saving and carbon mitigation, which have been implemented or are currently under discussions. Please indicate the acceptability of your company to these policies. (<u>Evaluation criteria for reference are</u>: 5 = 'easily accept', 4 = 'accept', 3 = 'moderate acceptability', 2 = 'not too much to accept', 1 = 'cannot accept at all'):

No.	Policies	Score					Unknown
1	GHG, energy target management system	5□	4□	3□	2□	1□	□
2	Energy use reporting system	5□	4□	3□	2□	1□	□
3	Energy audit requirement	5□	4□	3□	2□	1□	□
4	Energy efficiency management system	5□	4□	3□	2□	1□	□
5	MEPS: Minimum Energy Performance Standard [20]	5□	4□	3□	2□	1□	□
6	Subsidies for maintenance, improvement and replacement of energy saving facilities	5□	4□	3□	2□	1□	□
7	Soft loan for investment in energy saving facilities	5□	4□	3□	2□	1□	□
8	Soft loan and grant for installing the high-efficient production facilities and equipment	5□	4□	3□	2□	1□	□
9	Soft loan for Demand Side Management Investment Programs	5□	4□	3□	2□	1□	□
10	Soft loan for Energy Saving Companies (ESCO) projects	5□	4□	3□	2□	1□	□
11	Tax reduction [21] for investment in energy-saving facilities	5□	4□	3□	2□	1□	□
12	Carbon tax	5□	4□	3□	2□	1□	□
13	Emission Trading Scheme	5□	4□	3□	2□	1□	□
14	Voluntary Agreement	5□	4□	3□	2□	1□	□
15	Green Certification	5□	4□	3□	2□	1□	□
16	Environmental Management System (ISO14001)	5□	4□	3□	2□	1□	□
17	Green Company	5□	4□	3□	2□	1□	□
18	ESP (Energy Saving through Partnership)	5□	4□	3□	2□	1□	□
19	Caron Neutral Program	5□	4□	3□	2□	1□	□
20	Carbon Footprint Label	5□	4□	3□	2□	1□	□
21	Training for energy managers	5□	4□	3□	2□	1□	□

[20]Minimum Energy Performance Standard (MEPS): a mandatory regulation containing a number of performance requirements for an energy-using device to prohibit from producing low energy efficiency products that do not meet a standard, which effectively limits the maximum amount of energy.

[21]Tax reduction: Reduction of corporation tax or income tax with an equivalent to 20% of the amount of investment in energy-saving facilities in accordance with the Restriction of Special Taxation Act

22	Training for advanced energy related engineers	5□ 4□ 3□ 2□ 1□	□
24	Small and Medium Business Center	5□ 4□ 3□ 2□ 1□	□
25	Green Credit	5□ 4□ 3□ 2□ 1□	□
26	Energy Support[22]	5□ 4□ 3□ 2□ 1□	□

23. The table below lists the market-based policies on energy-saving and carbon mitigation, which have been implemented or are currently under discussions in Korea. Please indicate how much your company knows about these policies. (Evaluation criteria for reference are: 5 = 'knows very well', 4 = 'knows well', 3 = 'knows some', 2 = 'knows a little', 1 = 'knows nothing'):

No.	Market-based policies	Score
1	Subsidies for maintenance, improvement and replacement of energy saving facilities	5□ 4□ 3□ 2□ 1□
2	Soft loan for investment in energy saving facilities	5□ 4□ 3□ 2□ 1□
3	Soft loan and grant for installing the high-efficient production facilities and equipment	5□ 4□ 3□ 2□ 1□
4	Soft loan for Demand Side Management Investment Programs	5□ 4□ 3□ 2□ 1□
5	Soft loan for Energy Saving Companies (ESCO) projects	5□ 4□ 3□ 2□ 1□
6	Tax reduction[23] for investment in energy-saving facilities	5□ 4□ 3□ 2□ 1□
7	Carbon tax	5□ 4□ 3□ 2□ 1□
8	Emission Trading Scheme	5□ 4□ 3□ 2□ 1□

24. Direct rise of energy prices and/or government's levying of energy tax or carbon tax in energy production and conversion sector will bring a rise in energy prices and therefore increase the company's energy costs. We hope to know your company's opinion on the possible rise of energy costs due to above factors. Please evaluate and make your choice according to the willingness level of your company to accept the optional increasing rates of energy costs.

Rise rate of energy cost (%)	Your choice				
	Too low; Very easy to accept	Not high; Accept	Moderate; Moderately accept	High; Reject	Too high; Strongly reject
0.1	□	□	□	□	□
0.5	□	□	□	□	□
1.0	□	□	□	□	□
3.0	□	□	□	□	□
5.0	□	□	□	□	□
7.0	□	□	□	□	□
10.0	□	□	□	□	□
20.0	□	□	□	□	□
30.0	□	□	□	□	□
50.0	□	□	□	□	□

25. If the implementation of new carbon tax policy and carbon emission trading scheme caused the increase of energy use and production cost of your company, which of the following measures or actions would your company take? (Evaluation criteria for reference are: 5 = 'very probably', 4 = 'probably', 3 =

[22]Energy Support: Energy supporters in the regional center handle the energy related task for SMEs, using less 2,000 Toe of energy annually. It is implemented to support demand side management of energy from 2010.
[23]Tax reduction: Reduction of corporation tax or income tax with an equivalent to 20% of the amount of investment in energy-saving facilities in accordance with the Restriction of Special Taxation Act

‘moderate probability’, 2 = ‘unlikely’, 1 = ‘completely impossible’):

No.	Measures or actions	Score
1	Strengthen internal management and save energy through management measures	5□ 4□ 3□ 2□ 1□
2	Invest in more advanced energy-saving technologies and equipment	5□ 4□ 3□ 2□ 1□
3	Self-investment in research and develop of new energy-saving technologies and equipment	5□ 4□ 3□ 2□ 1□
4	Try to use low carbon energies, adjust and improve the company’s energy use structure	5□ 4□ 3□ 2□ 1□
5	Adjust product structure for reducing energy intensity per unit of product	5□ 4□ 3□ 2□ 1□
6	Raise the product price to transfer the increased costs	5□ 4□ 3□ 2□ 1□
7	Increase production amount to reduce the energy cost in average	5□ 4□ 3□ 2□ 1□
8	Reduce production amount to alleviate the market pressure due to cost increase	5□ 4□ 3□ 2□ 1□
9	Relocate part or all the company to the area with relatively loose policies	5□ 4□ 3□ 2□ 1□
10	Stop the production and business due to cost pressures	5□ 4□ 3□ 2□ 1□
11	No specific reaction by accepting the loss due to cost increase	5□ 4□ 3□ 2□ 1□

26. Has your company ever received any governmental subsidy or reward on energy-saving investment and management?

□ Has received and plans to apply it further.

