The Impact of Aging Water Facilities and Charge System on Water Charges*

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Abstract

The purpose of this paper is to empirically clarify how the aging of water pipelines and the declining population are reflected in household water charges, and also whether differences in the charge system such as water charges based on caliber of water pipelines or water charges based on purpose of water use, are a factor in generating disparities in water charges. The following facts are obtained from the verification using panel data.

Firstly, household water charges are significantly higher for water utilities with a higher percentage of aging water pipelines, but the parameter is very small, close to zero. This suggests that the setting and revision of water charges with an eye toward aging pipelines are not functioning. Secondly, household water charges are higher among water utilities that adopt water charges based on caliber of water pipelines as compared to those that follow water charges based on purpose of water use. Furthermore, it is confirmed that the higher the proportion of aged pipelines, the higher the water charges in caliber-based water utilities. In other words, due to the presence of a clearly distinct "household charges" category, water utilities that follow water charges based on purpose of water use may find it difficult to make decisions for fear of opposition to setting or revising household water charges to a high level. Thirdly, water utilities that adopt water charges based on caliber of water pipelines are found to have high profitability, while usage-based water utilities have low profitability.

As local public enterprises, water utilities, follow self-supporting accounting systems in principle, and are required to set or revise water charges to match the cost. By adopting a

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usage-based charge system, a situation in which water charges differ depending on what the water is used for implies that the setting of charges to match the cost is not functioning. A usage-based charge system is considered to be an institutional factor that hinders the setting and revision of water charges to an appropriate level in view of the aging of facilities and business earnings. Hence, from the perspective of sustainability, it is desirable to introduce a caliber-based charge system.

Keywords: local public enterprises, water utilities, aging infrastructure, water charge system

JEL Classification: H44, H54, H76, L95

I. Introduction

There is a growing concern about sustainability in the water supply business. This is because the management of the water supply business is struggling, such as the decline in water demand due to the declining population, while the cost of updating aging water supply facilities increased. The amount of paid water, which refers to the amount of water used to collect fees, has been on a downward trend since peaking in FY2000, and by FY2020 will have fallen to approximately 90% of its peak level[1]. This downward trend is expected to accelerate in the future due to the spread of water saving type equipment and the arrival of a society with the declining population, with some estimates predicting that the amount of paid water in 2065 will fall to approximately 60% of its peak level. On the other hand, the total distance of water pipelines (raw water transmission main, treated water transmission main, and distribution main), which has passed the useful life designated by law, has reached 20.7% of the total distance of water pipelines in FY2020. As shown in Table 1, the aging process is rapidly progressing, given that the percentage in FY2011 was 8.9%. In fact, in the 4 years between FY2016 and FY2020, the average annual increase of the updated water pipelines was about 13,000 km. On the other hand, the average update distance of water pipelines was about 5,000 km, and the update rate of water pipelines in fiscal 2020 was only 0.7%. Since the legal service life of water pipeline is set at 40 years, the update rate of water pipelines has not kept pace with the progress of aging.

Since water utilities are self-support accounting systems in principle, it is necessary to increase the water charges when faced with stagnant revenues and increased update costs. In fact, 44 water utilities equivalent to 3.5% of the total number, implemented water charges revisions between April 2, 2020, and April 1 of the following year. The average revision rate and the average time between revisions were 8.2% and 3.0 years, respectively[2]. Thus, the

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[1] The Figures are for water supply utilities, based on the "Local Public Enterprise Yearbook" (MIC: Ministry of Internal Affairs and Communications).

Table 1. Extension of pipelines beyond legal service life and Percentage of renewals

	2011	2013	2015	2017	2019	2020
Pipeline extension (km): (a)	653,674	665,094	679,170	721,976	737,350	756,359
Pipeline extension beyond useful life (km): (b)	58,294	74,301	89,774	117,426	144,055	156,757
Renewed pipeline extension (km): (c)	5,574	5,475	5,761	5,045	4,974	5,168
Aging rate: (b)/(a)	8.9%	11.2%	13.2%	16.3%	19.5%	20.7%
Renewal Rate: (c)/(a)	0.9%	0.8%	0.8%	0.7%	0.7%	0.7%

Note 1: The legal useful life of water pipelines is defined as 40 years. In practice, 40 years is a provision for calculating depreciation, but it is one guideline for planned improvements and renewals.
Source: "Local Public Enterprises Yearbook" (Ministry of Internal Affairs and Communications)

