American Journal of Climate Change, 2018, 7, 452-462
http://www.scirp.org/journal/ajcc
ISSN Online: 2167-9509
ISSN Print: 2167-9495

Economic Analyses of Regional Impacts with Adaptation to Climate Change for the Paris Agreement*

Shin Sakaue[1*], Koichi Yamaura[2], Toyoaki Washida[3]

[1]Faculty of Economics, Kumamoto Gakuen University, Kumamoto, Japan
[2]Department of International, Environmental and Agricultural Science, Tokyo University of Agriculture and Technology, Tokyo, Japan
[3]Graduate School of Global Environmental Studies, Sophia University, Tokyo, Japan
Email: *sakaue@kumagaku.ac.jp

How to cite this paper: Sakaue, S., Yamaura, K. and Washida, T. (2018) Economic Analyses of Regional Impacts with Adaptation to Climate Change for the Paris Agreement. *American Journal of Climate Change*, **7**, 452-462.
https://doi.org/10.4236/ajcc.2018.73027

Received: April 27, 2018
Accepted: August 31, 2018
Published: September 3, 2018

Abstract

This study measures regional impacts of adaptation to climate change for the Paris Agreement under the Shared Socio-Economic Pathways and Representative Concentration Pathways scenarios. We develop a global economic model with adaptation to climate change. Simulated results indicate that: 1) Asian and African adaptation costs exceed more than one percent of GDP in the year 2100 under the business as usual scenario; 2) adaptation costs under the 2.0˚C target are higher in Asia and Africa than other regions; and 3) adaptation costs amount to one percent of GDP in Japan, EU and Latin America under the 1.5˚C target scenario by adaptation.

Keywords

Adaptation, Climate Change, SSP, RCP, IAMs, CGE Models

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) reviewed many integrated assessment models (IAMs) to evaluate the impacts of climate change policies (IPCC [1]). Although many researchers have begun to measure the impacts of mitigating greenhouse gas (GHG) emissions for the 1.5˚C and/or 2˚C target in the Paris Agreement using IAMs, there are few studies focusing on adaptation under the Paris Agreement. One reason is that it is difficult to measure the cost

*This research was supported with funding from the Environment Research and Technology Development Fund (S-10-4) of the Ministry of the Environment, Japan. We would like to thank Yosuke Arino for helpful comments.

of adaptation to climate change by IAMs. However, some studies analyze adaptation to climate change by global economic models in other situations. Therefore, it is important to clarify regional adaptation and economic effects of the long-term temperature targets of the Paris Agreement and its climate policies in the world.

Latest IAMs research on climate change applies two scenarios for calculating impacts of climate change: Shared Socio-Economic Pathways (SSPs) and Representative Concentration Pathways (RCPs). The SSPs consist of five socio-economic scenarios with mitigation and adaptation to climate change and include GDP, population and GHG emissions scenarios. Each SSP scenario represents a possible societal future. The RCPs consist of four climatic scenarios on radiative forcing, and each RCP corresponds to a GHG mitigation policy. Integrated Assessment Modeling Consortium (IAMC), an IAM community, suggests that IAM researchers apply combined SSP-RCP scenarios to make it easier to assess literatures within and across research communities as well as across studies at different scales and in different regions (van Vuuren *et al.* [2]). In this study, we measure regional impacts of adaptation to climate change for the Paris Agreement under the SSPs and RCPs combination scenarios using a global economic model in which each region has multiple economic sectors. We first estimate the parameters of our Evaluation Model for Environmental Damage and Adaption (EMEDA) on adaptation under various scenarios to decompose the total costs and damages of climate change into climate change damages and adaptation costs. Second, we simulate EMEDA to obtain optimal adaptation levels and economic impacts of climate change under the SSP-RCP combination scenarios for the 2.0˚C target. Finally, we discuss the 1.5˚C target case which has lower climate impacts and aggressive adaptation.

