B-54.3 International Collaborative Studies for the Extension and Comparison of the Asian-Pacific Integrated Model (AIM) (Final Report)

Contact person Tsuneyuki Morita
Director of Social and Environmental System Division
National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki 305-0053, Japan
Tel:+81-298-50-2541 Fax:+81-298-50-2524
E-mail: t-morita@nies.go.jp

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Abstract The AIM simulation results have been compared with other integrated assessment models in the three international comparison projects: the IPCC new scenario project, the Stanford EMF project, and OECD economic modeling project. These comparisons show that future mitigation policies would be significantly dependent on future development patterns, and that the cost to implement Kyoto Protocol would be in a certain range which could be reduced by emission trading. In order to promote these comparisons, a database has been developed for providing more than 500 emission scenarios and their assumptions. Another important study is to refine and apply a computer model for assessing the climatic impacts on agriculture and water supply/demand in China, jointly promoted with IIASA. Furthermore training workshops were held in China and India to transfer the AIM model and to apply it for their policy making processes.

Key Words Global warming emission scenario, International comparison, agricultural model, technology evaluation

1. Introduction

Integrated assessment models have been developed rapidly for the last 10 years around the world. These models have differences in terms of the complexity of natural system, complexities of economic models, uncertainties and so on. It is important to compare these models so that modelers can refine their own models and make them user-friendly to policy makers. These studies compare scenarios developed by AIM model with those developed by other models in the processes of IPCC comparison study, Stanford Energy Modeling Forum and OECD economic modeling project, and clarifies the characteristics of AIM model to be updated. In order to support these studies, scenario database has been developed. Climate impact studies have also attracted much attention, especially agricultural impacts. Agricultural impact and water supply/demand model was developed and applied to China.

2. International comparison of integrated model

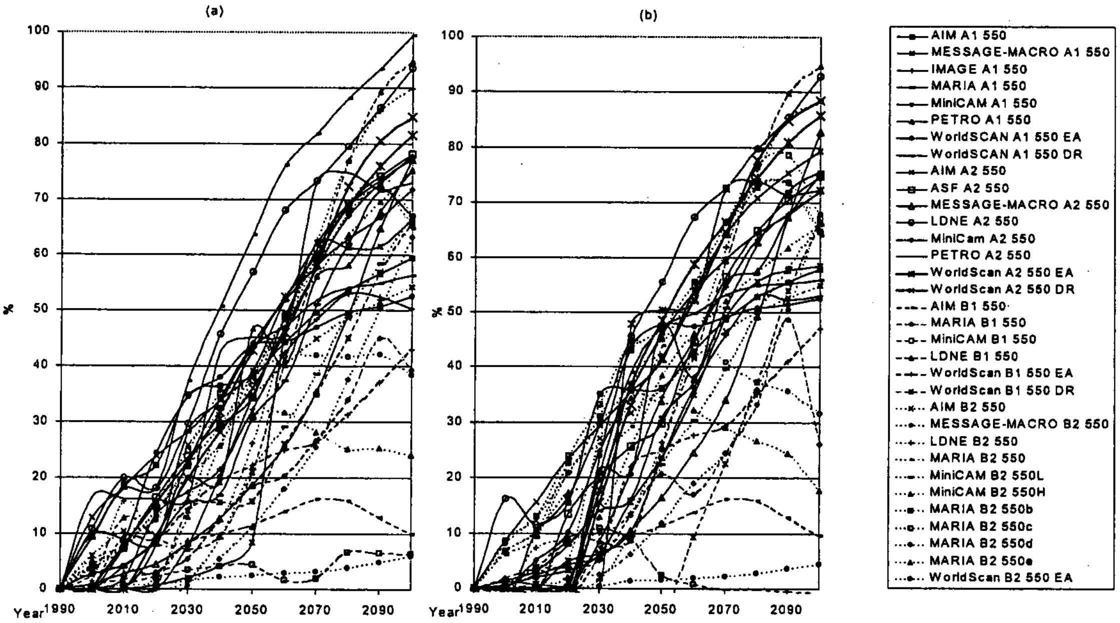
2.1. IPCC emission scenario comparison

Emissions scenarios provide an important input for the assessment of future climate change. The future GHG emissions depend on numerous driving forces including population growth, economic development, energy supply and use, land-use patterns and a host of other human activities. These main driving forces that determine the emissions trajectories in the scenarios often also provide input to assess possible emissions mitigation strategies and possible impacts of unabated emissions. In the view of many different uses, it is therefore not surprising that there are numerous emissions scenarios in the literature and that the number of scenarios of regional and global emissions is growing.

Given these large ranges of future emissions and their driving forces, there are an infinite number of possible alternative futures to explore. The IPCC SRES scenarios cover a finite, albeit a very wide range of future emissions. Four scenario "families" are adopted to describe future developments: A1 (rapid economic growth), A2 (divided world), B1 (sustainable development), and B2 (regional stewardship).

Several models were used to generate the scenarios. Among them are: AIM from NIES; Atmospheric Stabilization Framework Model (ASF) from ICF Consulting in the USA; Integrated Model to Assess the Greenhouse Effect (IMAGE) from RIVM, used in connection with the WorldScan model, the Netherlands; Multi-regional Approach for Resource and Industry Allocation (MARIA) from Science University of Tokyo in Japan; Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) from IIASA in Austria; and the Mini Climate Assessment Model (MiniCAM) from PNNL in the USA.

Modeling teams estimated both BaU and mitigation scenarios. Fig. 1 shows the reduction rates to BaU case for 550 ppmv stabilization. Although some models assume special technologies such as carbon sequestration would penetrate and would have a great reduction, the differences come mainly from the differences of future socio-economic scenarios.



(a) world (b) non-Annex I

Fig. 1 Reduction rates to BaU case for 550 ppmv stabilization

2.2. Comparison study by EMF project

The main objectives of the EMF study are: (i) identifying policy-relevant insights and analyses that are robust across wide ranges of models, (ii) providing explanations for differences in results from different models, and (iii) identifying high priority areas for future research. EMF has produced a particularly rich set of results in all three areas. The model results show a wide range that can be viewed as a manifestation of uncertainties inherent in projecting how the future will unfold with and without climate change policies. The models do not produce these uncertainties. They make them more transparent and help assess their magnitudes. This is important in the analyses of climate policies because of the complexities and interdependencies involved.

Each team participated in the EMF project made a special effort to run the stylized Kyoto scenarios varying on three dimensions: (i) the amount of international emissions trading assumed, (ii) the availability of sinks and "other greenhouse gas" emission reductions to satisfy the Protocol's requirements, and (iii) the required emission reduction beyond 2010.

Although the Kyoto Protocol does explicitly mention the possibility of international trading of carbon emission rights, the negotiators have yet to agree on the extent of participation in any trading regime and whether where will be constraints on how many emissions rights can be bought or sold by individual participants. In EMF scenario design some relatively simple implementations of the trading provisions in the Protocol was adopted in order to get a rough regime. Here we look at carbon tax results for four alternative scenarios: (i) No Trading of international emission rights, (ii) full Annex I Trading of emission rights, (iii) the Double Bubble, which considers separate EU and rest of Annex I emissions trading blocks, and (iv) Full Global Trading of emissions rights, with the non-Annex I countries constrained to their reference case emissions.

Fig. 2 (Left Panel) compares the marginal cost to achieve the Kyoto Protocol with no trading in 2010. Most models indicate that the marginal cost of Japan is the highest, the next is EU and the cheapest is USA among the three regions. Reasons are that the current energy intensity is low and little space is left to improve it further and that it is very difficult to introduce new carbon free energy in Japan. Fig. 2 (Right Panel) shows the marginal costs in Annex I Trading and Full Global Trading cases. The potential advantages of expanding the scope of the trading regime are evident in the figures. Moving from the No Trading to the Annex I trading case lowers the carbon tax required by a factor of two as a result of equalizing the marginal abatement cost across regions. This effect is particularly significant in this case because almost all models project a significant amount of "hot air" will be available from Russia. This represents reductions in Russia's Reference Case carbon emissions by 2010 relative to its 1990 baseline allocation.

The advantages of Global Trading relative to Annex I Trading are also significant. They result primarily from the fact that non-Annex I countries can reduce emissions more inexpensively relative to their unconstrained allocation of emissions rights than can the Annex I countries relative to their much more tightly constrained Kyoto allocation.

Although all the models show a similar pattern of results for the relative costs of the alternative trading regimes, there are significant differences in the model's projections of the magnitude of the economic dislocations projected for each regime. Part of the explanation for these differences is the differences in the reference case carbon emissions. The other reason for the observed differences is the degree of difficulty in adjusting energy demands embedded in the input assumptions and structure of each model.

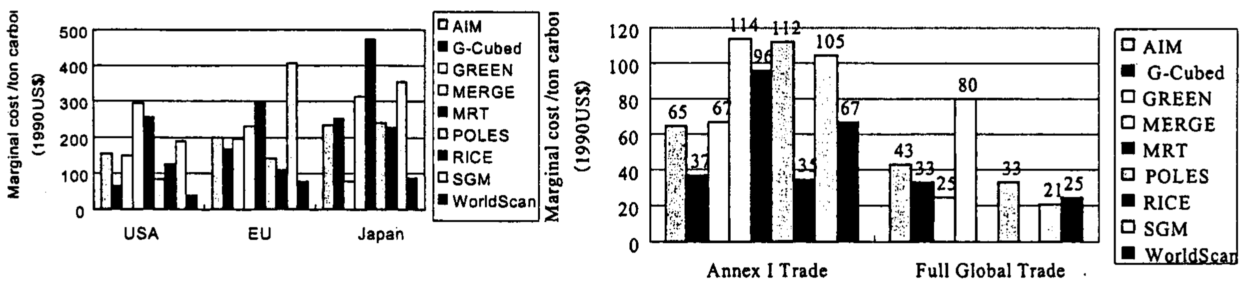


Fig. 2 Comparison of marginal costs to achieve the Kyoto Protocol: With no trading in 2010 (Left Panel) and Emission Trading Cases (Right Panel)

Despite these considerable uncertainties, a number of common results and insights emerge from the set of model results considered here. First, meeting the requirements of the Kyoto Protocol will not stop economic growth anywhere in the world, but it will not be free either. In most Annex I countries, significant adjustments will need to be undertaken and costs will need to be paid. Second, unless care is taken to prevent it, the sellers of intentional emissions rights (dominantly the Russian Federation in the case of Annex I trading, and China and India in the case of global trading) may be able to exercise market power raising the cost of the Protocol to the other Annex I countries. Third, meaningful global trading requires that the non-Annex I countries take on emissions targets; without them accounting and monitoring (even Annex I monitoring and enforcement may be quite difficult) becomes almost impossible. Finally, it appears that the emissions trajectory prescribed in the Kyoto Protocol is neither optimal in balancing the costs and benefits of climate change mitigation, nor cost effective in leading to stabilization of the concentration of carbon dioxide at any level above about 500 ppmv.

3. Analysis of climate change impact on food security

Climate change is considered to affect future food supply, demand, and prices significantly through the changes in crop productivity. In this study, we estimated the climate change impact on food production considering global trade by integrating the global agricultural trade model developed at IIASA (International Institute for Applied Systems Analysis) and the crop productivity model developed at NIES. For improving the ability to describe regional characteristics, some sub-modules are modified, and applied to the case study on China.

Fig. 3 shows overview of the study, the models developed and analyses practiced in this study. First, given the future scenarios of population increase and economic development and the crop productivities under climate change estimated by AIM/crop model, climate change impact on food production and trade is assessed. Fig. 4 shows the estimated impacts in some selected regions. Severe decrease of crop productivities in India will cause increase in crop prices and decrease the social welfare of Indian people at the end of next century.

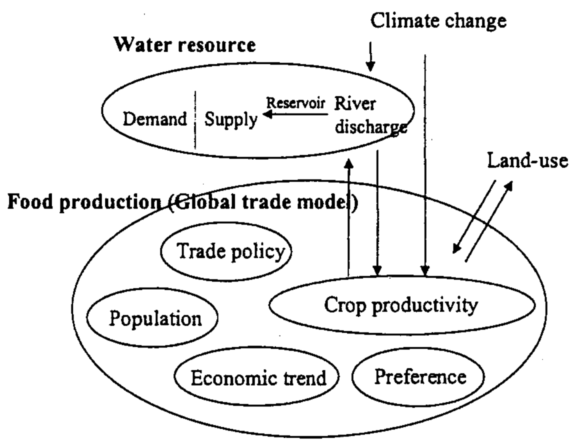


Fig. 3 Overview of food production study

Second, in order to improve production functions of crop sectors in the global trade model, analysis of soil suitability for crop production and correlation analysis between crop productivity and land-use pattern are done.

Since climate change affects crop productivity not only directly but also through water resources, climate change impact on water resources must be taken into account carefully for detailed analysis of impact on food production at regional scale. Surface runoff - River discharge model at terrestrial scale is developed and applied to the Yellow river basin study. Its applicability is validated by comparing the simulated result with the observed data. The efficiency of artificial reservoirs to control seasonal variability of discharge is studied. Jinghe and Luanhe rivers (both Yellow river branches) are selected as the target of case study. Construction and better management of reservoirs affect water availability more than climate change projected with GCMs. For water demand side, sector-wise and region-wise water demand in China is estimated.

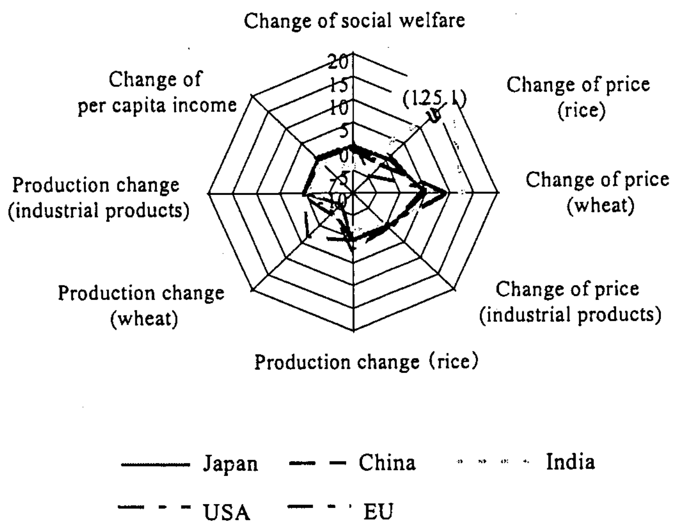


Fig. 4 Economic impacts of climate change in some regions

4. Development of IPCC scenario database

IPCC scenario database was developed in order to manage and access a large number of data sets and emissions scenarios documented in the literature. The current database version can be accessed through a web site (www-cger.nies.go.jp/cger-e/db/ipcc.html). It is the most comprehensive collection of emission scenarios, at least judging from the public available literature. It includes most of the recent global and regional scenarios and all of the scenarios used in the last IPCC evaluation of emission scenarios. Therefore, the emissions scenarios documented in the database are representative of the literature in general. However, there are a number of ways in which the coverage of the scenarios in the database could be extended in the future. For example, inclusion of long-term emissions scenarios for individual countries, when available, would improve the regional coverage. Also, a large majority of the scenarios report only energy-related CO2 emissions, while only some report non-energy CO2 and other GHG emissions.

The scenarios in the database were collected from more than 170 different literature sources and other scenario-evaluation activities such as the Energy Modeling Forum and the International Energy Workshop. The scenarios span a wide range of assumptions about demographic trends, level of economic development, energy consumption and efficiency patterns, and other factors.

Fig. 5 shows global CO2 emission scenarios. The scenarios in the database display a large range of future GHG emissions. Part of the range can be attributed to the different methods and models used to formulate the scenarios, which include simple spreadsheet methods, macroeconomic models and systems-engineering models. However, most of the range is due to differences in the input assumptions of the scenarios, in particular the difference in the main scenario driving forces and the difference in the modeling approaches and the structures of the models. In addition, just comparing alternative emission levels across different scenarios is not sufficient to shed light on internal consistency, plausibility and comparability of the assumptions behind the scenarios. Analysis of the underlying driving forces is thus also an important part of the valuation.

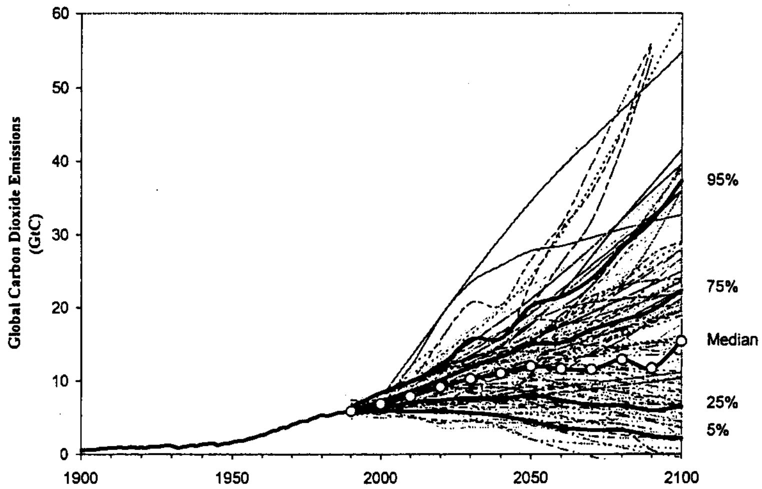


Fig. 5 Global CO2 emission scenarios

5. Concluding remarks

Sets of emission scenarios have been extensively examined through comparison studies and the scenarios database with more than 500 emission scenarios has been developed. This database is requested to be maintained thereby ensuring continuity of knowledge and specific progress in any future assessments of GHG scenarios. An equivalent database for documenting narrative and other qualitative scenarios is considered to be also very useful for future climate-change assessments.

It is also necessary new research activities to assess future developments in key GHG driving forces in greater regional, subregional, and sectoral detail, allowing for a clearer link between emissions scenarios and mitigation options.

Climate change impact on food security has also been analyzed by developing a global agricultural trade model, jointly developed by IIASA. The importance of such kind of impact models will also increase and other impact models should be developed and applied in Asian region.

Capacity building, particularly in developing countries, in the area of modeling tools and emission scenarios is also an import future work. The models developed so far have been transferred to Asian countries through AIM workshops and the training workshops.

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