first verification of this paper is to empirically clarify whether charges setting and charges revision based on aging of water pipelines and declining population is working. In addition to these rate settings and rate revisions, there have been a series of changes to charge systems in water utilities. Water utility charges can be broadly classified by use and caliber, but in the past, the majority of entities used charge systems based on use[3]. Since the initial purpose of installing waterworks in Japan was partly to combat infectious diseases such as cholera, it was required at that time to keep water charges for public bathhouses low from the standpoint of public health. In this context, in Japan, the charge system in water utilities, in which water charges differ according to the purpose of use, has become widespread. However, some argue that it lacks theoretical grounds for users to pay different water charges while using the same amount of water. Subsequently, the number of water utilities that are shifting from the adoption of a charge system based on use to the adoption of a charge system based on caliber is gradually increasing, based on the concept that the relationship between benefit and cost should be more considered and that the charge system commensurate with cost should be adopted based on the assumption of independent profitability. Since fiscal 2007, the number of water utilities adopting a charge system based on caliber has exceeded the number of water utilities adopting a charge system based on use, and in recent years, approximately 60% of water utilities have adopted a charge system based on caliber, as shown in Table 2. In general, it is not easy to make the decision to raise prices or fees because of the risk of customer disengagement or backlash. However, at the same time as changing rate structure, it can be seen that the user's burden is substantially increased[4]. In the water supply business as well, it is believed that many utilities have been able to raise water charges by adopting a charge system based on caliber, even if they are unable to secure update costs for aging countermeasures. On April 1, 1988, Toyama City

[2] The figures are based on the "Water charge Table" (Japan Water Works Association).
[3] The charge system by use is a system in which basic and metered rates are changed according to the use of water, such as for household use, government schools, business use, factories, and public bathhouses. The charge system by caliber is a system in which basic and metered rates are changed based on the size of the caliber of the water meter.
[4] For example, the cab industry may implement a revision to shorten the distance traveled at the starting fare, in effect raising the price.

Table 2. Number of entities by rate structure

	2008	2012	2015	2017	2019	2021
Rate structure by use	481 (36.4%)	438 (34.2%)	415 (32.6%)	404 (31.8%)	390 (30.9%)	380 (30.2%)
Rate structure by caliber	691 (52.3%	702 (54.8%)	721 (56.6%)	725 (57.1%)	735 (58.2%)	752 (59.6%)
Other rate Structure	149 (11.3%)	140 (11.0%)	138 (10.8%)	140 (11.1%)	137 (10.9%)	129 (10.2%)

Note 1: Other rate structures are those that adopt both by use and by caliber, or those that adopt a single rate structure without separating by use and by caliber.
Note 2: The rate structure categories are as of April 1 of each fiscal year. The upper row indicates the number of entities, and the lower row indicates the percentage of the total.
Source: "Water Supply Charge Table" (Japan Water Works Association)

shifted from a usage-based charge system to a caliber-based charge system, with an average increase of 9.5%. In the background, there was a sense of unfairness due to the difficulty in properly certifying the purpose of water, and it is believed that the aim was to ensure that the individual cost principle was thoroughly implemented. In a recent case, on July 1, 2021, Yokohama City increased its water charges by an average of 12% when it moved to a caliber-based charge system. As a recent example, an average 12% rate increase was implemented in Yokohama City on July 1, 2021, when the city shifted to a rate system based on caliber. Therefore, the second verification is to empirically clarify whether there is a possibility that water charges are set and revised at a higher level by water utilities that adopt a water charge system based on caliber than by water utilities based on use.

Most of the empirical analyses on water utilities in Japan focused on measuring economies of scale and verifying management efficiency, but not on setting water charges (see Section IV-1). Recently, a growing number of studies have taken up water charges as an object of analysis in the context of the strategic interdependence of local governments. However, these studies of water charges are not discussed in relation to the sustainability of water utilities. One study that focuses on sustainability is Nagamine (2015), which was a case study of a water utility in Nishiwaki City, Hyogo Prefecture, which found that the current water charge and revenue structure were insufficient to provide financial resources for the water utility. It can be said that no empirical analysis focused on the water charge system. Thus, the novelty of this paper is to empirically discuss the impact of pipeline aging and rate structure on water charges.

The purpose of this paper is to empirically clarify, using panel data, (1) whether the setting and revision of water charges in light of aging pipelines and declining population is working, and (2) whether there is a disparity in water charges between water utilities with rates by caliber and those with rates by use. The remainder of the paper is organized as follows. Chapter II provides an overview of the current status of charges disparities and charges revisions in the water industry, and the relationship between the aging of individual utilities and charges revisions. Chapter III summarizes the current state of charge revenue, the need for charges revisions in the water industry, and examples of charges revisions. In Chapter IV, we test the hypothesis, and finally summarize the policy implications.

II. Current Status of Water Supply Business

II-1. Status of Disparity in Water Charges

There are 1,794 water utilities operated by municipalities in FY2020. The breakdown is 1,320 water utilities (projects with a planned water supply population of over 5,000) and 474 small-scale water utilities (projects with a water supply population of 101 to 5,000). Compared to the 3,661 projects (1,991 water supply projects and 1,670 simple water supply projects) in FY2000, the number of projects has decreased by half. This downward trend is largely due to the expansion of the area through municipal mergers and the integration of water utilities and small-scale water utilities. However, compared to gas and electricity, which are also public utilities, the 1,794 water utilities are significantly larger, and the large number of utilities is one of the characteristics of the water industry[5].