2. Model

By calculating the global economic benefits and costs of aggressive adaptations to global warming using the PAGE model, Hope *et al.* [3] showed that aggressive adaptation was optimal. Rosenzweig and Parry [4] dealt with the adaptation benefits and/or costs of climate change in the agricultural sector. Later, AD-DICE (de Bruin *et al.* [5]) was developed as a one-region world economic model in which the total costs of climate change are decomposed into adaptation costs and residual costs. Based on AD-DICE, AD-RICE model (de Bruin *et al.* [6]) was developed as a multi-regional model with one sector per region. In this research, we use the dynamic EMEDA since it includes multiple sectors per region (Sakaue *et al.* [7]).

The dynamic EMEDA consists of eight regions, each of which has each eight sectors (see **Table 1**). *OECD*8 consists of EU countries, Canada, Australia and New Zealand, and *FSU_EEurope* consists of the Former Soviet Union (FSU) and other European countries. *OAsiaOceania* includes Asian and *Oceanian* countries while OAmerica represents the countries of Latin America. General economic data and GHG data in the year 2004 are from GTAP7. To calculate coefficients of change in CO_2 emissions, results from the Asia-Pacific Integrated Model

Table 1. Regions and sectors considered in dynamic EMEDA based on GTAP7.

Dynamic EMEDA		Country codes (GTAP7)
1	Japan	JPN
2	China	CHN
3	USA	USA
4	OECD8	AUS, NZL, CAN, AUT, BEL, CYP, CZE, DNK, EST, FIN, FRA, DEU, GRC, HUN, IRL, ITA, LVA, LTU, LUX, MLT, NLD, POL, PRT, SVK, SVN, ESP, SWE, GBR, TUR
5	FSU_EEurope	CHE, NOR, XEF, ALB, BGR, BLR, HRV, ROU, RUS, UKR, XEE, XER, KAZ, KGZ, XSU, ARM, AZE, GEO
6	OAsiaOceania	XOC, KOR, XEA, KHM, IDN, LAO, MMR, MYS, PHL, SGP, THA, VNM, XSE, BGD, IND, PAK, LKA, XSA
7	OAmerica	MEX, XNA, ARG, BOL, BRA, CHL, COL, ECU, PRY, PER, URY, VEN, XSM, CRI, GTM, NIC, PAN, XCA, XCB
8	Africa	IRN, XWS, EGY, MAR, TUN, XNF, NGA, SEN, XWF, XCF, XAC, ETH, MDG, MWI, MUS, MOZ, TZA, UGA, ZMB, ZWE, XEC, BWA, ZAF, XSC
Dynamic EMEDA		**Sector codes (GTAP7)**
1	Agriculture	PDR, WHT, GRO, PCR, V_F, OSD, C_B, PFB, OCR, CTL, OAP, RMK, WOL, CMT, OMT
2	Forestry	FRS
3	Fishing	FSH
4	Extraction	COA, OIL, GAS, OMN
5	Light Manufacturing	VOL, MIL, SGR, OFD, B_T, TEX, WAP, LEA, LUM, PPP, FMP, MVH, OTN, OMF
6	Heavy Manufacturing	P_C, CRP, NMM, I_S, NFM, ELE, OME, ELY, GDT, WTR, CNS
7	Transportation and Communication	TRD, OTP, WTP, ATP, CMN
8	Other Services	OFI, ISR, OBS, ROS, OSG, DWE

(AIM) are used (ICA-RUS [8]). GDP growth and population growth until the year 2100 under each SSP scenario are from the SSP database (IIASA [9]). CO_2 emissions until the year 2100 under RCP scenarios are from the RCP database (IIASA [10]).

In dynamic EMEDA, the value-added function with damage of global warming is as:

$$V_{jr,t} = \frac{1 - ACOST_{jr,t}\left(\mu_{jr,t}\right)}{1 + D_{r,t}\left(T_t, SLR_t, P_{r,t}\right)} F_{jr,t}\left(K_{jr,t}, L_{jr,t}\right), \tag{1}$$

where j is a sector, r is a region, and t is time. $F_{jr,t}(\cdot)$ is a value-added production function without global warming damages, $K_{jr,t}$ is capital, and $L_{jr,t}$ is labor. $ACOST_{jr,t}$ is a mitigation cost as a percent of GDP and $D_{r,t}(\cdot)$ is a sea level rise (SLR) and non-SLR damage function modified from RICE 2010 (Nordhaus [11]). A mitigation cost as a percent of GDP is as:

$$ACOST_{jr,t}\left(\mu_{jr,t}\right) = c_{jr,t}\sigma_{jr,t}\mu_{jr,t}^{2.8}, \tag{2}$$

where $\mu_{jr,t}$ is the rate of CO_2 emissions decline, $\sigma_{jr,t}$ is a CO_2 emissions coefficient and $c_{jr,t}$ is an EMEDA parameter of abatement cost functions. Damage function is as:

$$D_{r,t}\left(T_t, SLR_t\right) = a_{1,r}T_t + a_{2,r}T_t^2 + \left(b_{1,r}SLR_t + b_{2,r}SLR_t^2\right)\left(\frac{\sum_{k=1}^{n} V_{kr,t-1}}{\sum_{k=1}^{n} V_{kr,2004}}\right)^{0.25}, \tag{3}$$

where T_t is the rise in atmospheric temperature (in ˚C compared to the year 1900), SLR_t is the level of SLR caused by temperature rise (in meters compared to the year 2000), and $a_{1,r}$, $a_{2,r}$, $b_{1,r}$ and $b_{2,r}$ are parameters.

Following AD-DICE (de Bruin *et al.* [5]) and AD-RICE (de Bruin *et al.* [6]) models, modified damage function for adaptation is as:

$$D_{r,t}\left(T_t, SLR_t, P_{r,t}\right) = \left(1 - P_{r,t}\right)GD_{r,t}\left(T_t, SLR_t\right) + PC_{r,t}\left(P_{r,t}\right), \tag{4}$$

where $P_{r,t}$ is adaptation level, $GD_{r,t}$ is gross damage of global warming as a percent of GDP and $PC_{r,t}$ is adaptation cost as a percent of GDP. Gross damage of global warming as a percent of GDP is as:

$$GD_{r,t}\left(T_t, SLR_t\right) = \alpha_{1,r}T_t + \alpha_{2,r}T_t^{\alpha_{3,r}} + \left(\beta_{1,r}SLR_t + \beta_{2,r}SLR_t^{\beta_{3,r}}\right)\left(\frac{\sum_{k=1}^{n} V_{kr,t-1}}{\sum_{k=1}^{n} V_{kr,2004}}\right)^{0.25}, \tag{5}$$

where $\alpha_{1,r}$, $\alpha_{2,r}$, $\alpha_{3,r}$, $\beta_{1,r}$, $\beta_{2,r}$ and $\beta_{3,r}$ are parameters. These are natural extensions of the damage function in RICE 2010. Based on AD-DICE, adaptation cost as a percent of GDP is as:

$$PC_{r,t}\left(P_{r,t}\right) = \gamma_{1,r}P_{r,t}^{\gamma_{2,r}}, \tag{6}$$

where $\gamma_{1,r}$ and $\gamma_{2,r}$ are parameters. In this study, we set the SSP2, "middle-load" socio-economic scenario, as our standard scenario to simulate SSP-RCP combinations. We estimate all parameters, $\alpha_{1,r}$, $\alpha_{2,r}$, $\alpha_{3,r}$, $\beta_{1,r}$, $\beta_{2,r}$, $\beta_{3,r}$, $\gamma_{1,r}$ and $\gamma_{2,r}$, by minimizing the sum of discounted squared errors where the discount rate is three percent in the SSP2. Following de Bruin *et al.* [5] and Hsiang and Narita [12], we adopt several constraints for $PC_{r,t}$ $D_{r,t}$ and $P_{r,t}$: 1) $7\% \le PC_{r,2050}/D_{r,2050} \le 25\%$; 2) $0.1\% \le PC_{r,2050} \le 0.5\%$; 3) $0.3 \le P_{r,2050} \le 0.8$; and 4) $P_{r,2004} \le 0.3$. Table 2 shows the estimated parameters in the SSP2 scenario. Since the challenge of adaptation is different under SSP scenarios, we assume that $\gamma_{1,r}$ reflects the difference in adaptation technology of various SSP scenarios. For example, $\gamma_{1,r}$ is reduced (increased) by 30% in SSP1 (SSP3) compared to SSP2.

Table 2. Estimated parameters on adaptation for the SSP2.