□ Has not received but plans to apply it.

□ Has not received before and no plan

27. If your company has received the governmental subsidies or rewards before, from which of the followings did your company received? (Multi-selection is allowable)?

□ National level □ Provincial level □ Municipal level

28. If your company ever received governmental subsidies or rewards on energy-saving investment and management, please indicate the ratio of the amount you received to total energy-saving investment and management input:

□ Below 1% □ 1-5% □ 5-10% □ 10-30% □ 30-50% □ Over 50% □ Unclear

29. If your company ever received tax reduction on energy-saving investment and management, please indicate the ratio of the amount you received to total investment and management input:

□ Below 1% □ 1-5% □ 5-10% □ 10-30% □ 30-50% □ Over 50%

30. How would you evaluate the role of governmental policies listed in the table in promoting the company’s energy saving and carbon reduction activities? (Evaluation criteria for reference are: 5 = ‘Very effective’, 4 = ‘Relatively effective’, 3 = ‘Somewhat effective’, 2 = ‘Limited effectiveness’, 1 = ‘not effective at all’):

No.	Support policies	Score
1	Issue certifications of Eco-labels, Green company, etc., to support the businesses	5□ 4□ 3□ 2□ 1□
2	Tax benefits and the public procurement, etc., to support eco-friendly products’ consumption	5□ 4□ 3□ 2□ 1□
3	Support the investment in energy-saving facilities, and VA, etc.	5□ 4□ 3□ 2□ 1□
4	Support research and development related to green technologies and GR products, etc.	5□ 4□ 3□ 2□ 1□

5	Support joint facility and infrastructure including green partnership, etc.	5□ 4□ 3□ 2□ 1□
6	Establish green cluster, such as eco-industrial park [24] demonstration project	5□ 4□ 3□ 2□ 1□

31. How would you evaluate the merits of the Emission Training Scheme to be implemented from 2015 in Korea? Please indicate the score for each aspect about ETS from the perspective of your company. (<u>Evaluation criteria for reference are</u>: 5 = 'Very appropriate', 4 = 'appropriate', 3 = 'somewhat appropriate', 2 = 'inappropriate', 1 = 'inappropriate at all')

No.	Merits about ETS	Score
1	ETS is an effective measure to mitigate GHG emissions	5□ 4□ 3□ 2□ 1□
2	ETS is a cost-effective compared with regulative policies	5□ 4□ 3□ 2□ 1□
3	There would be an advantage to be better involved in international carbon market if introduced earlier	5□ 4□ 3□ 2□ 1□
4	It is a global policy trend to introduce ETS	5□ 4□ 3□ 2□ 1□
5	Compared with TMS, ETS has a possibly positive effect in generating economic revenues	5□ 4□ 3□ 2□ 1□
6	Introducing ETS may generate the opportunities for new business and employment	5□ 4□ 3□ 2□ 1□

32. Please evaluate the importance of each negative aspect listed below about ETS from the perspective of your company. (<u>Evaluation criteria for reference are</u>: 5 = 'very important', 4 = 'important', 3 = 'somehow important', 2 = 'little important', 1 = 'not important at all')

No.	Facing issues about ETS	Score
1	Considering manufacturing and export-oriented economic system of Korea, it would weaken the industrial competitiveness and lead to burdens for the companies due to the production cost increase if the ETS phased in earlier than major competition countries	5□ 4□ 3□ 2□ 1□
2	Unclearness of the detailed operation scheme including emission allowance allocation method, etc.	5□ 4□ 3□ 2□ 1□
3	Unclearness of the detailed measure to avoid the possible double burdens with TMS	5□ 4□ 3□ 2□ 1□
4	Ambiguity of the expected contribution of ETS to the national GHG reductions	5□ 4□ 3□ 2□ 1□
5	Company's lack of capacity to cope with the implementation of ETS	5□ 4□ 3□ 2□ 1□
6	Concern of the insufficient liquidity of the carbon market due to the limited credit volume in total	5□ 4□ 3□ 2□ 1□
7	Concern of the instability of carbon price and the speculative trading	5□ 4□ 3□ 2□ 1□
8	Carbon leakage problem	5□ 4□ 3□ 2□ 1□
9	Foreign companies hesitate to invest in Korea and the problem of domestic deindustrialization	5□ 4□ 3□ 2□ 1□
10	Ambiguity of the competent authorities and their responsibilities in implementing ETS	5□ 4□ 3□ 2□ 1□

33. Please indicate measures or actions for ETS listed below your company would take or are currently under discussions. (Multi-selection is allowable)

□ Establish a specific division for TMS and ETS
□ Sign the MOU with government for the self-implementation of ETS within the group company
□ Establish the company's inventory of GHG emissions and verified by a third party
□ Participate in the pilot project of ETS or TMS
□ Develop the offset programme for achieving carbon credits

[24] Eco-Industrial Park: an industrial park in which businesses cooperate with each other and with the local community to reduce waste and pollution, with aims to increase economic gains and improve environmental quality. There are 5 National EIPs in Korea including Ulsan, Pohang, Yeosu, Banwol and CheongJu.

