Influence of Deteriorating Public Infrastructure in Japanese Economy: Evidence from the Spatial Computable General Equilibrium Model

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ABSTRACT

Under recent budget cuts for public investment, most public facilities including irrigation and drainage facilities become aging and deteriorating, and will negatively affect productivity in Japan. To evaluate macroeconomic effect of changes in public facilities, the current study uses the recursive dynamic computable general equilibrium (CGE) model. This model considers endogenous technological progress changed by the agricultural land improvement projects and road construction projects. The simulation results demonstrated that a decrease in agricultural public facilities causes negative effects of agricultural production as well as Japanese gross regional production (GDP) via changes in prices. Decreased labour and capital stocks in agricultural sector shift to other industries and improve their production, so such shift eases changes in agricultural production. Public capital stocks in roads continue to increase but marginal increase rate will decrease and will diminish an increase rate of production. Maintaining public capital stocks by any counter measures is highly needed for sustainable growth of economy. Different policies on budget source for such measures result in different economic effect, so a CGE model can help decision makers to consider comprehensive effects of policies.

1. INTRODUCTION

Public infrastructure, such as road and irrigation facilities, has been constructed after World War II to improve Japanese economy. However, most of public facilities are aging and have great possibility of deteriorating without any suitable renovation under recent budget cut in public investment. In 2010, total public investment is about 1/3 of its peak budget spent in the 1990s. Facing such serious decrease, many people are worried about whether public facilities were kept in good condition in the future. To answer their questions, policy simulations about influences of future changes in public facilities attract great interest of society as well as academia.

The Japanese Cabinet Office (2012) estimates public capital stocks by kinds. Among several kinds of public facilities, the largest capital stocks are the road facilities, accounting for 40% of total public capital stocks. The second is sewage system accounting for 11%. The third is agricultural base facilities, such as irrigation and drainage facilities and consolidated farmland, accounting for 11%. Road facilities and agricultural base facilities are classified into production base capital stocks which aim to be constructed for achieving production effects for industries.

Several previous studies analysed the impacts of public facilities by estimating macroeconomic production function with aggregate data in economy. Aschauer (1989) showed that production effects of public facilities accounted for 40 % of total production in the US, and said that long term stagnation was caused because of a lack of public facilities stayed at the low level. Regarding Japanese public facilities, significant positive production effects were measured in most previous studies (Iwamoto, 1990; Mitsui *et al.*, 1995). Nakashima (1989) and Yokoyama and Kataoka (2006) showed that 1% increase in agricultural public capital stocks brought about 0.1 to 0.3% increase in rice production.

These production approaches can show the direct effects of public facilities, but they cannot show the total effects of which people know the concrete effects on their economy, such as changes in GDP, price of products, and income. To consider price effects of all markets, the computable general equilibrium (CGE) model is useful (Hertel, 1990). Ichioka and Tachibanaki (1989), Ichioka (1991) and Tanaka and Hosoe (2009) built the CGE model on Japanese economy and analyzed effects of a reduction in trade barrier of agricultural sector and a reduction in agricultural subsidies. Kunimitsu (2009) used the CGE model with consideration of agricultural public capital to show the effects of the changes in agricultural public investment. This study showed that the equivalent valuation as social welfare effects decreased by 0.39% if the agricultural public capital stocks went down by 1%. Most models used in the previous studies were static type and could not show chronological transition of economy. Based on these previous studies, future impacts of changes in public capital stocks need to be evaluated by making the CGE model dynamic. Also, regional impacts need to be measured to see the differences in regional policies on public projects by using regional CGE model and future effects in economy is important for policy making under deteriorating public facilities.

The current study evaluated comprehensive effects of public facilities in the future in Japanese regional economies as well as industrial influences by using recursive dynamic spatial CGE model. Features of this study were; (i) future situation on public facilities were shown based on the method employed in the Cabinet Office of Japan (2012) which was the first official documents on Japanese public capital stocks, (ii) the dynamic spatial CGE model was used with consideration of endogenous productivity growth by public facilities, and (iii) needed public investment to keep public capital stocks at the peak level was considered and the payment of certain sectors or all industries were considered to secure fund for such investment without an increase in public debts in Japan.

