Preliminary Analysis of Climate Change Damage in Korea Using the PAGE Model[1)]

Yeo-Ra Chae

PAGE 모델을 이용한 한국 기후변화의 피해비용 분석

채여라

한국환경정책평가연구원 국가기후변화적응센터

제 출 : 2009년 10월 8일　　승 인 : 2010년 3월 8일

국 문 요 약

기후변화 정책 분석 모델 (PAGE, Policy Analysis of Greenhouse Effect)을 이용해 여러 온실가스 배출 시나리오에 따른 기후변화의 피해 비용을 분석했다. 국내외 기후변화 영향에 관한 선행 연구 결과에 따르면 한국의 기후변화의 민감도는 경제 협력개발기구(OECD) 회원국들과 유사한 수준이 될 것으로 전망되었으나 구체적인 한국의 분야별 영향평가가 이루어져야 보다 정량적인 기후변화의 피해함수 추정이 가능할 것이다. 온실가스 배출량, 이산화황 배출량, 적응정책의 정도, 경제 성장, 인구 성장 등 많은 인자들이 기후변화로 인한 피해 정도에 영향을 미친다. 본 연구에서는 PAGE 모델을 이용해 미래의 여러 상황에 따른 기후변화의 피해 정도를 알아보기 위하여 A2, B1, Kyoto, 3가지 시나리오에 대한 분석을 하였다. 만일 전 세계가 온실가스 감축을 위한 아무 대책도 실행하지 않는다면 2100년 한국은 약 3도 정도의 온도상승이 예측되고 이로 인해 12조에서 58조정도의 피해가 일어날 것으로 분석되었다. 1990년에서 2100년까지 기후변화로 인한 누적 피해비용은 약 143조에서 921조에 이를 것으로 분석되었다.그러나 이는 소수의 피해함수에 대한 연구결과만을 반영해 산정한 결과며 분야별로 더 많은 연구가 수행되어야 보다 신뢰도 높은 피해비용을 산정할 수 있다.

주제어 기후변화, 피해비용, PAGE 모델, 적응, 불확실성, 한국

Abstract

This study aims to estimate potential climate change damage in Korea using the PAGE model. This study reviewed previous a reasearch to compare relative sensitivity to climate change in Korea

1) This study was based on "Estimating climate change damage using PAGE model" project supported by Korea Environment Institute. I would like to thank Ms. Jeongeun Kim, Seunghee Kim, and Inae Kim for their help in data management and manuscript preparation. I greatly acknowledge Dr. Chris Hope at Cambridge University for advise regarding PAGE modeling.

yrchae@kei.re.kr

and other regions to generate climate change damage function. It was found that sensitivity to climate change in Korea is similar to other Organization for Economic Cooperation and Development (OECD) countries. This study estimated climate change impact for three scenarios. If no action is taken, climate change damage cost in Korea could reach US$ 12,928 ~ 57,900 M. Cumulative Net Present Value (NPV)of climate change impact from 1990 to 2100 would be between US$ 143,226 ~ 921,701 Mdepending on emission scenarios. However, this result should be interpreted with caution as it draws its damage function based on only a few available references. Results also showed that an adaptation policy could decrease the degree of climate change impact significantly. If an adaptation policy is implemented, climate change impact will be decreased by US$ 11,355 million dollars in Korea in 2100.

❙ Keywords ❙ Climate Change, Damage Cost, PAGE Model, Uncertainty, Adaptation, Korea

Ⅰ. Introduction

The impact of climate change is already evident in Korea's recent heavy snowfall, severe flooding, drought, and temperature rises. According to the Korea Meteorological Administration (KMA), the temperature in the Korean peninsula has increased by 1.5℃since 1904 which is above global average. Precipitation has increased in the last 50 years. If the current trend continues, the effect of climate change in Korea will be more severe.

There have been only limited studies available on climate change impact in Korea. A few studies are available for climate impact which are specific for each sector, e.g., water resources, human health. Most research focuses on greenhouse gas mitigation and its associated costs. There are many critical research needs in the fields of climate science, technology development, and impact and adaptation. Expanding our knowledge in all of these areas is an essential part of Korea's response to the climate change challenge.

It is vital to estimate the potential impact of climate change to establish effective policy measures to deal with it. The challenge in this study is to provide a tool to the decision makers to estimate the implications of CO_2emissions over a range of policy options and provide a concise overview of the uncertainties involved. To explore damage costs of various emission scenarios, this study uses the PAGE model (Policy Analysis for Greenhouse Effect) (Hope, Anderson et al. 1993), (Plambeck, Hope et al. 1995). This study aims to estimate potential climate change damage costs in Korea. Major objectives of this study are as follows.

- Adjust the PAGE model for the Korean context
- Estimate the economic impact of climate change over various GHG emission scenarios
- Estimate the economic impact of climate change over adaptation policies
- Analyze the associated uncertainty with climate change (via scenario analysis).

Climate change is an additional source of uncertainty for the decision maker. The available scientific and economic information regarding the costs and benefits of climate change policies are subject to considerable uncertainty. Policy makers need to make decisions between competing options using scientific information that is irremediably uncertain. Reasonable estimates of the rangeof costs and benefits should serve as the basis for any decision making process. By investigating the probable outcomes of any emission controls, policy makers can get a sense of plausible outcomes and the uncertainty inherent in the analysis. This study evaluated the uncertainty in current scientific and economic opinion using probability distributions, rather than working only with a single 'best estimate'.

Designing a study to evaluate the impact of climate change in Korea is a formidable challenge. Limitations in data and scientific tools mean that the levels of detail that can be incorporated in the assessment are limited. This study examines the differences in climatic impact under various emission and adaptation scenarios. Many scientific studies are used as sources to estimate the impacts and associated damage under different scenarios. The effect of propagating the uncertainty of inputs to an endpoint is assessed using the Latin Hypercube Sampling (LHS) method in @RISK.