□ Plan to move the factory abroad with loose carbon regulations
□ Hire or outsource outside professional consultants or solution company for necessary preparations in response to the government policy
□ Other (Please specify:)

34. Please indicate the barriers or difficulties listed below your company may encounter in preparing measures and actions for ETS. (Multi-selection is allowable)

□ Lack of information for the analysis of future carbon market
□ Lack of technology
□ Limited reduction potential
□ Lack of specialists on energy management and reduction potential identification
□ Budget shortages
□ Lack of skill of the political negotiations for emission allowance allocation
□ Lack of effective incentive and support policies at national level
□ Lack of awareness at top management level
□ Other (Please specify:)

35. What are the expectations with respect to ETS from the perspective of your company? (Multi-selection is allowable)

□ To coordinate with existing regulations such as Energy Audit and TMS
□ To clarify the relevant competent ministries and their specific roles
□ To provide related information
□ To conduct training programmes to improve the understanding of the latest policy progress
□ To appropriately appreciate the early actions for GHG reduction such as KCER and Energy Audit
□ To diversify the offset credits
□ To clarify the allowance allocation method and declare in earlier
□ To expand incentives policies (tax reduction, subsidies, etc.)
□ To alleviate penalties on the excessive carbon emissions
□ Other (Please specify:)

36. The following factors may affect your company's management in participating in the voluntary carbon emissions reduction and trading system. Please evaluate the influence of these factors. (Evaluation criteria for reference are: 5 = 'very large', 4 = 'large', 3 = 'moderate', 2 = 'little', 1 ='not at all'):

No.	Factors	Score				
1	Enhance the company's image and reputation	5□	4□	3□	2□	1□
2	Enhance the competitiveness due to improved market position	5□	4□	3□	2□	1□
3	Requirement from the company's top management	5□	4□	3□	2□	1□
4	Requirement from the company's investors	5□	4□	3□	2□	1□
5	Pressure by environmental groups, i.e., NGOs	5□	4□	3□	2□	1□
6	Pressure by the clients	5□	4□	3□	2□	1□
7	Improve relations with the government	5□	4□	3□	2□	1□
8	Strengthen relations with the suppliers	5□	4□	3□	2□	1□
9	Consider the social responsibility for the environment	5□	4□	3□	2□	1□
10	Prepare for satisfying the future obligations	5□	4□	3□	2□	1□
11	Price of carbon allowance may rise as a kind of credit commodities	5□	4□	3□	2□	1□
12	Overcome trade barriers due to carbon emissions problem	5□	4□	3□	2□	1□
12	Trends in industrial sector	5□	4□	3□	2□	1□
13	Other (Please specify:)					

Questionnaire format 2

Topic: Companies' choice preference to the carbon tax and emission trading scheme

Target: Environmental and energy managers of 230 companies including mainly TMS target companies at cement, steel and iron, petrochemical, paper, and electronics sectors in Korea

Period survey implementation: December 2012 to January 2013

Valid answers: 150 companies

Output: Chapter IV-4

Question list

Part I: Company's general information

Ownership status	□ State-owned □ Domestically private □ Fully foreign-funded □ Join-venture □ Others (Please specify:)
Headquarters' size	□ Large □ Large Medium □ Medium-sized □ Small
Company's size	□ Large □ Large Medium □ Medium-sized □ Small
Industrial sector	□ Iron & Steel □ Cement □ Petro-chemical □ Paper making □ Others (Please specify:)
TMS involvement status	□ Involved □ Non-involved
The number of employees	___________ Persons
Annual turnover	___________ 10thousand Won
Registered capital	___________ 10thousand Won
Main market	□ Mainly for export (Export rate: _______%) □ Mainly for domestic market
Main products	□ Raw materials □ Intermediary goods □ Final consumption goods

1-1. Please assign the total amount of your company's annual energy consumption (Unit: ton of oil equivalent, toe) in the past 3 years:

□ Below 2,000 □ 2,000~10,000 □ 10,000~30,000

□ 30,000~100,000 □ Over 100,000

1-2. Please assign the amount of your company's CO_2 emissions (Unit: t-CO_2) in the past 3 years:

□ Below 5,000 □ 5,000~15,000 □ 15,000~25,000 □ Over 25,000

1-3. Please indicate the types of energies consumed by your company and their rough ratios of the total energy use in average in 2011:

□ Electricity (Ratio: _______) □ Coal (Ratio: _______) □ Oil (Ratio: _______)

□ Natural gas (Ratio: ________) □ Steam (Ratio: ________)

□ Renewable energies (Ratio: ________) □ Others (Please specify:____________)

1-4. The ratio of energy costs in the total sales revenue of your company in the past 3 years is:

□ Less than 5% □ 5~10% □ 10~20% □ 20~30%

□ 30~50% □ Over 50%

1-5. How do you evaluate the current domestic energy price level?

□ Very high □ High □ Reasonable □ Low □ Very low

1-6. Please assign the ratio of employees with education level of college and above in your company:

□ Below 10% □ 10~20% □ 20~30% □ 30~50% □ Over 50%

1-7. How would you evaluate the degree of market competition your company is facing?

□ Very high □ High □ Moderate □ Limited □ Very limited

1-8. Which of the following may describe the situation of your company in setting the target of energy-saving and carbon mitigation? (Multi-selection is allowable)

□ Has no specifically quantitative target

□ Has specific target for 10 years or even longer time

□ Has specific target for 3 to 5 years in short term

□ Has clear annual target

□ Has clear annual target and decomposed targets of internal divisions

1-9. How about your company's current situation regarding the monitoring and statistics management of internal energy use and carbon emissions? (Multi-selection is allowable)

□ Monitoring and statistics system of internal energy use has not been established yet

□ Has not done yet but will be established shortly

□ Has a comprehensive energy-using statistical system at the company's level

□ Has monitoring devices at key energy-using equipments and facilities, and has a complete statistical system of internal energy use

□ Has specific energy management department and staffs, and has a perfect energy-using monitoring and statistical system

1-10. Please indicate the production technology level and the potential for energy saving and carbon reduction of your company:

The production technology level		The potential for energy saving and carbon reduction	
□	Internationally advanced	□	Almost no potential
□	Domestically advanced	□	Limited potential
□	Domestically average	□	Relatively high potential
□	Domestically laggard	□	Very high potential
		□	Have no idea about this

