CHINA ENERGY MODELING FORUM
23-24 Jan. 2018
China Energy Modeling Forum Annual Meeting
International Modeling Seminar on Low-Emission Development Strategy

An Estimate of Internal Carbon Pricing of Korean Companies under the ETS

Suk Sunhee
Strategic Quantitative Analysis Center/IGES

Tsinghua University
China

Institute for Global Environmental Strategies (IGES)

IGES IS an international research institute conducting practical and innovative research for realising sustainable development and achieving a new paradigm for civilization both in the Asia-Pacific region and globally.

Its interdisciplinary research activities cover a wide range of areas such as climate change, natural resources management, sustainable consumption and production, and green economy in cooperation with international research institutes and stakeholders.

The Institute was established in 1998 with support from the Japanese.

IGES headquarters（Hayama, Kanagawa）

IGES and its Global Network

Exploration on business perspectives to carbon pricing in NE Asia

MBIs
(Market Based Instruments Project)
(2010-2012)

- Firm's policy understanding and its influence on policy acceptance and practice;
- Firm's affordability of energy cost increase due to carbon pricing;
- Firm's policy preference to carbon tax and emission trading scheme using choice excrement;
- Firm's perspective to the emission trading scheme introduction

PIDT
(Policy Initiation of Diffusion Technology Project)
(2013-2016)

- Barriers and determinant factors for firm's low carbon technology investment under the emission trading scheme
- A Study on the impact of carbon prices on the low carbon technology diffusion
- Determinants and characteristics of firm's proactive carbon management in response to Emission Trading Scheme
- **An Estimate of firm's Internal Carbon Pricing of under the Emission Trading scheme**

CML_NEA
(Carbon Market Linkage in NE Asia Project)
(2017~)

- A study on the institutional differences and impediments for carbon market linkage in NE Asia
- A study on the existing carbon market linkage mechanisms and major issues, based on theoretical considerations and empirical literature.
- A full-fledged quantitative assessment on the impact of linkages of the carbon markets in NE Asia

Study aims

- Under these circumstances of **emerging carbon pricing policy implementation**, there's growing momentum in the private sector. They see the risks of climate impacts as well as pressures of related government policy such as carbon pricing to their businesses.
- Seeking to manage these hurdles and not to weaken their competitiveness but turn them as an opportunity of a transition to low-carbon business models, companies are increasingly aware of the need for carbon management and are embedding relevant strategies such as **internal carbon pricing**.
- However, while the use of internal carbon prices in a company is becoming more common, the core part is '**how a particular internal carbon pricing value is decided upon**' and 'how to integrate the cost into the financial strategies?' since they provide insight into factors that may inform and influence in company's carbon strategies and business management.
- To answer it, this study attempts to estimate the internal carbon pricing using firm-level data focusing on **Korean companies** under the domestic emission trading scheme.

Contents

1. Different Dimensions of Carbon Pricing
2. Corporate Internal Carbon pricing
3. A estimate of ICP of Korean Company under K-ETS
4. Findings and further studies

Different Dimension of Carbon Pricing

Climate change is the greatest '**market failure**' the world has ever seen, and it interacts with other market imperfections. (*Stern Review* on *the Economics of Climate Change*, 2006)

Unregulated markets have overproduced CO_2 because the costs are not priced into the transaction. One of elements of policy are required for an effective global response is **pricing of carbon**, implemented through tax, trading or regulation.

To externalize the **social cost of carbon**, its cost as pollutant is followed by the PPP theory that suggested by Piguo (1920).

How much should one unit of carbon cost?

- Stern review (2006) proposed **2% of GDP** for the annual cost of achieving stabilisation between 500 and 550 ppm CO_2e.
- 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 and 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.
- Analysis by the UK government's Department of Energy and Climate Change and the Carbon Trust estimates that, in a scenario where warming is limited to less than 2 degrees, the global price of carbon is expected to converge at **$140 per ton of CO_2 by 2030 and $400 by 2050** (DECC, 2016).
- The US Environmental Protection Agency (EPA) estimates the social cost of carbon to range between **$16-152 by 2020 and $26-212 by 2050** (EPA, 2016)

Social cost of carbon of Korea

- 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**.