Ⅱ. PAGE2002 Model

1. Model Structure

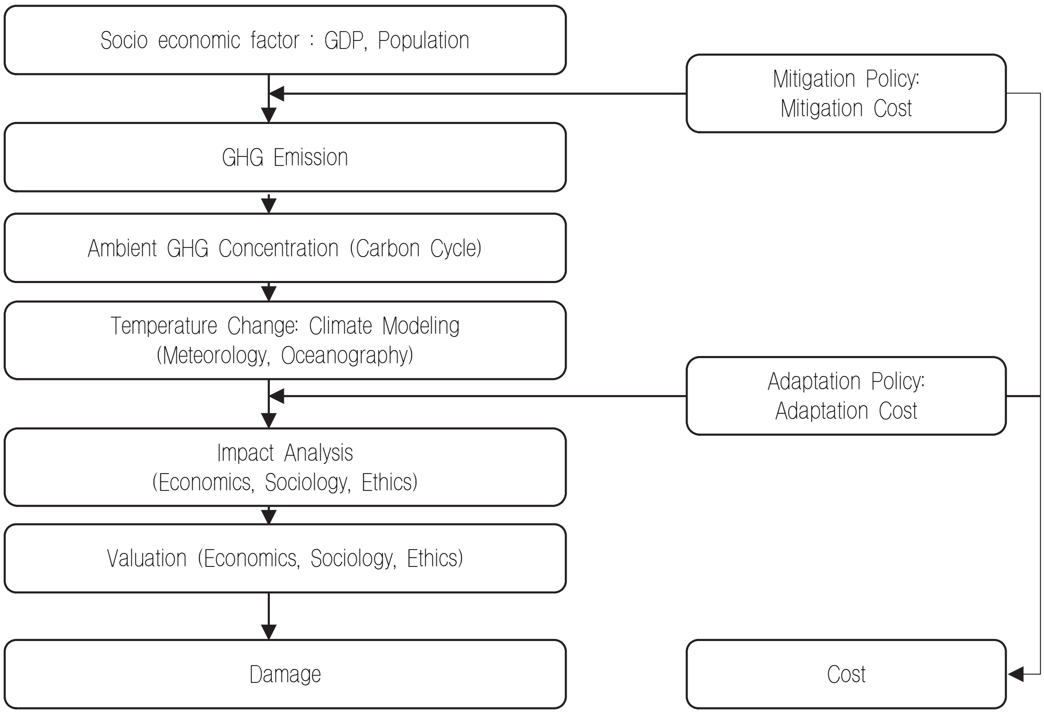
PAGE 2002 (Hope, 2006) is a computer simulation model originally developed for use in decision making by the Commissions of European Communities, Directorate General Environment in dealing with global warming problems. It uses relatively simple equations to approximate complex climatic changes in a minimal number of computations. The simplicity of the PAGE model allows for a rapid appraisal of various policy options and a thorough investigation of the uncertain nature of climate change situations. The basic PAGE model can be run rapidly with probabilistic sampling of the input parameters in order to build up an approximate probability distribution for each model output. The model output includes temperature change, climate change damage, adaptive cost, and preventative cost at a regional level for a given CO_2 and SO_2 emission scenario.

PAGE estimates the realized regional temperature in each analyzed year compared to pre-industrial temperature in 1765, caused by excess concentration of CO_2, CH_4, CFCs, HCFCs and sulphate aerosol. Economic effects are also represented in a highly aggregated form. This may yield higher, or lower for certain sector and region, valuation of impacts than a general equilibrium approach accounting for direct interactions, but the magnitude of difference may differ widely depending on a country and sector. Thorough climate change damage assessment for each damage category and country is not available yet. However, the extensive specification and propagation of uncertainty in current scientific and economic opinion in PAGE allows a range of interactions to be captured implicitly.

PAGE calculates regional climate change impact resulting from temperature change caused by CO_2 and SO_2 emission change in the region and globally. The global mixing of greenhouse gases means that no region protects itself by changing emissions level in that region alone. Although one region could experience a lower temperature increase due to high local SO_2 emission, it would be still susceptible to other climate change impacts caused by temperature increases on other regions, e.g., an increased frequency and severity of extreme weather events, and sea level rises. However, these second-order interactions are not modelled in PAGE.

PAGE divides the world into 8 regions in order to model regional variability in temperature change and global warming damage; The European Union (EC), Former USSR and Eastern Europe (EE), USA (US), China and Northeast Asia (CA), India and Southeast Asia (IA), Africa and the Middle East (AF), Latin America (LA), and other OECD countries (OT). The model uses 1990 data as a base year and it models up to the year 2200. The size of the time step between analysis years increases over time from 20 years in the 21st century to 25 years in the 22nd. Computational effort is concentrated in earlier years because emission forecasts become less accurate with time and because later emissions have a smaller effect on realised global temperature increase to 2200, and on net present costs and impact (Hope, Anderson et al. 1993 Plambeck, Hope et al. 1995).

Figure 1 Structure of PAGE Model



2. Climate Change Damage Calculation in PAGE2002 Model

PAGE2002 takes an ennumerative approach in which total damage is the sum of damages in individual sectors. This may yield a different valuation of impact than a general equilibrium approach accounting for higher order interactions such as the impact of changes in the agricultural sector on the food industry, but the magnitude of the difference is not well understood. PAGE2002 models two damage sectors: economic and noneconomic (corresponding to indices $d = 0$ and $d = 1$, respectively). Using highly aggregated damage estimates from the literature allows PAGE2002 to capture interaction effects implicitly.

