Asian Journal of Innovation and Policy (2020) 9.1:036-055
DOI: https://doi.org/10.7545/ajip.2020.9.1.036

A Conceptual Approach to Evaluating the Reliability of a Climate Change Adaptation System

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Abstract Climate change is one of the most discussed issues in international for a today. Evaluating the effect of climate change at a regional level and setting up an appropriate policy to address the issues associated with climate change require a proper evaluation process on the climate change and adaptation projects already implemented. Although various evaluation approaches to climate change adaptation programs have been proposed, it is rare to find a proper systematic approach to evaluating the reliability of those climate change adaptation programs. In the current situation regarding the system to evaluate climate change adaptation programs, the purpose of this study is to suggest a theoretical and standardized evaluation system on the reliability of climate change adaptation schemes. The new approach suggested in this paper will be appropriate when requiring a confidence level for adaptation programs that are specially localized and categorized. Using various quantitative and qualitative evaluation methods with the inherent reality mechanism, we provide a conceptual framework to measure the reliability of climate change adaptation programs with a flexible adjustment process. With the proposed framework, it is possible to provide the level of confidence on the results collected from the evaluation systems and construct a standardized, system-wide assessment procedure toward climate change adaptation policies. By applying this approach based on scientific evidence on the reliability of climate change adaptation policies, appropriate and efficient climate change adaptation programs will be properly designed for and implemented in Korea.

Keywords Climate change, adaptation, reliability, evaluation method, inherent reality mechanism.

Submitted, April 4, 2020; Accepted, April 10, 2020
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I. Introduction

1. Emergence of a New Climate Regime

Since climate change has emerged as a global issue, world leaders signed the United Nations Framework Convention on Climate Change (UNFCCC) at the United Nations Conference on Environment and Development (UNCED) in June 1992. This is considered the first global effort to respond to climate change. The UNFCCC objective was to "stabilize greenhouse gas concentrations in the atmosphere at levels that would prevent dangerous anthropogenic interference with the climate system." The convention listed equity, common but differentiated responsibilities, and respective capabilities as its guiding principles.

The UNFCCC did not specify a particular implementation process to carry out these greenhouse gas (GHG) reduction obligations. However, the Kyoto Protocol, which was adopted in December 1997, specifies the list of GHGs to be reduced, the countries that would carry out the reduction obligations, and the reduction amounts for each country. The Kyoto Protocol introduced market elements such as joint implementation, clean development mechanisms, and emission trading schemes to help effectively achieve the reduction goals at a low cost. This is significant because it laid the foundation for a global climate change response by an international treaty that states the obligations of developed countries to reduce GHG emissions.

The efforts of the international community to respond to climate change after the Kyoto Protocol led to the signing of the UNFCCC Paris Agreement in December 2015, launching the New Climate Regime. The 195 contracting parties adopted a final agreement that established a climate change response system and agreed to actively reduce GHGs. Both developed and developing countries participated in the discussions about the New Climate Regime; the comprehensive discussions included various relevant factors such as climate change adaptation, finance, technology, capacity building, and transparency, in addition to GHG reduction. The New Climate Regime has, thus, introduced a system in which states determine their own efforts to reduce greenhouse gases.

2. Domestic and international responses to climate change

At the 21st session of the UNFCC Conference of the Parties (December, 2015), all parties agreed to limit the rise of the global average temperature to less than 2 ℃. All parties were requested to submit plans for climate change adaptation, because this is a critical issue, as important as GHG reduction efforts. As the global climate change response strategy is shifting from the leadership of

developed countries to a universal response system in which all countries participate, the international community is striving to build a sustainable environment by reducing the dependency on fossil fuels and by introducing efficient GHG reduction measures to energy supply and demand plans.

South Korea is also experiencing changing climate patterns, such as rising annual average temperatures and sea levels, and damage due to increasing climate change. To cope with this, both central and local governments are preparing policies that include climate change adaptation measures. For national plans related to climate change adaptation, according to the Framework Act on Low Carbon Green Growth, the Ministry of Environment and related departments jointly established the First National Climate Change Adaptation Measures (2011–2015) and the Second National Climate Change Adaptation Measures (2016–2020). At the local government level, 16 regional local governments nationwide established the Detailed Implementation Plan for Climate Change Adaptation Measures, while 35 basic local governments nationwide established detailed implementation plans as pilot projects (Park et al., 2016).

As part of the legal adaptation measures in the First National Climate Change Adaptation Measures, 14 departments analyzed climate change vulnerabilities in agriculture and fisheries, health, ecosystems and infrastructure, and achieved results such as management strengthening and establishing local government measures (17 regional and 168 basic local governments). The Second National Climate Change Adaptation Measures complemented the insufficient sections in the first measures, strengthening the connections and integration of different fields that are based on scientific climate change risk analyses. In addition, the second measures reflected the emphasis of the importance of climate change adaptation in the international community and changing domestic circumstances, such as a rapidly aging population and increasing demographic issues due to low birthrates.