- However, it is difficult to obtain accurate information on social marginal costs, and even if it can be obtained, when it comes to the policy implementation, it is still needed to define what optimal price level 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).
- Some empirical studies estimated **affordable carbon pricing levels of industry** in North East Asia, including China, Japan and Korea, by applying the valuation methods such as contingent valuation (Liu et al, 2014, Suk et al., 2014), shown in Table.

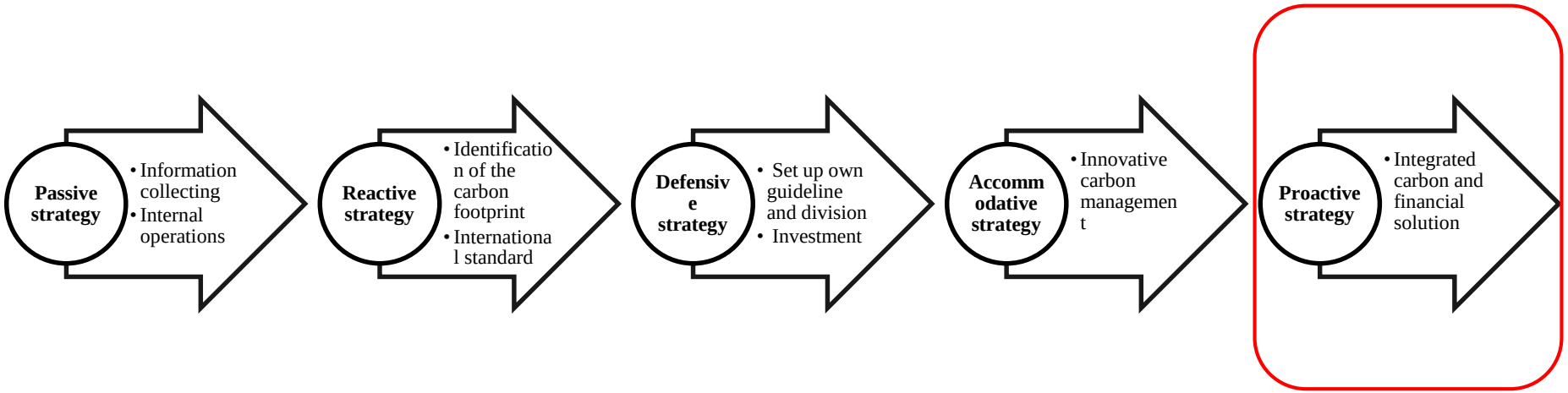
Willingness pay for carbon pricing

(Unit: US$/$tCO_2$)

Country	Sector	Carbon price
China[(a)]	Iron & steel	6.8
	Cement	6.2
	Chemical	13.4
Korea[(b)]	Iron & steel	3.3
	Cement	2.3
	Chemical	3.4
Japan[(c)]	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: (a) Liu et al (2014), (b) Suk et al. (2014), (c) Liu et al. (2015)

Corporate carbon management



Corporate internal carbon pricing

"Internal carbon price" has been defined in several documents, as below table.

Reference	Definition
I4CE (2016)	A value that companies voluntarily set for themselves, in order to internalise the economic cost of their greenhouse gas emissions.
United Nations (2014)	A financial value given, by a company, to a tonne of carbon dioxide emissions.
CDP (2013)	planning tool to help identify revenue opportunities, risks, and as an incentive to drive maximum energy efficiencies to reduce costs and guide capital investment decisions

A common penetration concept that the **company's carbon management** is a step forward from the existing environmental management and instituted their own price on carbon in their **financial planning** to help weigh the risks and opportunities related to climate change.

Carbon Disclosure Project (CDP)

- According to the London-based Carbon Disclosure Project (CDP), a number of companies around the world taking climate action placed a monetary value on GHG emissions in their financial panning companies is increasing (CDP, 2017).
- It is to take a measurable approach of carbon management and investment strategy in business operations.
- Multiple benefits including: (1) advancing a company's greenhouse gas reduction goals, (2) preparing for future carbon regulations, (3) responding to stakeholder demand for climate-risk disclosure, (4) creating resilient supply chains, building a competitive advantage, and (5) showcasing corporate responsibility.