Impact is assumed to occur only for temperature rises in excess of some tolerable rate of change, $TR_{d,r}$, or that has magnitude above the tolerable plateau, $TP_{d,r}$. The tolerable plateau in the focus region, $\mathrm{TP}_{d,0}$, and tolerable rate, $\mathrm{TR}_{d,0}$, are uncertain parameters. The tolerable level and rate in each of the non-focus regions are assumed to be proportional to the values for the focus region. The regional multiplier TM_r is an uncertain parameter.

[1] $TR_{d,r} = \mathrm{TR}_{d,0} \cdot \mathrm{TM}_r$ °C/year

$d = 0-1,\ r = 1-7$.

[2] $TP_{d,r} = \mathrm{TP}_{d,0} \cdot \mathrm{TM}_r$ °C

$d = 0-1,\ r = 1-7$.

Adaptation can increase the tolerable level of the temperature rise. $\mathrm{PLAT}_{i,d,r}$ and $\mathrm{SLOPE}_{i,d,r}$ are nonegative factors characteristic to an adaptive policy. If additional adaptation is not undertaken in analysis year i, $\mathrm{SLOPE}_{i,d,r}$ and $\mathrm{PLAT}_{i,d,r}$ are zero.

[3] $ATP_{i,d,r} = TP_{d,r} + \mathrm{PLAT}_{i,d,r}$ °C

$d = 0-1,\ r = 0-7,\ i = 1-10$.

[4] $ATR_{i,d,r} = TR_{d,r} + \mathrm{SLOPE}_{i,d,r}$ °C/year

$d = 0-1,\ r = 0-7,\ i = 1-10$.

The regional impact of global warming, $I_{i,d,r}$, corresponds to temperature increases in excess of the adjusted tolerable level, $ATL_{i,d,r}$.

[5a] $ATL_{0,d,r} = 0$ ˚C

$d = 0-1, r = 0-7.$

[5] $ATL_{i,d,r} = \min\left\{ATP_{i,d,t}, ATL_{i-1,d,r} + ATR_{d,r} \cdot (Y_i - Y_{i-1})\right\}$ ˚C

$d = 0-1,\ r = 0-7,\ i = 1-10.$

[6] $I_{i,d,r} = \max\left(0, RT_{i,r} - ATL_{i,d,r}\right)$ ˚C

$d = 0-1,\ r = 0-7,\ i = 1-10.$

For the discontinuity,

[6a] $IDIS_i = \max\left(0, GRT_i - TDIS\right)$ ˚C

$i = 1-10$

where GRT is the global mean realised temperature

In the literature, regional damages are usually estimated as a percentage of gross domestic product lost per doubling of [CO_2]. PAGE2002 computes regional GDP in each analysis period in Million economic currency units (Mecu); most applications of PAGE2002 use $M(US). The growth rate, $\mathrm{GRW}_{i,r}$, is assumed to apply from the previous analysis year, i-1, up to the corresponding analysis year, i:

[7] $GDP_{i,r} = GDP_{i-1,r} \cdot (1 + \mathrm{GRW}_{i,r} / 100)^{Y_i - Y_{i-1}}$ Mecu

$r = 0-7,\ i = 1-10.$

Weights are used to monetise the impact to allow for comparison and aggregation across economic and noneconomic sectors. The weights Wd,r express the percentage of GDP lost for benchmark warming of 2.5 C in each impact sector and region, where $\mathrm{W}_{d,0}$ is the value for the focus region and WF_r is the regional multiplier. Note that weights may be negative, representing a gain, as in the case of agriculture in Northern Europe.

[8] $W_{d,r} = \mathrm{W}_{d,0} \cdot \mathrm{WF}_r / 100$ per 2.5°C

$d = 0-1,\ r = 0-7$.

For the discontinuity, we need to check that the regional weight does not exceed 100% of GDP

[8a] $WDIS_r = \min(100, \mathrm{WDIS}_0 \cdot \mathrm{WF}_r)/100$

$r = 0-7$.

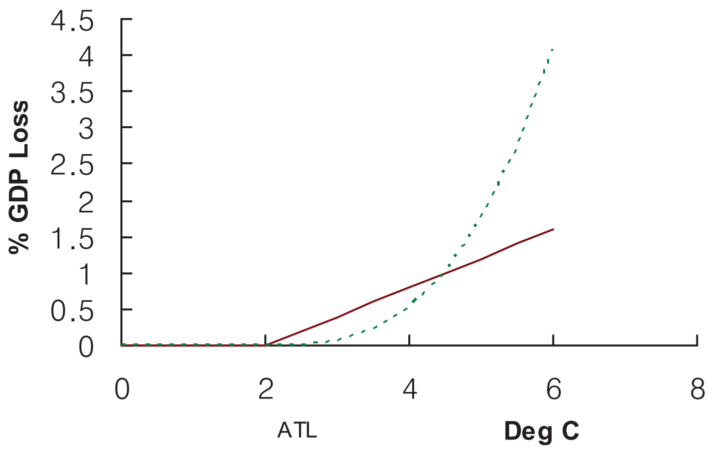
The PAGE2002 model with eight regions and two impact sectors lends itself to using improved aggregate damage estimates from the literature. These damage estimates often correspond to a benchmark doubling of CO_2 but PAGE2002 computes damagesbased on temperature increase, not greenhouse gas concentration. Therefore, the damage estimates are assumed to correspond to a 2.5C increase in temperature, the mean expected warming for a doubling of CO_2 (IPCC, 2001b). Impacts are computed for each region, sector, and analysis period as a power function of regional temperature increase above the tolerable level. An adaptive policy, characterised by the factor $\mathrm{IMP}_{i,d,r}$, can mitigate these impacts.

[9] $WI_{i,d,r} = \left(I_{i,d,r} / 2.5\right)^{\mathrm{POW}} \cdot W_{d,r} \cdot \left(1 - \mathrm{IMP}_{i,d,r} / 100\right) \cdot GDP_{i,r}$ Mecu

$d = 0-1,\ r = 0-7,\ i = 1-10$.