3. Climate change measures and evaluation

Many countries around the world are preparing and implementing various measures to respond to the expected impacts of climate change. However, in order to achieve the goals of these response measures on long-term impacts, it is necessary to establish an iterative system that reflects improvements through an evaluation of the response measures. Climate change response measures have only recently been discussed in earnest, and there are few cases of practical applications so far. Therefore, publications related to evaluating climate change adaptation policies are limited. Moreover, quantitative data that can be used to evaluate these policies have not been sufficiently accumulated and few proposals for evaluation methodologies have been made.

In light of the lack of quantitative data for evaluation and actual application cases of response measures, when climate change-related measures are evaluated, deriving the results of the response measures and the conditions or situations in which the measures operate smoothly need to be considered. This is crucial because the comprehensive nature of climate change response measures will affect the entire society. Furthermore, the evaluation method for the adaptation measures should also include reliability evaluation, so the adaptation measures can be established and implemented properly. Therefore, this study proposes a reliability evaluation methodology that is related to the specific adaptation measures.

In the next chapter, we will briefly explain the changing process of climate change adaptation policies and examine representative evaluation methods. Because consideration of uncertainties is required for this type of evaluation, we will examine the need for reliability in the evaluation of the climate change measures. Finally, we propose a reliability evaluation model.

II. Climate Change Adaptation and Policies

1. Climate change adaptation

Climate change adaptations include all ecosystem or socioeconomic system responses that occur in order to adapt to changes in climate conditions. It also includes measures that directly reduce climate change damage and measures that indirectly reduce climate change damage by enhancing future adaptability. Adaptation is recognized as a key issue in domestic and international discussions related to climate change; the term and concept have been discussed in the context of the IPCC reports and the UNFCCC, and are being applied widely. Adaptation processes can reduce the number of situations that are at risk due to climate change and can also increase the amount of opportunities to actively respond to climate change. Hence, we can mitigate the impacts of climate change by using adaptation measures (Chae & Cho, 2011). In particular, successful adaptation is a process that generates short- and long-term net benefits to society with no net losses in social welfare. Successful adaptation to climate change requires adjustments that reduce vulnerabilities or risks related to climate change at a pre-determined level, while maintaining sustainable social, economic, and environmental conditions (Doria et al., 2009).

2. Impacts of climate change and adaptation policies

The impacts of climate change may differ between regions or classes due to the differing social, economic, and environmental conditions experienced by members of different regions and classes. Their vulnerabilities to climate change impacts also differ. The influence of climate change impacts on social and natural ecosystems, such as heat waves, droughts, floods, typhoons, and forest fires, is generally increasing over time. These impacts tend to accelerate vulnerabilities to climate change by causing secondary and tertiary damage. Although climate change phenomena occur globally, the extent of their impacts and the capabilities of countries to respond to such impacts differ. Moreover, the risks and opportunities of climate change differ by region. Therefore, we need to closely examine the differences between the effects using a strict analysis of climate change adaptation measures.

Article 7 Paragraph 1 of the Paris Agreement calls on the parties to enhance adaptive capacities, strengthen resilience in damage situations, and reduce vulnerabilities to climate change. Furthermore, Article 7 Paragraph 5 emphasizes that adaptation actions should follow a transparent country-driven approach, taking into consideration vulnerable groups, communities, and ecosystems. It also mentions that the adaptation actions should be guided by the best available science, traditional knowledge, and local knowledge systems, with the intent of integrating adaptation into relevant socioeconomic and environmental policies and actions.

Climate change adaptation policies involve various joint measures that are required for adaptation concurrently with mitigating the influence of climate change. Managing the risks of climate change, while also considering the economic and ecological environments of future generations and strengthening resilience in the event of damage, is considered important for climate change adaptation policies. Therefore, in order to establish effective climate change adaptation measures, it is necessary to approach them from a perspective that considers all social areas combined, rather than targeting only specific social areas. In addition, many experts and stakeholders, including individuals, social groups, and governments, should participate and make an effort to reach a consensus regarding adaptation measures. All adaptation measures should reflect the social, economic, and environmental factors and various situations in the relevant region.

The IPCC Climate Change Reports on academic research results written by experts can be used at a glance to identify changes in policy decisions over time. Until the third IPCC Climate Change Report (IPCC, 2001) was published, discussions on climate change response policies for countries around the world had focused on GHG reduction. However, after the fourth IPCC Climate Change

Report (IPCC, 2007), the importance of a system that interconnects GHG reduction and climate change adaptation was emphasized. In particular, the fifth IPCC Climate Change Report (IPCC, 2014) derived common benefits of GHG reduction and climate change adaptation by linking efforts at the local level with sustainable development concepts. Thus, when GHG reduction and climate change adaptation projects are implemented at local levels, they can cultivate the capacity to respond to climate change during the implementation process and the importance of information and systems ultimately attracts attention. Moreover, the need for an integrated approach to the systems that implement GHG reduction and climate change adaptation projects is also emphasized, thus spreading climate change adaptation policies that integrate efforts at local and national levels (Hwang & Kim, 2016).