1-11. Has your company ever participated in a pilot GHG emission trading scheme (Multi-selection is allowable)

□ Has never participated

□ Has participated in the pilot GHG ETS implemented by the Ministry of Environment (2010)

□ Has participated in the pilot GHG ETS implemented by the Ministry of Knowledge Economy in the first phase during July, 2011 ~ June 2012

□ is being participated in the pilot GHG ETS implemented by the Ministry of Knowledge Economy in the second phase since June, 2012

Part 2: Company's Opinions on Energy Saving Subsidy Policies

Financial Aid for Energy Efficiency Investment: Ministry of Knowledge Economy provides long-term low-interest loans from the 'Rational Energy Utilization Fund' for firm's energy efficiency investments. The projects eligible for these loans include the establishment of cogeneration facilities for industries and large buildings; production of high-efficiency products; operation of non-electrical cooling and heating systems; installation of energy saving facilities; and, the promotion of energy service companies (ESCOs) currently. The total volume of loans is 530 billion KRW in 2012.

2-1. Please indicate whether your company has ever received preferential long-term loans for investment in energy-saving facilities or R&D of energy technologies. If your company has never received yet, does your company have any plan to apply for it (Multiple selections allowable for those in the parenthesis).

□ Never received and no plan to apply

□ Yes, has received from the government of (□ National level □ Provincial & Municipal □ County level)

□ Not received yet but will apply for it from the government of (□ National level □ Provincial & Municipal □ County level)

2-2 Loan coverage is up to 80% of the total investment for large companies and 100% for small and medium-sized enterprises. The interest rates range at 1.75~2.00% and 1.75~2.75% for the investment of energy-saving facilities and ESCO project, respectively, which are about 4~5% lower than the normal rates commercially. Loans for installing energy-saving facilities or equipment usually have a grace period of three years and a five-year period for the loan repayment. Please indicate your company's evaluation of current conditions for this policy.

Policy attribute	Satisfied with current conditions	If you are not satisfied with current conditions, please indicate the expected one of your company among the followings
Loan coverage	□	□ More than 80% □ More than 90% □ 100%
Interest rates	□	□ Free of interest □ Below 1% □ 1~1.75%
Loan period	□	□ Shorten the repayment period □ Extend the repayment period □ Extend the grace period □ The grace period and repayment period can be different in response to specific interest rate

Tax incentives: The Korea government provides tax incentives for energy efficiency investments. 10%

of the total cost for investments in retrofits or installations of facilities and equipment are exempted from income tax credit.

2-3 Please indicate whether your company has ever received tax incentive for energy saving investment.

□ Never □ Yes

2-4 Which of the following is the appropriate ratio of tax incentive in the total investment for energy-saving technological retrofit and equipment replacement from your company's viewpoint?

□ Below 10% □ 10~20% □ 20~30% □ More than 30%

<u>Rewards:</u> The Korea government subsidizes the installation or replacement of high-efficiency product and equipment such as LED, high-efficiency inverter, high-efficiency chillers, etc.

2-5 Please indicate whether your company has ever received rewards for high-efficiency equipment.

□ Never □ Yes

2-6. If your company ever received rewards on energy-efficient equipment, please indicate the ratio of the amount you received in the price of the equipment.

□ Below 5% □ 5-10% □ 10-30% □ 30-50% □ Over 50%

2-7. The government is now providing rewards up to 20% of the total cost of the energy-efficient equipment installation and replacement. Which of the following is the appropriate ratio of reward in the total investment for energy-efficient equipment from your company's viewpoint?

□ Less than 20% □ 20-30% □ 30-40% □ 40-50% □ More than 50%

<u>Evaluation of subsidy policies:</u>

2-8 The table below lists the items, which are usually regulated as the fields to be supported by financial funds specific for energy saving at national level. Please evaluate the priority of these fields for being subsidized (<u>Evaluation criteria</u>: 5 = 'Very high'; 4 = 'High'; 3 = 'Moderate'; 2 = 'Low'; 1 = 'Very low').

No.	Fields to be subsidized	Your evaluation				
1	Development and use of new energy sources, such as wind, solar and biomass, etc.	5□	4□	3□	2□	1□
2	Research and development of new technologies, processes and products for energy saving	5□	4□	3□	2□	1□
3	Demonstration and diffusion of new technologies and processes for energy saving	5□	4□	3□	2□	1□
4	Promotion of energy efficient products, such as energy efficient air conditioner, automobile and green lighting, etc.	5□	4□	3□	2□	1□
5	Energy-saving retrofit to the existing production processes and equipment	5□	4□	3□	2□	1□
6	Compensate to the earlier and voluntary elimination of out-of-date production capacities of companies in energy-intensive industries	5□	4□	3□	2□	1□
7	Consultative service like energy audit for the key energy-consuming companies	5□	4□	3□	2□	1□
8	Promotion of new energy saving mechanisms, especially contract energy management projects	5□	4□	3□	2□	1□
9	Building of energy-saving enforcement and management capacity and service system	5□	4□	3□	2□	1□
10	Awards to the excellent companies in the assessment of energy saving target management system	5□	4□	3□	2□	1□

2-9. The Table below lists the possible problems for energy saving subsidy policy. Please indicate to what extent your company agree with these policy shortcomings (<u>Evaluation criteria</u>: 5 = 'Strongly agree’; 4 = ‘Agree’; 3 = ‘Moderate agreement’; 2 = ‘Disagree’; 1 = ‘Completely disagree’).