Note that the damage function in [9] is calibrated to agree with a linear damage function for a benchmark 2.5C rise above the tolerable temperature level, $ATL_{i,d,r}$, as depicted in Figure 2.

Figure 2 Linear (POW=1) and Cubic (POW=3) Damage Functions



The addition for a possible discontinuity, assuming risk neutrality in computing a certainty equivalent, is

[9a] $WIDIS_{i,r} = IDIS_i \cdot (PDIS/100) \cdot WDIS_r \cdot GDP_{i,r}$ Mecu

$r = 0-7, i = 1-10$.

So the total weighted impact is

[9b] $WIT_{i,r} = \sum_d WI_{i,d,r} + WIDIS_{i,r}$ Mecu

$r = 0-7, i = 1-10$.

Each analysis year represents a period, typically from half way back to the previous analysis year to half way forward to the next.

[10a] $Yhi_{10} = Y_{10}$

[10] $Yhi_i = (Y_i + Y_{i+1})/2$

$i = 1-9$

[11a] $Ylo_1 = Y_0$

[11] $Ylo_i = (Y_i + Y_{i-1})/2$

$i = 2-10$

[12] $AD_{i,r} = WIT_{i,r} \cdot \left(Yhi_i - Ylo_i\right)$ Mecu

$r = 0-7, i = 1-10$.

PAGE2002 allows for regional and time variable discount rates. Different values may also be used to discount the costs of policy implementation and the costs related to climate change impact. The weighted impact in a non-analysis year is assumed to be equal to that of the nearest analysis year. Weighted impacts are aggregated over time with the time-variable discount rate for impacts, $\mathrm{dr}_{i,r} \cdot ric$, and summed over all regions, economic and noneconomic impact sectors and impacts from a possible discontinuity, to compute the net present value of global warming impact:

[13] $$DD = \sum_{i,r}\left(AD_{i,r}\right)\cdot \prod_{k=1}^{i}(1+\mathrm{dr}_{k,r}\cdot ric/100)^{-(Y_k - Y_{k-1})}$$ Mecu.

Ⅲ. Climate Change in Korea

1. Climate Change Damage in Korea

Climats changes that has been observed in Korea were as summarized as follows in Table 1 . (Han, 2005)

Table 1 Observed climate change damage in Korea

Sector	Damages
Climate	• The average temperature has increased by 1.5℃since 1904. • The temperature increased more in winter than summer, and also the minimum temperature increased much more than the maximum temperature. • The wind velocity has declined in all areas. This is the evidence of the negative affection of the Asian monsoon circulation effect. • The number of precipitation days decreased (14%), but the amount of precipitation increased (7%). This means that the frequency of heavy precipitation (18%) increased as well. • The severe cloud days such as frosty days and freezing days decreased but cool days and tropical nights increased. • Winter is getting shorter than before and summer and fall are getting longer due to rising winter temperature.
Agriculture	• Crop yield will changed -50 ~ 16% for doubling of CO_2. • The cultivation period will be extended from 10-29 days by 2~3℃temperature increase • The cultivation area will be extended northward • Temperate fruit (apple, grape) cultivation will be possible for all of Korea by a 2℃ temperature increase • Subtropical at fruit cultivation area will spread out.
Forestry	• Forest distribution patterns will change. • The proportion of bristle tooth oaks will be increased and pine trees will be reduced.
Water resources	• Koreais very vulnerable to floods and droughts due to high rainfall fluctuation and population density. • Precipitation intensity is high.
Human health	• Considerable mortality rates during severe hot weather will be observed. • Increases in potential transmission of vector born diseases are also expected. • Non-vector born infectious disease may be spread to the Korean peninsula.
Sea level rise	• Sea level rises will be slightly higher than the global mean average.

It is not easy to compare relative vulnerability of climate change in Korea based on the limited number of studies. Relative vulnerability can be compared as shown in Table 2. However, this is based on only a limited number of studies available and can be changed in the future when more studies become available.

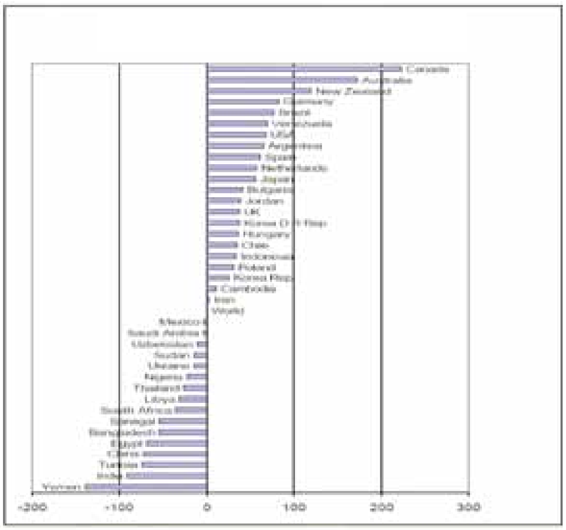
Table 2 Relative Sensitivity

Sector	Relative Vulnerability (Compared to EU and USA)	Reference
Agriculture	-?	Shin,JinChul et.al(2000), Oh. S.(1995), Yun,J.(1990),
Water Resource	=?	Kwon(2005), Bae (2005)
Human Health	-?	Park(2005), IPCC(1996),
Energy	?	Han (2005)
Sea level rise	-?	Jeon(2002), IPCC(1996)
Total	=-?	OECD(2004)

-: more sensitive than the EU and USA
=: same as the EU and USA
+: less sensitive than the EU and USA
?: uncertain

Moss (2001) assessed vulnerability and resilience to climate change given present circumstances. Moss (2001) calculated indicators of sensitivity to climate change by country as shown in Figure 3 and 4. Figure 5 indicates that sensitivity to climate change in Korea is similar to other OECD countries.

