Macroeconomic Effects of the Stock Management for Irrigation and Drainage Facilities in Japan: Application of Recursive-Dynamic CGE model

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Abstract

The stock management of irrigation and drainage facilities was macro-economically evaluated. The recursive-dynamic CGE model was developed and used for policy simulation. Results demonstrated that effects of activity spread to other industries and total benefit calculated by the consumers' surplus change was more than the total costs.

Keywords: Computable General Equilibrium Model, Recursive dynamic model, Consumers' surplus, Cost-benefit ratio

JEL Classification Code: H30, Q12, Q14, Q18

1. Introduction

The fourth report of IPCC (International Panel for Climate Change) said that the amount of available water would decrease due to the change of the precipitation pattern affected by the global warming. Agriculture depends heavily on inland water, using 70% of inland water in the world. A decrease in available water quantity definitely brings about reduction of agricultural production. Even in Japan where water resource is relatively abundant, it is important to maintain irrigation water for keeping stable food production.

Rice production dominates in Asian monsoon region as well as Japan, so irrigation and drainage facilities, such as reservoir, intake dam, and canals, are critical to use and control irrigation water. The budget for construction of irrigation and drainage facilities has been drastically cut under economic reformation program in Japan. In 2010, the investment budget for public projects is 1/6 of the peak level in 1998. Because of such reduction, 80 % of the total investment is for renewal of old facilities, and the amount of aging facilities is increasing recently. If the public investment remains at this level, there would be many aged facilities abandoned in the field without renovation. To keep the public capital stocks in use, the stock management is critical. In Japan, stock management activities consist of monitoring for immediate repair when it breaks and prevention treatments at the initial stage of the failure. However, there were few studies on the policy evaluation on the stock management activities in the agriculture.

To measure effects of public capital in agricultural production, the aggregate production function was estimated from statistical data with considering irrigation and drainage facilities (Nakashima, 1989; Yokoyama and Kataoka, 2006). These previous studies found that the production elasticity of public capital was about 10 %. Other than above studies, many researchers used production function approach (Binswanger, 1974; Ray, 1982; Ito, 1993; Gdo, 1993), but they did not consider irrigation and drainage capital as an input factor.

On the other hand, construction of irrigation and drainage facilities is subsidized by the government with tax from people. An economic benefit at the consumer side should be evaluated and macro economic indexes should be taken into accounts in evaluation in order to get an agreement from them. The Computable General Equilibrium (CGE) model is suitable to analyze benefit transfer from producer side to consumer side via the market price with consideration of market supply and demand balance. In terms of Japanese economic studies, the environmental issues were analyzed by Son et al. (2006), a change in agricultural import and export structure was demonstrated by Saito (1996), effects agricultural public facilities were analyzed by the static CGE model (Kunimitsu, 2009a) and recursive-dynamic CGE model was developed by Shibusawa et al. (2007). However, there were few studies on application of the CGE model to evaluation of agricultural public facilities.

The purpose of this study is to evaluate macroeconomic effects of the stock management activities for irrigation and drainage facilities in Japan. For measuring macroeconomic effects, we developed the recursive-dynamic CGE model and discussed the policy decision on budget for agricultural public projects according to the simulation results by this model.

After this section, Section 2 explains the structure of the model and simulation process. Section 3 shows the simulation results for evaluation of the stock management activities in agriculture. Then, we summarize and discuss the policy for renovation of public facilities in Japan as a conclusion.

2. Model and simulation

2.1 Structure of the recursive-dynamic CGE model

The model used here was the recursive dynamic type of the CGE model in accordance with Ban (2007) which used the GAMS (GAMS Development Corporation) with MPSGE (modeling tool using the mixed complementary problem) (Rutherford, 1997). The forms of the model were as follows.