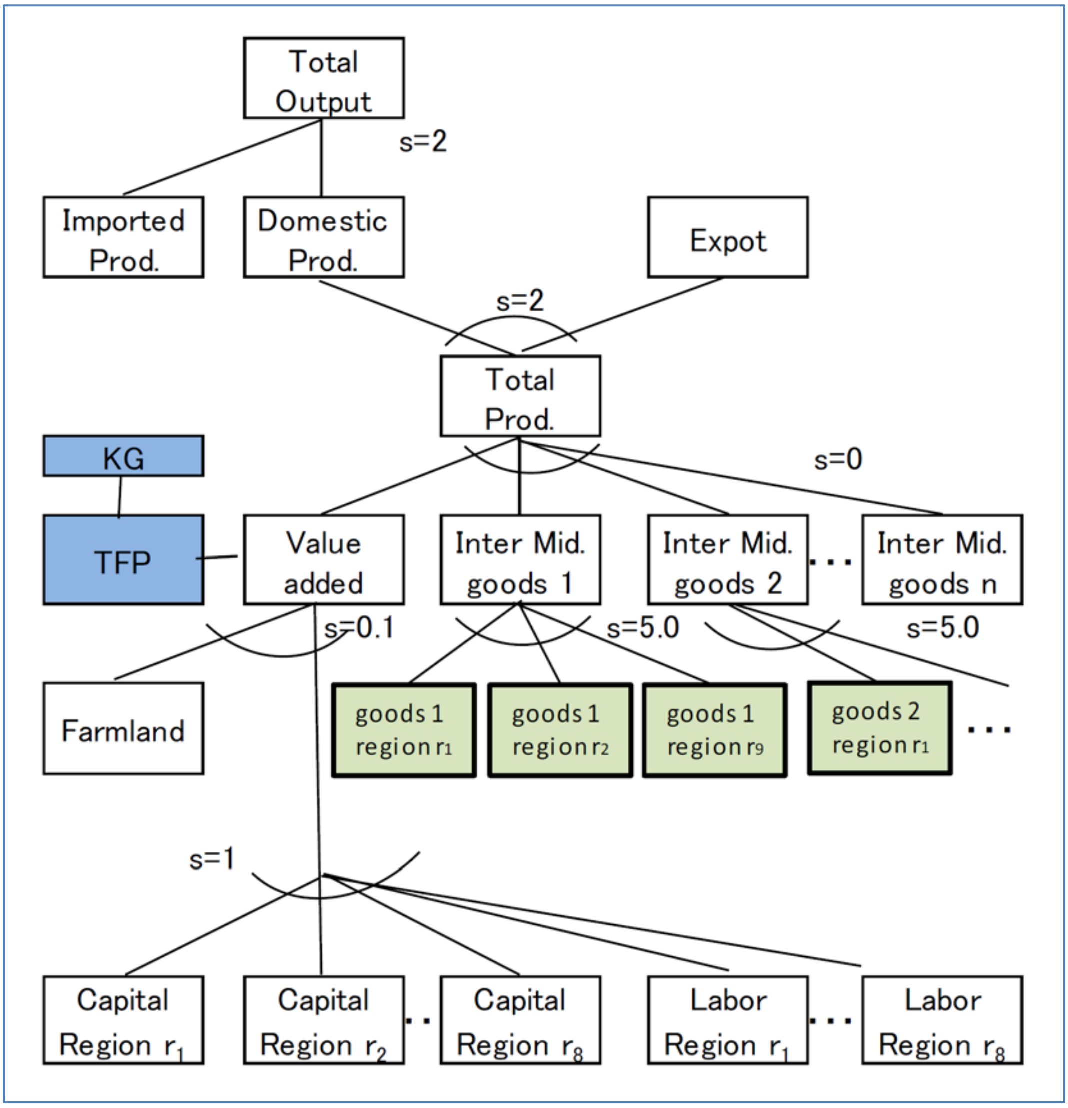
2. METHODOLOGY

2.1 Structure of the Recursive-dynamic Spatial CGE Model

The model used here is the recursive-dynamic spatial CGE model, with multiple regions and commodity sectors. The structure of our model is based on Bann (2007) and Kunimitsu (2014), which use GAMS (GAMS Development Corporation) and MPSGE (a modelling tool using the mixed complementary problem), as developed by Rutherford (1999). The major modification points of this model are as follows.

The cost functions derived from the production functions are defined as nested-type CES (constant elasticity of substitution) forms. The structure of production part is shown in Figure 1. In this part, degrees of spatial dependence among regional products for intermediate inputs are represented by spatial trade substitution elasticities (σ^r). The spatial substitution elasticities on commodity flows were measured by empirical studies Koike *et al*. (2012) showed these values were less than one, showing inelastic situation of spatial commodity flows and low spatial dependence. On the other hand, Tsuchiya *et al*. (2005) showed that these values used in previous SCGE models differed from 0.40 to 2.87 and were higher than substitution elasticities between domestic goods and imported goods. There were big differences in these values according to data, methods and kinds of commodities. Furthermore, spatial substitution elasticities differ according to time span considered in the study. In the long run, these values probably become higher than the case of short run. Considering these features of spatial substitution elasticities, this study took adopted two scenarios in which Japanese economy keeps inelastic spatial dependence and elastic spatial dependence for comparison of influences of climate change.