	$\alpha_{1,r}$	$\alpha_{2,r}$	$\alpha_{3,r}$	$\gamma_{1,r}$	$\gamma_{2,r}$	$\beta_{1,r}$	$\beta_{2,r}$	$\beta_{3,r}$
Japan	0.001111	0.001328	2.572	0.081668	5.569	0.001985	0.000000	2.798
China	0.000320	0.000433	3.427	0.104324	4.719	0.04574	0.000000	1.475
USA	0.001514	0.000773	2.903	0.043936	5.054	0.000638	0.000000	2.469
OECD8	0.000734	0.001404	2.426	0.415125	6.617	0.01580	0.000000	2.503
FSU_EEurope	0.001537	0.000536	3.119	0.028435	4.673	0.000903	0.000000	3.072
OAsiaOceania	0.005226	0.000656	3.201	0.067599	4.318	0.007832	0.007515	6.765
OAmerica	0.002263	0.000867	2.718	0.07174	5.243	−0.000062	0.000000	1.970
Africa	0.006196	0.000375	3.604	0.049928	3.023	0.006252	0.021050	7.477

3. Results

We analyze three SSP and two RCP combination scenarios with business as usual (BaU) scenario, a reference scenario in which no region reduces CO_2 emissions: SSP1-RCP2.6, SSP1-RCP4.5, SSP1-BaU, SSP2-RCP2.6, SSP2-RCP4.5, SSP2-BaU, SSP3-RCP2.6, SSP3-RCP4.5 and SSP3-BaU. Then, we discuss the 1.5˚C target case under SSP2 scenario, which is SSP2-1.5˚C.

The path of temperature rise in SSP1-BaU, SSP2-BaU, SSP3-BaU, SSP2-RCP2.6 and SSP2-RCP4.5 are shown in **Figure 1** left. The highest temperature rise scenario is SSP3-BaU, in which temperature rises by about 4˚C in the year 2100. In the case of SSP2-RCP2.6, temperature rises are moderate with an increase of around 2˚C. In SSP2-RCP4.5, temperature rise amounts to about 2.8˚C above 1900 temperatures by the year 2100. There is little difference in sea level rise across scenarios until about 2070, when changes of different magnitudes start to be seen (**Figure 1**, right).

3.1. Regional Optimal Adaptation Level

Each region executes adaptation for reducing the total damages from climate change. An optimal adaptation level of a region is defined as that which a region chooses for minimizing its total damages from climate change with respect to an adaptation level. Therefore, we obtain optimal adaptation levels by region at time t by minimizing the modified damage function $D_{r,t}(\cdot)$ with respect to adaptation level $P_{r,t}$ (de Bruin *et al.* [5]). SSP-RCP combination optimal adaptation levels in EMEDA are shown in **Figure 2**. Our model shows higher damages from climate change compared to AD-DICE. This is because we use climate module, damage function and cost function with the latest pathways.

In each scenario, adaptation level increases as temperature rises because of increment of gross damage of climate change. Focusing on RCP scenarios, the optimal adaptation level in RCP2.6 is lower than that of BaU, since global warming damages are lower in RCP2.6. In the year 2100, the optimal adaptation level ranges from 0.4 to 0.7 in the BaU, from 0.3 to 0.5 in the RCP2.6 and from 0.4 to 0.6 in the RCP4.5. This indicates that gross damages by global warming are

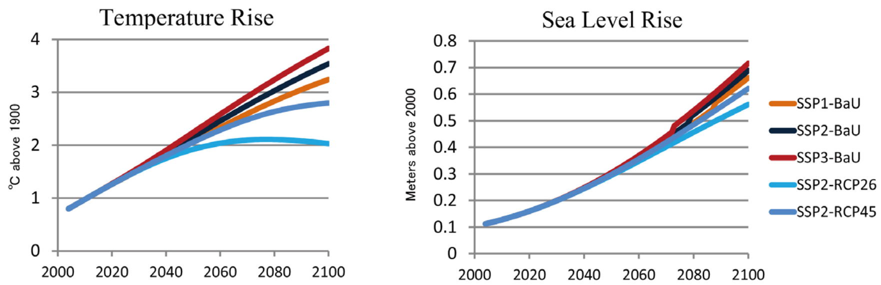

Figure 1. Left: temperature rise (˚C above 1900) and Right: sea level rise (meters above 2000).