(Zero-profit condition)

$$f_i^c(w, r, kg, tax) = pd_i \quad \perp \quad Y_i \geq 0 \tag{1}$$

$$f_i^A(pm, pd) = pa_i \quad \perp \quad A_i \geq 0 \tag{2}$$

$$pfx = f^T(pm) \quad \perp \quad M_i \geq 0 \tag{3}$$

$$f^T(pe) = pfx \quad \perp \quad E_i \geq 0 \tag{4}$$

$$f^T(pa) = pk \quad \perp \quad I \geq 0 \tag{5}$$

$$pc = f^u(pa) \quad \perp \quad C \geq 0 \tag{6}$$

$$pcg = f^u(pa) \quad \perp \quad Cg \geq 0 \tag{7}$$

$$pig = f^{u}(pa) \quad \perp \quad Ig \geq 0 \qquad (8)$$

(Market clearance condition)

$$Y_i f_i^{R}(pd, pe) = A_i f_i^{A}(pm, pd) \quad \perp \quad pd_i \geq 0 \qquad (9)$$

$$\sum A_i = G + C + I \quad \perp \quad pa_i \geq 0 \qquad (10)$$

$$M_i = A_i f_i^{A}(pm, pd) \quad \perp \quad pm_i \geq 0 \qquad (11)$$

$$Y_i f_i^{R}(pd, pe) = E_i \quad \perp \quad pe_i \geq 0 \qquad (12)$$

$$\sum X_i - \sum M_i = \overline{Bdef} \quad \perp \quad pfx \qquad (13)$$

$$I = f^{u}(pk, M_i) \quad \perp \quad pk \geq 0 \qquad (14)$$

$$\overline{K} = Y_i \frac{\partial f^{c}(w, r, kg, tax)}{\partial r} \quad \perp \quad r \geq 0 \qquad (15)$$

$$\overline{L} = Y_i \frac{\partial f^{c}(w, r, kg, tax)}{\partial w} \quad \perp \quad w \geq 0 \qquad (16)$$

$$C = f^{u}(pc, M_i) \quad \perp \quad pc \geq 0 \qquad (17)$$

(Income restriction)

$$M = r\overline{K} + w\overline{L} + pf\,\overline{F} \qquad (18)$$

$$G = pfx \cdot \overline{Bdef} + tax - pcg \cdot Cg - pig \cdot Ig \qquad (19)$$

Here, *i* shows classification of industrial sector, and *kg* and *tax* are the public capital relating to production and tax. *Y, A, M, E, I, C, Cg*, and *Ig* are respectively domestic production, armington's composite good, import, export, investment, household consumption, government consumption and public investment. *pd, pa, pm, pe, pfx, rk, w*, and *pc* are the price indexes, respectively, relating to domestic production, armington's composite good, import, export, foreign currency, investment goods, rental cost of capital, wage, and consumption goods. *M, G, K* and *L* are, respectively, household income, government revenue, initial capital stock and initial labour amount. Also, *f(・)* shows function, and superscript of this function, i.e. *c*, *a*, *r*, and *u*, respectively, shows cost function, armington function, profit function, and utility function. The functions used here are all constant elasticity of substitution (CES) type including Cob・Douglas type and Leontief type.

The public capital, *kg*, is assumed to increase the total factor productivity of value added sector with the production elasticity of 0.1. In the simulation, assuming that kg increase by 1%, the unit cost would decrease by 0.1%, and (*kg_ref* / *kg*)^0.1 is multiplied to the cost function, where *kg_ref* is the reference value of public capital and *kg* is the simulated public capital. The value of production elasticity is derived from Yokoyama and Kataoka (2006).

To form the recursive dynamic path, the capital stock equation is defined as follows.

(private capital stock)

$$K(t) = (1-\delta)K(t-1) + I(t) \qquad (20)$$

(public capital stock)

$$kg_j(t) = (1-\delta_g)kg_j(t-1) + IG_j(t) \qquad (21)$$

Here, δ and δg are both depreciation rate of 0.04. In the model, Ig is defined according to the share of public investment in each sector in 2005. However, the agricultural public investments and public investment for other production are assumed to be the exogenous variables in order to get the pure effects of simulation. As a result, the public investment for other purposes, such as flood control, sewage system etc., changes according to the economic conditions simulated by the model.