ICP in NE Asia (CDP, 2017)

- Asia including China, India, Japan, Korea, Hong Kong, Taiwan, Thailand and the Philippines, 111 companies set carbon prices. Majority of them are Japanese companies, sharing 44% of the total Asia. Korea is the second, 18%. The carbon price level vary in a range **of 3.4-908.9 USD (76% of them is 3.4-20.5 USD)**.
- The report also indicates companies that set carbon prices within the next two years. A total of 198 companies in Asia are listed, among which **China** and Japan accounted for **35%** and 22%, respectively.

	Country	Consumer discretionary	Consumer staples	Energy	Financials	Health Care	Industrials	Information technology	Materials	Telecom services	Utilities	Sum	
												Total	%
2017 CDP (2017)	China	1				1	2	7	1	1		13	12%
	Japan	8	2		5	3	12	6	7	2	4	49	44%
	Korea	3	2		1		3	2	5		4	20	18%
	Other	2	0	3	2	0	3	9	9	1	0	29	26%
												111	100%
To be within 2 years	China	11	3		2	2	15	15	16	5		69	35%
	Japan	14	3	1	5		8	6	7			44	22%
	Korea	9			4		4	6	1	3		27	14%
	Others	7	4	0	4	2	6	17	11	2	5	58	29%
												198	100%

Types of Internal Carbo Pricing (1/2)

There are varying ways to describe the concept of corporate internal carbon pricing.

(1) Carbon fee (Internal carbon tax) using self-imposed-carbon fees (EDF (2016), I4ce (2016), CDP(2016), Goldstandard (2016), C2ES Report (2017))

- Actual charge to business units (i.e. Microsoft $5-$10 per ton for electricity consumption and employee air travel, $10-$20 per ton, respectively, Microsoft, (2015)).

(2) ***Explicit carbon price based on regulation***

- A company that is subject to emission trading systems or a regulatory carbon tax in the countries where it operates may use the levels **of prices available explicit market or regulatory price** as the lower limit for determining its price (i.e. ConocoPhillips $6-38 per metric ton (EDF, 2016))
- Under the differences in stringency of regulations, the current actual price implemented in each scheme currently vary significantly, from under 1 USD/tCO_2 in the Shanghai ETS market up to 137 USD/tCO_2 in Sweden. Prices in most countries tend to be lower, clustering under 13 USD/tCO_2.

Types of Internal Carbo Pricing (2/2)

(3) ***Shadow carbon price***

- It is **a theoretical price** on carbon in contrast to an actual fee. It is used to better understand the potential impact in anticipation of future carbon regulations such as potential carbon prices, policies and caps in project planning processes to test the profitability of future investment decision and expenditure (R&D, infrastructure, financial assets, etc.) under a range of different scenarios (C2ES, 2017).
- i.e. Novartis, a Swiss-based global healthcare company, $100/tCO$_2$, UK utilities company Pennon Group gives a spread of $84.24- $324.00 (Confino, 2014)

(4) *Implicit price considering marginal cost*

- **The marginal abatement cost** to reduce its greenhouse gas emissions and comply with regulations. It is calculated retroactively based on the measures implemented to mitigate emissions. An implicit carbon price also differs from a shadow price because it is not used to assess the implications of future carbon constraints.

(5) ***Hybrid carbon price***

A company may use a combination of these approaches CDP (2016).

A estimate of ICP of Korean Company under K-ETS

- Questionnaire implementation period: from January to February 2017
- Target: environmental and energy managers at mid-management level
- Sample valid: 100 samples

Classification criteria		Number of respondents	Percentage (%)
Sector	Petrochemical	16	16
	Cement	6	6
	Steel & iron	14	14
	Paper	11	11
	Non-ferrous	10	10
	Machinery	5	5
	Refining	2	2
	Electronics	7	7
	Others	29	29
ETS	Targeted	83	83
	Non-targeted	17	17
Size	Large	6	6
	L-medium	36	36
	Medium	35	35
	Small	23	23
In total		100	100.0

Method measuring the tradable emission credit price (1/2)

- The price of emission a company decides to buy the credit is used as a proxy for an internal carbon pricing of Korean company.
- In order to estimate it, the **multiple-bounded discrete choice (MBDC)** is used in this study.
- 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.