No.	Policy shortcomings	Your evaluation				
1	To subsidize energy saving and carbon mitigation by financial budget violates the polluter pays principle	5□	4□	3□	2□	1□
2	The subsidy scope is limited and the non key energy-consuming companies and small and medium-sized enterprises (SMEs) have no chance to get the subsidies	5□	4□	3□	2□	1□
3	The subsidy is small in amount and cannot effectively influence the company’s decision making in energy saving management and investment	5□	4□	3□	2□	1□
4	Policy information dissemination is limited and most companies cannot get relevant information for the subsidy application in time	5□	4□	3□	2□	1□
5	Required documents and procedures are complex and the companies lack of capabilities for the application	5□	4□	3□	2□	1□
6	The policy implementation is not open and transparent	5□	4□	3□	2□	1□
7	The criteria is too high for the low-interest loans	5□	4□	3□	2□	1□
8	Major banks may provide loans with lower interest rate for energy-saving projects	5□	4□	3□	2□	1□
9	Stable and long-term support such as lowering the electricity price is more important than the one-time subsidies and rewards.	5□	4□	3□	2□	1□

Evaluation on the electricity price increase: Electricity price has been increased by 4.9% in average from August 6, 2012. For industries, the increase rate is higher with a rate of 6%. The rate is 3.9% for small merchants, small businesses and households.

2-10. How do you evaluate this increase of electricity rate?

□ Very high □ High □ Reasonable □ Low □ Very low

2-11. The table below lists the impacts for electricity price increase. Please indicate to what extent your company agree with these evaluation (Evaluation criteria: 5 = ‘Strongly agree’; 4 = ‘Agree’; 3 = ‘Moderate agreement’; 2 = ‘Disagree’; 1 = ‘Completely disagree’).

No.	Impacts of the electricity price increase	Your evaluation				
1	Weaken the international competitiveness of industries due to the manufacturing cost increase	5□	4□	3□	2□	1□
2	An appropriate measure that reduce the net losses of KEPCO	5□	4□	3□	2□	1□
3	It is positive for stimulating the installation of high energy-efficient equipment and investments in R&D	5□	4□	3□	2□	1□
4	It is unplanned and unilateral price increase for industrial sector. More systematic and predictable plan for price increase should be declared in earlier.	5□	4□	3□	2□	1□

2-12. Electricity price increase caused the increase of production cost of your company, which of the following measures or actions would your company take? (Evaluation criteria for reference are: 5 = ‘very probably’, 4 = ‘probably’, 3 = ‘moderate probability’, 2 = ‘unlikely’, 1 = ‘completely impossible’):

No.	Measures or actions	Score				
1	Strengthen internal management and save energy through management measures	5□	4□	3□	2□	1□
2	Invest in more advanced energy-saving technologies and equipment	5□	4□	3□	2□	1□
3	Self-investment in research and development of new energy-saving technologies and equipment	5□	4□	3□	2□	1□
4	Try to adjust and improve the company’s energy use structure	5□	4□	3□	2□	1□
5	Adjust product structure for reducing energy intensity per unit of product	5□	4□	3□	2□	1□
6	Raise the product price to transfer the increased costs	5□	4□	3□	2□	1□
7	Increase production amount to reduce the energy cost in average	5□	4□	3□	2□	1□

8	Reduce production amount to alleviate the market pressure due to cost increase	5□ 4□ 3□ 2□ 1□
9	Relocate part or all the company to the area with relatively low energy price	5□ 4□ 3□ 2□ 1□
10	Stop the production and business due to cost pressures	5□ 4□ 3□ 2□ 1□
11	No specific reaction by accepting the loss due to cost increase	5□ 4□ 3□ 2□ 1□

Part 3: Company's Choice Preferences to the Design of Carbon Tax Policy

[Brief descriptions] Carbon tax refers to a tax levied on fossil fuels including coal, oil and natural gas according to their carbon contents or actual carbon emissions. The major factors for designing carbon tax policy include tax rate, tax relief measures, utilization of the tax revenues and the starting time, etc. The policy attributes defined for this questionnaire and their possible impacts to the companies are briefly described in the table below.

Policy attribute	Attribute level	Impacts of various attribute levels
Tax rate (KRW/t-CO_2)	3,000 5,000 10,000 15,000	• The company's energy cost would increase along with the rise of tax rate. The increasing rate of various energies differs depend on their emission coefficients and current prices. • A tax rate of 1,000 KRW/t-CO_2 implies an cost increase of % for electricity; or % for coal; or % for oil use; or % for natural gas. • Companies may roughly evaluate the impact of different tax rates on their energy costs.
Tax relief measures	No relief measure Preferential treatment to energy-intensive companies Preferential treatment to companies actively reducing emissions to a certain level	• No tax relief measure helps the equity of carbon tax policy. • Since carbon tax has a relatively significant impact on the production costs of energy-intensive companies, setting preferential treatment to them may keep their international competitiveness. • Providing tax preferential treatment to companies actively reducing carbon emissions to a certain level would encourage the industries in to energy-saving and carbon mitigation.
Use of tax revenues	General budget Specific fund for energy saving and climate change To reduce company's other taxes	• To manage the carbon tax revenues as general budget helps strengthen the country's financial management. • To use carbon tax revenues as specific fund can provide more adequate funding for encouraging companies to actively practice in energy saving and carbon mitigation. • To use carbon tax revenues to cut off company's other tax burdens can reduce the policy negative impact on economic growth and industrial competitiveness.
Starting time	Since 2015 Since 2021	• Levying carbon tax earlier allows this policy to play a positive role in energy saving and carbon mitigation at an early stage. • To launch carbon tax later may give companies and the society more time to learn about this tax and make necessary preparation in advance. So that the resistance to policy implementation and adverse impact could be reduced.

Please compare each pair of carbon tax policy alternatives in the six choice sets as listed in 3.1 to 3.6 below, and select the ones your company relatively prefers.