The large number of water utilities is due to the fact that the management entity is defined as "in principle, managed by municipalities". Since management is based on municipal units, each operator is subject to diverse management environments, including differences in the type of water source and its acquisition conditions, population density, industrial structure, and other factors. In addition, since management must be conducted under a special account based on the premise of independent profitability, resulting in a difference in large charges between regions and utilities. As shown in Figure 1, the average charges per 10 m^3 for household use by prefecture is 916 yen in Kanagawa Prefecture, and 2,198 yen in Aomori Prefecture. There is a charge difference of about 2.4 times between prefectures. In general, water charges are low in the prefectures of urban areas with large water supply populations and tend to be high in the prefectures of the Tohoku region. When comparing individual entities, of course, the charges disparity becomes even larger. Similarly, comparing water charges per 10 m^3 for household use, the lowest rate is 374 yen in Ako City, Hyogo Prefecture, and the highest is 3,550 yen in Rausu Town, Hokkaido. This means that there is a charge difference of nearly 10 times between individual entities[6].

There is also a disparity in water charges based on the size of the water supply population. As shown in Figure 2, in FY2019, the average charges per 10 m^3 of household use for entities with a current water supply population of 1 million or more is 1,074 yen, while the charges for entities with a water supply population of less than 50,000 is 1,654 yen. Due to differences in population size, there exists a charge difference of about 1.5 times. The number of entities affected by diseconomies of scale is 897, accounting for about 70% of the total.

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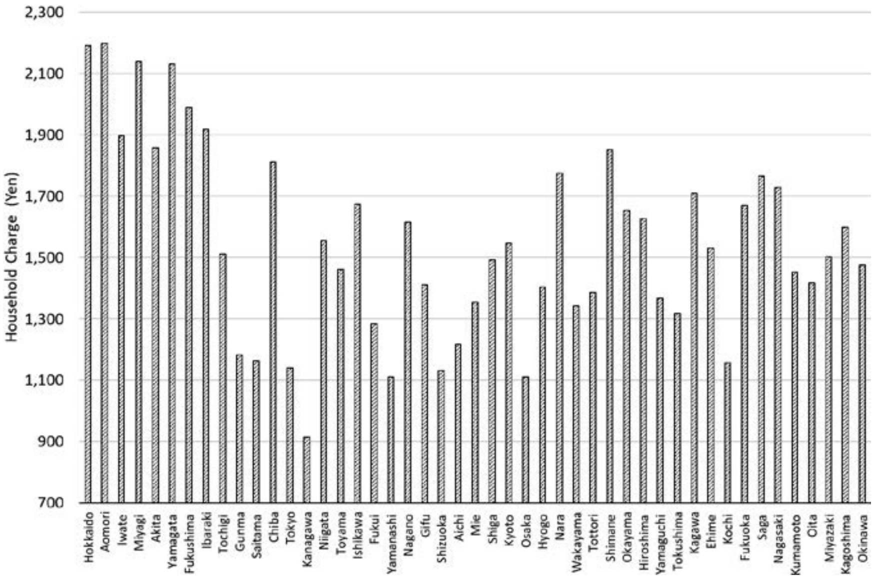
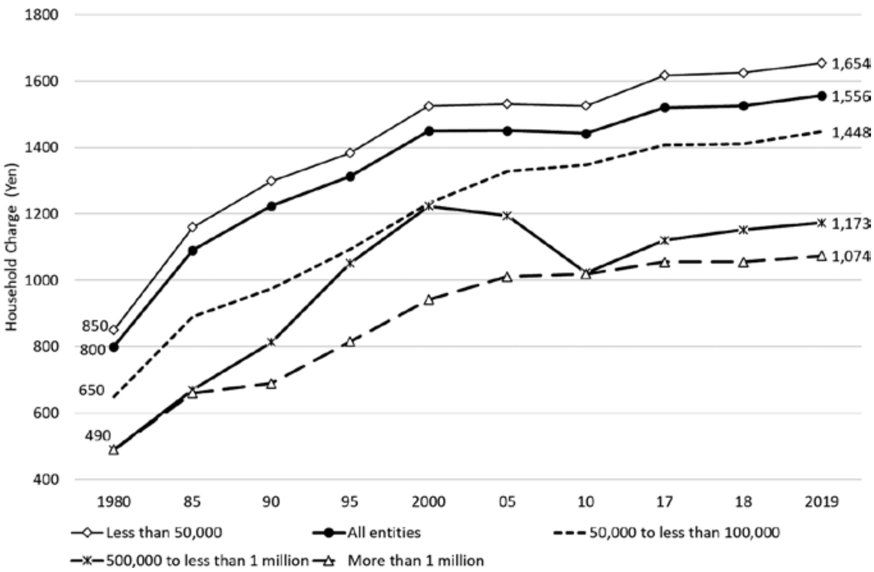
[5] The 1,794 entities are based on the "Local Public Enterprises Yearbook," but according to the "Waterworks Statistics," there were 12,653 water utilities with 101 or more users (excluding small-scale water utilities) as defined by the Waterworks Law as of the end of FY2019.
[6] These amounts are based on the "Water Supply Charge (as of April 1, 2021)" (Japan Water Works Association).