Figure 3 Vulnerability Resilience Indicators in 1990



Source: Moss, 2001

Figure 4 Vulnerability-Resilience Indicators in 2095 for the rapid growth scenario (A1v2), the local sustainablility scenario (B2h)and the delayed development scenario (A2A1)

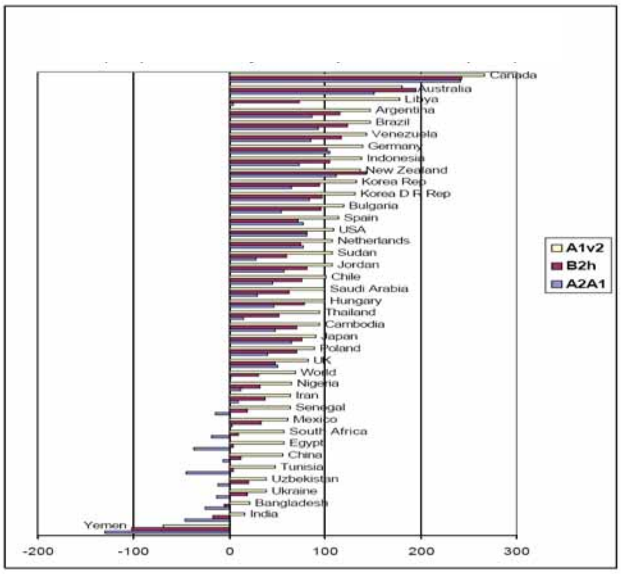
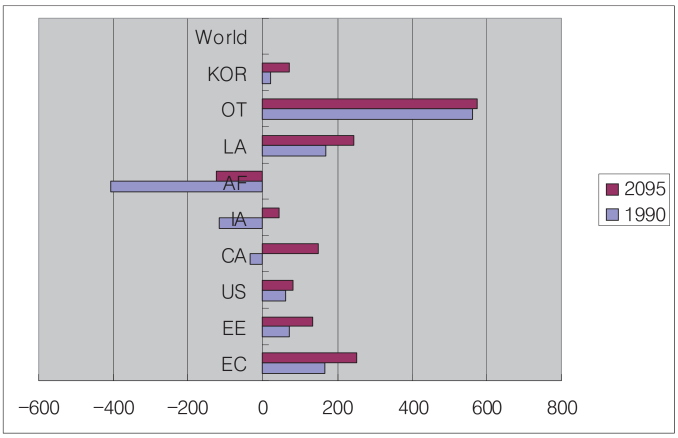


Figure 5 Relative Vulnerability of Climate Change by Region



Available estimates on the impact costs of climate change are neither accurate nor complete, and there is a considerable margin of error. Methods of identification of impact sectors vary significantly across studies. Figures on developing countries, in particular, are usually based on approximation and extrapolation and are clearly less reliable than those for developed regions. Nevertheless, available estimates may serve as an indication of the relative vulnerability of different regions. Nevertheless, the relative ranking of regions appears to be reasonably robust, with the most severe impacts expected in Asia and Africa, and developed regions suffering less. IPCC (2001) summarizes the regional impact of climate change from existing studies as shown in Table 3.

Table 3 Regional Impact of Climate Change (% of GDP)

	IPCC (2001)	Mendelsohn et al. (2000)		Nordhaus and Boyer (2000)	Tol (2002)
	2.5℃arming	1.5℃Warming	2.5℃Warming	2.5℃Warming	1℃Warming
North America					3.4
- United States			0.3	-0.5	
OECD Europe					3.7
- EU				-2.8	
OECD Pacific					1.0
- Japan			-0.1	-0.5	
Eastern Europe/FSU					2.0
- Eastern Europe				-0.7	
- Russia			11.1	0.7	
Middle East				-2.0	1.1
Latin America					-0.1
- Brazil			-1.4		
South, Southeast Asia					-1.7
- India			-2.0	-4.9	
China			1.8	-0.2	2.1
Africa				-3.9	-4.1
Developed countries	-1.0 to - 1.5	0.12	0.03		
Developing countries	-2.0 to - 9.0	0.05	-0.17		
World					
- Output weighted	-1.5 to - 2.0	0.09	0.1	-1.5	2.3
- Population weighted				-1.9	
- At world average prices					-2.7
- Equity weighted					0.2

Source: IPCC, 2001

2. Drawing a Damage Function for Climate Change in Korea

Drawing an economic damage function in Korean context is a critical step in estimating climate change damage in Korea. However, as summarized in previous chapters, there is only a limited number of studies available. It could be said with caution that Korea is not very much sensitive to climate change compared to OECD countries based on available studies of climate change impact assessment in Korea. Mendelssohn (2000) and Tol (2000) predicted that climate change impacts could be beneficial in the Northeast Asia (NEA) region. Obviously more research is needed to draw a more precise damage function of climate change damage. This study assumes that sensitivity to climate change in Korea is similar to the EU and USA based on available studies. Comparison of each sector's vulnerability with the EU/USA region is explained in Chae (2006).

Weights are used to monetise the impacts to allow for comparison and aggregation across economic and noneconomic sectors. The weights express the percentage of GDP lost for benchmark warming of 2.5°C above the tolerable level in each impact sector in the EU, with regional multipliers for other regions. Note that weights may be negative, representing a gain, as in the case of Eastern Europe and the former Soviet Union. Impacts are computed for each region, sector, and analysis period as a power function of regional temperature increase above the tolerable level. Table 5 shows the weights used in this investigation. The minimum and maximum values, particularly for the regional weights factors, involve a large amount of judgement to encompass the different studies cited by the IPCC.