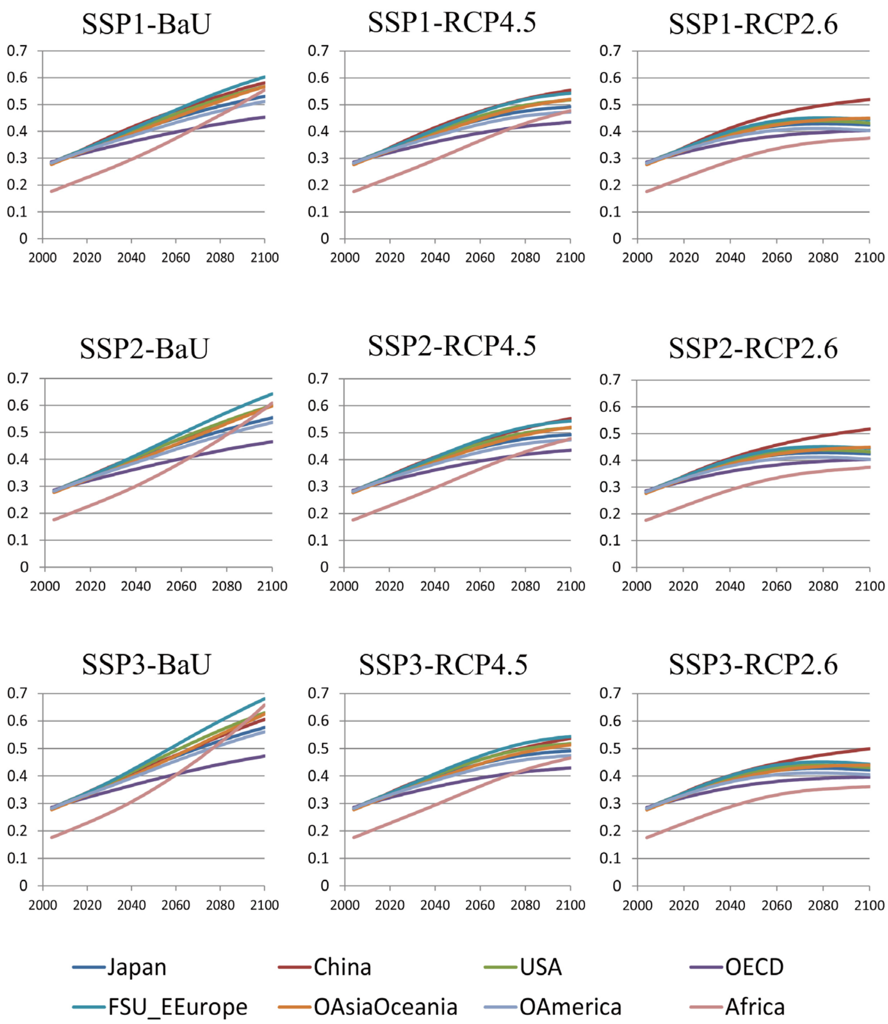

Figure 2. Adaptation levels by SSPs-BaU, -RCP4.5 and -RCP2.6 scenarios.

reduced by approximately half though adaptation. Under BaU, the optimal adaptation level in SSP1 is lower than in SSP2 while higher in SSP3. However, RCP2.6 and RCP4.5 scenarios are less different among SSPs because reduction in CO_2 emissions largely affects SSP scenarios.

Comparing regions, the optimal adaptation level in Africa is lower than other regions in the year 2100 under SSP2-BaU. Changes in adaptation levels are faster in Africa since they have rapid economic development and population growth.

OECD countries also have lower adaptation levels because the costs of adaptation are higher (**Figure 3**). Interestingly, the optimal adaptation level in China is higher in several scenarios since China suffers more damages from sea level rise.

3.2. Regional Adaptation Costs

In the results of adaptation costs, we mainly discuss the SSP2-combination scenarios: SSP2-BaU, SSP2-RCP4.5 and SSP2-RCP2.6. SSP2-RCP2.6 is the 2.0˚C target scenario achieving the CO_2 emissions reductions proposed by the Paris Agreement, while SSP2-RCP4.5 is the most modest CO_2 emissions reduction scenario among all SSP2-combination scenarios.