III. Evaluation Methodology for Adaptation Measures

Given the uncertainties involved in predicting climate change and analyzing vulnerabilities as well as distinct adaptation policy characteristics, even if we analyze climate change impacts using data available at the time and establish adaptation measures based on the results, the risks associated with climate change still remain a challenge to be addressed. Therefore, the process of evaluating climate change adaptation measures should be approached differently from general policy evaluation processes (Chae & Cho, 2013). There are three grounds for this claim. First, it is difficult to calculate the expected future benefits when climate change adaptation measures are implemented. Second, when the policy project scale is an individual unit project or a combination of individual unit projects, scientific and systematic evaluation of these projects is difficult. Third, climate change impacts can differ by region and sector. The priorities of climate change adaptation measures can also differ by region and sector, even if they have the same policy goals.

1. Need for evaluation of climate change adaptation measures

To actualize effective policies while minimizing the uncertainties that accompany adaptation measures to climate change impacts that will occur far in the future, requires a rational and scientific process for evaluating the adaptation policies. Therefore, the adaptation measures need to be measured in terms of whether they are cost-effective or how much of an adaptation effect they have.

The objective of evaluating the adaptation measures is to identify and evaluate all possible measures in order to prevent wasted human and material resources

that are invested for reducing current and future vulnerabilities to climate change using specific adaptation strategies and policies (Chae et al., 2012). Hence, proper evaluation of the climate change adaptation strategies or policies is crucial because it allows us to predict future changes in society. Furthermore, all responses that occur in the policy adjustment process that reinforce elasticity while reducing vulnerability should be referenced during the evaluation process so actions to increase the expected benefits of climate change are included in the evaluation of adaptation measures (Rodel & Rizaldi, 2006).

The major characteristics of the evaluation process for climate change adaptation measures are as follows (Chae et al., 2016). First, climate change adaptation measures include various social, environmental, and economic data related to the impacts of climate change. In most cases, basic information such as the current status of the relevant system, stress factors, and climate trends in the target area should be identified before establishing any adaptation measures. Second, it is difficult to determine if the objectives of the adaptation measures were achieved and to collect the relevant results. Because many of the expected benefits of adaptation measures occur in a long-term scale, there are uncertainties in measuring immediate achievements from the implemented adaptation measures and in predicting long-term adaptation effects. Moreover, the evaluation targets of major policies are often large projects, making it more difficult to collect achievements or identify concrete results than for other measures. Third, the priorities of adaptation measures can vary by sector and region. Therefore, when a budget is allocated to a certain project, the relevance of the evaluation method to determining whether the project was cost-effective or how many achievements were made should be examined in detail by region and sector.

To evaluate climate change adaptation measures, we need to utilize an integrated perspective by combining expert skills regarding policy evaluation and broad climate change knowledge. In other words, it is crucial to prepare standards and systems for the evaluation method in order to carry out the adaptation measures efficiently. There are limitations to evaluating climate change adaptation measures that produce uncertainty over a long period when using existing policy evaluation systems. Thus, to establish and implement efficient adaptation measures with a limited budget, we should systematically analyze the implementation times, costs, and effects of various adaptation alternatives before constructing a system that can evaluate the results (Chae et al., 2012). Furthermore, because the scope, characteristics, and available data regarding climate change impacts differ by region and section, the availability of climate change impact data and the distinctiveness of adaptation measures should be managed systematically by region and sector when evaluating the adaptation measures.

2. Evaluation methodology for climate change adaptation measures

2.1 Domestic research case: Priority evaluation method

Because quantitative data regarding climate change adaptation measures are limited, we can use evaluation metrics that provide a basis for judging the degree to which goals were achieved and the status of adaptation measures. To derive appropriate evaluation metrics, we should consider techniques that reflect the opinions of stakeholders and experts in various fields in a comprehensive manner. Even though methodological limitations exist, we can statistically extract common factors based on the values of each item and assign appropriate weights to the evaluation metrics. In addition, it is also important to include the systematic integration process of various evaluation metrics in the development of the evaluation model. However, because policy evaluations are performed multilaterally, it is appropriate to examine both qualitative and quantitative methods when deciding the importance of evaluation metrics that may intersect each other. The biggest differences between these two evaluation methods are whether the data are partitioned and how to use the data.

Qualitative evaluation methods applied to a priority evaluation of climate change adaptation measures include the analytic hierarchy process (AHP), multi-attribute utility theory (MAUT), fuzzy theory, and fuzzy-AHP analytical methods. Quantitative evaluation methods include climate change impact evaluation, climate change vulnerability evaluation, cost-benefit analyses, cost effectiveness analyses, and primary component analyses (PCA) (Chae & Cho, 2011). In addition, network theory or various econometric methods can be used, depending on the amount and characteristics of the available data (Kang et al., 2018; Park & Cho, 2015).