Method measuring the tradable emission credit price (2/2)

Q. Considering the marginal cost of unit GHG reduction of your company, indicate the possibility of credit buy of each price of emission credit indicated in the below table for complaining the short allowance.

Price of emission credit (KRW/tCO_2)	Possibility for purchasing permits				
	Very high	High	Modest	Low	Very low
3,000	√	④	③	②	①
5,000	√	④	③	②	①
8,000	√	④	③	②	①
10,000	⑤	√	③	②	①
12,000	⑤	√	③	②	①
15,000	⑤	√	③	②	①
18,000	⑤	④	√	②	①
20,000	⑤	④	√	②	①
23,000	⑤	④	③	√	①
26,000	⑤	④	③	√	①
30,000	⑤	④	③	②	√
33,000	⑤	④	③	②	√
37,000	⑤	④	③	②	√

Methodology for quantitative analysis

Given a carbon price threshold of $PB_{ij,}$ the probability for a company to buy the credit will be

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

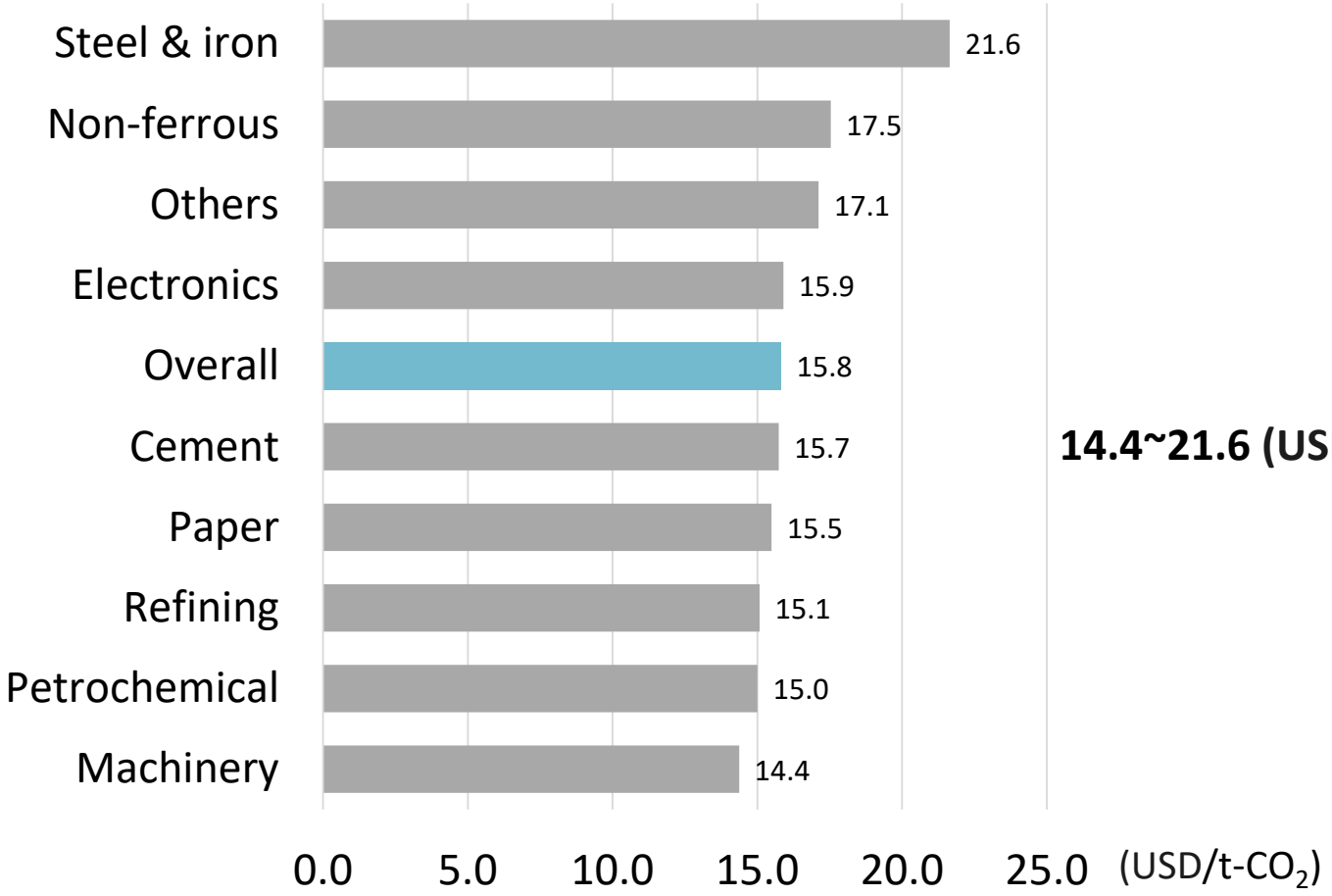
Once P_{ij}, the probability for company *i* to buy under the emission credit price PB_{ij}, is known by assigning numerical values to the verbal MBDC answers, equation (1) can be estimated for each company. Assuming a specific function for $F(PB_{ij})$, such as a normal accumulative distribution with 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 trade; PB_{ij} is the threshold of emission credit price; 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.