Figure 1. Household water charge per 10 m^3: As of April 1, 2021



Note 1: The amount includes consumption tax and meter usage fees. In the case of caliber, it is the amount of 13 mm.
Source: "Water Supply Charge Table" (Japan Water Works Association)

Figure 2. Average water charges by size of current water supply population



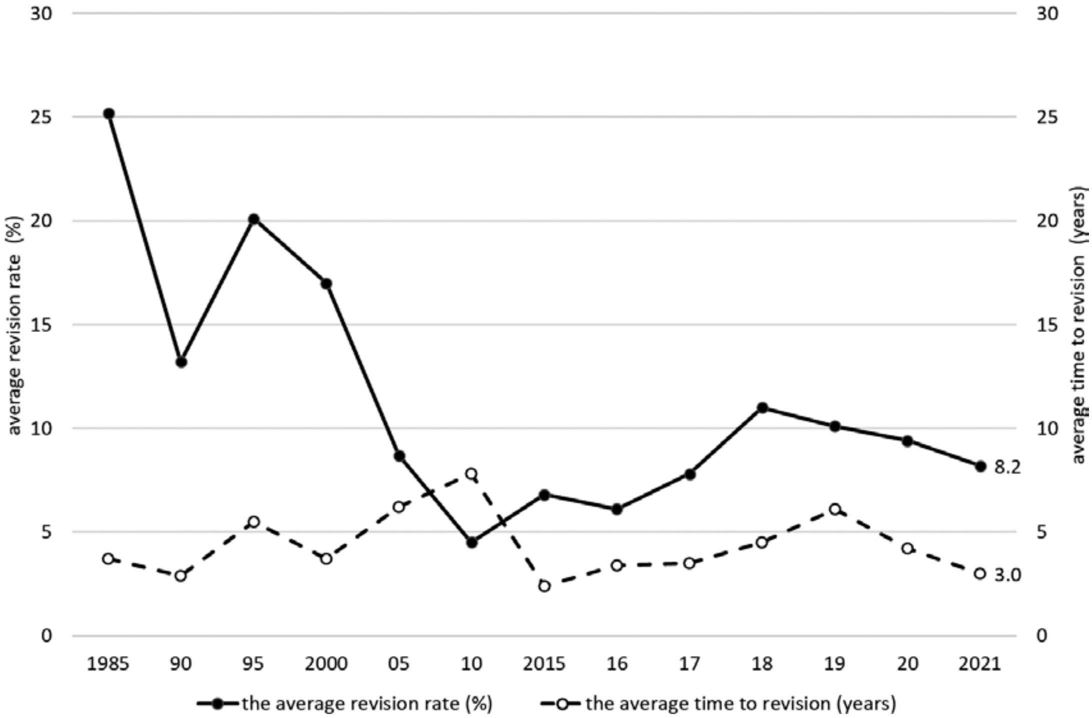
Note 1: The amount is per 10 m^3 for household use, including meter usage fees, and from FY1989 also includes consumption tax.
Note 2: Data for entities with a current water supply population of less than 100,000 to 500,000 were omitted.
Source: "Waterworks Statistics" (Japan Water Works Association)

II-2. Status of Water Charge Revision

According to the “Water Pricing Chart” (as of April 1, 2021), 44 of the 1,261 surveyed entities revised their charges for the period from April 2, 2020, to April 1, 2021, accounting for 3.5% of the total. Since 2014, this rate has hovered around 5% to 7%, compared with the last revised rate of 3.5%, which was lower. In addition, Figure 3 shows changes in the average revision rate (%) and the average time to revision (years) for entities that have revised water charges. In 2021, the average revision rate was 8.2% and the average time to revision was 3.0 years. The rate of revision of water charges was high until around 2000, but in the following 20 years, the movement seems to have stopped somewhat.

Table 3 shows increases and decreases in water charge revisions on “Yearbook of Local Public Enterprises”. The percentage of entities raising water charges has not increased despite the aging of the water facilities, indicating that the implementation of raising water charges is not working well enough. In addition, the percentage of entities that cut water charges is on the decline, suggesting that they can’t afford to lower water charges.

Figure 3. Average revision rate (%) and average time to revision (years) in water charges



Note 1: The sample consists of entities surveyed by the Japan Water Works Association.
Source: “Water Supply Charge Table” (Japan Water Works Association), “Overview of Waterworks” (Japan Water Works Association)

Table 3. Percentage of charge increases and charge reductions for rate revisions

	2010	2012	2014	2016	2018	2020
Number of entities with rate revisions	132	64	1087	62	71	81
Percentage of revised entities	10.1%	4.9%	83.5%	4.8%	5.4%	6.0%
Revision of charge increases	4.8%	2.8%	3.0%	3.9%	3.8%	3.9%
Revision of charge reductions	4.7%	1.1%	2.3%	0.5%	0.7%	0.7%