The elasticity values of substitution (s) in the production, consumption, import and export functions are set at the same values in Bann (2007) which were based on GTAP data base (Fig. 1 to 3). However, substitution elasticity between farmland and other input factors in agriculture is assumed to be 0.1. This is based on the empirical studies

(Nakashima, 1986) indicating that farmland as an input factor is hardly flexible in agricultural production.

< Insert Fig. 1, 2, and 3 >

Public capital is assumed to increase the total factor productivity in the value added production. Agricultural public capital is used for agricultural production and other public capital is used for production in other sector. The elasticity of production with regard to the public capital was assumed to be 0.1 according to the empirical evidence by Yokoyama and Kataoka (2004).

Concrete values of parameters were calibrated by the data of the social accounting matrix (SAM) in 2005, which was estimated from the Japanese I/O table according to Hosoe et. al. (). To make results more stand out, the sectors were aggregated into four, such as (i) agriculture including agriculture and husbandry, (ii) forestry, fishery and food industry, (iii) mining and manufacturing, and (iv) service sector.

2.2 Simulation

In order to measure effects of policy change quantitatively, the following two cases were set regarding to the stock management policy.

Case 0: Status quo which is shown by the present SAM data

Case 1: The depreciation rate of public capital is decreased by 17 % owing to the stock management activities. This rate was measured by Kunimitsu (2009b) in the the field survey data.

For evaluation of policy change in view of the social welfare level, Hicksian Equivalent Variation (HEV) was calculated from simulation results as follows.

$$HEV \equiv ep(pcp_0, UU_1) - ep(pcp_0, UU_0) \qquad (22).$$

Here, ep(•) shows the expenditure function derived from maximization of utility level, UU. pcp is the price of consumption goods. To compare two situations, price influence was extracted by using Laspeyres method.

3. Results

3.1 Effects of the stock management activities

Table 1 and Figure 4 show the effects calculated from difference between Case 1 and 0 at year 2020. These results show the following features. First, the stock management activities improved agricultural production by increasing public capital stocks in the agriculture and food industry. Consequently, Japanese GDP was increased by the stock management.

Second, the increase in GDP improved consumption and private investment, and decreased the general price of goods and service.

Third, the labor inputs and private capital inputs were both decreased in the agricultural sector, because the price of products drastically went down by the stock management activities. However, these input factors were increased in the forestry, fishery and food sector.

Fourth, CS values were increased by the stock management activities, because consumer price went down and consequently consumption level went up.

Next, calculated cost-benefit ratio from simulation results show interesting features. The total costs for the stock management activities were estimated as 124.2 billion yen per year (US$ 1.242 billion / year) for the whole public facilities in agriculture. The total present value of the annual costs discounted by 4 % was 1436.5 billion yen (US$ 14.4 billion).

On the other hand, the total present value of annual CS value calculated by the model for 15 years was 1624.1 billion yen (US$ 16.2 billion). Actually, annual CS value continuously increased by year, because difference in price and equilibrium quantity between two cases expanded. Consequently, the cost-benefit ratio can be calculated as 1.18 for the stock management activities in Japan.

<Insert Table 1, Fig. 4>

4. Summary and conclusion

This paper aimed to evaluate macroeconomic effects of the stock management activities for irrigation and drainage facilities in Japan. For measuring macroeconomic effects, we developed the recursive-dynamic computable general equilibrium (CGE) model and discussed the policy decision on budget for agricultural public projects according to the simulation results by this model.

The results obtained from the simulation of the CGE model were as follows. First, stock management activities for prolonging durable year of agricultural public facilities increased not only agricultural production but also other industries via reallocation of production factors and prices. Consequently, GDP improved by this activity. Second, consumers' price went down by the stock management activities, and consequently consumers' surplus increased. In this sense, the stock management activities have positive ripple effects to economies. Third, total benefit of the stock management calculated from consumers' surplus was 1.2 times larger than the total costs. So the stock management for agricultural public facilities is effective in Japan.