Regional adaptation costs in SSP-RCP4.5, SSP2-RCP2.6 and SSP2-BaU are shown in **Figure 3**. Large regional differences in adaptation costs can be found in SSP2-BaU. Adaptation costs in OAsiaOceania and Africa amount to more than one percent of GDP in the year 2100 while those in Japan, USA, OECD8, FSU_EEurope and Latin America are less than 0.5 percent of GDP. This indicates that adaptation costs in developing countries are higher than in other countries. This is consistent with adaptation funds for developing countries in the Paris Agreement (UNFCCC [13]) and similar to AD-RICE results (de Bruin *et al.* [6]). There are smaller regional differences in SSP2-RCP2.6. Chinese adaptation costs are higher than in other regions because of higher damages from sea level rise. In SSP2-RCP4.5, there are some differences among regions. Adaptation costs in Africa, China, and OAsiaOceania are higher than other regions while the costs in Africa, China, and OAsiaOceania are less than one percent of GDP in the year 2100.

Figure 4 shows global total damages and costs (TOTAL), mitigation cost (MTGC), adaptation cost (ADPC), gross damage without adaptation (GDMG), reduced damage with adaptation (RDMG) in SSP2-BaU, SSP2-RCP2.6 and SSP-RCP4.5, respectively. Reduced damage with adaptation is calculated by the product of gross damage and adaptation level. Total damages and costs are given by the sum of mitigation cost, adaptation cost and reduced damage with adaptation. Compared to adaptation cost, reduced damage of climate change in SSP2-BaU is more than double adaptation cost in SSP2-BaU. Total damages and costs in SSP2-RCP2.6 are more than in other scenarios because of higher mitigation cost. That is, CO_2 emissions reduction with adaptation in SSP2-RCP2.6 creates a great burden to the world. Total damages and costs in SSP2-RCP4.5 are slightly more than that in SSP2-BaU because of higher mitigation cost.

3.3. Aggressive Adaptation for the 1.5˚C Target

Finally, we consider the SSP2-1.5˚C combinations scenario by calculating aggressive adaptation level using revised AD-DICE (ICA-RUS [8]) temperature path of SSP2-1.5˚C. The aggressive adaptation level is defined as adaptation level under the CO_2 emissions path of SSP2-RCP2.6 which keeps reduced damage of

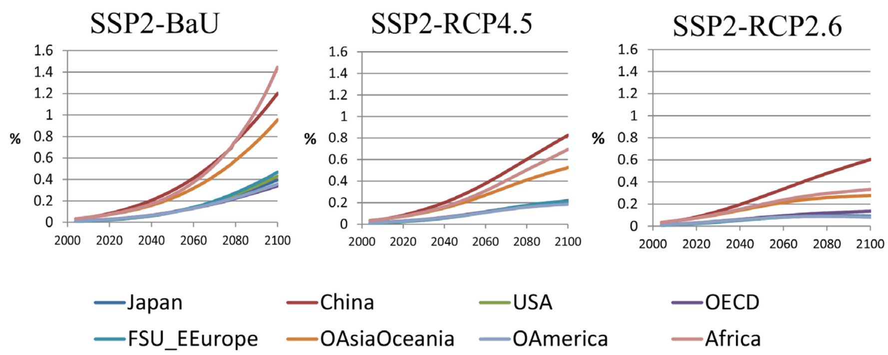

Figure 3. Regional adaptation costs of the world (percent of GDP) of SSP2-BaU, -RCP4.5 and -RCP2.6 scenarios.