Figure 1: Production Structure of Spatial CGE Model



The elasticity of substitution of farmland to other input factors, which was not used in Bann (2007), is assumed to be 0.2 for agriculture. Egaitsu (1985) concluded that the substitutability of farmland for other input factors was low, but the substitutability between capital and labour was high, according to empirical evidence on Japanese rice production from several studies.

Based on these findings, we assumed that farmland is a semi-fixed input for agricultural production and cannot really be substituted by other factors.

Consumption is defined by the nested type function (Figure 2). The first nest is defined by the linear expenditure system (LES) function derived from consumers' maximization assumption on utility with Stone-Geary form. The second nest shows spatial dependence among commodities produced in different regions. As is the case of intermediate inputs in cost function, the spatial substitution elasticities take two different values, i.e. 0.5 and 5.0, showing low and high spatial dependence in economy. Other elasticity values of substitution in the consumption, import, and export functions are set to be the same as those used by Bann (2007), which were based on the GTAP database. The government consumption and government investment are Leontief type fixed share function.

Figure 2: Consumers' Utility Structure in the Model

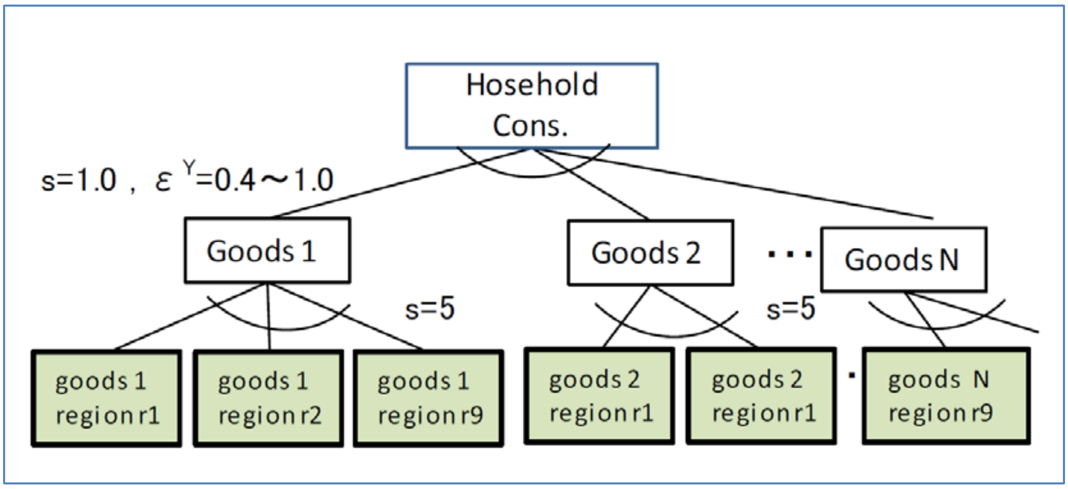
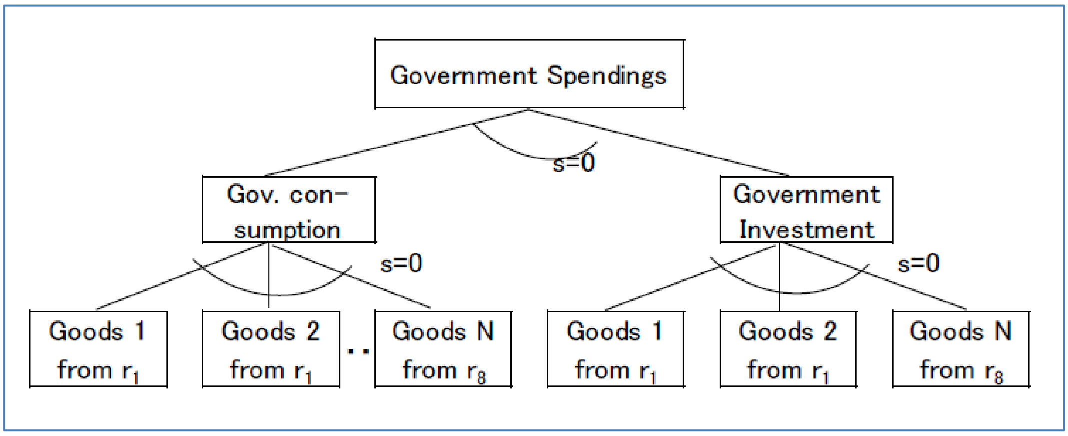


Figure 3 shows the government spending structure assuming Leontief substitution elasticity.