3.1 Please compare comprehensively the two options for carbon tax policy given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A01	Option B01
Tax rate (KRW/t-CO_2)	3,000	5,000
Tax relief measure	No relief measure	Preferential treatment to companies actively reducing emissions to a certain level
Use of tax revenues	Specific fund for energy saving and climate	General budget

	change	
Starting time	Since 2015	Since 2015
Please tick the one you prefer	□	□

3.2 Please compare comprehensively the two options for carbon tax policy given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A02	Option B02
Tax rate (KRW/t-CO_2)	10,000	1,000
Tax relief measure	Preferential treatment to energy-intensive companies	Preferential treatment to companies actively reducing emissions to a certain level
Use of tax revenues	Specific fund for energy saving and climate change	Specific fund for energy saving and climate change
Starting time	Since 2015	Since 2021
Please tick the one you prefer	□	□

3.3 Please compare comprehensively the two options for carbon tax policy given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A03	Option B03
Tax rate (KRW/t-CO_2)	3,000	3,000
Tax relief measure	Preferential treatment to energy-intensive companies	No relief measure
Use of tax revenues	General budget	To reduce company's other taxes
Starting time	Since 2021	Since 2021
Please tick the one you prefer	□	□

3.4 Please compare comprehensively the two options for carbon tax policy given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A04	Option B04
Tax rate (KRW/t-CO_2)	10,000	1,000
Tax relief measure	Preferential treatment to companies actively reducing emissions to a certain level	No relief measure
Use of tax revenues	To reduce company's other taxes	General budget
Starting time	Since 2015	Since 2015
Please tick the one you prefer	□	□

3.5 Please compare comprehensively the two options for carbon tax policy given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A05	Option B05
Tax rate (KRW/t-CO_2)	1,000	10,000
Tax relief measure	Preferential treatment to companies actively reducing emissions to a certain level	Preferential treatment to companies actively reducing emissions to a certain level
Use of tax revenues	To reduce company's other taxes	General budget
Starting time	Since 2015	Since 2021
Please tick the one you prefer	□	□

3.6 Please compare comprehensively the two options for carbon tax policy given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A06	Option B06
Tax rate (KRW/t-CO_2)	5,000	5,000
Tax relief measure	Preferential treatment to energy-intensive	Preferential treatment to energy-intensive

	companies	companies
Use of tax revenues	To reduce company's other taxes	Specific fund for energy saving and climate change
Starting time	Since 2015	Since 2021
Please tick the one you prefer	□	□

Part 4: Company's Choice Preferences to the Design of Carbon Emissions Trading Scheme

[Brief descriptions] Carbon emissions trading is a system, which sets a cap on the target company's total carbon emissions in a certain period, and allows the trading of carbon credits among the market participants. This market mechanism is an effective measure for mitigating carbon emissions at lower costs of the society as a whole. In Korea, the GHG ETS has been decided to be started since January 1st, 2015 to manage the GHG emissions of large energy-consuming entities. This policy regulates the companies producing energies like coal, oil and electricity and thus may increase the energy prices and affect small and medium energy-consuming companies. The scope of this policy will also gradually expand along with the policy implementation. Therefore, the design and implementation of this policy will have a direct or indirect impact on your business and energy management. The policy factors of carbon emissions trading scheme include cap setting, allocation of emission allowance, criteria for defining carbon leakage companies and penalty for the emissions exceeding the cap. The policy attributes in this questionnaire and their possible impact on the companies are described in the table below.

Policy attribute	Attribute level	Impacts of various attribute levels
Cap setting	Based on the company's historical emissions Based on the sector's advanced emission levels Differentiated measures for the existing and new established companies	• The method based on the company's historical emissions is simple and viable for operation, but not fair for those that have taken active measures in emissions reductions. • The method based on the sector advanced emission levels is relatively fair. Since emission efficiency standards vary for different industrial processes and products, this approach would be complex for the policy implementation.
Allowance allocation	All for free 3% auction, the rest for free 10% auction, the rest for free 30% auction, the rest for free	• Free allocation won't bring the company extra burden. • Revenues from auctions can be used for company's energy saving and emission reductions. • The price of KVER is 5,000 KRW/t-CO_2?? • A carbon price of 1,000 KRW/t-CO_2 means a price increase of % for electricity, or % for coal; or % for oil; or % for natural gas. • Companies can roughly estimate the possible burden on their energy costs under different auction ratios.
Penalty	A fine of the same as the market price A fine of 3 times of the market price) A fine of 5 times of the market price	• The stringency of the penalty to the emissions exceeding the cap will affect the company's decision making on emissions reductions.
Criteria for carbon leakage industry	By energy intensity By trade intensity	• The company with high tendency of carbon leakage may be defined by two criteria, by its energy intensity or by its trade intensity. • Companies with carbon leakage risk will be allocated 100% free of allowance.

Please compare each pair of alternatives for carbon emissions trading scheme in the six choice sets as listed in 4.1 to 4.6 below, and select the ones your company relatively prefers.

4.1 Please compare comprehensively the two options for carbon emission trading scheme given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A01	Option B01

Cap setting	Grandfathering	Benchmark
Allowance allocation	10% auction, the rest for free	3% auction, the rest for free
Carbon leakage criteria	By energy intensity	By trade intensity
Penalty	A fine of 3 times of the market price	A fine of 5 times of the market price
Please tick the one you prefer	□	□

4.2 Please compare comprehensively the two options for carbon emission trading scheme given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A02	Option B02
Cap setting	Hybrid	Hybrid
Allowance allocation	All for free	10% auction, the rest for free
Carbon leakage criteria	By trade intensity	By trade intensity
Penalty	A fine of 3 times of the market price	A fine of the same as the market price
Please tick the one you prefer	□	□

4.3 Please compare comprehensively the two options for carbon emission trading scheme given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A03	Option B03
Cap setting	Hybrid	Grand fathering
Allowance allocation	3% auction, the rest for free	10% auction, the rest for free
Carbon leakage criteria	By energy intensity	By trade intensity
Penalty	A fine of 5 times of the market price	A fine of 5 times of the market price
Please tick the one you prefer	□	□

4.4 Please compare comprehensively the two options for carbon emission trading scheme given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A04	Option B04
Cap setting	Bench mark	Bench mark
Allowance allocation	30% auction, the rest for free	10% auction, the rest for free
Carbon leakage criteria	By energy intensity	By trade intensity
Penalty	A fine of 3 times of the market price	A fine of 3 times of the market price
Please tick the one you prefer	□	□

4.5 Please compare comprehensively the two options for carbon emission trading scheme given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A05	Option B05
Cap setting	Grandfathering	Benchmark
Allowance allocation	All for free	All for free
Carbon leakage criteria	By trade intensity	By energy intensity
Penalty	A fine of the same as the market price	A fine of the same as the market price
Please tick the one you prefer	□	□

4.6 Please compare comprehensively the two options for carbon emission trading scheme given in the Table below, and select the one that your company prefers relatively.

