Measurement of the long-term flood damage cost in Japan: Dynamic multi-regional computable general equilibrium analysis[1]

Kazunori Nakajima[2], Masa Morisugi[3] and Naoki Sakamoto[4]

Abstract

Objectives:

In order to examine regional economic impacts of the long-term flood damage due to climate change in Japan, we develop a dynamic multi-regional computable general equilibrium (CGE) model and measure flood damage costs and adaptation benefits by some numerical experiments.

Backgrounds:

It is inferred that the frequency and the intensity of flood are on the long-term increase. In the category of flood damage in Japan, there are serious flood damages to social overhead capital, including houses, buildings, roads and so on. These observations are described in the statistical research on flood by Japanese government. Also, these economic damages have been measured by a variety of methods, such as an econometric approach, a computable general equilibrium approach and an engineering approach. However, there remain questions regarding each approach. For instance, as a CGE approach that is assumed to be a static economy does not basically consider a capital accumulation, it is inappropriate for a traditional CGE model to evaluate the long-term flood damages due to climate change.

On the other hand, according to Morisugi and Morisugi (2012), we define these damages as a direct damage cost, and they are different from decrease in equivalent consumption due to a direct damage. Morisugi and Morisugi (2012) theoretically derived the long-term flood damage cost based on a Ramsey growth model. It was assumed that the depreciation rate of capital stock includes the annual disaster physical damage of capital stock loss and climate change increases in the depreciation rate. Compared to two steady-states with or without flood due to climate change, the relations among a direct damage cost, a dynamic damage cost and a dynamic multiplier of damage cost were shown. Then, it was ensured that a dynamic multiplier of dynamic cost that was the proportion of a dynamic damage cost to a direct damage cost was always over 1 theoretically, and the dynamic multiplier was calculated as 1.357 by a tentative numerical analysis.

Therefore, it is necessary to develop a dynamic model that has an endogenous capital stock and to evaluate economic impacts of flood damage due to climate change.

---

[1] This work was supported in part by the Social Implementation Program on Climate Change Adaptation Technology (SI-CAT) by the Ministry of the Education, Culture, Sports, Science and Technology (MEXT), Japan. We gratefully acknowledge the generosity of this fund.

[2] School of Human Science and Environment, University of Hyogo

[3] Faculty of Urban Science, Meijo University

[4] Faculty of Literature and Social Sciences, Yamagata University

Methods:

We develop a dynamic multi-regional computable general equilibrium model that consists of 8 regions (Hokkaido, Tohoku, Kanto, Chubu, Kinki, Shikoku, Chugoku and Kyushu), 20 sectors (Agriculture, Forestry, Fishery, Mining, Foods, Other manufacturing products, Chemical products, Petroleum and coal products, Iron and steel, Metal products, Industrial machinery, Electrical equipment, Construction, Electricity, Gas, Water supply, Commerce Transport, Medical service, and Services sectors) and some economic agents (representative household, government, investment and import-export) in each region of Japan, based on that of Nakajima et al. (2017). We use the 2000 Inter-regional Input-Output Table (47 prefectures and 45 sectors) that has been developed by Miyagi et al. (2003) and Ishikawa and Miyagi (2004) as the reference data set.

In our economic model, we assume all production functions and utility function to be a nested constant elasticity of substitution (CES) style. A production sector inputs labor, capital and intermediate inputs, and produces a commodity. A representative household initially endows labor and capital, and demands household final consumptions and private investments. Government in each region earns revenue from income tax, production tax and indirect tax, and spends government consumption and government investment. And, in accordance with Hosoe et al. (2010), we develop the relation of the substitution between imports and domestic goods, and that of the transformation between exports and domestic goods. About imperfect substitution between imports and domestic goods, we assume the Armington's assumption. A sector producing an Armington composite good aggregates domestic goods and imports into composite goods by using a CES function. On the other hand, we assume that a domestic output is transformed into domestic goods and exports by using a constant elasticity of transformation (CET) function.

In order to develop dynamic model, we extend the way of describing the structure of dynamic model by Lau et al. (2002), Paltsev (2004) and Ban (2007). These studies have adopted a Ramsey growth model to develop a dynamic structure, so our dynamic model is not a backward-looking (quasi-dynamic or sequential dynamic) but a forward-looking type based on a Ramsey model. Dynamic conditions are derived from solving a dynamic optimal problem that a representative household maximizes the present value of lifetime utility under some constraints. For simplicity of calculation, we use three assumptions in describing a neoclassical growth model; 1) Over all periods, an economy is on a steady-state equilibrium path, 2) In the initial period, an economy in on a steady-state, and 3) In the terminal period, an economy is on a steady-state under constraint that the growth rate of investment equals the growth rate of output. Our simulation periods are assumed to be 50 periods. Nakajima et al. (2017) showed that the forward-looking dynamic model, despite strict constraints and unrealistic assumptions, could show some realistic results. Also, in dynamic analysis with the long-term perspectives, it is important to obtain various impacts of the change in economic and environmental situation in the future on not only the economy after the change but also the economy before the change. Therefore, by using the forward-looking dynamic model, we can show the economic impacts that the backward-looking dynamic model cannot analyze.

In setting of flood damage scenario, we employ 5 scenarios in our numerical experiments. We describe the long-term change in flood damage as the change in the capital depreciation. That means

that the flood damage scenario due to climate change is assumed to increase in the capital depreciation rate of the private capital stock by the flood damage rate calculated by a climate model. For the calculation of flood damage rate, we use a total of 5 scenarios that consist of four calculation results made by CSIRO, GFDL, MIROC and MRI, and one result employed in Morisugi and Morisugi (2012), where flood damage rate is assumed to be uniform throughout Japan. The annual flood damage rate (% per year) calculated by these climate models is described as the proportion of differences between flood damage costs in 1981 and in 2081 to the private capital stock in 2000.
In this study, we define two economic indices as “direct damage cost” and “dynamic damage cost”. The direct damage cost is defined as damages like the flood observations mentioned above. On the other hand, the dynamic damage cost is defined as a discounted present value of a decrease in consumption with flood due to climate change in each period, compared to consumption without flood. And, the dynamic multiplier of damage cost is defined as the proportion of these damage costs. In addition, we consider the transition dynamics that is defined as the differences between flood damage costs by a baseline scenario and by a flood scenario, on the transition path to a new steady-state equilibrium. As we could describe the transition path, we show possible dynamic spillover effects of flood damage due to climate change over time.

Results:

The findings in this study are shown below.

(1) By our numerical simulation analyses, the total amount of flood damage cost in Japan was estimated to be from about 26 billion yen per year to about 535 billion yen per year in the 50th period.

(2) The decrease in the rate of investment return by the long-term increase in flood damage causes decreases in savings and consumption, so that the dynamic multiplier of damage cost was estimated to be from 1.211 times to 1.248 times.

(3) The primary industry including the agriculture sector and the fishery sector, the foods sector, the electricity sector, the water supply sector and the tertiary industry were affected negatively by decreases in their outputs due to flood damage. On the other hand, many of the secondary industry did not suffer their outputs damage due to flood, and there were marked increases in their outputs in the construction sector in some regions including Kanto region, Chubu region and Kinki region.

Keywords:

flood, damage cost, climate change, forward-looking dynamic, computable general equilibrium model

JEL Classification:

C68, D58, D61, H54, Q54