Figure 3: Government Spending



To form the recursive dynamic path, the capital stock equation is defined by annual investment (I) and depreciation rate (δ= 0.04), as follows.

$$K_{i,r,t} = (1-\delta)K_{i,r,t-1} + I_{i,r,t}$$

In this model, $K_{i,r,t}$ shows capital stocks in *i*-th industry of *r*-th region at year *t*, and is defined for every year from *I*, which is endogenously defined by the CGE model as follows.

$$I_{i,r,t} = I_{i,r,t_0}\left(\frac{PK_{i,r,t}}{\overline{PK}_{r,t}}\right)^{0.5}$$

Here, $I_{i,r,t0}$ is initial level of investment in i-th industry of r-th region, *PK* is service price of capital stocks representing rate of return of capital stocks and $\overline{PK}$ is average service price among industries. 0.5 represents the adjustment speed of investment.

2.2 Estimation Method on Amounts of Public Capital Stocks

Estimation of JOC used the perpetual inventory (PI) method which was commonly used for estimation of capitals stocks by many countries in the world. Based on their estimation method, the value of public capital stocks (KG_t) in year *t* can be estimated as follows.

$$KG_t = IG_t + F(1)IG_{t-1} + F(2)IG_{t-2} + \cdots = \sum_{i=0}^{a} F(i)IG_{t-i} \tag{1}$$

Here, subscript *i* was used for manipulating year, IG_t was public investment, $F(i\ )$ was survival rate of public facilities lived for i years, a was the year when survival rate became zero. The survival rate was based on the Weible distribution showing that public facilities started death just after construction and some could live longer than standard life time.

Public investments for disaster recover could not increase public facilities, because such public investment just reconstructed the same facilities as damaged one. However, public investment for disaster recover can reset the life process of public facilities destroyed and recovered afterward. To make calculation simple, we assumed public facilities were damaged when public facilities spent half of their life time with consideration average situation of chances of disaster incidents. The following equation was used to consider such situation.

$$KD_t = ID_t + F(1)\cdot ID_{t-1} + F(2)\cdot ID_{t-2} + \cdots \qquad -\left\{F(n/2)\cdot ID_t + F(n/2+1)\cdot ID_{t-1} + \cdots\right\}$$

$$= \sum_{i=0}^{a}\left[\left\{F(i) - F(i+n/2)\right\}ID_{t-i}\right] \tag{2}$$

Here, *KD* is public capital stocks accumulated by public investment for disaster recover, *ID*. The right hand side of the first line shows survival value of recovered public capital stocks, the second line shows survival value of old capital stocks which became zero after disaster. In more detail, the public investment for disaster recover corresponds to the same amount of old capital stocks destroyed by the disaster. *i* started from the year when recovered facilities were constructed, so *i*=1 means the year when old facilities past n/2 years of life time.

The needed investment for keeping public capitals stocks as previous year could be calculated by setting investment level, $\hat{I}_t$, as $K_t = K_{t-1}$ in Eq. (1). Hence, needed investment could be shown as follows.

$$\hat{I}_t = \left\{F(0) - F(1)\right\}\cdot I_{t-1} + \left\{F(1) - F(2)\right\}\cdot I_{t-2} + \cdots \quad = \sum_{i=0}^{a}\left[\left\{F(i) - F(i+1)\right\}\cdot I_{t-i}\right] \tag{3}$$

Since, this equation had investments from one to a years before year *t*, changes in needed investment at present year affect future needed investment. Considering these features, recursive calculation was applied to quantify needed investment amounts.

The public investment accumulated public capital stocks and could improve production in each industry. An increase in public capital stocks could increase the total factor productivity of each industry as:

$$TFP_{i,t} / TFP_{i,t0} = \alpha \cdot \left(KG_{s,t} / KG_{s,t0} \right)^{\beta_s} \tag{4}$$

Here, β s is the elasticity value of s-th public facility, KGs, to the TFPi of i-th industry. These values were based on Yokoyama and Kataoka (2008) which estimated production functions by industries and regions with chronological data. The measured elasticity values were shown in Table 1. According to their estimation, an increase in agricultural public facilities was assumed to affect only agricultural sector, but road facilities were expected to change all industries as pure public goods.