Note 1: The samples are business entities surveyed in the Local Public Enterprise Yearbook. This applies to terminal water supply, including small-scale water utilities subject to the Local Public Enterprise Act.
Note 2: FY2014 includes rate revisions due to revisions to consumption tax and local consumption tax.
Note 3: Since revisions such as changes in the rate structure that make it difficult to distinguish between charge increases and charge reductions are included, the sum of the percentage of entities raising charges and the percentage of entities lowering charges does not match the overall percentage.
Source: "Local Public Enterprises Yearbook" (Ministry of Internal Affairs and Communications)

II-3. Status of Aging Pipelines and Charge Revisions for Individual Entities

Table 4 shows a list of 12 entities with more than 50% of water pipeline extensions exceeding the statutory useful life in FY2020. However, only cities, excluding ordinance-designated cities, are included in the list. Towns, villages, and small-scale water utilities are excluded[7]. Even for the 12 entities with significant aging, it can be seen that their pipe renewal rates are not significantly different from the overall renewal rate of 0.7% (see Table 1), with the exception of Gosen City, Niigata Prefecture. In addition, in Kadoma City, Osaka Prefecture, water charges were reduced by 7.3% from March 2021. In the background of the revision, it is said that there are factors such as the effect of reducing operating expenses (personnel expenses, etc.) and securing profits that exceed its plan. Thus, we cannot confirm the fact that the rate of pipeline renewal is high or that the rate of charge revisions is high in entities with significant aging. In other words, it is considered that the setting of water charges and the revision of water charges based on the aging of the pipelines are not working.

III. Cost Recovery and Water Rate Increase

III-1. Water Charge Collection and Challenges Faced by Water Utilities

III-1-1. Status of Cost Recovery Rate for Water Utilities

Table 5 shows the status of unit cost and unit price of supply. Looking at the cost of water supply and unit price of supply (corresponding to selling prices) in the water supply business since FY2014, when the local public enterprise accounting system was revised, both the unit cost and unit price of supply tended to increase gradually until FY2019, while

[7] In the terminal water supply run by towns and villages, small-scale water utilities, and water supply projects operated by the corporate group, there are entities with more than 80% of pipeline extensions exceeding the legal service life.

Table 4. Entities with more than 50% of aging pipelines: FY2020

No	water utilities	Aging rate	Renewal Rate	Water charges (yen)	Date of implementation of current charges	Rate revision percentage	Date of previous revision
1	Kumano, Mie	78.5%	0.9%	1,100	2019.10. 1	1.9%	2014. 4. 1
2	Nanto, Toyama	72.4%	0.5%	1,595	2019.10. 1	1.9%	2014. 4. 1
3	Ebino, Miyazaki	72.4%	0.3%	1,760	2019.10. 1	1.9%	2014. 4. 1
4	Tomisato, Chiba	71.6%	0.1%	2,068	2019.10. 1	1.9%	2014. 4. 1
5	Kiyosu, Aichi	61.5%	1.5%	731	2019.10. 1	1.8%	2014. 6. 1
6	Minami-Boso, Chiba	58.1%	0.5%	1,987	2019.10. 1	1.8%	2018. 4. 1
7	Kasaoka, Okayama	56.3%	1.0%	2,178	2019.10. 1	1.9%	2014. 4. 1
8	Abashiri, Hokkaido	54.5%	1.2%	2,068	2019.10. 1	1.9%	2014. 5. 1
9	Kadoma, Osaka	52.9%	1.0%	985	2021.01. 1	-7.3%	2018. 10. 1
10	Gosen, Niigata	52.1%	12.0%	1,430	2019.10. 1	1.9%	2016. 4. 1
11	Akahira, Hokkaido	51.8%	0.8%	2,441	2019.12. 1	1.9%	2014. 4. 1
12	Otake, Hiroshima	50.7%	0.5%	720	2019.10. 1	1.8%	2014. 4. 1

Note 1: The sample is municipal water supply utilities (664 operators), excluding ordinance-designated cities. In addition, small-scale waterworks are excluded from the target.
Note 2: The water charge is the amount per 10 m^3 for household use (13 mm caliber).
Note 3: The figures are calculated from the Yearbook of Local Public Enterprises (Ministry of Internal Affairs and Communications).

Table 5. The status of unit cost and unit price of supply

	unit cost	unit price	selling profits
2014	164.2	171.8	7.6
2015	163.7	171.9	8.2
2016	163.3	172.4	9.1
2017	165.7	172.9	7.2
2018	167.1	173.6	6.5
2019	168.4	173.8	5.5
2020	166.4	166.5	0.1

Source: "Local Public Enterprises Yearbook" (Ministry of Internal Affairs and Communications)

selling profits were secured (but gradually decreased). However, in FY2020, the unit price of supply fell sharply, resulting in a situation in which sales profits were almost nonexistent. This is thought to be due to a drop in water demand caused by the spread of COVID-19 mainly for commercial and industrial users, who are large consumers and often set their unit water prices high, as well as to the fact that many water utilities took measures to reduce or exempt water supply charges.