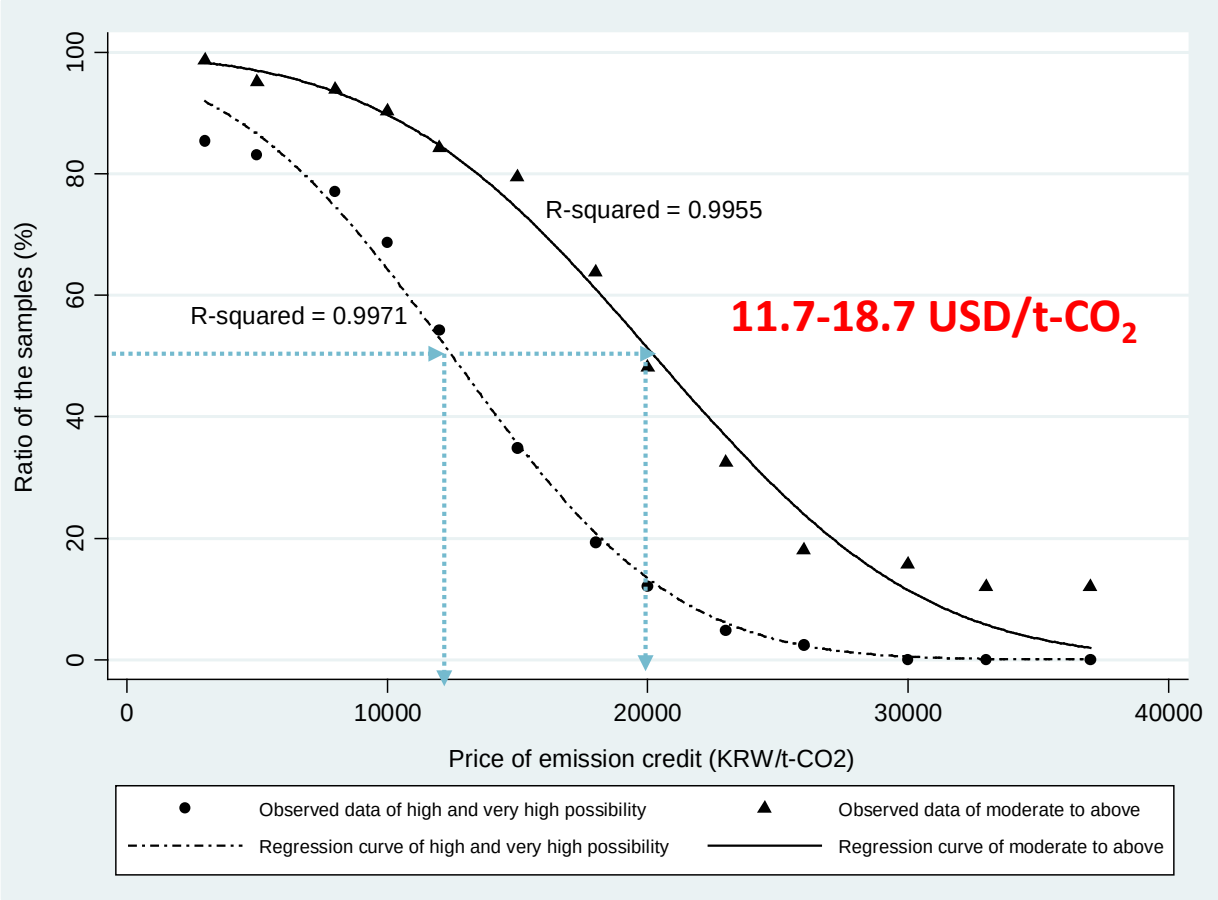
Statistic results by sector



14.4~21.6 (USD/t-CO_2)

www.iges.or.jp
22

Korean companies' internal carbon price (1/2)



www.iges.or.jp
23

Korean companies' internal carbon price (2/2)

- The range of the emission price on the part of 50% of the samples corresponds to about **12,500~20,000 KRW/t-CO_2 (11.7-18.7 USD/t-CO_2).**
- The average price in each compliance year of K-ETS during first phase (2015-2017) is **9.9, 15.1 and 19.3 USD/t-CO_2**.
- The range of internal carbon pricing of Korean companies in the CDP (2017) was **8.9-20.5USD/t-CO_2**.

Companies' carbon management activities

Item		Carbon Management Activities	Valuation	
			0	1
STAGE 1	CMA01	Collecting information on policy related to energy savings and GHG emission reduction		
	CMA02	Regular in-house training program for energy saving and GHG emission reduction		
	CMA03	Encouraging daily energy saving activities in office (ex. turning off lights)		
	CMA04	Participating in training programs for energy saving and GHG emission reduction held by the government/local government		
STAGE 2	CMA05	Short & long-term targets for energy savings and GHG emission reduction in place		
	CMA06	Conducting analysis on energy use and GHG emissions to identify potential areas for energy savings and emission reduction		
	CMA12	Installing monitoring equipment on energy consuming facilities		
	CMA08	Enhancing daily facility maintenance for energy saving and GHG emission reduction		
STAGE 3	CMA09	Setting up an internal standard for energy savings and GHG emission reduction management		
	CMA10	Establishing a unit or department for emission trading		
	CMA11	Purchase new production facilities to save energy and reduce GHG emissions		
	CMA07	Investing in R&D to improve production processes for energy savings and emission reduction		
STAGE 4	CMA13	Enhancing optimization in transporting materials and goods		
	CMA14	Making adjustments in energy mix to use more clean energy sources		
	CMA15	Releasing sustainability reports regularly that contain data for energy consumption and GHG emissions		
	CMA16	Set up a strategic carbon management (plan-do-check-act)		
STAGE 5	CMA17	Setting up a plan and allocating budget for purchasing permits and trading		
	CMA18	Establishing decision making process in relation to carbon trading (e.g., purchase, sell, price projection, etc.)		
	CMA19	Establishing carbon management strategy based on regular analysis of carbon market		
	CMA20	Adopting a green or carbon management accounting system		