Policy attribute	Option A06	Option B06
Cap setting	Hybrid	Benchmark
Allowance allocation	30% auction, the rest for free	30% auction, the rest for free
Carbon leakage criteria	By energy intensity	By trade intensity
Penalty	A fine of the same as the market price	A fine of 5 times of the market price
Please tick the one you prefer	□	□

Questionnaire format 3

Period survey implementation: February to March in 2015

Target: Environmental and energy managers of 134 petrochemical companies, including all the 84 companies designated for the domestic ETS. Another 11 companies are under the TMS, and the remaining 39 are non-ETS and non-TMS petrochemical companies.

Valid answers: 35 companies

Topic: Low Carbon Technology Diffusion in Petrochemical Industry of Korea under the ETS

Output: Chapter IV-5

Question list

Part 1: Company's general information

Ownership status	□ State-owned □ Domestically private □ Fully foreign-funded □ Join-venture □ Others (Please specify:)
Headquarters' size	□ Large □ Large Medium □ Medium-sized □ Small
Company's size	□ Large □ Large Medium □ Medium-sized □ Small
TMS involvement status	□ Involved □ Non-involved
ETS target status	□ Targeted □ Non-ETS
TMS or ETS Pilot project	□ Participated Year ________ □ No
Annual turnover	___________ 10thousand Won
Registered capital	___________ 10thousand Won
Main market	□ Mainly for export (Export rate: _______%) □ Mainly for domestic market
Main products	□ Raw materials □ Intermediary goods □ Final consumption goods

1-1 Please assign the total amount of your company's annual energy consumption during product process (Unit: ton of oil equivalent, toe) in 2013:

□ Below 2,000 □ 2,000~5,000 □ 5,000~10,000

□ 10,000~30,000 □ 30,000~100,000 □ Over 100,000

1-2 Please assign the amount of your company's CO_2 emissions (Unit: t-CO_2) in 2013:

□ Below 15,000 □ 15,000~25,000 □ 25,000~50,000 □ 50,000~100,000 □ Over 100,000

1-3 Please indicate the types of energies consumed by your company and their rough ratios of the total energy use in 2011:

□ Electricity (Ratio: _______) □ Coal (Ratio: _______) □ Oil (Ratio: _______)

□ Natural gas (Ratio: ________) □ Steam (Ratio: ________)

□ Renewable Energy (Ratio: ________) □ Others (Please specify:____________)

1-4.The ratio of energy costs in the total sales revenue of your company in the past 3 years is:

□ Less than 5% □ 5~10% □ 10~20% □ 20~30%

□ 30~50% □ Over 50%

1-5 How do you evaluate the current domestic energy price level?

Energy sources		Evaluation				
		Very high	High	Reasonable	Low	Very low
1	Electricity	⑤	④	③	②	①
2	Coal	⑤	④	③	②	①
3	Oil	⑤	④	③	②	①
4	Natural gas	⑤	④	③	②	①
5	Steam	⑤	④	③	②	①
6	Renewable Energy	⑤	④	③	②	①
7	Overall	⑤	④	③	②	①

1-6 Please assign the ratio of employees with education level of college and above in your company:

□ Below 10% □ 10~20% □ 20~30% □ 30~50% □ Over 50%

1-7 .Please assign the average education level of top managers in your company:

□ Senior high school and below □ Junior college

□ Undergraduate degree □ Graduate degree and above

1-8 How would you evaluate the degree of market competition your company is facing?

□ Very high □ High □ Moderate □ Limited □ Very limited

Part II: Energy Saving and GHG Mitigation Management

2-1 Please indicate the energy-saving and carbon mitigation activities listed below that your company has practiced (Multi-selection is allowable)

□	Set up the company's environmental and energy saving strategies
□	Strengthen the network between companies in the same sector to exchange information of energy-efficient technologies, etc.
□	Publish periodical environmental report containing information of energy consumption and GHG emissions, e.g., Sustainable development report, carbon report, etc.
□	Implement environment accouting (Green accout)[25]
□	Achieve ISO14001 certification
□	Achieve ISO50001 certification
□	Achieve Green Company certification
□	Participate in GHG-related and energy management training organized by the governments
□	Participate in Green Credit

2-2 Which of the following may describe the situation of your company in setting the target of energy-saving and carbon mitigation? (Multi-selection is allowable)

□ Has no specifically quantitative target

□ No target but will set up soon

□ Has clear annual target

□ Has specific target for 3 to 5 years in short term

□ Has specific target for 10 years or even longer time

[25]**Environment account (Green account)**: While the usual business accounting contains company's sales and financial status, environment account (also known as Green account) is to specify the environment-related expenses in financial statement.

2-3 How about your company's current situation regarding the monitoring and statistics management of internal energy use and carbon emissions? (Multi-selection is allowable)

□ Monitoring and statistics system of internal energy use has not been established yet

□ Has not done yet but will be established shortly

□ Has a comprehensive energy-using statistical system at the company's level

□ Has monitoring devices at key energy-using equipments and facilities, and has a complete statistical system of internal energy use

□ Has specific energy management department and staffs, and has a perfect energy-using monitoring and statistical system

2-4 What fraction of the annual funds for research & development in your company is used for R&D of energy saving and carbon mitigation technologies and products?

□ Less than 5% □ 5~10% □ 10~20% □ 20~30% □ More than 30%

2-5 The following table lists areas that can be improved for companies' energy saving and GHG reduction.

(1) Evaluate the potential of the energy saving of each area (evaluation scale: 5 = very high energy saving potential, 4 = high energy saving potential 3 = some energy conservation potential, 2 = not much of energy conservation potential, and 1 = no energy).

(2) Indicate the field in which the company actually promotes energy conservation among the presented items (Evaluation scale: 5 = field of promotion of energy conservation most, 4 = priority promotion of energy conservation, 3 = energy saving promotion field, 2 = not much considered, 1 = no promotion field).