Table 4 Economic Parameters of PAGE 2002 Model

	Mean	Min	Mode	Max	Source
Econ impact in EU(%GDP for 2.5 degC)	0.5	-0.1	0.6	1	IPCC, 2001a, p940, 943
Non-econ imp EU(%GDP for 2.5 degC)	0.73	0	0.7	1.5	IPCC, 2001a, p940, 943
Impact function exponent	1.76	1	1.3	3	As in PAGE95
Eastern Europe & FSU weights factor	-0.35	-1	-0.25	0.2	IPCC, 2001a, p940
USA weights factor	0.25	0	0.25	0.5	IPCC, 2001a, p940
NEA weights factor	0.2	0	0.1	0.5	IPCC, 2001a, p940
India weights factor	2.5	1.5	2	4	IPCC, 2001a, p940
Africa weights factor	1.83	1	1.5	3	IPCC, 2001a, p940
Latin America weights factor	1.83	1	1.5	3	IPCC, 2001a, p940
Other OECD weights factor	0.25	0	0.25	0.5	IPCC, 2001a, p940
Tolerable temp OECD economic (degC)	2				As in PAGE95a
Drop in econ impact OECD (%)	90				As in PAGE95a
Drop in econ impact RoW (%)	50				As in PAGE95a
Drop in non-econ impact (%)	25				As in PAGE95a

Note: a. Tolerable temperature rises and drops in impact come from aggressive adaptation efforts.

3. Economic Impacts Depending on Damage Functions

This study estimated net present value (NPV) of climate change impact in Korea for three scenarios. A2 and B1 scenarios are taken from IPCC (2000). The Kyoto scenario assumes hypothetically all countries would adopt Kyoto protocol. CO_2 emission projection from 3 scenarios is as follows.

Figure 6 Global CO_2 Emissions by Scenario

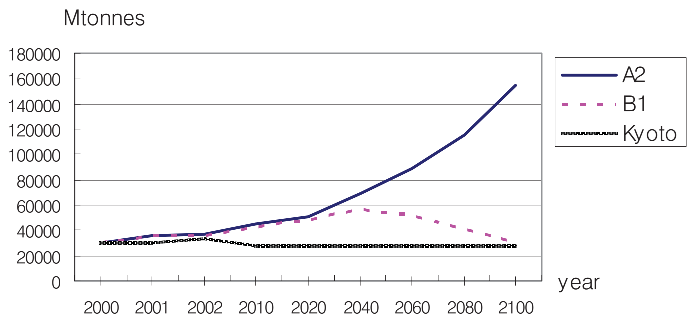
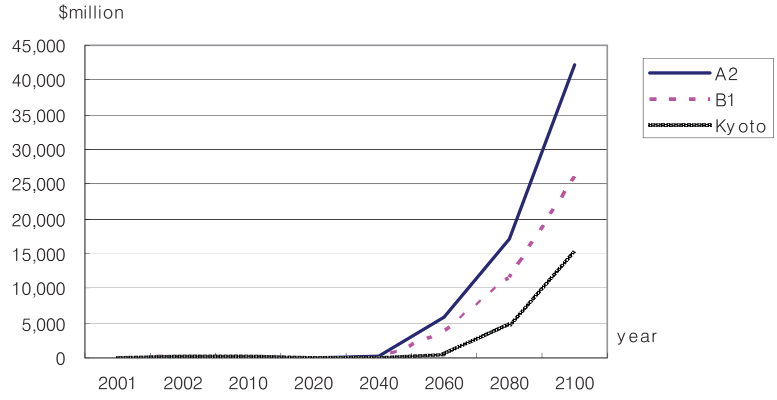


Figure 7 Climate Change Impacts in Korea



PAGE modeling results indicates that if no action has been taken, climate change damage cost in Korea could be $ 838~ 3,795million in 2040 and $ 2,928~57,900 million in 2100. NPV of cumulative climate change impacts in Korea from 2000 to 2100 is $ 921 billion for A2 scenario.

Another round of analysis has been carried out applying a lower damage function (same as NEA countries) to see the potential damage level in Korea. NPV of climate change damage is $ 12,928 million in 2100. Damage was significantly lower then expected.

Figure 8 Climate Change Impacts in Korea for A2 Scenario Depending on Damage Function

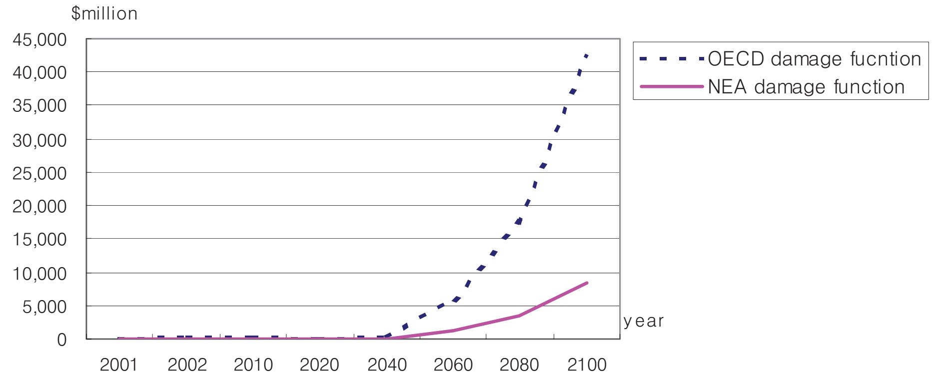


Table 5 NPV of Climate Change Impact in Korea in 2100 by Emission Scenarios (million $)

Scenarios	Min	Mean	Max	Std Dev
A2 (OECD damage fnc.)	1,903.11	57,900.41	328,288.16	54,976.70
A2 (NEA damage fnc.)	163.14	12,928.32	136,040.91	16,934.20
B1(OECD damage fnc.)	640.10	35,455.23	296,531.72	39,242.72
Kyoto(OECD damage fnc.)	0	20,033.07	176,408.95	21,865.10

Table 6 NPV of Cumulative Climate Change Impact in Korea from 2000 to 2100 by Emission Scenarios (million $)

Scenarios	Cumulative NPV of climate changing impacts
A2 (OECD damage fnc.)	921,701
A2 (NEA damage fnc.)	143,226
B1(OECD damage fnc.)	578,690
Kyoto(OECD damage fnc.)	228,856

4. Climate Change Impacts Depending on Adaptation Policy

To see the effects of adaptation policy, climate change impacts are calculated with and without adaptation policy. This study assumes Korea implements the same degree of adaptation policy as in other OECD countries. It assumed that adaptation policy would increase the economic slope by 1°C /decade and economic plateau to 2°C. Figure 4-6 shows NPV of climate impacts depending on adaptation policy. It indicates that adaptation policy could decrease NPV of climate change impacts in Korea by about 11,355 million dollars in 2100.