The evaluation metrics that should be considered when evaluating climate change adaptation measures are as follows. To consider the distinctiveness of the adaptation measures, we selected changing risk, policy, and sustainability as representative evaluation metrics. For detailed metrics of climate change risk, we selected damage occurrence time, damage occurrence possibility, and damage intensity. For detailed metrics of policy, we selected equity, consistency with existing policies, and democracy. For detailed metrics of sustainability, we selected economic sustainability, additional effects, and democracy. This method was designed to combine qualitative and quantitative evaluation systems for each selected metric and to use different evaluation systems for selecting priorities.

2.2 UNDP research case: realistic review for program evaluation

To examine the global effects of climate change adaptation measures, we performed a meta-analysis of the final evaluation reports from the Climate

Change Adaptation (CCA) programs in Armenia, Egypt, Malawi, Mozambique, Namibia, Philippines, Tanzania, Turkey, and Zimbabwe. For the meta-analysis tool, we used the realistic review method (UNDP, 2015), which is used to find the CMO (C: Context, M: Mechanism, O: Outcome) configuration according to the realistic review procedure, establish hypotheses, and select appropriate evaluation criteria.

CMO configuration refers to investigating inherent mechanisms (M) and contexts (C) to determine the achievement of an outcome (O) for the adaptive measure selected by a realistic evaluator. It has the advantage of being comparable with the deterministic evaluation approach, which finds a specific mechanism to calculate a fixed result. The deterministic approach considers that the adaptation policy evaluation mechanism can be effectively applied regardless of the situations faced by individual entities. However, this has the disadvantage of discussing whether to ignore the importance of context for policy makers. By contrast, the CMO configuration is based on a procedure in which the program activities can yield successful results when appropriate ideas and opportunities (mechanisms) can be introduced to a specific group of people in an appropriate sociocultural context. In the CMO configuration, a mechanism (M) indicates a causality that can be generated by a program or action. A mechanism can be regarded not as an action, but an important variable in a system or method that causes organizational changes.

As a result of analyzing 577 item-wise evaluation opinions from the CCA programs of the above-mentioned nine countries, four evaluation criteria of 'relevance', 'efficiency', 'effectiveness', and 'sustainability' were applied for the CMO configuration. Finally, the methodological implications and recommendations about the program were presented in the evaluation results. Through this analysis, major program activities that created results in specific situations and the resulting change mechanism were verified. However, the realistic analysis is not perfect and it is impossible to adhere to all realistic principles. The designs and implementations of individual CCA programs were very complex and attention needs to be paid to the individual situational conditions as well. Therefore, when applying the CMO configuration, each situation should be explored systematically so that the description and implications according to the realistic review can be considered useful.

Table 1 Summary of evaluation methodology cases of climate adaptation measures

	Priority evaluation methodology for climate change adaptation measures (Domestic research case)	Realistic review for climate change adaptation program evaluation (UNDP research case)
Methodology	**Qualitative methodologies** - Analytic hierarchy process (AHP) - Multi-attribute utility theory (MAUT) - Fuzzy-AHP method **Quantitative methodologies** - Climate change impact: vulnerability evaluation - Cost-benefit (B/C): cost effectiveness analysis - Primary component analysis (PCA)	**Realistic review methodology** - CMO (C: Context, M: Mechanism, O: Outcome) configuration - A process of investigating all the inherent mechanisms (M) and contexts (C) to determine whether or not the outcome (O) of the adaptive measure selected by a realistic review has been attained.
Main evaluation factors	**Climate change risk:** damage occurrence time, damage occurrence possibility, damage intensity **Climate change policy:** equity, consistency with existing policies, democracy **Climate change sustainability:** economic sustainability, additional effects, democracy	Relevance Efficiency Effectiveness Sustainability
Characteristics	- Apply various quantitative and qualitative evaluation methodologies for evaluating the metrics - Network analysis and various econometric methodologies can be applied.	- Apply the realistic review method to the meta-analysis of each program. - Reflect reality that considers the situation or conditions under which the situation or conditions are derived are considered through CMO configuration.

IV. Evaluation System and Reliability of Adaptation Policies

To appropriately establish climate change adaptation measures and evaluate their effects, it must be possible to solve the reliability problem related to evaluation. This means that the reliability must be determined in order to build a scientific evaluation system for various integrated models developed for

climate change adaptation policies. The evaluation system reliability problem occurs when a new evaluation tool or new norms are introduced. Accordingly, we proposed a methodology for determining the reliability of an adaptation policy evaluation system that used qualitative/quantitative methodologies applied to climate change adaptation policies. A newly-introduced system can generally have a variety of unexpected risks. Hence, including a reliability evaluation process in an adaptation policy evaluation system enables verification of the evaluation system and the relevance and effectiveness of the results. Therefore, in this study, we devised a method for verifying the reliability when building an evaluation system for climate change adaptation policies that is based on a research case for the development, verification, and upgrade of an integrated evaluation decision support tool for constructing the basis of an integrated evaluation model for the impact and vulnerability of climate change by sector, the development of utilization technology, and the selection of climate change adaptation policies, which is currently in progress in the Ministry of Environment. The purpose of this particular project is to develop environmental technologies to respond to climate change. In addition, we investigated a method to pursue the completeness of the evaluation system research related to climate change.