No	Energy saving area	(1) Energy saving potential					(2) Actually area implemented energy saving promotion				
1	Introduction of alternative energy such as low carbon energy source	⑤	④	③	②	①	⑤	④	③	②	①
2	Introduction of low-carbon technology and equipment in production process	⑤	④	③	②	①	⑤	④	③	②	①
3	Improve procurement of raw materials and transportation	⑤	④	③	②	①	⑤	④	③	②	①
4	Development of environmentally friendly new products	⑤	④	③	②	①	⑤	④	③	②	①
5	Promotion of energy-saving activities in the office	⑤	④	③	②	①	⑤	④	③	②	①
6	Others (details:)										

2-6 Do you think that environmental management activities including saving energy currently being promoted and greenhouse gas reduction activities will help your company manage greenhouse gases? (2) How do you think that management of these greenhouse gases affect future economic activities?

(1) Greenhouse gas management	(2) Impact on economic activity
① Very useful	① Very positive impact
② Useful	② Positive impact
③ Somehow useful	③ Somehow useful
④ Not very useful	④ Negative influence
⑤ Not useful at all	⑤ Risk of adverse effect

Part III Low Carbon Technology Application of Companies

3-1 Please indicate the production technology level and the potential for energy saving and carbon reduction of your company:

The production technology level	The potential for energy saving and carbon reduction
□ Internationally advanced	□ Almost no potential
□ Domestically advanced	□ Limited potential
□ Domestically average	□ Relatively high potential
□ Domestically laggard	□ Very high potential
	□ Have no idea about this

3-2 In the next how many years is your business planning expansion/introduction facilities?

① within 2-3years ② within 3~5 years ③ within 5~10 years

④ within 10~15 years ⑤ over15 years

3-3 The adoption of energy saving low carbon technologies can reduce energy use and carbon emissions of companies. Accordingly, energy and carbon emissions costs of companies can be reduced. The initial investments and operation expenditures of energy saving low carbon technologies may be recouped within a certain period. The payback time of different technologies may be different due to various initial investments, operation costs, energy saving potentials and life spans, etc. We would like to know your company opinion on the decision making of investment in energy saving low carbon technologies with different payback times. Please tick the possibility of your company to invest in the technologies under various payback times.

Payback time (Year)	The possibility of your company to make the decision of investment				
	Very high	High	Moderate	Low	Very low
0.25 (3 Months)	□	□	□	□	□
0.5 (Half a year)	□	□	□	□	□
1.0	□	□	□	□	□
1.5	□	□	□	□	□
2.0	□	□	□	□	□
2.5	□	□	□	□	□
3.0	□	□	□	□	□
3.5	□	□	□	□	□
4.0	□	□	□	□	□
5.0	□	□	□	□	□
6.0	□	□	□	□	□

7.0	□	□	□	□	□
8.0	□	□	□	□	□
9.0	□	□	□	□	□
10.0	□	□	□	□	□

3-4 The factors listed below may affect your company's decisions in adding new investments and adopting new technologies and equipments for energy saving. Please rate the influence levels of these factors. (Evaluation criteria for reference are: 5 = 'very strong', 4 = 'strong', 3 = 'moderate', 2 = 'little ', 1 = 'no influence at all'):

No.	Factors	Score				
1	Company needs to invest in other more important projects	5□	4□	3□	2□	1□
2	Energy cost of the company is not important and no emphasis has been given to energy efficiencies	5□	4□	3□	2□	1□
3	The existing technologies and equipments are highly efficient	5□	4□	3□	2□	1□
4	Company's internal management factors make it difficult to implement energy-saving projects	5□	4□	3□	2□	1□
5	Company's lack of internal budget	5□	4□	3□	2□	1□
6	Difficult to get external financing	5□	4□	3□	2□	1□
7	Uncertainty in quality and reliability of new technologies and equipments	5□	4□	3□	2□	1□
8	The price of the technologies and equipments may decrease soon	5□	4□	3□	2□	1□
9	Rely on financial subsidies on energy saving from the government	5□	4□	3□	2□	1□
10	Pay the mild fines of TMS or ETS rather than to invest huge money for energy efficiency in the early stage	5□	4□	3□	2□	1□
11	Lack of supporting at the national level (E.g., lack of tax incentives and so on)	5□	4□	3□	2□	1□
12	Economic losses due to the production suspending during the new equipment replacement	5□	4□	3□	2□	1□
13	Lack of awareness at top management level	5□	4□	3□	2□	1□
14	No large economic advantage for introducing efficient equipment due to affordable electric energy price	5□	4□	3□	2□	1□

3-6 The table below lists the policies in implementation or under discussions for enhancing company's energy saving and carbon mitigation. How does your company evaluate these policies in their effectiveness for promoting the application and diffusion of energy saving low carbon technologies in cement industry? Please give your evaluation of the policy effectiveness degree (Evaluation criteria for reference are: 5 = 'very effective'; 4 = 'effective'; 3 = 'moderate effectiveness'; 2 = 'low effectiveness'; 1 = 'not effective at all').

No	Supportive Policy	Score				
1	Introduction of economic incentive policies such as emission trading system	⑤	④	③	②	①
2	Tax benefits for eco-friendly products, expansion of purchases by public institutions, etc.	⑤	④	③	②	①
3	Funding for energy saving facilities and energy new technology projects	⑤	④	③	②	①
4	Providing system for dissemination of information on new technologies	⑤	④	③	②	①
5	R & D investment related to green technology	⑤	④	③	②	①
6	Building infrastructures such as joint facilities and green partnerships	⑤	④	③	②	①
7	Others (detail:)					

APPENDIX 2: LIST OF PUBLICATION

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Suk Sunhee, Lee Sang-youp, Jeong Yushim, 2017. The Korean emissions trading scheme: business perspectives on the early years of operations. Journal of Climate Policy in 2017 (http://www.tandfonline.com/eprint/iFPZusqC95cvNDCi3Jvn/full)

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