Table 1: Estimated Production Elasticities of Public Capital Stocks

Regions	Agricultural KG	Road KG			
	Agriculture	Forestry, fishery	Manufacture	Construction	3rd industry
Hokkaido	0.2844	0.0550	0.2460	0.1090	0.0300
Tohoku	0.1111	0.0560	0.2510	0.1050	0.0290
Kanto	0.1866	0.0596	0.2554	0.1022	0.0228
Chubu	0.1800	0.0618	0.2632	0.1078	0.0293
Kinki	0.2333	0.0680	0.2690	0.1090	0.0280
Chugoku	0.1742	0.0625	0.2600	0.1010	0.0305
Sikoku	0.1319	0.0580	0.2610	0.1000	0.0260
Northern kyushu	0.1878	0.0460	0.2475	0.1000	0.0275
Southern Kyushu and Okinawa	0.2087	0.0420	0.2350	0.1030	0.0250

2.3 Data and Simulation

To calibrate the parameters of the model, the social accounting matrix (SAM) was estimated on the basis of Japan’s 2005 inter-regional input-output table. To analyse rice production more precisely, the rice sector was separated from the aggregated agriculture, forestry, and fishery sectors in the IO table, based on regional tables (404 × 350 sectors). Then, the sectors were reassembled into 14 sectors: rice; other agriculture, forestry, and fishery; mining and fuel; food processing; chemical products; general machinery; electric equipment and machinery; other manufacturing; construction; electricity and gas; wholesale and retail sales; financial services; and other services. Regions were assembled into nine regions: Hokkaido; Tohoku; Kanto, including Niigata Prefecture; Chubu; Kinki; Chugoku; Shikoku; and Kyushu and Okinawa, according to the original inter-regional IO table.

The factor input value of farmland, which was not shown in the Japanese I/O Table, was estimated using farmland cultivation areas (Farmland statistics, Ministry of Agriculture, Forestry, and Fishery, and every year) and multiplying the areas and farmland rents. Then, the farmland factor input value was subtracted from the operation surplus in the original IO table. The value of capital input was then composed of the rest of operation surplus and the depreciation value of capital.

To simulate future situation and measure comprehensive effects of public facilities, the following simulation cases were considered with regard to the level of public investment as well as payment level for needed investment (Table 2).

Table 2: Simulation Cases and Their Settings.

Case	Public capital stocks (Agri. Base; KGA)		Public capital stocks (Road; KGR)	
	Public investment	Production effect of KGA	Public investment	Production effect of KGR
BAU	status quo	not considered	status quo	not considered
CASE1	status quo	considered	status quo	not considered
CASE2	Invest needed investment amount, and its cost is payed by only agricultural sector.	considered	status quo	not considered
CASE3	Invest needed investment amount, and its cost is payed by all industries according to production level	considered	status quo	not considered
CASE4	status quo	not considered	status quo	considered
CASE5	status quo	considered	status quo	considered

BAU: Business As Usual or CASE0 was used for the base line of simulation, assuming no production effect of public capital stocks. Exogenous variables, such as farmland supply and labour supply in each region, were fixed at the present levels shown in the SAM data. Other exogenous variables, i.e. government savings, foreign savings, regional transfer, were also fixed at the present levels.

CASE1: This case considered production effects of public capital stocks only in agricultural base. Other settings were the same as CASE0. The differences between this case and CASE0 show effects of public capital stocks for agricultural base. Due to a lack of investment, future public capital stocks for agriculture were decreased after 2014, so agricultural TFP in this case was also decreased according to Eq. (1).

CASE2: This case shows keeping agricultural public capital stocks at the 2010 level by increasing public investment with additional payment as production tax for such costs by only agricultural sector. Farmers would repair and renovate agricultural public facilities to maintain their production by paying extra burden. Other exogenous variables were set as CASE0. Tax rate was calculated as:

$$tax_{agri,t} = \left(\tilde{IGA}_t - \overline{IGA}_t + TAX0_{t0}\right) / X_{agri,t0}$$

Here, tax is the tax rate for agricultural sectors, $\tilde{IGA}_t$ is needed public investment for agricultural base in year *t*, $\overline{IGA}_t$ is public investment and the amount is the same as CASE0, $TAX0_{t0}$ is production tax payment in initial year, and $X_{agri,t0}$ is agricultural gross production.

CASE3: This case shows keeping agricultural public capitals stocks at the 2010 level by additional payment of all sectors as production tax for agricultural public investment. Tax rate for each industry was calculated as:

$$tax_{i,t} = \left(\tilde{IGA}_t - \overline{IGA}_t\right) / \sum_i X_{i,t0} + TAX0_{i,t0} / X_{i,t0}$$

Here, the first term at the left hand side of equation shows an increased tax rate in each industry and the second term shows the original tax rate in each industry.

CASE4: This case was used to show production effects of public capital stocks for roads. The differences between this case and CASE0 show effects of public capital stocks for road. The level of public investment was set as the same as 2014, so TFP of each industry in this case was also changed according to Eq. (1). Other exogenous variables were set as CASE0.