Next, Table 6 shows the cost recovery rate (unit price of supply/unit cost of supply) in FY2020 for the water utilities by the size of the current water supply population. 628 businesses, or 50.2% of the total, were found to have a cost recovery rate of less than 100% (below cost).[8] The Ministry of Health, Labour and Welfare (MHLW) similarly prepared an

Table 6. The cost recovery rate (unit price of supply/unit cost of supply): FY2020

the current water supply population	Number of entities	Number of entities below cost	ratio
Less than 5000	40	27	67.5%
Less than 5000 -10,000	191	127	66.5%
Less than 10,000 -15000	133	72	54.1%
Less than 15,000 -30,000	252	138	54.8%
Less than 30,000 -50,000	204	98	48.0%
Less than 50,000 -100,000	198	81	40.9%
Less than 100,000 -150,000	86	31	36.0%
Less than 150,000 -300,000	77	27	35.1%
300,000 or more	50	17	34.0%
Metropolitan and ordinance-designated cities	20	10	50.0%
All entities	1,251	628	50.2%

Source: "Survey on Local Public Enterprises Financial Statements" (Ministry of Internal Affairs and Communications)

analysis for FY2019 based on the Municipal Public Enterprises Yearbook, which showed that about 40% of all utilities were below cost, an increase of about 10 percentage points. Half of the metropolitan and designated cities were also below cost, perhaps due to the impact related to the new coronavirus infection, but basically, as the population size decreases, the number of projects with a cost recovery rate of less than 100% tends to increase.

Figure 4 shows the rate of cost recovery for individual utilities by the size of the population served. The number of utilities with a particularly low rate of recovery (less than 80%) is increasing among the utilities with smaller populations. Overall, there are 175 utilities with a recovery rate of less than 80%, of which 164 currently have a water supply population of less than 50,000.

Table 7 shows the detailed cost items per 1 m^3 of water sold. Looking at the costs per m^3 sold, it can be seen that small municipalities in particular tend to spend more on depreciation and interest expenses than large municipalities. This may be attributed to the fact that the amount of water supplied by small municipalities is small compared to the amount of assets of water supply facilities that require investment.

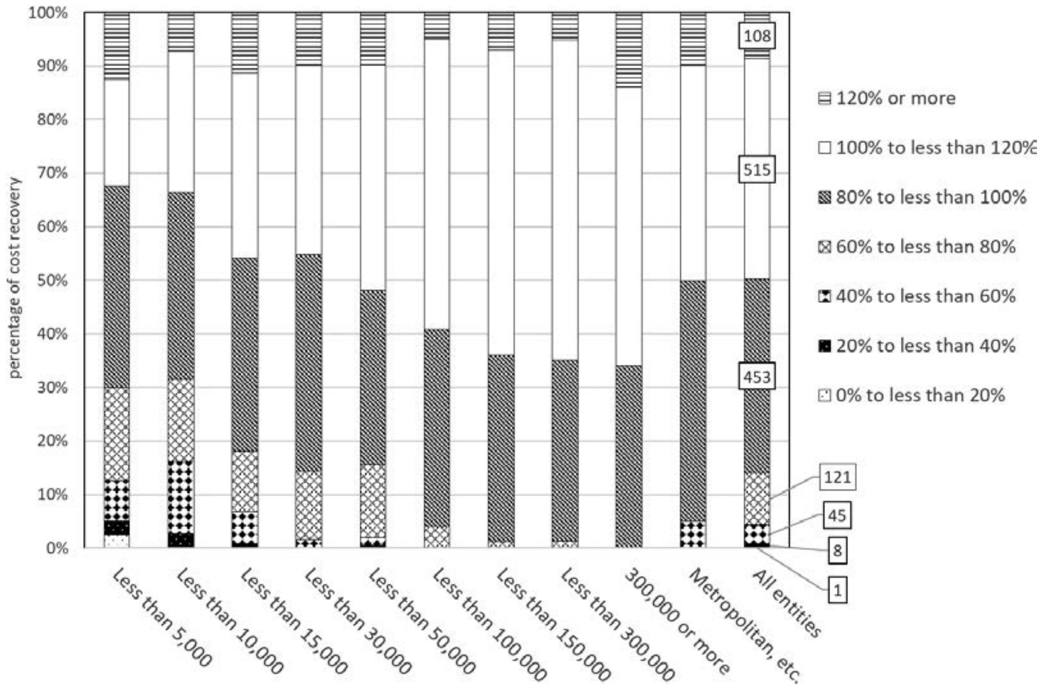
III-1-2. Challenges Faced by Water Utilities with respect to Cost Recovery

In water utilities, the structural issues that cause the under-cost situation include population decline, water conservation (including not only conscious water conservation but also the trend toward water conservation in toilets and plumbing fixtures due to technological innovation), and the decline in revenues due to the shift to groundwater.

Why does groundwater migration occur in water utilities, which are generally consid-

[8] Rural community water projects in a municipality are combined to general water projects if they are accounted for under a single water account. The same as in Table 5.