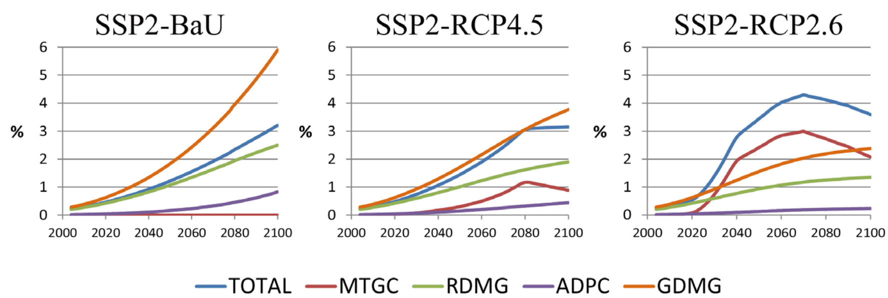

Figure 4. Mitigation and adaptation costs of the world (percent of GDP) of SSP2 scenarios in BaU, RCP4.5 and RCP2.6.

climate damage below the climate damage calculated by the temperature path of SSP2-1.5˚C and the damage function given by Equation (3).

Regional adaptation levels and costs in SSP2-1.5˚C are shown in **Figure 5**. We find that SSP2-1.5˚C requires more adaptation levels than other SSP2 combination scenarios (**Figure 3**) even if CO_2 emissions in SSP2-RCP2.6 can be attained. The adaptation level of each region peaks around the year 2070 since the damages from global warming in SSP2-1.5˚C increase slower than in SSP2-RCP2.6. Compared to SSP2-BaU, aggressive adaptation level in SSP2-1.5˚C is higher than optimal adaptation level in SSP2-BaU. This means that under the 1.5˚C target each region pays more adaptation costs than in the cases of high temperature rise. Interestingly, regional adaptation level in SSP2-1.5˚C tends to be higher in Japan, USA and Latin America than OAsiaOceania, China and Africa. This tendency is different to other SSP2 scenarios. One reason is that damage from climate change in developed countries increase more rapidly as temperature rises from 1.5˚C to 2.0˚C.

Most regional adaptation costs in SSP2-1.5˚C are higher than in SSP2-BaU, SSP2-RCP4.5 and SSP2-RCP2.6. For example, it amounts to more than one percent of GDP in the 2070s in Japan and FSU. In addition, adaptation cost of OECD8, including EU, amounts to about one percent of its GDP in 2070s. One reason for these high costs is that their economic growth rates are lower than other regions. If a strong target is attained by adaptation, in a region with lower economic growth, adaptation costs are relatively higher.

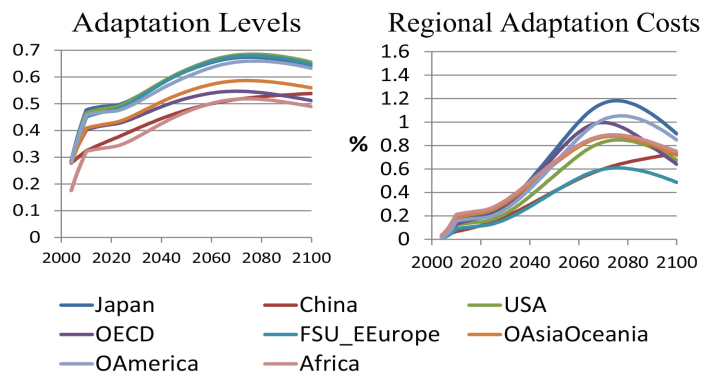

Figure 5. Adaptation levels and regional adaptation costs (percent of GDP) in the SSP2-1.5˚C scenario.

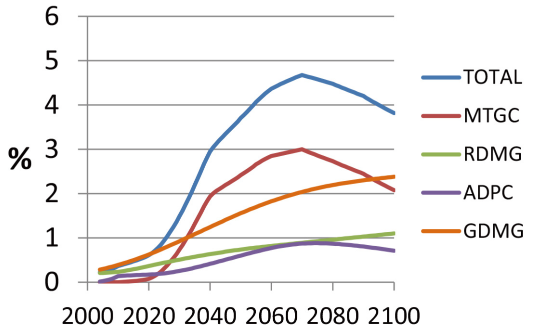

Figure 6. Damages of climate change, mitigation and adaptation costs of the world (percent of GDP) in the SSP2-1.5˚C scenario.

Damages from climate change, mitigation costs and adaptation costs in SSP2-1.5˚C of the world are shown in Figure 6. The difference between adaptation costs and reduced damages in SSP2-1.5˚C is smaller than in other SSP2 combination scenarios. This indicates that under the 1.5˚C target adaptation costs are high in addition to high mitigation costs for the SSP2-RCP2.6. Therefore, when considering a strong target, it is important to calculate both adaptation costs as well as the costs of damage from global warming.