CASE5: This case was the mixture of CASE1 and CASE4 and shows business as usual in some sense. The level of public investment for agricultural base and road were set as the level in 2014 which shows the present situation in Japan. Other exogenous variables were set as CASE0.

3. RESULTS

3.1 Future Level of Public Capitals Stocks

Figure 4 shows chronological trend of public capital stocks for agricultural base and road by simulation cases, and investment amount needed to keep the level of public capital stocks for agricultural base at the same level as 2010.

Road capital stocks could continue to increase even though its growth rate was decreased. Contrarily, agricultural capital stocks decreased in most regions after 2010. The growth rate of road capital stocks was the highest in Okinawa and Kyushu, but those in Sikoku and Kinki achieved low growth rate. Sikoku and Kinki will experience a decrease in capital stocks after 2030 if this tendency in public investment in these regions will continue.

Agricultural capital stocks remarked positive growth rate in Okinawa, but other regions had negative growth rate after 2010. In order to keep agricultural capital stocks, an increase in public investment for this sector is needed as shown in the right side of the figure. In this figure, the level of needed investment was downed in 2013, because actual public investment was increased after 2013 because of the change of cabinet. Kanto, Tohoku and Hokkaido, where agriculture is relatively large industry, need big amount of needed investment as compared to other regions.

3.2 Production Change

Figure 5 shows chronological changes in total agricultural production and gross regional products (GRP) in each region. Each line was calculated by substituting values of CASE0 from values of each case. The production itself increased in every case, but growth rate was different by cases, so difference between CASE0 and other cases took both negative and positive values. If the difference became negative, it shows that growth rate of such case was lower than CASE0.

A decrease in agricultural capital stocks resulted in negative effects in agricultural production, but road capital stocks increased regional production year by year. Since there are many industries which use road capital stocks, production effects of road capitals stocks are higher than agricultural capital stocks. Although this figure cannot show precise tendency, changes in total production caused by a decrease in agricultural capital stocks can become positive in some cases (CASE2 and CASE3). This is because labour and private capital stocks shift to other industry from agriculture under a decrease in agricultural production caused by a decrease in agricultural capital stocks. These positive effects in other sector cancel out the negative effects in agriculture.

Figure 4: Chronological Trend of Public Capital Stocks and Needed Investment for Agricultural Base