Figure 4. Rate of cost recovery by the size of the population served



Source: "Survey on Local Public Enterprises Financial Statements" (Ministry of Internal Affairs and Communications)

Table 7. The detailed cost items per 1 m^3 of water sold (yen)

the current water supply population	payroll	interest	depreciation	power	repair	outsourcing	others	total
Less than 5,000	37.6	20.2	135.0	12.1	15.0	26.7	47.8	294.5
Less than 5,000 -10,000	28.5	16.5	132.7	12.3	13.4	25.0	46.4	274.8
Less than 10,000 -15000	24.2	13.3	106.8	10.9	12.0	19.8	46.7	233.8
Less than 15,000 -30,000	21.5	11.5	86.5	10.4	10.4	20.6	45.7	206.7
Less than 30,000 -50,000	17.8	10.3	83.9	8.9	9.1	21.6	45.2	196.6
Less than 50,000 -100,000	16.3	8.7	74.5	7.3	8.3	23.0	51	189.2
Less than 100,000 -150,000	15.4	6.2	62.9	6.1	7.4	21.7	53.8	173.6
Less than 150,000 -300,000	20.7	7.5	65.4	5.8	8.2	20.3	49	177.0
300,000 or more	18.4	6.9	63.1	5.1	9.4	21.7	43.9	168.5
Metropolitan and ordinance-designated cities	24.7	5.1	56.7	5.5	30.6	23.1	35.3	180.9
All entities	20.6	7.2	66.8	6.4	15.9	22.1	43.8	182.6

Source: "Survey on Local Public Enterprises Financial Statements" (Ministry of Internal Affairs and Communications) ered regional monopolies? In many cases, water rates are based on increasing increments that set higher metered rates for high-volume users. This means that in some cases, large users (mainly commercial and industrial users) may be able to use water more cheaply by drilling on their land and pumping up groundwater for use. In addition, since consumers who use groundwater generally maintain a water supply contract with the water utility as a backup water source, a situation tends to occur where the water utility incurs the cost of securing supply capacity while its revenue is limited to the fixed charge portion and the cost cannot be recovered (conventionally, the water rates have tended to be set more heavily on the metered charge portion). In FY2020, the decrease in demand for water, mainly for commercial and industrial use, due to the new coronavirus infection, and the reduction in revenues when the rate is reduced or exempted for livelihood support, are considered to be factors that overlapped with the above.

It can also be pointed out that in the past few years, the cost of the entire water supply has been integrated and visualized due to the impact of the integration of community water systems. The rural community waterworks projects are those with a water supply population of 101 or more to 5,000 or less under the Waterworks Law, and the government promoted the integration of licenses for simplified waterworks from FY2007 to FY2016. Specifically, the government has taken measures to exclude from government subsidy those community waterworks that meet one of the following requirements: they are connected to other waterworks in the same local public entity, they are located less than 10 km from each other by road, or they have the same accounting records. If they are not integrated by FY2019, they would not be eligible for government subsidies. As a result, the integration of community waterworks into city waterworks rapidly progressed, and the number of approved community waterworks was approximately halved from 7,630 in 2016 to 3,561 in 2017. As a result, the waterworks business absorbed the low-density and unprofitable community waterworks business, which had a negative impact on the revenue and expenditure display as a water utility. In the water utilities that integrated the community waterworks, subsidies for the maintenance of the old simple waterworks facilities continue, but after FY2020, the situation would be limited (only projects with severe management situations will be eligible for subsidies).

Referring to the case of Ichinoseki City, Iwate Prefecture, as an example of integration of community waterworks projects, various management indicators, including the rate of cost recovery, have deteriorated as of the end of FY2016 due to the integration of 18 community waterworks that existed in the city through municipal mergers, etc. into the waterworks business.[9] As described above, there are various headwinds in the environment that forms the basis for the profitability of the waterworks business. However, the waterworks

[9] According to the Ichinoseki City Water Supply and Sewerage Department, "Current Status and Issues of Waterworks Business Integrated with Community Waterworks Business" (April 22, 2020), it is estimated that the rate recovery ratio will increase from over 100% to just under 80%, the ratio of corporate debt balance to water supply revenue will increase to 1.8 times that before the integration, and the cost of water supply will increase to 1.3 times that before the integration. As a result, water rates will be raised by about 15% in two phases, starting in November 2022 and May 2024.