As shown by above results, recursive dynamic CGE model can be used for evaluation of the projects in view of price, equilibrium quantity and ripple effects to other sectors. However, several issues are remained in this study. First of all, above results based on the assumption that present tariff policy will continue, but a trade policy may be changed as a result of the WTO negotiation. The policy mix regarding trade policy and public investment policy may be one of the important issues in agricultural policy making. Second, there are some rooms for the CGE model structure and application. For example, the dynamic regional CGE model can be used for evaluation of agricultural public facilities in view of rural revitalization.

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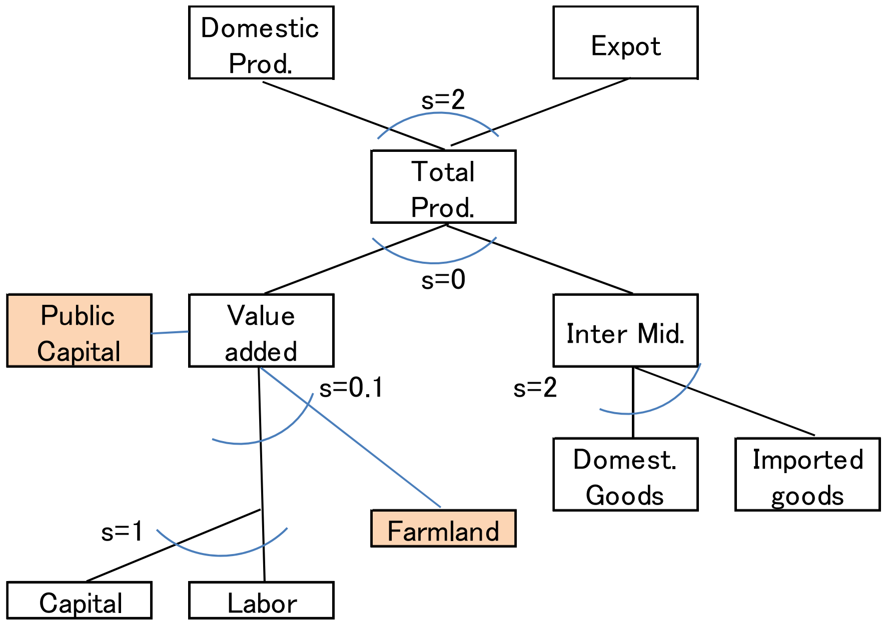