1. Adaptation policy evaluation system and reliability model

The reliability evaluation model for climate change adaptation policies that is proposed in this study is designed to compare the evaluation results of the adaptation policy evaluation system with the reliability evaluation results. Furthermore, the model is designed to verify reliability through a self-testing process by applying actual evaluation results from the adaptation policy evaluation system to the reliability evaluation model. Figure 1 shows the overall structure of this reliability evaluation model for the adaptation policy evaluation system.

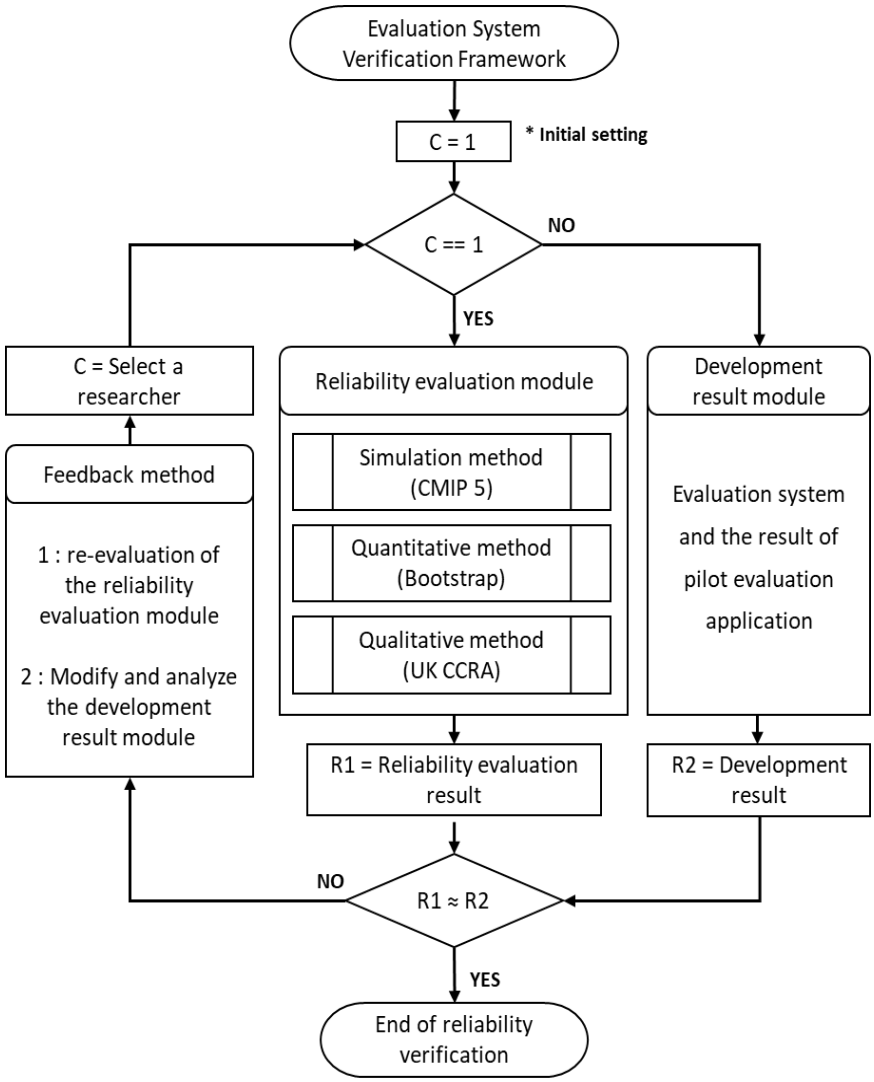

Figure 1 Reliability evaluation model system of climate change adaptation policies

One of the important considerations in the design of the reliability evaluation model is its flexibility for easy application to new evaluation methods. When considering the uncertainty of climate change, we strived to improve the integrity of the reliability evaluation model by complementing insufficient parts with continuous follow-up research that considered the uncertainty of climate change. Therefore, we need a system to update the reliability evaluation model

by reflecting the climate change vulnerability evaluation results by sector. To this end, we designed each part of the evaluation model as a module such that the changes in individual models cannot affect the total reliability evaluation model. The overall consistency was maintained while securing the flexibility and scalability of the model through partial modular processing. We configured the reliability evaluation method for the adaptation policy evaluation system by combining simulations, quantitative methods, and qualitative methods, which are briefly explained in the following section.

2. Reliability evaluation method for adaptation policy evaluation model

2.1 Simulation methodology

This is a reliability evaluation method that combines simulation techniques based on the RCP scenario first introduced in the fifth IPCC Climate Change Report. The RCP scenario is closely associated with the evaluation of climate change adaptation policies and is considered to play a key role in recent climate change research.

When future climate change risks and impacts are analyzed, the future prospects for each RCP scenario can be presented by using the Coupled Model Intercomparison Project Phase 5 (CMP 5) (IPCC, 2014). The risk reliability is evaluated in the process of deriving future prospects using the multi-model average method included in the CMP 5. The multi-model average method in the CMP 5 integrates more than 20 existing climate change models, selecting the appropriate models according to the future prospecting purpose of the researcher. Then, it averages the prospects of each model and presents the results with the distribution range (Taylor et al., 2012).

2.2 Quantitative methodology

The quantitative methodology evaluates reliability by using the big data analysis method, which uses non-standard data as well as existing quantified data and a bootstrapping method that generates new data by re-samples the data several times. The reliability of the adaptation policy evaluation model is evaluated by comparing the adaptation policy evaluation results derived by the researcher with the results derived using the bootstrapping method.

2.3 Qualitative methodology

Qualitative evaluation plays the role of evaluating the influence of climate change, based on local phenomena being evaluated, or complementing the limitations of the quantitative analysis. Therefore, studies often evaluate only specific cases in each region or sector individually. In this study, we proposed a systematic approach using analyses of complex social phenomena in diverse and

in-depth ways, which is an advantage of the qualitative evaluation method, while at the same time complementing the vulnerabilities of qualitative evaluation.

In this study, the Climate Change Risk Assessment (CCRA) method from the UK was modified in accordance with domestic situation to function as a reliability evaluation method for the qualitative adaptation policy evaluation system. We developed the evaluation model by focusing more on reliability evaluation. The CCRA methodology was introduced as a procedure for systematically performing qualitative evaluations in the UK, and is an adaptation policy evaluation method that makes comparisons by generalization. According to the Kyoto Protocol, the UK Parliament enforced the Climate Change Act in 2008 and the UK CCRA performed the first risk evaluation (Defra, 2012).

3. Comparing the reliability evaluation process of the adaptation policy evaluation model

The reliability evaluation model for the adaptation policy evaluation system proposed in this study adopted a simulation structure that allows for the modification of the evaluation results in the reliability evaluation module through iterative processes. The researcher records the improvement process of the first evaluation result through iterative processes and can identify the characteristics of the adaptation policy evaluation system and the evaluation results by using this process.

As shown in Figure 2, the researcher selects one or two evaluation methods in the reliability evaluation module and derives the evaluation result. Different methodologies are converted to forms that allow for comparison using a standardization process. When two or more methods are applied, their average value is applied. Furthermore, the model was designed to select a method that shows a higher reliability result after comparing the evaluation results between methods in the reliability evaluation module. We presented a few guidelines for selecting an evaluation method in the reliability evaluation module to prevent selection bias issues. Figure 3 shows an example combination of the reliability evaluation modules used to prevent selection bias.

In addition to standardizing the reliability evaluation module, the results derived from the module can be also compared through a standardization process. This enables the degree of similarity to be compared between two modules. We defined this process such that the verification of the climate change adaptation policy evaluation system was complete if the difference in the results of two modules was lower than the significance level.

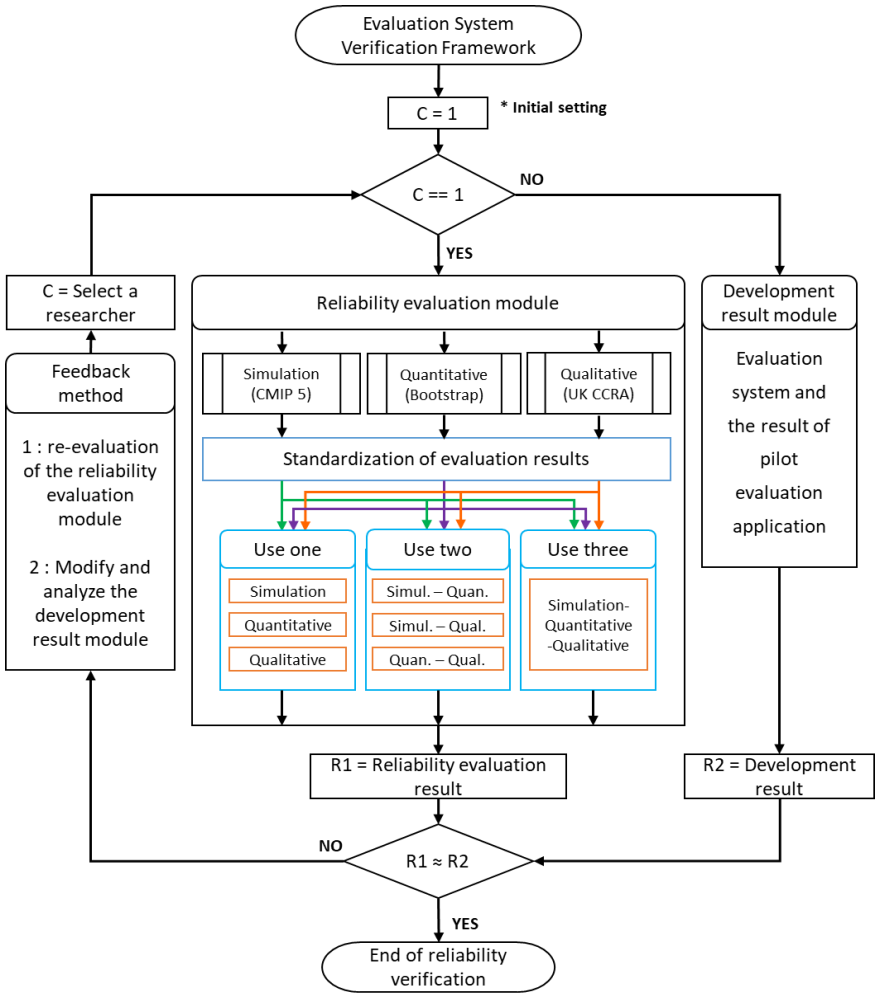

Figure 2 Process used to derive the results of the reliability evaluation module

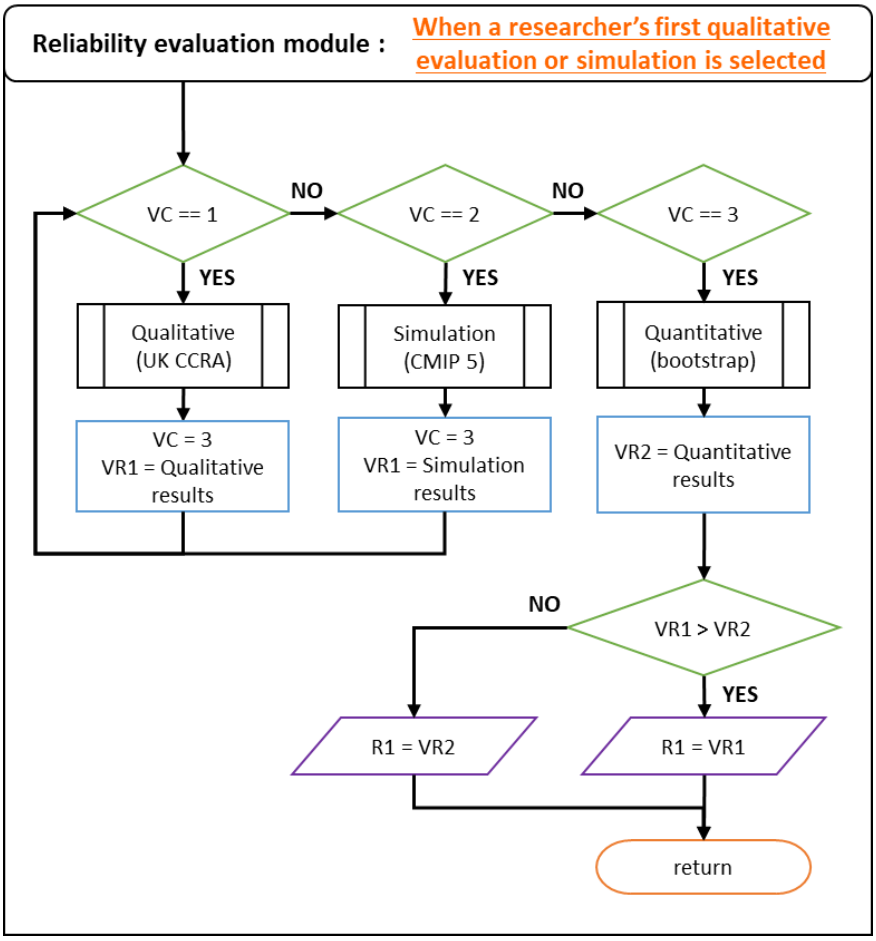

Figure 3 Example combination of reliability evaluation modules used to prevent selection bias

V. Conclusions

Climate change is currently being discussed as a key issue in South Korea, as well as in the international community. Korea is already experiencing environmental and ecological changes caused by climate change. The effects and damage caused by climate change are also spreading globally. Consequently, the Paris Agreement (Article 7) defined the global adaptation objective for all countries to enhance adaptive capacities, strengthen resilience in damage

situations, and reduce vulnerabilities to climate change. South Korea also presented a vision of 'building a society in which the people are happy and safe through climate change adaptations' and established First and Second National Climate Change Adaptation Measures, which include basic adaptation policies. Furthermore, the Korean government has established and is implementing basic plans to respond to climate change based on Article 40 of the Framework Act on Low Carbon Green Growth.

Research related to climate change has difficulty in regards to setting the scope because climate change phenomena have large uncertainties and variabilities that make it challenging to predict changes and analyze vulnerabilities. This shows the limitations in research directions and integrated problem solving. Therefore, in order to effectively respond to the worsening effects of climate change, we should predict the possibility of risk occurrence due to climate change more precisely and quantitatively, as well as evaluate the impacts of these risks on our society, economy, culture, and environment in greater detail.

This study examined the adaptation measures evaluation method based on existing studies of various adaptation evaluation metrics that are related to climate change. First, we examined the characteristics and briefly compared the representative domestic and overseas evaluation methods for adaptation policies. In the priority evaluation method analysis case, we selected climate change risk, policy, and effectiveness as representative metrics for selecting priorities that consider the existing general policy evaluation metrics and the distinctiveness of climate change. Then, we examined priority evaluation methods that are applicable within the range of available data. Second, we examined a UNDP case that utilized a meta-analysis for a final evaluation report of a climate change adaptation program using the realistic review methodology to evaluate the effectiveness of the adaptation measures. We analyzed the CMO configuration according to the realistic review procedure along with identifying the CMO configuration as the key element.

To evaluate the climate change adaptation measures realistically by region and sector, we should also consider the reliability of the evaluation method while simultaneously evaluating the climate change measures. Various evaluation methods for climate change adaptation measures have been proposed, but few methods can solve the problem of the evaluation system's reliability. In this situation, our research objective was to propose a standardized reliability evaluation system method to provide the reliability of the adaptation policy evaluation system by region and sector when predicting the future of climate change. We designed the reliability evaluation model using a reality-inherent mechanism combined with various qualitative and quantitative methods so that the reliability evaluation could be performed flexibly. The model was designed to verify the reliability during the process of evaluating the results after individual projects were carried out for a group of projects related to climate

change adaptation that was implemented in different forms. The reliability evaluation model for the adaptation policy evaluation system was interlinked with a vulnerability evaluation model for climate change impacts by sector so the result of the adaptation policy evaluation system could be compared with the reliability evaluation result. The reliability of the adaptation policy evaluation model can finally be verified through a self-testing process in the reliability evaluation module, whereby the result derived from applying the model to the adaptation policy evaluation system is applied back to the evaluation model.

The reliability evaluation system proposed in this study is expected to be actually applicable to climate change adaptation measures because it provides relatable evaluations of climate change adaptation policies. This study has significance because the reliability evaluation model constructed for the climate change adaptation evaluation system can provide scientific criteria when establishing climate change adaptation policies in accordance with the domestic circumstances using a standardization process for the reliability of the adaptation policy evaluation in the future.

Acknowledgement

This research was supported by Korea Environment Industry & Technology Institute (KEITI) through Climate Change R&D Program, funded by Korea Ministry of Environment (MOE). (2018001310002)

References

Chae, Y. R., & Jo, H. J. (2011). *Analysis of Methodologies for Prioritizing Climate Change Adaptation Measures*. Korea Environment Institute.

Chae, Y. R., Kang, Y., Bae, H. J., Rhee, J., & Cho, K. (2012). *Prioritization of Climate Change Adaption Measures by Sectors*. Korea Environment Institute.

Chae, Y. R., Song, Y., Ahn, Y., & Lee, J. H. (2016). *Developing Climate Change Combat Capability Assessment Framework*. Korea Environment Institute.

Defra. (2012). *Climate Change Risk Assessment Methodology Report. Department for Environment*. Food and Rural Affairs, London, UK.

Doria, M. D. F., Boyd, E., Tompkins, E. L., & Adger, W. N. (2009). Using expert elicitation to define successful adaptation to climate change. *Environmental Science & Policy, 12*, 810-819.

Hwang, I. C., & Kim, D. S. (2016). *The Integration of Climate Mitigation and Adaptation: Strategy and Methods*. Korea Environment Institute.

IPCC. (2001). Climate Change 2001: Impacts, Adaptation and Vulnerability. *Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, Eds.*, Cambridge University Press, Cambridge, UK.

IPCC. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds.*, Cambridge University Press, Cambridge, UK.

IPCC. (2014). Climate Change 2014: Synthesis Report. *Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]*. IPCC, Geneva, Switzerland.

Jo, H. J., & Chae, Y. R. (2013). Analysis of Methodologies for Prioritizing Climate Change Adaptation Measures. *Journal of environmental policy, 12*(4), 23-44.

Kang, Y., Park, C. S., Park, JY., & Cho, D. (2018). Spatial differences in the heavy precipitation risk intensity in South Korea. *Human and Ecological Risk Assessment: An International Journal, 24*(6), 1579-1594. DOI: 10.1080/10807039.2017.1418655.

Park, J., & Cho, D. (2015). A conceptual framework assessing economic impacts stemming from disasters in Korea. Journal of Governance Studies, 10(1), 17-40.

Park, C. S., Kang, Y., and Shin, M. (2016). *Regional Resource Management Strategies Considering on the Adaptation Plan from Climate Change (II)*. Korea Environment Institute.

Rodel, D. L., & Rizaldi, B. (2006). *An Integrated Assessment of Climate Change Impacts. Adaptations and Vulnerability in Watershed Areas and Communities in Southeast Asia*. Washington, DC, The International START Secretariat.

Taylor, K. E., Stouffer, R. J., & Meehl, G. A. (2012). An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society, 93*(4): 485-498.

UNDP. (2015). *A Realist Review of Climate Change Adaptation Programme Evaluations: Methodological Implications and Programmatic Findings.* UN Plaza, New York, USA.