Companies' carbon management activities

			STAGE 4			STAGE 5			TCMA		
			Model1	Model2	Model3	Model1	Model2	Model3	Model1	Model2	Model3
External pressure		GOVERNMENT	0.199	0.308	-0.127	0.761 [b]	0.777 [c]	0.070	-0.261	-0.291	-0.677 [c]
		COMPETITION	0.058	-0.001	0.385	-0.236	-0.350	0.205	0.187	0.152	0.454
		ENERGY_PRICE	-0.100	-0.036	-0.045	-0.068	-0.006	-0.025	-0.447	-0.449	-0.391
		STAKEHOLDER	0.237	0.030	0.537	0.784 [c]	0.710	1.768 [b]	0.518	0.430	0.658
Internal factors		TOP_SUPPORT	0.738[b]	0.780 [b]	0.539 [c]	0.648 [b]	0.651 [b]	0.386	1.281 [a]	1.310 [a]	1.220 [a]
		UNDERSTANDING	0.465 [c]	0.562 [c]	0.532	1.040 [a]	1.159 [a]	1.414 [a]	0.636 [b]	0.707 [b]	0.800 [a]
		IN_CARBON_PRICE	0.000	0.000	0.000	0.000 [b]	0.000 [b]	0.000 [a]	0.000	0.000	0.000
		TECH_LEVEL	0.123	-0.067	0.007	0.114	-0.314	-0.532	0.556 [c]	0.261	0.222
Control	Production type	RAW		0.231			0.881			0.463	
		INTERMEDIARY		0.756	-0.012		1.165	-0.157		0.759	-0.411
		FINAL			-0.879		2.238	-1.876 [b]			-1.104 [c]
	Size	SMALL		2.611 [c]	2.265		0.573	1.132		1.810	0.495
		MEDIUM		2.408 [c]	1.813		0.906	-1.709		0.565	-1.279
		L_MEDIUM		2.478 [c]	1.882			-1.179		0.904	-0.808
	Sector	CHEMICAL			-0.567			-1.002			-2.212
		CEMENT			-35.257			-37.644			-6.787[a]
		STEEL			-3.321			-4.813 [b]			-3.308 [c]
		PAPER			-0.143			-1.508			-0.569
		NON-FERROUS			-2.467			-1.517			-2.331
		MACHINERY			-3.755 [c]			-40.268			-2.184
		ELECTRICS			-2.833			-2.715			-2.446
		OTHERS			-2.169			-2.937			-2.053
Number of obs			71	71	71	71	71	71	71	71	71
LR chi2(8)			17.55 [b]	24.63 [b]	43.71 [a]	37.8 [a]	45.56 [a]	75.53 [a]	46.66 [a]	52.35 [a]	69.00[a]
Pseudo R2			0.085	0.119	0.211	0.187	0.226	0.374	0.122	0.137	0.180

Stakeholders

Stakeholders	Mean	Min	Max
Central government	**4.11**	1	5
Financial institution	2.68	1	5
Internal needs for cost management	3.56	1	5
Top manager's willingness	**4.12**	1	5
Labors union in company	2.04	1	5
Customers	2.64	1	5
Media, press, SNS etc.	2.68	1	5
Industrial association	3.05	1	5
Environmental NGO etc.	2.53	1	4

Firm`s view on the carbon market linkage

Variable	Obs.	Mean	Std. Dev.	Min	Max
GHG mitigation effect	100	3.54	0.797	1	5
Principal agent in IMM	100	2.84	0.825	1	5
Linking mechanisms and option	100	2.69	0.940	1	5
States of following discussions to Paris Agreement	100	2.87	0.906	1	5
Opportunities for domestic low-carbon technologies to expand the market	100	3.04	0.920	1	5

Findings and further studies

- Companies in NE Asia are facing a momentum in their carbon management responding to the carbon pricing.
- The internal carbon pricing company embedding a monetary on emissions is increasingly implemented by companies in the world.
- However, there is lack of studies in academic side to determine a particular internal carbon pricing value and to integrate the cost into the financial strategies.
- Employing the Multiple-bounded discrete choice (MBDC) the internalized carbon pricing of Korean companies is estimated, a range of 12 -19 USD/CO_2.
- The internal carbon price of companies is associated with company carbon performance, especially at the higher stages of carbon management.
- The most influential stakeholder in a company's internal carbon pricing is the top manager and government.
- Under the in-depth analysis to derive the policy implications of the findings.

Thank you for you attention.

Further comments and questions to
sunhee@iges.or.jp