Figure 1 Outline of the production part in the CGE model

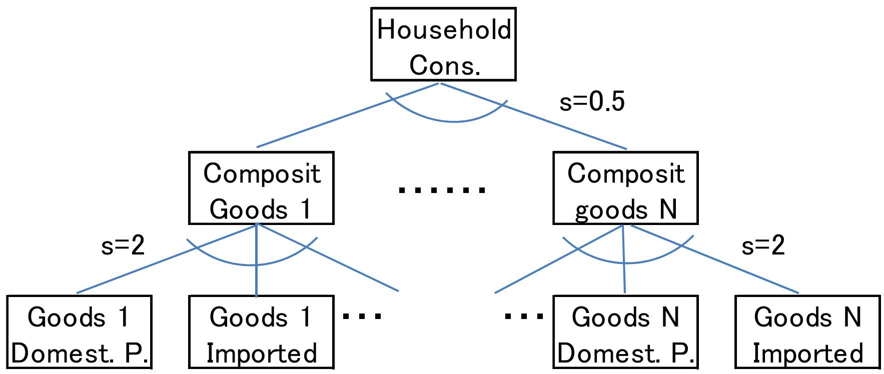

Figure 2. Outline of the household consumption part in the CGE model

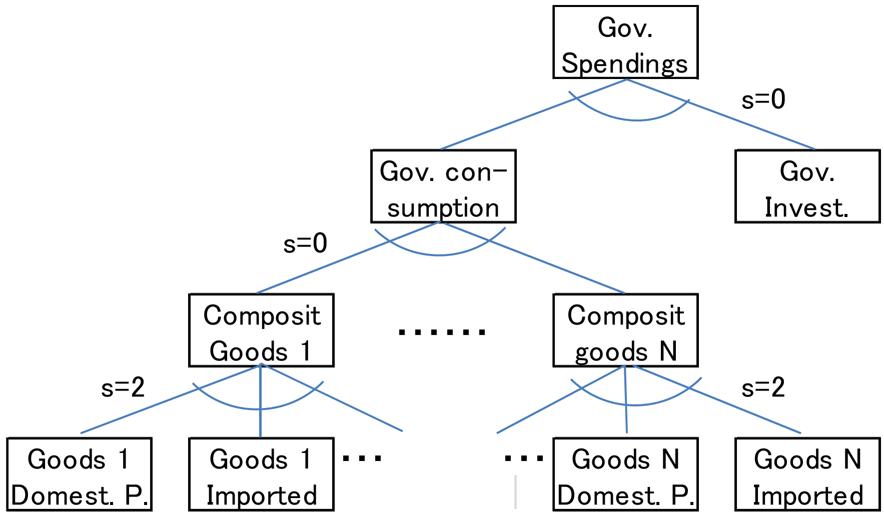

Figure 3. Outline of the government behavior part in the CGE model

Table 1. Difference in each variable between Case 1 and 2 in 2020 (after 15 years)

(%, billion yen)

Variables	Agriculture	Forest., Fishery, Food	Mining, Manufucture	Service
Input Factors				
Private Capital	0.00	1.09	−0.07	0.00
Labor	−0.01	1.08	−0.08	−0.01
Price of Factor				
Private Capital		0.06		
Labor		0.07		
Land		−5.31		
Supply and Demand				
Domestic Prod.	3.59	1.07	−0.05	−0.01
GDP		0.07		
Consumption		0.09		
Investment		0.09		
Export		−0.23		
Import		−0.28		
Output Price				
Domestic P	−4.86	−1.07	0.06	0.03
Consumer P		−0.11		
Government				
Consumption		−0.02		
Investment		−0.02		
Capital		0.34		
Equivalent Variation		356.7 billion yen		

(note) Values in this table show percent change in each variable between Case 1 and 0.

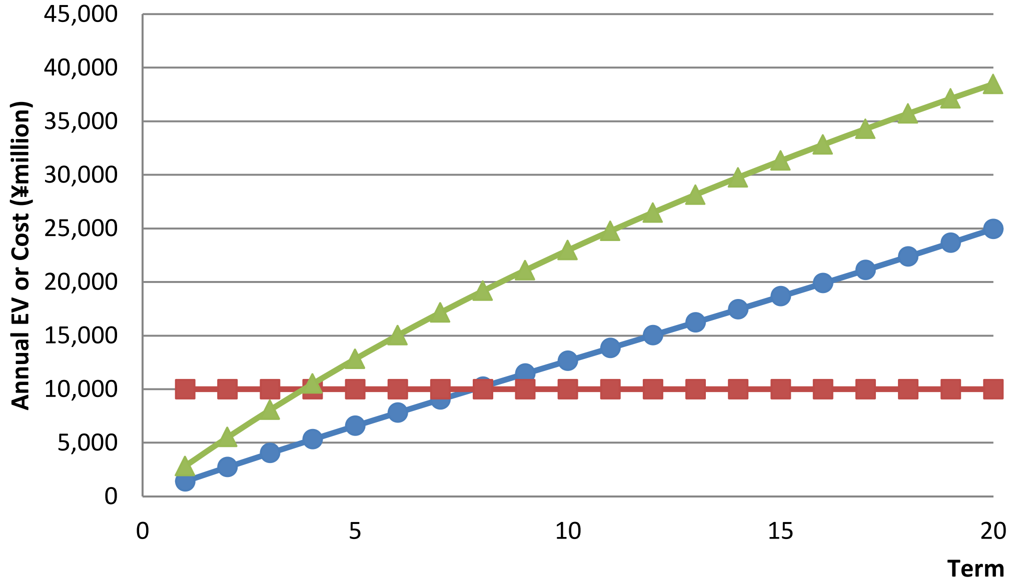

Fig. 4 Effect and cost of the stock management