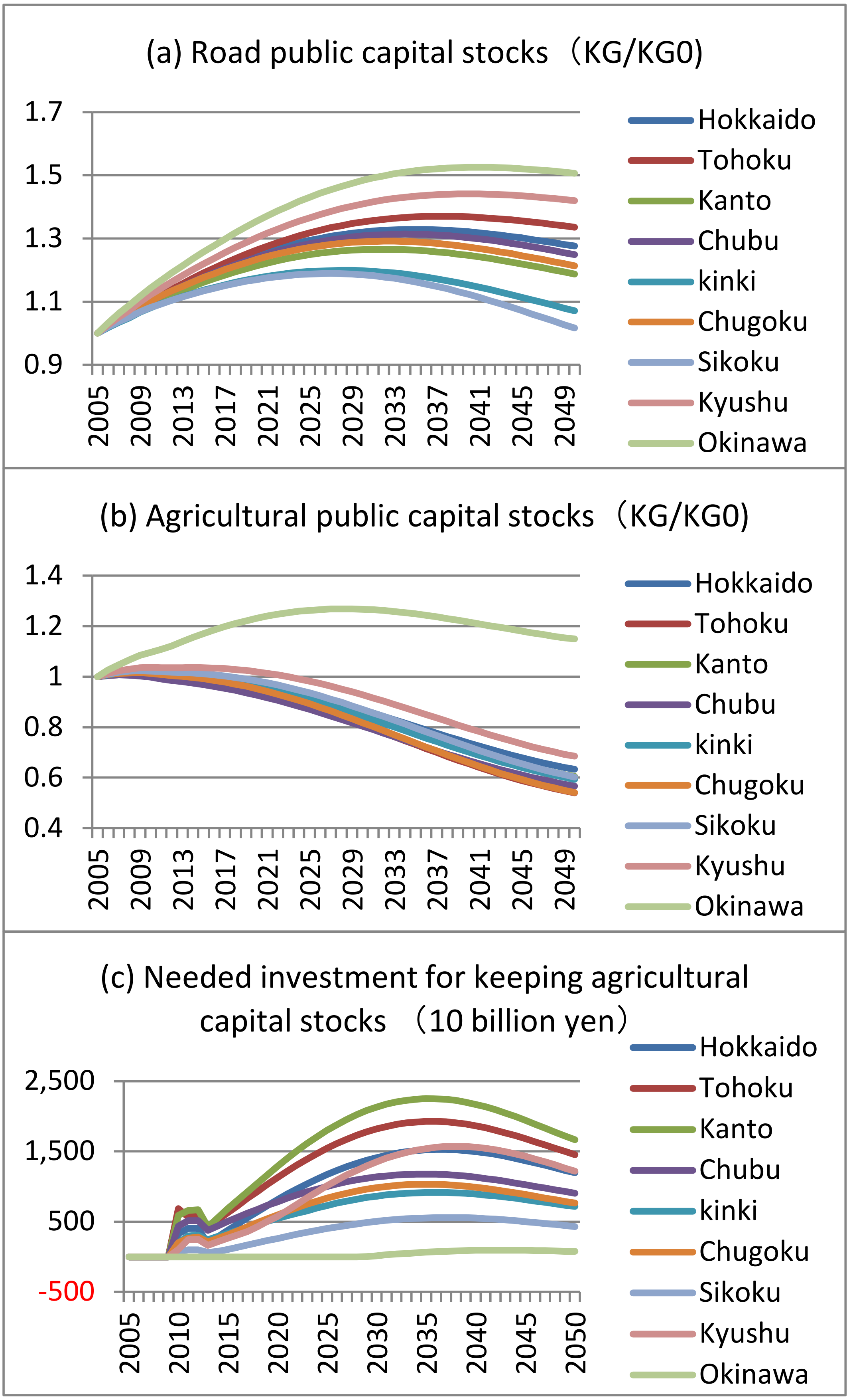


Figure 5: Gross Production in Agriculture (Agri. KG) and Total GRP of All Regions (Road KG)

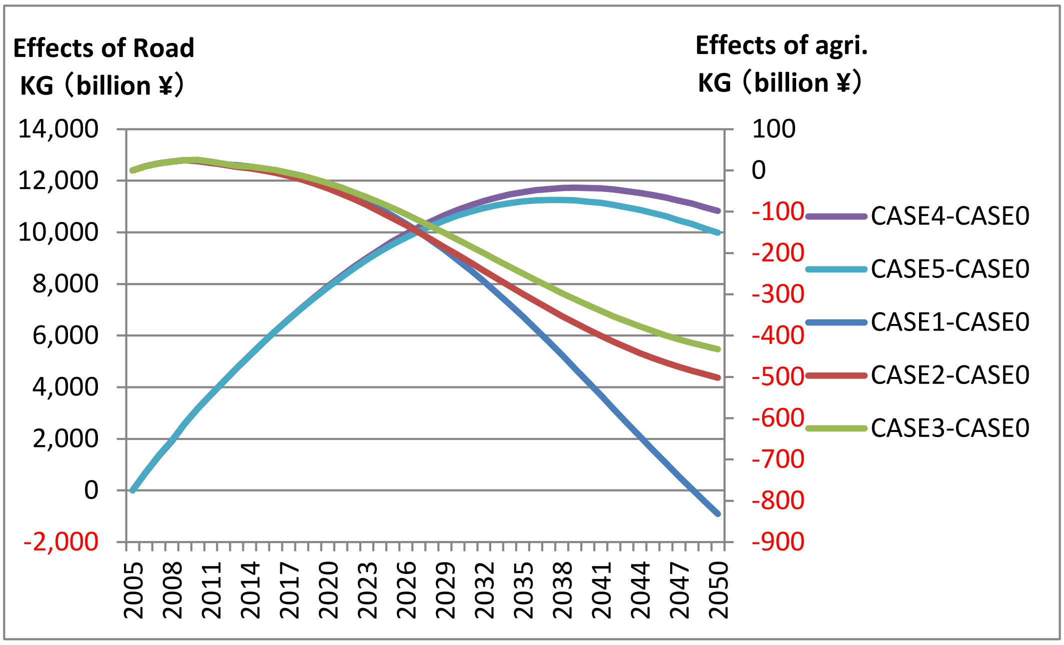


Table 3 shows differences in GRP components between each case and CASE0 in the last year, 2050, of simulation. Private consumption decreased in CASE2 and CASE3 due to burden of additional payment to needed investment and a decrease in agricultural production. However, total public investment can increase owing to additional revenue in government sector, and an increase in public investment overcomes a decrease in private consumption, making total GRP positive. The difference between CASE2 and CASE3 are payment sectors, which is agriculture in CASE2 and all industries in CASE3. This difference of payment sectors appears in export and import. When government taxes all industries, imports related to the energy decrease with export's decrease in the secondary industry due to decline in exports.