4. Conclusions

This research examines regional impacts of adaptation to climate change under the Paris Agreement using a multi-sector model with SSP-RCP combination scenarios.

We firstly find that adaptation costs of Asia and Africa in the 2.0˚C target are higher compared to the other regions in the 2.0˚C target. Thus, some developing countries would have to pay higher adaptation costs than other countries.

The adaptation costs of Japan, EU and Latin America, which are higher than in other countries, amount to one percent of GDP under the SSP2-1.5˚C scenario. This indicates that with the 1.5˚C target, these regions would have higher adaptation costs in comparison to the 2.0˚C target.

To achieve the goal of the Paris Agreement, we need to know not only mitigation costs, which many IAM researchers have simulated, but also adaptation costs. There are large differences among regional adaptation costs which vary by climate change target scenario. Therefore, we should consider both mitigation and adaptation costs for executing policies for challenging climate change.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Intergovernmental Panel on Climate Change (IPCC) (2014) Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment. Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

[2] van Vuuren, D.P., Kriegler, E., O'Neill, B.C., Ebi, K.L., Riahi, K., Carter, T.R., Edmonds, J., Hallegatte, S., Kram, T., Mathur, R. and Winkler, H. (2014) A New Scenario Framework for Climate Change Research: Scenario Matrix Architecture. *Climatic Change*, **122**, 373-386. https://doi.org/10.1007/s10584-013-0906-1

[3] Hope, C., Anderson, J. and Wenman, P. (1993) Policy Analysis of the Greenhouse Effect: An Application of the PAGE Model. *Energy Policy*, **21**, 327-338. https://doi.org/10.1016/0301-4215(93)90253-C

[4] Rosenzweig, C. and Parry, M.L. (1994) Potential Impact of Climate Change on World Food Supply. *Nature*, **367**, 133-138. https://doi.org/10.1038/367133a0

[5] de Bruin, K.C., Dellink, R.B. and Tol, R.J.S. (2009) AD-DICE: An Implementation of Adaptation in the DICE Model. *Climatic Change*, **95**, 63-81. https://doi.org/10.1007/s10584-008-9535-5

[6] de Bruin, K.C., Dellink, R.B. and Agrawala, S. (2009) Economic Aspects of Adaptation to Climate Change: Integrated Assessment Modelling of Adaptation Costs and Benefits. OECD Environment Working Papers 6. http://www.oecd-ilibrary.org/environment/economic-aspects-of-adaptation-to-climate-change_225282538105

[7] Sakaue, S., Yamaura, K. and Washida, T. (2015) Regional and Sectoral Impacts of Climate Change under International Climate Agreements. *International Journal of Global Warming*, **8**, 463-500. https://doi.org/10.1504/IJGW.2015.073051

[8] (2015) The Human Choices to Climate Change Risk of Global Scale. Integrated Climate Assessment-Risks, Uncertainties and Society (ICA-RUS). (In Japanese) http://www.nies.go.jp/ica-rus/report/version1/index.html

[9] International Institute for Applied Systems Analysis (IIASA) (2013) Shared Socio-Economic Pathway Database. *SSP Database*. https://secure.iiasa.ac.at/web-apps/ene/SspDb

[10] International Institute for Applied Systems Analysis (IIASA) (2013) Representative Concentration Pathways Database. *RCP Database*. http://tntcat.iiasa.ac.at/RcpDb/dsd?Action=htmlpage&page=welcome

[11] Nordhaus, W.D. (2010) Economic Aspects of Global Warming in a Post-Copenhagen Environment. *PNAS*, **107**, 11721-11726. https://doi.org/10.1073/pnas.1005985107

[12] Hsiang, S.M. and Narita, D. (2012) Adaptation to Cyclone Risk: Evidence from the Global Cross-Section. *Climate Change Economics*, **3**, Article ID: 1250011. https://doi.org/10.1142/S201000781250011X

[13] (2015) Adoption of the Paris Agreement. United Nations Framework Convention on Climate Change (UNFCCC). https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf