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COMPREHENSIVE WATERSHED MANAGEMENT

Impact of the municipal merger on watershed management: a study of Lake Kasumigaura, Japan

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Abstract

In the early 2000s, Japan instituted the Great Heisei Consolidation, a national strategy to promote large-scale municipal mergers. This study analyzes the impact that this strategy could have on watershed management. We select the Lake Kasumigaura Basin, the second largest lake in Japan, for the case study and construct a dynamic expanded input–output model to simulate the ecological system around the Lake, the socio-environmental changes over the period, and their mutual dependency for the period 2012–2020. In the model, we regulate and control the following water pollutants: total nitrogen, total phosphorus, and chemical oxygen demand. The results show that a trade-off between economic activity and the environment can be avoided within a specific range of pollution reduction, given that the prefectural government implements optimal water environment policies, assuming that other factors constraining economic growth exist. Additionally, municipal mergers are found to significantly reduce the budget required to improve the water environment, but merger budget efficiency varies nonlinearly with the reduction rate. Furthermore, despite the increase in financial efficiency from the merger, the efficiency of installing domestic wastewater treatment systems decreases drastically beyond a certain pollution reduction level and eventually reaches a limit. Further reductions require direct regulatory instruments in addition to economic policies, along with limiting the output of each industry. Most studies on municipal mergers apply a political, administrative, or financial perspective; few evaluate the quantitative impact of municipal mergers on the environment and environmental policy implications. This study addresses these gaps.

Keywords Municipal merger · Watershed management · Environmentally expanded I–O model · Computer simulation · Factors hindering economic growth

JEL classification Q25 · Q58 · R11

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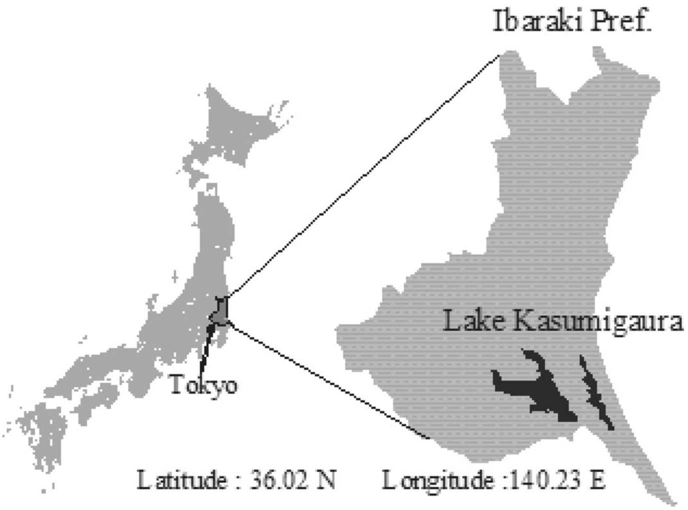

Fig. 1 Location of Lake Kasumigaura

1 Introduction

Since the early 2000s, Japan has enforced a national strategy called the Great Heisei Consolidation that promotes large-scale municipal mergers. According to Yokomichi (2007), this consolidation is directed at several issues, including (1) excessive decentralization, (2) the declining birthrate and aging population, (3) the deteriorating financial situation of national and local governments, and (4) the expansion of daily living space. Under this national strategy, the number of municipalities in Japan has decreased from 3232 in 1999 to 1718 in 2014 (Ministry of Internal Affairs and Communications 2020). Recently, there have been discussions about the introduction of a super-prefecture system in Japan. This system could be considered a merger of prefectures. This study attempts to analyze the impact that such changes could have on watershed management throughout the country by studying a representative case.

This study examines the case of the Lake Kasumigaura area in Ibaraki Prefecture, the second largest lake in Japan, located northeast of Tokyo. The Lake's basin comprises one-third of the Ibaraki Prefecture (Fig. 1). As throughout the country, the number of municipalities in the Basin has decreased, going from 41 to 22. After the municipal mergers, the budget per resident for each municipality increased, on average, by 148,000 Japanese yen (JPY), to a maximum of 458,000 JPY. In addition, the ratio of bond issuance for sewerage system construction to municipal finances fell, on average, by 1.5%, to a maximum of 4.7%. These changes are attributed to budget efficiency improvement from the mergers.

As a critical settlement area containing approximately 1 million people, the water from Lake Kasumigaura is used to meet the needs of households, agriculture, and industry. However, due to rapid economic and population growth in the 1970s, the condition of the Lake has seriously deteriorated. For the Ibaraki prefectural government, improving the water quality of this lake ranks as a key policy issue. However, despite huge budget expenditure, there is no clear evidence of improvement in water quality.

This study has four main objectives: (1) to clarify the impact of municipal mergers on the trade-off between regional economic activity and reducing water pollution; (2) to clarify the impact of municipal mergers on the budget efficiency of environmental policy; (3) to identify the optimal watershed management policy needed to reduce water pollutants emitted into the Basin and ultimately, the Lake; and (4) to clarify the impact of municipal mergers on production in each sector. The study period is 2012–2020.

We use an environmentally extended input–output model to simulate the total ecological system in and around the Lake, the socio-environmental changes over the study period, and their mutual dependency. In the model, the following water pollutants are regulated and controlled: total nitrogen (TN), total phosphorus (TP), and chemical oxygen demand (COD). These are the critical indices in Japanese environmental laws which prescribe the effluent standards in wastewater treatment associated with socio-economic activities.

Among environmental studies, Baumol and Oates (1988) and Oka (1997) analyze the political aspects of environmental problems. Mizunoya et al. (2007) examine a dynamic optimal policy and evaluate new technologies to improve water quality in a lake through numerical simulation. They report that introducing new technologies reduces pollution and increases social welfare compared to status quo (Mizunoya et al. 2007). In analyzing municipal mergers, Hansen (2012), Hansen et al. (2014), Moisio and Uusitalo (2013), Nishikawa (2002), and Pickering et al. (2016) focus on their financial aspects. Hansen et al. (2014) investigate the causal relationship between municipal mergers and fiscal outcomes based on administrative data from Danish municipalities. The study reveals that municipal mergers improved fiscal outcomes, measured by the municipality's balance of revenues and expenses, liquid assets, and debts, over a 5-year period, although the pre-reform effects tended to be negative (Hansen et al. 2014).

Most previous research on this topic applies a political, administrative, or financial perspective. Few studies quantitatively evaluate the impact of municipal mergers on the environment or examine its implications from the perspective of environmental policy. This study addresses these gaps.

2 Simulation model

2.1 Framework of the simulation model

The simulation comprises two sub-models and one objective function. The material flow balance model describes how pollutants flow into the rivers and the Lake. The socio-economic model describes the relationship between socio-economic activities in the Basin and the emissions of pollutants. All policy measures to improve water quality directly, indirectly, and potentially are built into the model as alternatives to provide an optimal hybrid of policy measures. The objective function is the

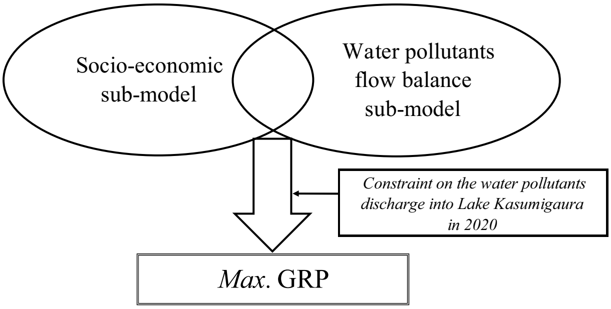

Fig. 2 Interrelationship between sub-models

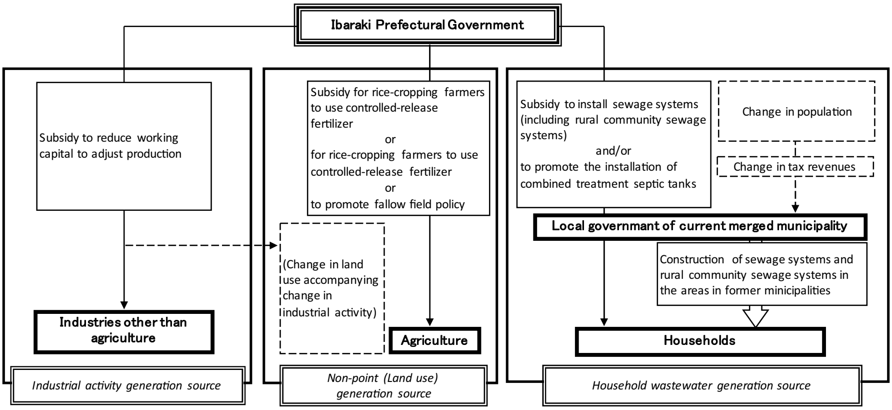

Fig. 3 Framework of the socio-economic model

discounted sum of the gross regional product (GRP) produced in the Basin over the planning horizon. The model simulates the socio-economic activities when the load of total water pollutants is restricted. It endogenously clarifies an optimal hybrid of environmental and economic policies, namely, how to control the timings and regions of economic activities, and how to allocate the environmental budget effectively. The sub-models are depicted in Fig. 2, and the core framework of the socio-economic model is depicted in Fig. 3.

2.2 Sub-basins and municipalities in the Kasumigaura Basin

The Kasumigaura Lake Basin comprises several sub-basins, which are mainly river basins. Table 1 shows the 41 former municipalities in the 17 sub-basins and Table 2 shows the relationship between the current merged municipalities and former municipalities. For example, Sakuragawa City was established in 2005 by merging Iwase Town, Yamato Village, and Makabe Town. The framework describes the spatial structure of water pollutants, showing them as initially generated in the sub-basins, then emitted into the water system, and ultimately transported into the Lake.

Table 1 Target area (name and index no. of former municipalities)

River index No (index *i* in the model)	Name of river (Name of sub-basin)	Former municipality index No. (index *j* in the model)	Name of municipality before merger
1	Sakura River	1	Iwase Town
		2	Yamato Village
		3	Makabe Town
		4	Akeno Town
		5	Kyowa Town
		6	Shimodate City
		7	Shimotsuma City
		8	Tsukuba City
		9	Niihari Village
		10	Tsuchiura City
2	Seimei River	11	Miho Village
3	Koise River	12	Chiyoda Town
4	Sonobe River	13	Yasato Town
		14	Ishioka City
		15	Tamari Village
5	Kajinashi River	16	Tamatsukuri Town
6	Ono River	17	Kukizaki Town
		18	Ushiku City
		19	Ryugasaki City
		20	Ami Town
		21	Edosaki Town
		22	Sakuragawa Village
7	Ichinose River	23	Kasumigaura Town
8	Shin-Tone River	24	Tone Town
		25	Kawachi Town
		26	Shin-Tone Town
		27	Azuma Town
9	Hokota River	28	Asahi Village
10	Tomoe River	29	Iwama Town
		30	Minori Town
		31	Ibaraki Town
		32	Ogawa Town
		33	Hokota Town
11	Yamada River	34	Kitaura Town
12	(Direct Discharge into the lake)	35	Taiyo Village
13	Gantsu River	36	Asou Town
14	(Direct Discharge into the lake)	37	Kashima City
15	Yogoshi River	38	Ushibori Town
16	Maekawa River	39	Itako Town
17	Hitachi-Tone River	40	Hasaki Town
		41	Kamisu Town

Table 2 Relationship between former municipalities and current municipalities

Index No (index *h* in the model)	Name of current merged municipality	Name of former municipalities (and index No. of *j*)			
1	Sakuragawa City	Iwase Town (1)	Yamato Village (2)	Makabe Town (3)	
2	Chikusei City	Akeno Town (4)	Kyowa Town (5)	Shimodate City (6)	
3	Shimotsuma City	Shimotsuma City (7)			
4	Tsukuba City	Tsukuba City (8)	Kukizaki Town (17)		
5	Tsuchiura City	Niihari Village (9)	Tsuchiura City (8)		
6	Kasumigaura City	Chiyoda Town (12)	Kasumigaura Town (23)		
7	Ishioka City	Yasato Town (13)	Ishioka City (14)		
8	Omitama City	Tamari Village (15)	Minori Town (30)	Ogawa Town (32)	
9	Namegata City	Tamatsukuri Town (16)	Kitaura Town (34)	Asou Town (36)	
10	Inashiki City	Edosaki Town (21)	Sakuragawa Village (22)	Shin-Tone Town (26)	Azuma Town (27)
11	Hokota City	Asahi Village (28)	Hokota Town (33)	Taiyo Village (35)	
12	Kasama City	Iwama Town (29)			
13	Itako City	Ushibori Town (38)	Itako Town (39)		
14	Kamisu City	Hasaki Town (40)	Kamisu Town (41)		
15	Miho Village				
16	Ushiku City				
17	Ryugasaki City				
18	Ami Town				
19	Tone Town				
20	Kawachi Town				
21	Ibaraki Town				
22	Kashima City				

Table 3 Classification of households by disposal system

Index No (index k in the model)	Facility
1	Sewage system
2	Rural community sewage system
3	Combined treatment septic tank
4	Treatment septic tank
5	Night soil septic tank
6	Untreated domestic wastewater

Table 4 Classification of land use

Index No (index l in the model)	Land use
1	Rice field
2	Upland field
3	Mountain forest
4	City area
5	Other land use

Table 5 Classification of industries

Index No (index m in the model)	Industry
1	Rice cropping
2	Upland cropping
3	Dairy farming•Beef farming
4	Pig farming
5	Fisheries (Eel farming)
6	Manufacturing industry
7	Service industry

2.3 Classification of water pollutant sources and environmental policy options

2.3.1 Classification of water pollutant sources

We classified water pollutants into three categories: household, non-point, and industrial. The water pollutants discharged from households depend on the wastewater disposal system adopted by each household. The households in the Basin are grouped into six categories (see Table 3) according to their disposal system.

Land use is categorized into five types according to the Ibaraki prefectural government (2013) and the outflow characteristics of water pollutants (Table 4).

Table 5 shows seven categories of industries affecting the Basin. The classification is based on activities directly linked to the land-use patterns, that directly and indirectly affect the water environment of the Lake. Note that the service sector does not directly emit any water pollutants.

Table 6 Policy measures to reduce water pollutants discharged into Lake Kasumigaura

Source of water pollutants	Counter measure
Industrial activity	I. Subsidy for industries to reduce working capital to adjust production
Household wastewater	II. Subsidy for municipalities to install sewage systems and rural community sewage systems
	III. Subsidy for municipalities to promote installation of combined treatment septic tanks
Non-point (Land use)	IV. Subsidy for usage of the rice transplanter with fertilizer distributor (subsidy of 5.6% on the purchase price[a])
	V. Subsidy for rice-cropping farmers to use controlled-release fertilizer (subsidy 15% on the purchase price[b])
	VI. Subsidy to promote fallow field policy (conversion of rice or paddy field into fallow field)

[a] Actual subsidy rate of Ibaraki prefecture

[b] Assumed based on a difference in the purchase prices

2.3.2 Environmental policy options

The policy measures listed in Table 6 are assumed in the simulation. From these, the Ibaraki prefectural government would select a hybrid policy to achieve the most efficient improvement in the water quality of Lake Kasumigaura. Most measures have already been adopted. Hirose and Higano (2000) report that the Ibaraki prefectural government spent 20 billion JPY (approximately 160 million US$) per year directly or indirectly to improve the water quality in Kasumigaura in the 1990s. In this simulation, we derive the necessary budget and its allocation endogenously by reflecting the economic and environmental situation in the Basin. We restrict the total budget allocated to measures I and VI in Table 6 to no more than 20 billion JPY, as shown in Hirose and Higano (2000), to prevent excessive production adjustment. At the least, this ensures that no more than the annual budgeted amount used to improve water quality in the 1990s is used for production adjustments. Measure I is a policy whereby the government subsidizes industries to reduce production by increasing the amount of idle capital, thereby reducing emissions of water pollutants from these industries.

2.4 Model structure

This simulation consists of more than 70 equations. For conciseness, we describe only the most important ones. In the model, there are exogenous variables (ex.) and endogenous variables (en.). The exogenous variables are calculated based on existing data and the endogenous variables are determined by the model's structure. Hereafter, the merged municipality is referred to as "the municipality" and the municipalities before the merger as "former municipalities."

2.4.1 Objective function

We consider the GRP of the Basin as an index that reflects the levels of all socio-economic activities. The market mechanism and driving force of the economy are simulated by the non-linear maximization of the discounted GRP in the period subject to the structural constraints of socio-economic activities, and emission and transportation of water pollutants, among other factors. In this simulation, we constrain annual GRP growth to a maximum of 2.3%, reflecting the recent average economic growth in Ibaraki Prefecture, where Kasumigaura is located. The average growth rate is calculated based on data provided by the Ibaraki Prefectural Government (2019). The constraint on the average economic growth rate assumes that there are factors that hinder economic growth in Japan, as shown in Matsuzaki (2010) and Hoshi and Kashyap (2011). This paper also analyzes the impact of the factors that impede economic growth on watershed management:

$$\max \sum_{t=1} \frac{1}{(1+\rho)^{(t-1)}} \mathrm{GRP}(t) \tag{1}$$

$$\mathrm{GRP}(t) = \boldsymbol{v} \cdot \boldsymbol{x}(\boldsymbol{t}), \tag{2}$$

where $t = 1$: 2012, …, $t = 9$: 2020;GRP(t) is the gross regional product at time period t (en.); ρ is the social discount rate (=0.05) *(ex.)*; $\boldsymbol{v}$ is a row vector of the mth element, the value-added rate of industry m (ex.); and $\boldsymbol{x}(\boldsymbol{t})$ is the column vector of the mth element, the total product of industry m in the entire target area at time period t (en.).

2.4.2 Water pollutant flow balance sub-model

In this model, the water pollutants in the Lake are defined as the sum of those that flow through the rivers and that are discharged by sewage treatment plants, fisheries, and rainfall on the surface of the Lake. We used the Unit Value Method (UVM) (Kunimatsu and Muraoka 2002) to calculate the water pollutant loadings from each pollutant source. The pollutant load generated by a source and the manner of its generation vary from source to source depending on the time of day, weather, season, and other conditions. However, it is practically impossible to continuously measure the pollutant load from all sources over a long period of time. UVM is a method of calculating the generated load by multiplying a frame, such as population or land area, by the general average of the load per year or per day (it is called "emission coefficient" or "unit value") from each of the pollution sources. This method has been used in many studies and reports to estimate the pollutant load to public water bodies, such as Kimengich et al. (2019) and Takano et al. (2010). Since the unit of time in this simulation model is 1 year, we used an emission coefficient with 1 year as the unit of term.

1. Water pollutant load flow into Lake Kasumigaura

$$Q^p(t) = \sum_i \mathrm{RQ}_i^p(t) + \mathrm{QF}^p(t) + \sum_d \mathrm{QD}_d^p(t) + \mathrm{QR}^p(t), \tag{3}$$

where $Q^p(t)$ is the total load of pollutant p into the Lake at time period t (en.), $\mathrm{RQ}_i^p(t)$ is the load of pollutant p from river i at time period t *(en.)*, $\mathrm{QF}^p(t)$ is the load of pollutant p from fisheries into the Lake at time period t (en.), $QD_d^p(t)$ is the load of pollutant p from sewage treatment plant d discharging processed water into the Lake directly at time period t (en.), and $\mathrm{QR}^p(t)$ is the load of pollutant p from rainfall at time period t (ex.).

2. Pollutants emitted by socio-economic activities

   The total pollutants emitted by socio-economic activities in the sub-basin comprise pollutants from households, non-point sources, and industrial sources:

$$r_{ij}^p(t) = \mathrm{QZ}_{ij}^p(t) + \mathrm{QL}_{ij}^p(t) + \mathrm{QX}_{ij}^p(t), \tag{4}$$

   where $r_{ij}^p(t)$ is pollutant p from socio-economic activities in former municipality j from river i at time period t (en.), $QZ_{ij}^p(t)$ is pollutant p (excluding sewage) from households in former municipality j from river i at time period t (en.), $QL_{ij}^p(t)$ is pollutant p emitted by non-point sources in former municipality j from river i at time period t (en.), and $QX_{ij}^p(t)$ is pollutant p emitted by industrial sources in former municipality j from river i at time period t (en.).

3. Load of water pollutants from household sources

   Based on the UVM, the amount of water pollutants discharged from households in a year is calculated by multiplying the population using each household wastewater treatment system, by the emission coefficient of each household wastewater treatment system:

$$\mathrm{QZ}_{ij}^p(t) = \sum_{k \neq 1} E^{pk} \cdot Z_{ij}^k(t), \tag{5}$$

   where E^{pk} is the emission coefficient of pollutant p from household wastewater treatment system k ($k \neq 1$) (ex.), and $Z_{ij}^k(t)$ is the population using the household wastewater treatment system k ($k \neq 1$) in municipality j and discharging pollutants into river i at time period t (en.).

4. Load of water pollutants from non-point sources

   Based on the UVM, the amount of water pollutants discharged from non-point sources is calculated by the area of each land-use category and its emission coefficients:

$$\mathrm{QL}_{ij}^p(t) = G^{pl} \cdot L_{ij}^l(t), \tag{6}$$

   where G^{pl} is the coefficient of pollutant p emitted through land use l *(ex.)*, and $L_{ij}^l(t)$ is the area of land use l in former municipality j that emits pollutants into river i at time period t (en.).

5. Load of water pollutants from industrial activities

Based on the UVM, the amount of water pollutants emitted from industrial activities is calculated by the volume of production of each industry and its emission coefficients:

$$\mathrm{QX}_{ij}^{p}(t) = P^{pm} \cdot X_{ij}^{m}(t), \tag{7}$$

where P^{pm} is the coefficient of pollutant p emitted by industry m (ex.), and $X_{ij}^{m}(t)$ is the production of industry m in the former municipality j area that emits pollutants into river i at time period t (en.).

2.4.3 Socio-economic model

1. Treatment measures for household wastewater sources

    a. Municipality budget

    In all the municipalities in the target area, a minimum of 20% of the revenue comes from local taxes, the majority of which are population-dependent resident tax revenues. A correlation analysis between total revenue and population from 1989 to 2018 for each of the target municipalities shows strong associations, with 17 out of 22 municipalities after the merger having correlation coefficients above 0.8. Therefore, we assume that the budget of a municipality is dependent on the size of its population:

    $$R_h(t) = \rho_h \cdot Z_h(t) \quad \text{(with merger)} \tag{9-1}$$

    $$R_j(t) = \rho_j \cdot Z_j(t) \quad \text{(without merger)} \tag{9-2}$$

    where $R_h(t)$ is the budget of municipality h at time period t (en.), ρ_h is the budget per resident of municipality h (ex.), $R_j(t)$ is the budget of former municipality j at time period t (en.), and ρ_j is the budget per resident of former municipality j (ex.).

    b. Systems for sewage and rural community sewage services

    An increase in the population using a sewage system or a rural community sewage system is dependent on construction investment:

    $$\Delta Z_j^k(t) \le \Gamma_j^k \cdot i_j^k(t) \quad \text{(with merger)} \tag{10-1}$$

    $$\Delta Z_j^k(t) \le \Gamma_j^k \cdot i_j^k(t) \quad \text{(without merger)} \tag{10-2}$$

    $$i_h^k(t) = \sum_j i_j^k(t), \tag{11}$$

    where $\Delta Z_h^k(t)$ is the change in the population using sewage system ($k=1$) and rural community sewage system ($k=2$) in municipality h at time period t (en.), Γ_h^k is the reciprocal of the necessary per-capita construction investment using the sewage ($k = 1$) and rural community sewage systems ($k = 2$) in municipality *h (ex.)*, $i_h^k(t)$ is total construction investment of municipality h for the sewage ($k = 1$) and rural community sewage systems ($k = 2$) at time period t (en.), $\Delta Z_j^k(t)$ is the change in population using the sewage ($k = 1$) and rural community sewage systems ($k = 2$) in municipality j at time period t (en.), Γ_j^k is the reciprocal of the necessary per-capita construction investment using the sewage ($k = 1$) and rural community sewage systems ($k = 2$) in municipality j (ex.), and $i_j^k(t)$ is the construction investment in former municipality j for the sewage ($k = 1$) and rural community sewage systems ($k = 2$) at time period t (en.)

c. Sewage system and rural community sewage system

The investment for construction of a sewage system or rural sewage system is determined by the construction allotment for the merged municipality and subsidies provided by the prefectural and central governments:

$$i_h^k(t) = \left(\frac{1}{1 - M^k}\right)\mathrm{cc}_h^k(t) \quad \text{(with merger)} \tag{12-1}$$

$$i_j^k(t) = \left(\frac{1}{1 - M^k}\right)cc_j^k(t)\text{(without merger)}, \tag{12-2}$$

where M^k is the subsidy from the prefectural and central governments (ex.), $cc_h^k(t)$ is the construction allocation of municipality h ($k = 1$: sewage system; $k = 2$: rural community sewage system) at time period t (en.), and $cc_j^k(t)$ is the construction allocation of municipality j at time period t (en.).

d. Construction allocation of merged municipality for the sewage system

The merged municipality construction allocation is covered by a transfer from the general municipality account and a municipal bond:

$$cc_h^k(t) = db_h^k(t) + b_h^k(t) \quad \text{(with merger)} \tag{13-1}$$

$$\mathrm{cc}_j^k(t) = \mathrm{db}_j^k(t) + b_j^k(t), \quad \text{(without merger)} \tag{13-2}$$

where $db_h^k(t)$ represents the local bonds needed to construct facility k ($k = 1$: sewage system; $k = 2$: rural community sewage system) issued by municipality h at time period t (en.), $b_h^k(t)$ is the amount transferred from the general municipality account h to construct facility k ($k = 1$: sewage system, $k = 2$: rural community sewage system) at time period *t (en.)*, $db_j^k(t)$ represents the local bonds required to construct the facility issued by former municipality j at time period t (*en.*), and $b_j^k(t)$ is the transfer from the former municipality j general account to construct the facility.

e. Maintenance costs of the sewage system

The sewage and rural community sewage system maintenance costs are covered by the users and the merged municipality:

$$\mathrm{mc}_h^k(t) = v_h^k \cdot Z_h^k(t) = N_h^k \cdot Z_h^k(t) + g_h^k(t) \quad \text{(with merger)} \tag{14-1}$$

$$\mathrm{mc}_j^k(t) = v_j^k \cdot Z_j^k(t) = N_j^k \cdot Z_j^k(t) + g_j^k(t) \quad \text{(without merger)}, \tag{14-2}$$

where $mc_h^k(t)$ is the total maintenance cost of facility k ($k=1$: sewage system, $k=2$: rural community sewage system) in municipality h at time period t (en.), v_h^k is the maintenance cost per user of k in municipality h (ex.), N_h^k is the sewage charge per capita of k in municipality h (ex.), $g_h^k(t)$ is the transfer from the general municipality account of h to cover maintenance costs of k at time period t (en.), $mc_j^k(t)$ is the total maintenance cost of facility k in former municipality j at time period t (en.), v_j^k is the maintenance cost per user of k in former municipality j (ex.), N_j^k is the charge per capita of k in former municipality j (ex.), and $g_j^k(t)$ is the transfer from the former municipality j general account to cover maintenance costs of k at time period t (en.).

f. Limitation of the policy budget

The construction of sewage ($k=1$) and rural community sewage systems ($k=2$) and the installation of a combined treatment septic tank ($k=3$) are covered by a specific portion of the municipality's general account and the household wastewater treatment subsidy from the prefectural government for construction and installation measures for the treatment of household wastewater:

$$b_h^1(t) + b_h^2(t) + b_h^3(t) + g_h^1(t) + g_h^2(t) \le \omega_h \cdot R_h(t) + sw_h(t) \text{(with merger)} \tag{16-1}$$

$$b_j^1(t) + b_j^2(t) + b_j^3(t) + g_j^1(t) + g_j^2(t) \le \omega_j \cdot R_j(t) + sw_j(t) \text{(without merger)}, \tag{16-2}$$

where ω_h is the transfer rate for the treatment of household wastewater from the general account of municipality h (ex.), $sw_h(t)$ is the subsidy for household wastewater measures in municipality h granted by the prefectural government to the municipality (en.), ω_j is the transfer rate for the treatment of household wastewater from the general account of former municipality j (ex.), and $sw_j(t)$ is the subsidy for household wastewater measures in former municipality j granted by the prefectural government to the municipality (en.)

2. Treatment measures for non-point sources

a. Fallow field policy

The prefectural government subsidizes the conversion of rice fields and upland fields to fallow fields (categorized as "other land use"):

$$L_h^{l5}(t) \geq \lambda^l \cdot s_h^l(t) \quad \text{(with merger)} \tag{17-1}$$

$$L_j^{l5}(t) \geq \lambda^l \cdot s_j^l(t) \quad \text{(without merger)} \tag{17-2}$$

$$s_h^l(t) = \sum_j s_j^l(t) \quad \text{(with merger)}, \tag{18}$$

where $L_h^{lL}(t)$ is the conversion of land use from l to L in municipality h (en.), $L_h^{Ll}(t)$ is the conversion of land use from L to l in municipality h (en.), λ^l is the reciprocal of the subsidy for the conversion of one unit of land use from l to land use for another purpose (index = 5) (ex.), $s_h^l(t)$ is the subsidy from the prefectural government for conversion of land use from l ($l = 1$: rice field, $l = 2$: upland field) into land use for another purpose in municipality h (en.), $L_j^{lL}(t)$ is the conversion of land use from l to L in former municipality j (en.), $L_j^{Ll}(t)$ is the conversion of land use from L to l in former municipality j (en.), and $s_j^l(t)$ is the subsidy from the prefectural government for conversion of land use from l into land use for another purpose in former municipality j (en.).

3. Treatment measures for industrial activity sources

   a. Production function and curtailment

      Production in each industry is decided not only by supply and demand but also by working capital. The prefectural government restricts the cultivation of rice fields ($m = 1$) and upland fields ($m = 2$) through the fallow field policy. The production in other industries ($m = 3, \ldots, 7$) is restricted by leaving capital idle and subsidizing the loss due to idle capital. The production in rice and upland fields is also dependent on the area of cultivated land:

$$x_h^m(t) \leq \alpha^m \cdot \left\{k_h^m(t) - s_h^m(t)\right\} (\text{for} m = 3, \ldots., 7) \quad \text{(with merger)} \tag{19-1}$$

$$x_j^m(t) \leq \alpha^m \cdot \left\{ k_j^m(t) - s_j^m(t) \right\} (\text{for} m = 3, \ldots., 7)\text{(without merger)} \tag{19-2}$$

$$s_h^m(t) = \sum_j s_j^m(t) \quad \text{(with merger)}, \tag{20}$$

where $x_h^m(t)$ is the production of industry m [$m = 3$: dairy farming and beef farming, $m = 4$: pig farming, $m = 5$: fisheries (eel farming), $m = 6$: manufacturing industry, and $m = 7$: service industry] in municipality h (en.), α^m is the capital-output ratio in industry m (ex.), $k_h^m(t)$ is the working capital of industry m in municipality h (en.), $s_h^m(t)$ is the subsidy from the prefectural government for industry m to reduce working capital to adjust production in municipality h (en.), $x_j^m(t)$ is the amount produced by industry m in former municipality j (en.),$k_j^m(t)$ is the working capital of industry m in former municipality j (en.), and$s_j^m(t)$ is the subsidy from the prefectural government for industry m to reduce working capital to adjust production in former municipality j (en.).

4. Necessary budget of Ibaraki prefectural government

The budget needed by the prefectural government comprises the cost of implementing countermeasures toward household wastewater generation, land-use wastewater generation, and industrial activity wastewater generation:

$$y(t) = \sum_h sw_h(t) + \sum_h \sum_m s_h^m(t) + \sum_h \sum_l s_h^l(t)(\text{with merger}) \tag{21-1}$$

$$y(t) = \sum_j sw_j(t) + \sum_j \sum_m s_j^m(t) + \sum_j \sum_l s_j^l(t) \quad (\text{without merger}), \tag{21-2}$$

where $y(t)$ is the total budget spent by the prefectural government to implement the countermeasures in time period t (ex.).

5. Flow balance in the commodity market

The total product of each industry is decided by the balance between supply and demand:

$$x(t) \geq \boldsymbol{A} \cdot x(t) + \boldsymbol{c(t)} + \boldsymbol{i^P(t)} + \boldsymbol{B^S}\left\{i^1(t) + i^2(t)\right\} + \boldsymbol{B^C}\left\{\delta \cdot \Delta Z^3(t)\right\} + mc^k \cdot Z^k(t) + \boldsymbol{e(t)}, \tag{22}$$

where $\boldsymbol{A}$ is the input–output coefficient matrix (ex.); $\boldsymbol{c(t)}$ is the column vector of consumption (en.); $\boldsymbol{i^P(t)}$ is a column vector of the mth element, the total investment in industry m (en.); $\boldsymbol{B^S}$ is the column vector of the ith coefficient, the induced production in industry i by construction of sewage and rural community sewage systems (ex.); $i^1(t)$ is the total investment in construction of the sewage system *(en.)*; $i^2(t)$ is the total investment in construction of the rural community sewage system ($k=2$) (en.); $\boldsymbol{B^C}$ is the column vector of the ith coefficient, induced production in industry i by construction of a combined treatment septic tank (ex.); δ is the installation cost per capita of the combined septic tank (ex.); $\Delta Z^3(t)$ is the change in population using the combined septic tank at time period t *(en.)*; mc^k is the total maintenance cost of facility k (ex.); $Z^k(t)$ is the population using facility k (en.); and $\boldsymbol{e(t)}$ is the column vector of net export (en.).

2.4.4 Constraints on water pollutant inflow

We set constraints on the amount of TN, TP, and COD flowing into Lake Kasumigaura in 2020:

$$Q^{p^*}(9) \geq Q^{p^*}(9), \tag{23}$$

where $Q^{p^*}(9)$ represents the restrictions on each pollutant flowing into Lake Kasumigaura at $t = 9$ (2020) (ex.).

2.5 Case and scenario setting

We establish two simulations: “with merger” and “without merger.” The “with merger” simulation analyzes the optimal water improvement policy and its impact on the situation post-merger, that is, the current situation. In this case, the merged municipal governments receive subsidies for countermeasures to household wastewater generation (II and III in Table 6) from the Ibaraki prefectural government and install sewage and rural community sewage systems and/or promote the installation of combined treatment septic tanks for households. In addition, other direct policies of the Ibaraki Prefecture (I, IV, V, and VI in Table 6) are implemented considering the framework of the current municipality. However, the “without merger” simulation assumes that no merger takes place and the former municipalities still exist. In this case, the former municipalities receive subsidies from the Ibaraki prefectural government for countermeasures to the household wastewater generation and install sewage and rural community sewage systems and/or promote the installation of combined treatment septic tanks for households. In addition, other policies of the Ibaraki Prefecture are implemented taking into account the framework of the former municipality.

In the “with merger” case, parameters that define the characteristics of the municipality, such as budget per resident, budget per capita needed to construct each household’s wastewater disposal system, the per-capita maintenance cost of the sewage system, and so on, are given at the merged municipality level based on data from 2012, the year municipality mergers were completed. However, in the “without merger” case, each of the parameters is given at former municipality levels based on data before the mergers.

For both cases, we run a set of *n* simulation scenarios that assume that water pollutants flowing into Kasumigaura Lake are reduced by *n*% by the year 2020 compared with the baseline year 2012. For example, the reduction is 20% in Scenario 20. We estimate the flow of TN, TP, and COD into Lake Kasumigaura in 2012 as 3860 tons, 223 tons, and 8006 tons, respectively.

3 Results

3.1 Trade-off: socio-economic activity and water environment

In this simulation, we obtained feasible solutions using Scenarios 0–25 in both “with merger” and “without merger” cases. The results show that the Basin economy cannot withstand a reduction of more than 26%, regardless of any policy given the current technology. Figure 4 illustrates the change in the total GRP considering the social discount rate and the values of the objective function (objective values)

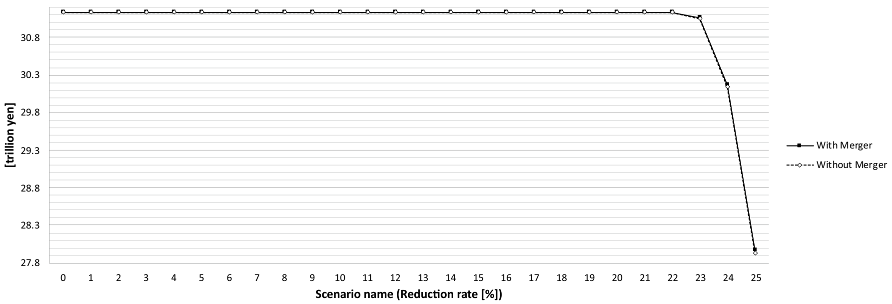

Fig. 4 Trade-off between socio-economic activity (discounted GRP) and water environment

in the simulation. An increase in the objective value means that economic welfare improves. An increase in pollution reduction means that the water environment in the Basin and the Lake improves. There is a trade-off between these two indices, such that an increase in pollution reduction inevitably implies a reduction in the objective value. Calculating the slope of the trade-off curve yields the social opportunity cost of improving the environment in terms of the discounted GRP. However, there is no change in the objective value in Scenarios 0–22, with the same values in both “with merger” and “without merger” cases.

The main reason for this is that we set a constraint on annual GRP growth, at a maximum of 2.3%, reflecting recent average economic growth in the Ibaraki prefecture, assuming that there are factors hindering economic growth. To verify the economic growth potential, we run a simulation without GRP constraints for comparison. The result reveals that not only is GRP growth larger than the actual value in all scenarios in both cases, but there is also a difference in the objective values, depending on the “with”/“without merger” case. For example, the average annual growth rate in Scenario 17 “with merger” is 5.80% and “without merger” is 5.78% (see Fig. 5; this figure also shows the actual GRP from 2012 to 2018, the years for which data could be obtained). Figure 5 shows the change in GRP over the entire simulation period, with the vertical axis scaled to trillion JPY. For further ease of interpretation, the bar graph in Fig. 6, scaled to 1 billion JPY, shows the difference in GRP between the “with” and “without merger” cases for the unconstrained GRP growth rate case shown in Fig. 5. Figure 6 shows that for all years except 2012, the GRP in the “with merger” case was larger than the GRP in the “without merger” case, with the largest difference in 2019, when the “with merger” GRP was 9.46 billion yen more than the “without merger” GRP. This result shows that despite the Japanese economy originally having a relatively high growth potential, the economy could not sustain it due to certain factors hindering growth. This also suggests that the Japanese macroeconomy may not have experienced the positive impact expected from the municipality mergers. Hoshi and Kashyap (2011) point out the existence of “zombie firms” (unproductive and unprofitable firms that should exit the marketplace but stay in business with help from creditors or the government) as a factor hindering economic growth in

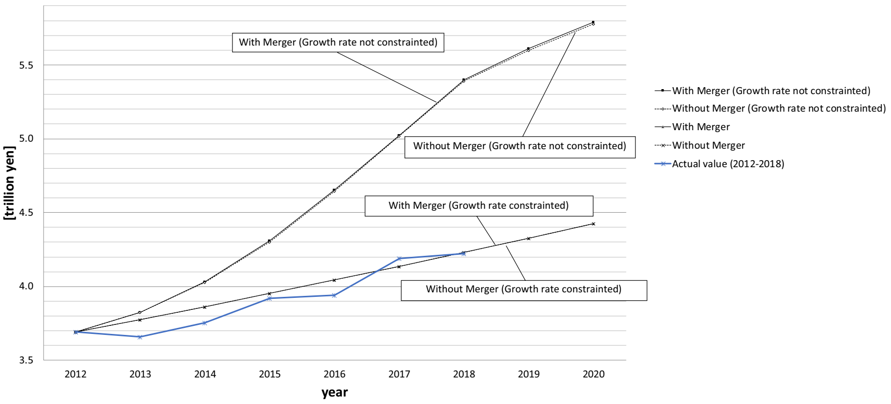

Fig. 5 Change in GRP in Scenario 17: "with merger" and "without merger" with/without constraint on GRP

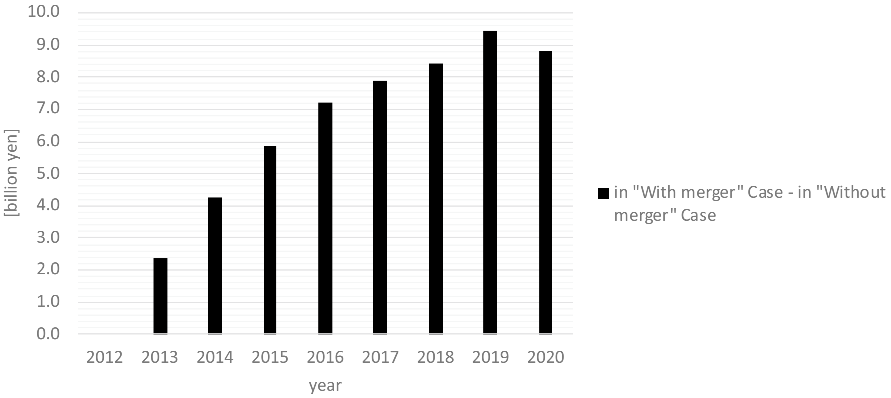

Fig. 6 Difference in GRP with and without municipal mergers in Scenario 17 with no growth rate constraints

Japan. Additionally, their research points to heavy government regulation in some sectors and macroeconomic policy mistakes as other limiting factors.

From these results, we found that there is no environment-economy trade-off for a reduction of 0–22% as long as the prefectural government implements an optimal water environment policy in the presence of factors hindering economic growth.

3.2 Municipal merger: social benefit and impact on the cost of reducing water pollution

Once the water pollutant reduction rate exceeds 23%, despite the constraint of 2.3% on the economic growth rate, there is a positive impact of the municipal merger

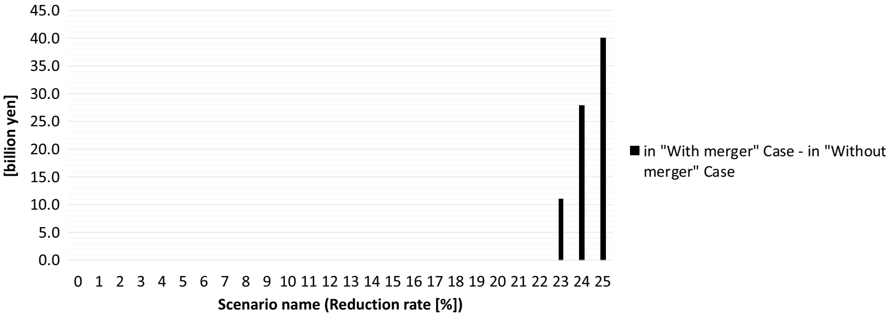

Fig. 7 Difference in the objective value with and without municipal mergers

on the environment–economy trade-off. Figure 4 shows the values of the objective function for each scenario in the “with merger” and “without merger” cases, with the vertical axis scaled to trillion JPY. For further ease of interpretation, Fig. 7 shows the difference in the objective values “with” and “without merger” (for all the scenarios in Fig. 4) as a bar graph, with the vertical axis scaled to billion JPY.

While the objective value in Scenarios 0–22 in the “with merger” and “without merger” cases is 31.13 trillion JPY in all scenarios, there is a difference in the objective value in the cases in Scenarios 23–25. The objective value in Scenario 23 “with merger” is 31.063 trillion JPY and "without merger" is 31.052 trillion JPY. Similarly, the objective value in Scenario 24 “with merger” is 30.167 trillion JPY and “without merger” is 30.140 trillion JPY. Additionally, the value in Scenario 25 “with merger” is 27.963 trillion JPY and “without merger” is 27.923 trillion JPY. From these results, we see that the municipal merger in the Basin generates 11.9 billion JPY of social benefit (in terms of GRP) over 9 years in Scenario 23, 27.95 billion JPY in Scenario 24, and 40.19 billion JPY in Scenario 25. These results show that if we set the reduction target above a certain value, the merger would bring at least 1.4 times more social benefit over 9 years than the amount spent by the Ibaraki prefectural government each year in the 1990s (see Sect. 2.3.2). Moreover, the benefit increases as the reduction rate increases.

We also calculate the social opportunity cost of improving pollution reduction in both cases from these results. For the “with merger” case, by increasing pollution reduction from 22 to 23%, the social opportunity cost in terms of GRP over 9 years is 67.03 billion JPY (31.13 trillion JPY–31.063 trillion JPY); from 23 to 24% is 895.69 billion JPY (31.063 trillion JPY–30.167 trillion JPY); and from 24 to 25% is 2.20 trillion JPY (30.167 trillion JPY–27.963 trillion JPY). Similarly, in the “without merger” case, by improving pollution reduction from 22 to 23%, the social opportunity cost is 78.22 billion JPY (31.13 trillion JPY–31.052 trillion JPY); from 23 to 24% is 912.45 billion JPY (31.052 trillion JPY–30.140 trillion JPY); and from 24 to 25% is 2.22 trillion JPY (30.140 trillion JPY–27.923 trillion JPY). Comparing the cases, “with merger” shows a smaller opportunity cost than “without merger” in each instance. This implies that improvement in the municipality improves the trade-off, even though the trade-off cannot be eliminated.

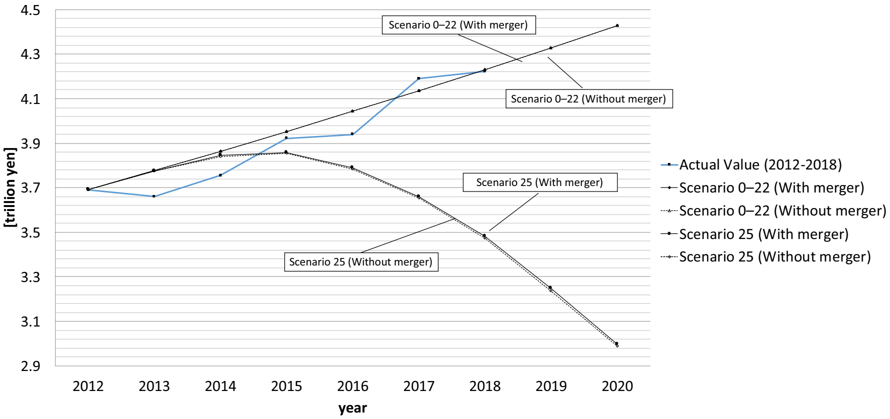

Fig. 8 Change in GRP in Scenarios 20 and 25: with merger, without merger, and actual value

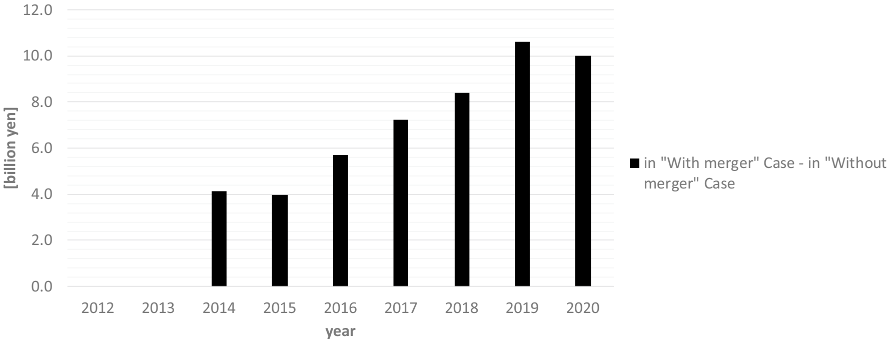

Fig. 9 Difference in GRP with and without municipal mergers in Scenario 25

Figure 8 shows the change in GRP over the simulation period for "with merger" and "without merger" cases in Scenarios 0–22, and Scenario 25, which is the maximum feasible reduction rate scenario. In Scenarios 0–22, the change in GRP is the same regardless of whether there are a merger and the different scenarios. The figure shows the change in GRP over the simulation period, with the vertical axis scaled to trillion JPY. Figure 9 shows the difference in GRP “with” and “without merger” in Scenario 25 (based on Fig. 8) as a bar graph, with the vertical axis scaled to billion JPY. We consider that these differences in GRP represent the annual impact on socio-economic activity due to the merger of municipalities at a 25% reduction rate, which is the maximum feasible reduction rate. We find that the impact of the merger on socio-economic activity is non-linear. It peaks in the penultimate year to reach a maximum of 10.6 billion JPY.

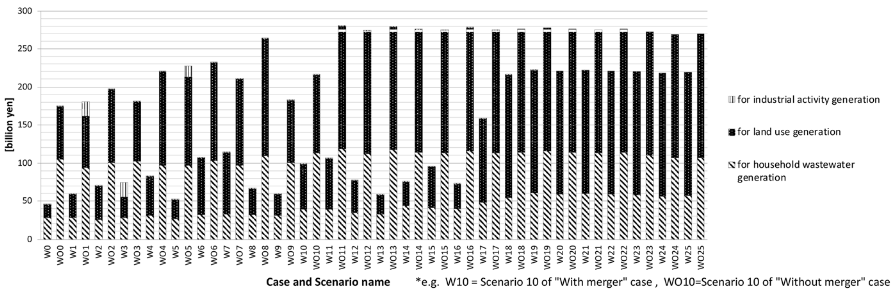

Fig. 10 The total policy budget required and its allocation in the simulation period for each scenario

3.3 Difference in required policy budget depending on the case

While the difference in the objective value for the cases with and without the municipal merger occurs only in Scenarios 23–25, there are significant differences in the budget required to achieve the reduction rate target. Figure 10 shows the total budget required and its allocation in the period for each scenario.

In every scenario, the budget required is smaller in the “with merger” case. This shows that the merger has a positive impact on reducing the budget required for water pollution countermeasures. Moreover, the budget does not necessarily increase as the reduction rate increases, but depends on the target reduction rate in both cases. This indicates the difficulty of formulating environmental policies in line with reduction targets.

We can interpret the difference between the heights of the bars representing both cases in every scenario as the magnitude of the budget efficiency improvement from the merger. We see that efficiency improvement value reaches a maximum of 220 billion JPY in Scenario 13. This is equivalent to 11 years of budgetary allocation by the prefectural government on the improvement of water quality of Lake Kasumigaura in the early 1990s. Notably, the budget efficiency from the merger appears to vary nonlinearly with the reduction rate. When the reduction rate exceeds 17%, the required budget amount increases sharply in the “with merger” case, and the budget reduction efficiency due to the merger decreases drastically.

In Fig. 10, we also see that the budget required to combat household wastewater generation is smaller in the “with merger” case than in the “without merger” case for all scenarios. The reason is that more efficient domestic wastewater treatment systems can be installed less expensively owing to improved fiscal efficiency after the merger. Figures 11, 12, 13, 14, 15, 16 show the changes in the user population of combined treatment septic tank and sewerage system in Scenarios 16, 17, and 18. In this simulation, in Scenarios 0–16, the user population of the combined treatment septic tank increased significantly more in the “with merger” than in the “without merger” case by the final year of the simulation period. Among these scenarios, the difference in the user population of combined treatment septic tank with and without merger becomes the largest in Scenario 16.

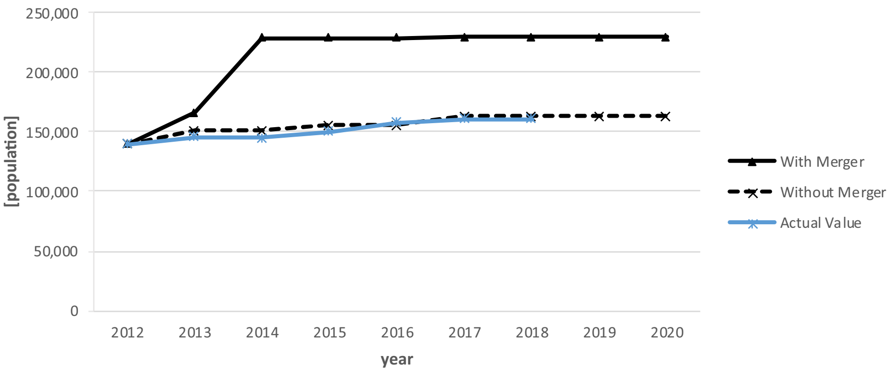

Fig. 11 Change in the user population of the combined treatment septic tank in Scenario 16

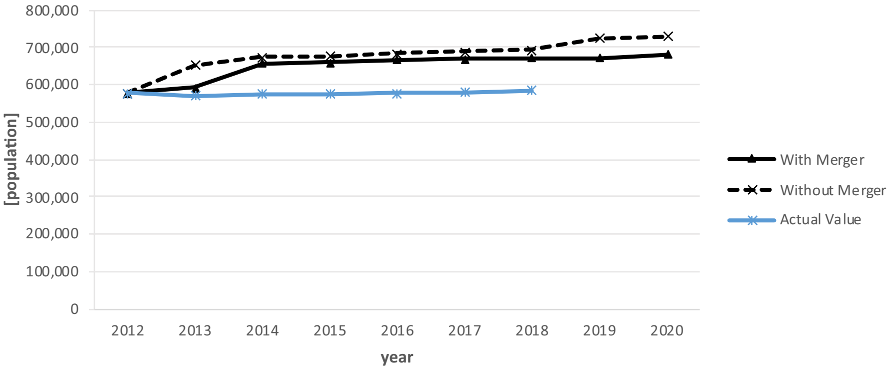

Fig. 12 Change in the user population of the sewage system in Scenario 16

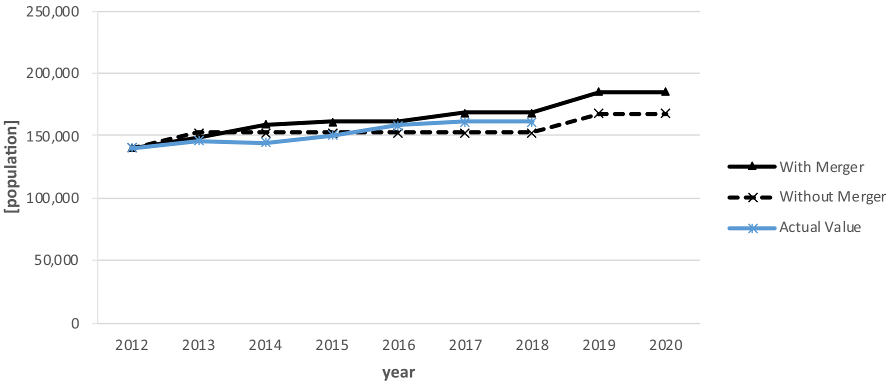

Fig. 13 Change in the user population of the combined treatment septic tank in Scenario 17

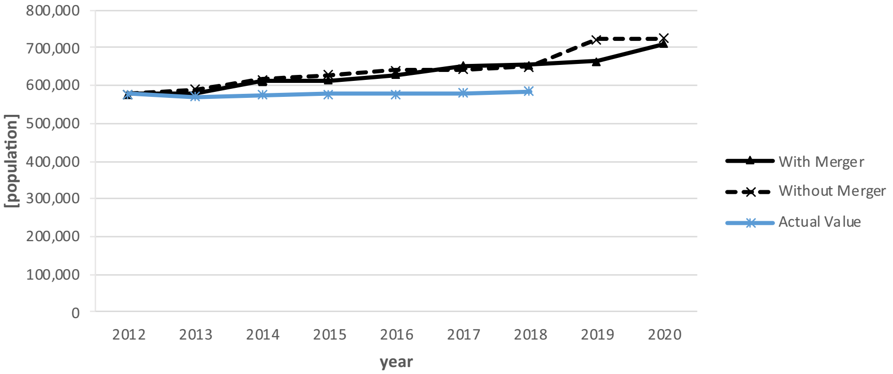

Fig. 14 Change in the user population of the sewage system in Scenario 17

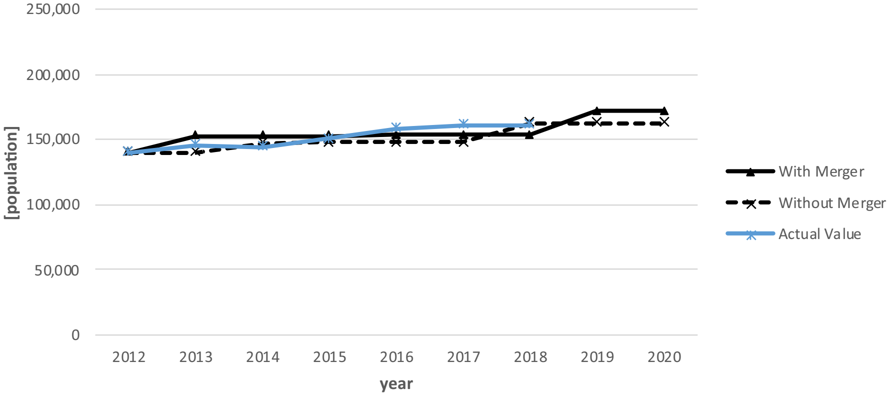

Fig. 15 Change in the user population of the combined treatment septic tank in Scenario 18

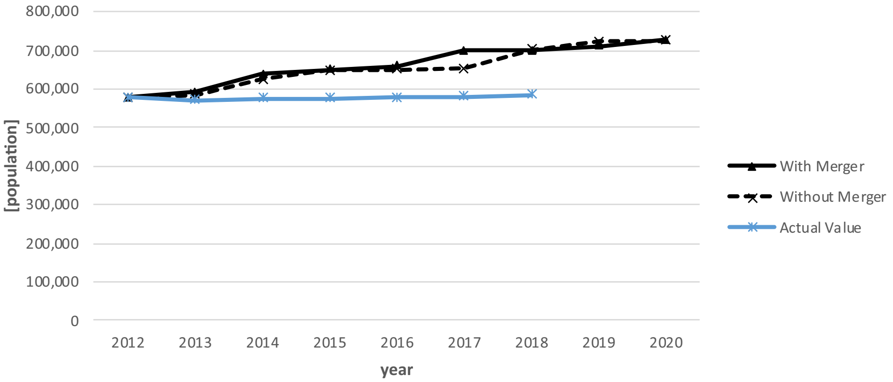

Fig. 16 Change in the user population of the sewage system in Scenario 18

On the other hand, the user population of the sewerage system in this scenario is almost the same or slightly smaller in the "with merger" than in the "without merger" case (see Figs. 11 and 12 for Scenario 16).

Figure 13 shows the changes in the user population of the combined treatment septic tank in Scenario 17. Figure 15 also shows the changes in the user population of the combined treatment septic tank in Scenario 18. Comparing Figs. 11 and 13, we see that the difference between the user population of the combined treatment septic tank with and without merger in Scenario 17 drastically decreases compared to that in Scenario 16. In Scenario 17, the difference is smaller but still larger in the case of a merger (see Fig. 13). Furthermore, in Scenario 18, the difference becomes even smaller, and the difference in the population using the merged septic tank in the "with merger" and "without merger" cases is almost eliminated. (See Fig. 15). Additionally, Figs. 14 and 16 show the change in the user population of the sewage system in Scenarios 17 and 18. In these scenarios, there is almost no difference between the "with merger" and "without merger" cases. This trend continues until Scenario 25.

This result shows that the municipal merger in the Basin increases the efficiency of the combined treatment septic tank development compared to that of the sewage system, at least up to a 17% reduction rate. Thus, depending on the rate of reduction which it seeks to achieve, the government should prioritize increasing the user population for the combined septic tank instead of the sewage systems to take advantage of the financial efficiencies of the municipal merger. In Japan, the number of people using the sewage system is an indicator of urbanization; therefore, local governments have concentrated on the development of that system. However, the development of the sewage system has not been cost-effective in some regions, particularly, in the Kasumigaura Basin, where many municipalities have lower population density (i.e., the distance between houses is larger compared to urban areas). For this reason, the per-capita construction cost of the sewage system is more expensive, making it cost-effective to install the combined treatment septic tank in those municipalities. The simulation results indicate now that the merger is complete, the conventional approach and methods need to be reviewed and suggest that according to target environmental standards.

Figure 17 shows the optimal budget allocation for the countermeasures to land-use generation in the "with merger" case. As shown in this figure, after Scenario 18, the total fallow field land promotion subsidy and fallow paddy land promotion subsidy reached an upper limit of 160 billion JPY, 20 billion JPY each year.[1]

These results show that even after municipal mergers, the benefits of the development of household wastewater treatment facilities approach their limits after Scenario 18. Therefore, after Scenario 18, it is more efficient for the economy of the Basin to strengthen non-point source measures.

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[1] Note that the simulation period is 9 years; however, we assume that the implementation of fallow land and the reduction of production capital take place the year following the subsidies. Therefore, those subsidies are not derived in the last year of the simulation.

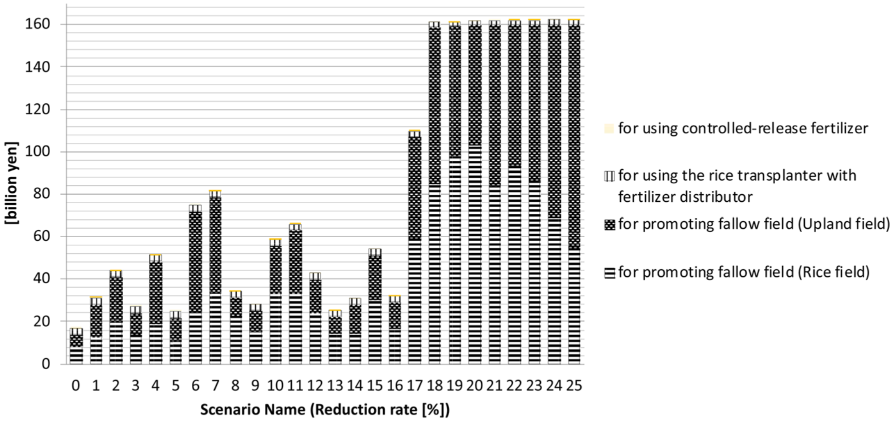

Fig. 17 Optimal budget allocation of countermeasures for land-use generation in "with merger" case

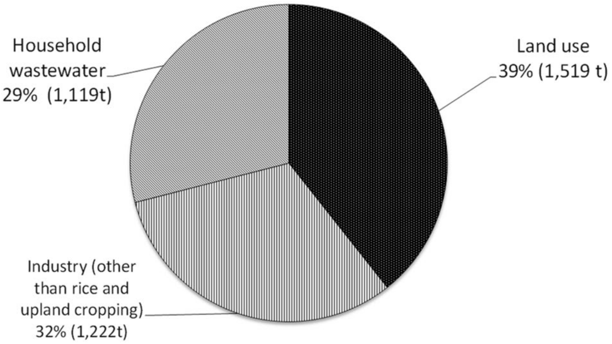

Fig. 18 Current situation of water pollutant discharge of TN (2012)

3.4 Limitation of economic policy to reduce water pollutant inflow into Lake Kasumigaura

Figures 18, 19, and 20 illustrate the current situation of water pollutant emissions in the Basin. In these figures, we see that the proportions of TN, TP, and COD emissions from households to all emissions are 29, 44, and 23%, respectively, with COD having the smallest share. This indicates that even if the prefectural government prioritizes implementing the most efficient countermeasures to household wastewater generation, we can reduce pollutants by 23% at best. Although the efficiency of countermeasures to household wastewater generation may be high, as the reduction rate approaches 23%, the advantages of the countermeasures reach their limit.

In both "with merger" and "without merger" cases, the total required budget gradually decreases after Scenario 22 (see Fig. 10). This indicates that to achieve a 23% or higher reduction rate, the government needs to abandon water pollutant reduction policies that rely solely on economic policy instruments such as

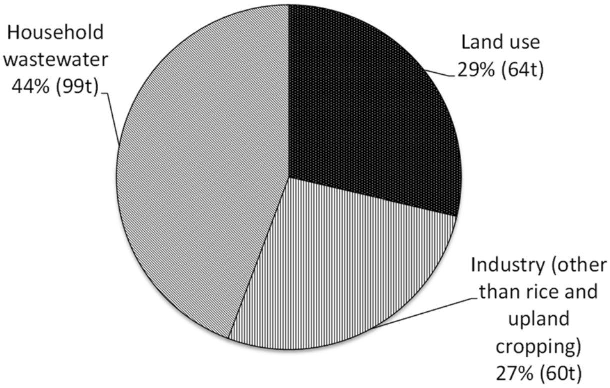

Fig. 19 Current situation of water pollutant discharge of TP (2012)

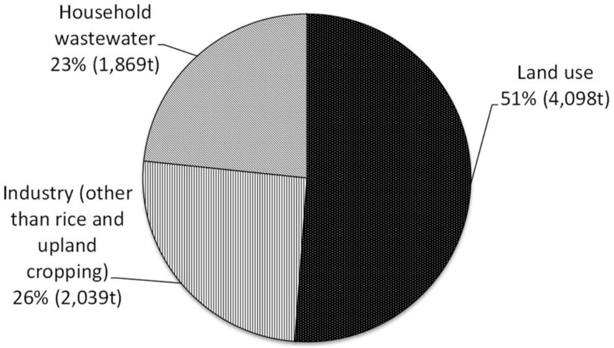

Fig. 20 Current situation of water pollutant discharge of COD (2012)

subsidies and introduce direct regulatory measures in addition to these. In this simulation, the budget to control water pollutant emissions from agriculture is derived in Scenario 23 and later scenarios, while the budget to control water pollutants from industrial activities other than agriculture is not derived in these scenarios. This result implies that the government should introduce direct regulatory instruments for industries other than agriculture, such as fisheries and manufacturing, to achieve a 23% or higher reduction rate.

Tables 7, 8, 9 depict water pollutant emissions from fisheries and manufacturing each year in Scenario 23. The emissions for each pollutant each year are the same regardless of the case. These values can be considered as emission caps for each industry when the government introduces direct regulatory measures. They can also be considered the initial allocations for each industry when the government introduces inter-industry emission caps to achieve 23% reduction. Indeed, direct regulatory instruments usually accompany a decrease in GRP. Figure 4 (see Sect. 3.1) shows that the objective value decreases drastically after Scenario 23.

Table 7 TN emissions (in tons) from fisheries and manufacturing in each year in Scenario 23

Industry name	Year	"With merger" case	"Without merger" case	"With merger" case—"Without merger" case
Fisheries	2012	64.0	64.0	0.0
	2013	57.6	57.6	0.0
	2014	51.8	51.8	0.0
	2015	46.6	46.6	0.0
	2016	42.0	42.0	0.0
	2017	37.8	37.8	0.0
	2018	34.0	34.0	0.0
	2019	30.6	30.6	0.0
	2020	27.5	27.5	0.0
Manufacturing industry	2012	343.0	343.0	0.0
	2013	369.5	369.5	– 0.1
	2014	383.0	383.0	– 0.1
	2015	391.0	391.0	– 0.2
	2016	378.8	378.8	– 0.1
	2017	358.6	358.6	– 0.1
	2018	331.8	331.8	– 0.1
	2019	301.4	301.4	– 0.1
	2020	271.2	271.2	– 0.1

Table 8 TP emissions (in tons) from fisheries and manufacturing in each year in Scenario 23

Industry name	Year	"With merger" case	"Without merger" case	"With merger" case—"Without merger" case
Fisheries	2012	14.1	14.1	0.0
	2013	12.7	12.7	0.0
	2014	11.4	11.4	0.0
	2015	10.3	10.3	0.0
	2016	9.2	9.2	0.0
	2017	8.3	8.3	0.0
	2018	7.5	7.5	0.0
	2019	6.7	6.7	0.0
	2020	6.1	6.1	0.0
Manufacturing industry	2012	35.0	35.0	0.0
	2013	37.7	37.7	0.0
	2014	39.1	39.1	0.0
	2015	39.9	39.9	0.0
	2016	38.7	38.7	0.0
	2017	36.6	36.6	0.0
	2018	33.9	33.9	0.0
	2019	30.8	30.8	0.0
	2020	27.7	27.7	0.0

Table 9 COD emissions (in tons) from fisheries and manufacturing in each year in Scenario 23

Industry name	Year	"With merger" case	"Without merger" case	"With merger" case—"Without merger" case
Fisheries	2012	162.0	162.0	0.0
	2013	145.8	145.8	0.0
	2014	131.2	131.2	0.0
	2015	118.1	118.1	0.0
	2016	106.3	106.3	0.0
	2017	95.7	95.7	0.0
	2018	86.1	86.1	0.0
	2019	77.5	77.5	0.0
	2020	69.7	69.7	0.0
Manufacturing industry	2012	822.5	822.5	0.0
	2013	886.0	886.0	− 0.2
	2014	918.3	918.3	− 0.2
	2015	937.6	937.6	− 0.4
	2016	908.5	908.5	− 0.4
	2017	859.9	859.9	− 0.3
	2018	795.7	795.7	− 0.3
	2019	722.6	722.6	− 0.3
	2020	650.4	650.4	− 0.2

The figure shows the decrease in the objective value (social opportunity cost to increase the reduction rate from 22 to 23%) as 67.03 billion JPY in the "with merger" case and 78.22 billion JPY in the "without merger" case. These values increase as the reduction rate increases. We can assume that these values represent the impact of introducing direct regulatory instruments on socio-economic activities.

3.5 Impact of efficiency improvement of the sewage system on manufacturing and service production

Figures 21 and 22 show the accumulated production of the manufacturing and service sectors, respectively, which considered the social discount rate in Scenario 23 where the GRP differs despite the same reduction rate. In this simulation, while services output in the "with merger" case is larger than that in the "without merger" case, manufacturing output in the "with merger case" case is smaller than that in the "without merger" case. Annual maintenance per capita for the sewerage system is 22,000 JPY, on average, before the merger, which decreases to 18,000 JPY after the merger. Here, the service sector does not emit pollutants from production, but it generates derived demand for other industrial production, thereby increasing the latter's emission of pollutants; therefore, the service sector is an indirect emitter of

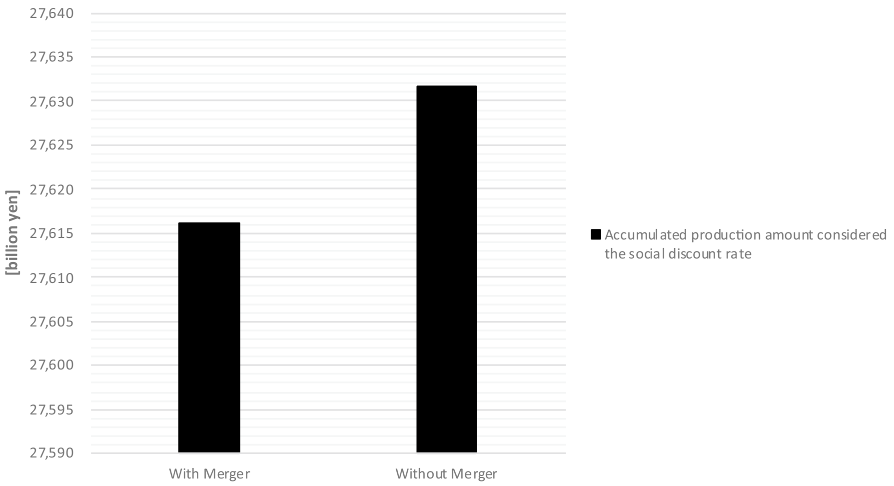

Fig. 21 Accumulated production of manufacturing considered the social discount rate in Scenario 23

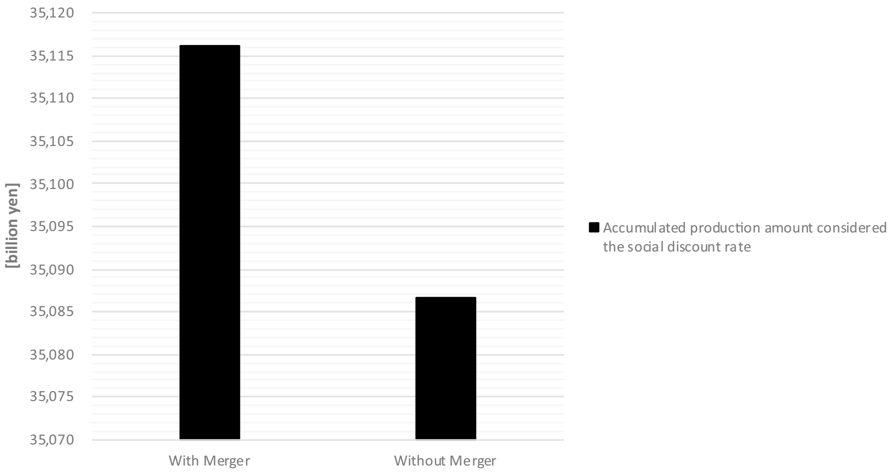

Fig. 22 Accumulated production of service industry considered the social discount rate in Scenario 23

pollutants. In the Ibaraki Prefecture, approximately 30% of the intermediate demand from the service sector is for the manufacturing sector with dependence on manufacturing relatively high among all industries (Ibaraki prefectural government 2012, 2016 and 2020). The manufacturing sector needs to conduct production activities to meet demand, but when pollution constraints are imposed, production activity is limited. As a result, the service sector will not receive sufficient input of raw materials from manufacturing, which means that the service-based industries will be limited in the Basin, as well. However, the improvement in the financial efficiency of the sewage system decreases demand from the public sector for manufacturing, which allows the manufacturing sector to supply more goods to the service sector. As a result, the service sector can expand production after the merger even in the same reduction scenario. However, since the decrease in demand for manufacturing due to the efficiency of the sewerage system is greater than the increase in demand from services, manufacturing must bear the negative impact, a net decrease in demand. Nevertheless, since the service sector has a large value-added ratio, expanding its production has a positive impact on GRP in the Basin. Therefore, GRP in the "with merger" case is larger than in the "without merger" case in Scenarios 23–25, which are the maximum feasible reduction rate scenarios. Yet, the GRP in both cases decreases compared with Scenarios 0–22.

4 Conclusion

This research analyzes the impact of municipal mergers on the watershed management of Lake Kasumigaura. The research findings indicate that, at first, we may be able to eliminate the trade-off between economic activity and water environment improvement within a specific range of water pollutants reduction (in this simulation, that reduction rate was less than 22%) given that the prefectural government implements an optimal water environment policy, assuming the presence of factors hindering economic growth. However, they also show that while Japan has a relatively high growth potential that could be accelerated by municipal mergers, it has failed to realize it because of factors hindering economic growth. The results show that better economic policies will not only contribute to the development of the economy, but also increase the benefits of institutional changes such as municipal mergers.

The study also found that while the benefits of municipal mergers for watershed economic activity do not emerge until the reduction rate exceeds 23%, municipal mergers could sufficiently reduce the policy budget required to achieve any reduction rate. The effect of the budget reduction depends on the rate of reduction, but the greatest effect is achieved for a 13% reduction rate, reaching 220 billion JPY over 9 years. However, when the reduction rate exceeds 17%, the efficiency of budgetary savings resulting from municipal mergers is significantly reduced. In addition, even after municipal mergers, at a reduction rate of 18% or higher, the effectiveness of developing domestic wastewater treatment facilities, which are more efficient than other policy measures, approaches a limit, which is finally reached in Scenario 23. Further reductions would require direct regulatory tools in addition to economic policy measures such as subsidies. If we aim for a reduction of more than 23%, the output of each industry will be significantly reduced. For this to be achieved, the government needs substantial consensus from industry.

This study examines a recent period (the past eight years) to assess the impact of municipal mergers on the environment and the economy in Japan. However, it has the following limitations. As Japan enters an era of demographic decline, government revenue, in the form of taxes and sewage charges, is expected to decrease while the infrastructural maintenance related to sewage treatment is expected to increase, due to aging. This study does not consider this dilemma. Future research should evaluate the Great Heisei Consolidation strategy by conducting simulations that consider such uncertainties. In addition, investigation of collaborative partnership approaches in watershed management, such as those presented in Kim and Batey (2020), using the Mersey Basin Campaign as an example, may also be an important area of focus for gaining public consensus on policy implementation.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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