Figure 9 Climate Change Impacts in Korea Depending on Adaptation Policy

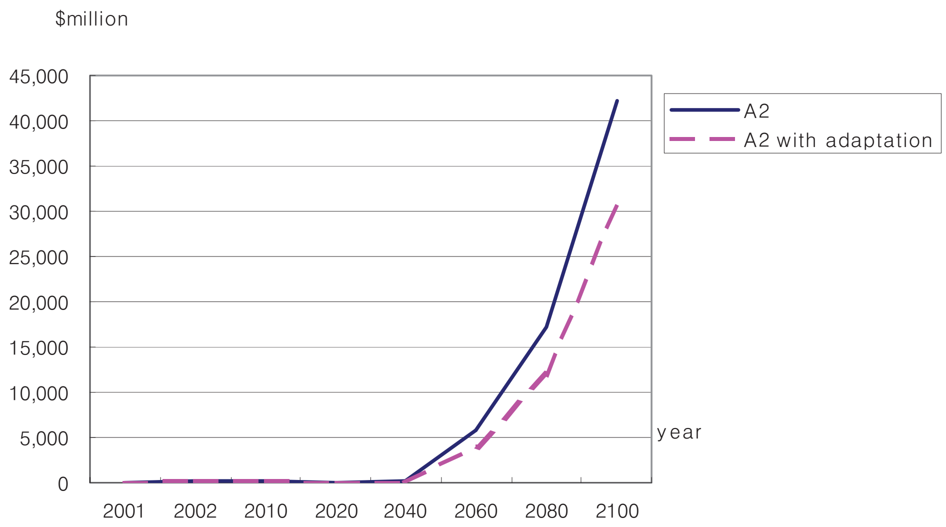


Table 7 Effects of Adaptation Policy in Korea in 2100 (million $)

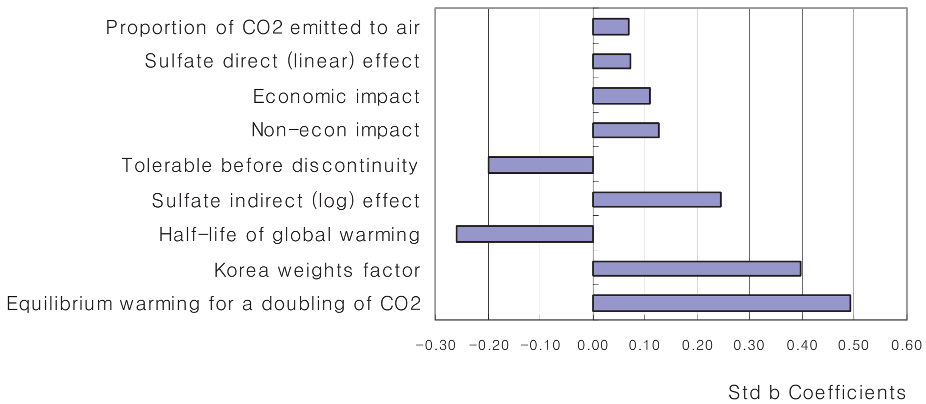
Scenarios	Min	Mean	Max	Std Dev
A2	1,903.11	57,900.41	328,288.16	54,976.70
A2 with Adaptation	270.93	46,544.93	293,716.94	50,489.70
Difference	1,632.18	11,355.48	34,571.22	4,487

5. Uncertainty Analysis

Sensitivity analysis is carried out to see the magnitude of the impact of each input uncertainty on the result. Sensitivity analysis presents the potential effect of alternative assumptions on the output. It provides an indication of how the result might change if some of the input assumptions were changed. This study computes a partial rank correlation coefficient (PRCC) to measure the sensitivity of output to the uncertain input parameter. Partial rank correlation coefficients are a measure of the contribution of each input variable to the output uncertainty, after removing the effects attributable to the other inputs. The PRCC values range between －1 and 1. PRCC values close to plus or minus 1 indicates a strong positive or negative relationship while values near zero indicates a weak relationship between input and output. (Morgan 1990).

Figure 4-8 shows the PRCC correlation coefficient of climate change impact calculation for the A2 scenario. It shows that uncertainty on climate sensitivity, Korea's regional weight factor, and global warming half-life have the largest impact in estimating climate change impact in Korea. To increase the robustness of the result, further research on these areas will be needed.

Figure 10 Sensitivity Analysis of Climate Change Impacts Calculation



Ⅳ. Conclusion and Discussion

It is vital to estimate potential impact to establish effective policy measures to deal with climate change. The challenge of this study is to provide a tool to the decision makers to estimate the implications of CO_2 emissions over a range of policy options and provide a concise overview of the uncertainties involved. To explore damage costs of various emission scenarios, this study uses the PAGE model (Hope et al. 1993), (Plambeck et al. 1995) to estimate potential climate change damage costs in Korea.