Table 3: Changes in GRP Components

(billion yen)

Regions	2030			2050		
	CASE1-CASE0	CASE2-CASE0	CASE4-CASE0	CASE1-CASE0	CASE2-CASE0	CASE4-CASE0
Public cons.	17	769	1,106	32	615	1,186
Private cons.	−181	−904	7,554	−680	−985	7,418
Public inv.	5	1,310	346	9	1,086	371
Private inv.	−67	−335	2,851	−252	−365	2,815
Exports	86	106	2,674	262	65	2,446
Imports	98	123	2,798	302	80	2,568
Total GRP	−239	823	11,733	−931	336	11,668

Changes in total GRP of all regions becomes negative in CASE1 but positive in other cases. This indicates that stopping agricultural capital stocks by an increase in tax totally brings about positive effects in economy.

Table 4 shows changes in gross production, GRP, by regions. In CASE1 and CASE2, all regions except for Okinawa experience decrease in production. Hokkaido and Kanto where agricultural production is relatively larger than other regions marked huge loss in production caused by decrease in agricultural capital stocks.

Table 4: Changes in GRP between CASE Values and CASE0.

(billion yen)

Regions	2030			2050		
	CASE1-CASE0	CASE2-CASE0	CASE4-CASE0	CASE1-CASE0	CASE2-CASE0	CASE4-CASE0
Hokkaido	−106	−40	576	−365	−87	620
Tohoku	−64	−106	1,060	−194	−166	1,206
Kanto	−163	−136	6,085	−573	−262	6,294
Chubu	−65	−91	1,960	−190	−133	2,066
Kinki	−52	−63	1,927	−193	−119	1,504
Chugoku	−37	−55	854	−127	−90	835
Shikoku	−9	−10	293	−41	−24	171
Kyushu	−37	−27	1,545	−239	−83	1,874
Okinawa	9	9	124	6	2	151
Total GRP	−524	−519	14,423	−1,914	−962	14,721

In terms of road capital stocks shown in CASE4, all regions can increase their production, but amount of such regional effects are different. This is because the growth rate of road capital stocks is different by regions and industrial production which is influenced by road capital stocks is different by regions.

3.3 Price Change

Table 5 shows ratio of consumer price index calculated by dividing values in each case by CASE0. Road capital stocks in CASE4 show the effect which lowers the product price of all the industry. On the other hand, CASE1, 2 and 3 shows a little change in consumer price index, because these cases are about agricultural capital stocks which influence only to agricultural sector, even though price change in agricultural sector is relatively high.

If we compare among CASE1, 2 and 3, we see that Hokkaido and Tohoku marked higher price changes caused by changes in agricultural capital stocks. These regions hold larger agricultural production inside the region, so a change in the agricultural productivity easily brings about a change in a price in these regions. However, other regions have relatively small agricultural sector and a change in productivity is hard to cause price change, because a change in productivity is substituted by imports or production in other sectors.

Table 5: Changes in Price of Agricultural Products and Consumer Price Index

(2005=1.0)

Regions	2030			2050		
	CASE1-CASE0	CASE2-CASE0	CASE4-CASE0	CASE1-CASE0	CASE2-CASE0	CASE4-CASE0
Hokkaido	1.024	1.030	0.960	1.075	1.029	0.968
Tohoku	1.018	1.031	0.958	1.056	1.029	0.966
Kanto	1.012	1.018	0.954	1.038	1.017	0.965
Chubu	1.014	1.024	0.953	1.041	1.022	0.963
Kinki	1.010	1.017	0.954	1.033	1.017	0.969
Chugoku	1.016	1.029	0.956	1.050	1.028	0.966
Shikoku	1.016	1.029	0.960	1.052	1.029	0.974
Kyushu	1.015	1.025	0.956	1.052	1.025	0.963
Okinawa	1.005	1.013	0.952	1.032	1.019	0.957
Whole	1.014	1.024	0.956	1.048	1.024	0.966

4. POLICY IMPLICATION AND CONCLUSION

The current study uses the recursive dynamic computable general equilibrium (CGE) model. This model considers endogenous technological progress changed by the agricultural land improvement projects and road construction projects.

The simulation results demonstrated that a decrease in agricultural public facilities causes negative effects of agricultural production as well as Japanese gross regional production (GDP) via changes in prices. Decreased labour and capital stocks in agricultural sector shift to other industries and improve their production, so such shift eases changes in agricultural production. Public capital stocks in roads continue to increase but marginal increase rate will decrease and will diminish an increase rate of production. Maintaining public capital stocks by any counter measures is highly needed for sustainable growth of economy. Different policies on budget source for such measures result in different economic effect, so a CGE model can help decision makers to consider comprehensive effects of policies.

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