Climate change affects many areas including agriculture, forestry, human health, water resources, etc. Impact differs by sector and across regions. This study examines the relationship between climate change and impact in each sector. A review of the global impact literature was conducted, with particular attention to Korea, to assess the general shape of the damage curve. There are many studies available on climate change and its effect on global scale and relatively few studies on regional level climate change impact. Only a limited number of studies are available on climate change and its impact in Korea. Based on this, this study tried to draw a climate change damage function in Korea based on available studies. It could be said with caution that Korea seems to be slightly more sensitive to climate change than the EU and the USA. Mendelssohn (2000) and Tol (2000) predicted that climate change impact could be beneficial in the NEA region. Obviously more research is needed to draw a more precise quantitative damage function of climate change damage in the Korean context. In the mean time, this study assumesthat sensitivity of climate change in Korea is between OECD and developing countries in high latitude countries.

This study estimates climate change impact in Korea using the PAGE model. Many factors affect climate change damage including global GHG emissions, regional sulphate emissions, degree of adaptation policy, economic growth, population growth, etc. To see the potential impact of climate change over an uncertain future, this study estimated the climate change impact for three scenarios, A2, B1, and Kyoto scenarios. If no action had been taken, the climate change damage cost in Korea could be $million 12,928 ~ 57,900. The Cumulative NPV of climate change impact from 1990 to 2100 would be between $million 143,226 ~ 921,701 depending on emission scenarios. However, this result should be interpreted with extra caution as it draws a damage function based on only the few studies available. This preliminary result highlights the urgent need for developing the quantitative damage function of climate change in Korea. The uncertainty range is vast, and climate change damage costs greatly differ depending on the damage function applied.

It has been found that an adaptation policy could decrease the degree of climate change impact significantly. If adaptation policy were implemented, climate change impacts would be decreased by 11,355 million dollars in Korea in 2100. The difference of climate change impact between the A2 and B1 scenario is 22,475 million dollars although the difference of carbon emission is huge. This demonstrates the great importance of adaptation.

Uncertainty analysis result shows that confidence of climate change damage estimation is very low. Sensitivity analysis reveals that climate sensitivity, Korean's regional weight factor, and global warming half-life has the largest impact in estimating climate change impacts in Korea. Further research would enhance robustness of the result. However, Morgand and Dowlatabadi(1996) recommended that "Parts of the problem about which we have little knowledge must not be ignored. Order-of-magnitude analysis, bounding analysis, and carefully elicited expert judgement should be used when formal models are not possible."

To estimate climate change damage in Korea with more confidence, more research is required in many sectors. First, quantitative analysis of climate damage functions for each sector is needed in the Korean context. Currently, only a very limited number of studies are available for each sector. Sectoral quantitative damage assessment is vital to estimate climate change damage. Quantitative assessments of climate change damage in agriculture, forestry, industry, human health, sea level rise are required. It is also important for identifying the most sensitive sector. Secondly, the effect of adaptation deserves more attention. This study found that adaptation policy could decrease climate change impact significantly. However, more research is needed to identify how we adapt to climate change and which policy measure is most effective among many options.

References

Bae, D. H. 2005. "The impact of climate change on water resource and Task". *Climate change and land development.*

Chae, Y. 2006. *Estimating climate change damage using PAGE model*. Korea Environment Institute.

Han, H. et al. 2005. *Climate change impact assessment and development of adaptation strategies in Korea*. Korea Environment Institute.

Hope, C., J. Anderson, and P. Wenmen. 1993. "Policy analysis of the greenhouse effect". *Energy Policy*. March:327-338.

Hope, C. 2006. "The marginal impact of CO_2 from PAGE2002: an integrated assessment model incorporating the IPCC's five reasons for concern". *Integrated Assessment* 6(1):19-56.

IPCC. 2000. *Emission scenarios*. Cambridge University Press, UK.

_____. 2001. *Climate Change 2001, The Scientific Basis*, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate. Change, In J. T. Houghton, Y. Ding, G. J. Griggs, M. Noguer, P. van der Linden, X. Dai, K. Maskell and C. J. Johnson eds. Cambridge University Press, Cambridge, UK, 881.

_____. 2001a. *Climate Change 2001, Impacts, adaptation, and vulnerability*. Cambridge University Press. Cambridge, UK.

Jeon, SungWoo. 2002. *Sea level rise and its possible impact near the Korea due to global warming Ⅱ*. Korea Environment Institute.

Kwon, JiHayng. 2005. "Climate change and water resource". *Nature Conservation* 131:9-15.

Mendelsohn, R. et al. 2000. "Country-Specific Market Impacts from Climate Change". *Climatic Change* 45:553-569.

Morgan, M. G. and M. Henrion. 1990. *Uncertainty: A guide to dealing with uncertainty in quantitative risk and policy analysis*. Cambridge, Cambridge University Press.

Morgan, M. G. and H. Dowlatabadi. 1996. "Learning from integrated assessment of climate change". *Climatic Change* 34(3/4):337-368.

Moss, R. H., A. L. Brenkert, and E. L. Malone. 2001. *Vulnerability to climate change: a quantitative approach*. Prepared for the US Department of Energy.

Nordhaus, W. and J. Boyer. 2000. *Warming the world: Economic models of climate change*. MIT Press.

OECD. 2004. *The Benefits of Climate Change Policies*.

Oh, S. 1995. "Study on impact of doubling atmospheric CO_2 climate change on lowland rice in Korea". *Jour. Korean Meteor. Soc* 31(3):267-312.

Park, J. I. 2005. "The impact of climate change on human health: mortality by summer severe hot weather". *Nature Conservation* 132:22-29.

Plambeck, E. L. and C. Hope. 1996. "PAGE95: an updated valuation of the impacts of global warming." *Energy Policy* 24(9):783-793.

Shin, JinChul. et al. 2000. "Crop production response and technical counterplan as climate change". *The Korean Society of Crop Science, KSAFM, KSAIS, Union Symposium*:12-27.

Tol, R. S. J. 2002. "Estimates of the damage costs of climate change, PartI: Benchmark estimates". *Environmental and Resource Economics* 21:41-73.