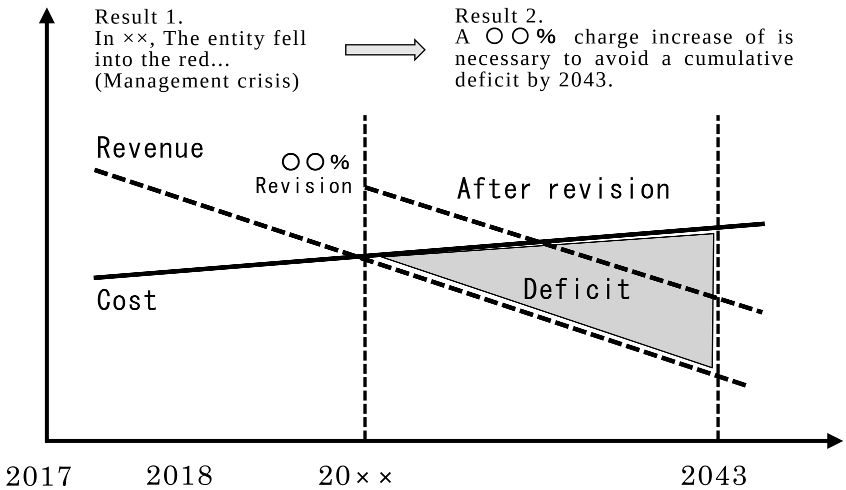
business is a capital-intensive business model that is obligated to provide water in the water supply area, and it is difficult to reduce costs in response to declining revenues. Rather, water supply facilities, mainly pipelines, are aging. The Ministry of Health, Labour and Welfare (MHLW) (2021) points out that the demand for future pipeline renewal will continue to grow even if future water pipelines are to be renewed in a 60-year cycle, which is longer than their statutory service life (40 years). Specifically, it is estimated that the current pipeline renewal demand of 5,000 km/year (pipeline renewal rate of 0.67%/year) will increase to an average of 7,000 million km/year (pipeline renewal rate of 0.96%/year) over the next 20 years, reaching 20,000 km/year by around 2050. It is estimated that the demand for renewal will reach 20,000 km/year around 2050. Thus, the cost of future renewal investment is expected to increase in the face of a declining population.

III-2. Water Rate Increase to Ensure Sustainability

Ernst & Young ShinNihon LLC and the Secretariat of the Organization for Water Security Strategy (2021) have estimated the level of water charges that will be required in the future by each public waterworks utility.

The image of the estimation is shown in Figure 5, which estimates the level of water supply charges for each utility as of 2043, based on 2018 data from "Water Supply Statistics" (Japan Water Works Association). Although there are some limitations in this estimation, such as the fact that it mainly examines profit and loss and does not necessarily fully consider balance sheets and fund balances, it assumes a decrease in water supply revenues due to a decline in population and per capita consumption for each water utility, and also as-

Figure 5. Image of estimated future water charges

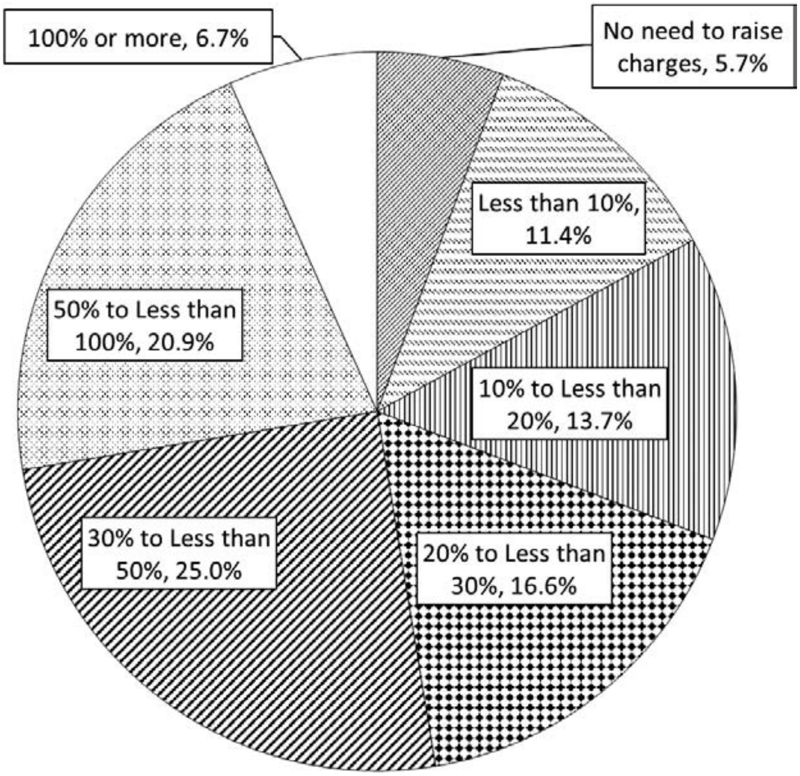


Note 1: Reprinted from Ernst & Young ShinNihon LLC and the Secretariat of the Organization for Water Security Strategy (2021).

sumes that revenues from the national treasury and other financial subsidies will be zero by FY2043 (FY2041).[10] The population growth rate is calculated based on the National Institute of Population and Social Security Research's "Estimated Future Population of Japan by Region (2018)" data to calculate the rate of population change, and the average cost over multiple years was used to eliminate as much as possible the impact of cost fluctuations in a single year.

In addition, the increase in depreciation and interest expenses due to the increased demand for investment in the renewal of water supply facilities in the future is estimated, then the assumed water rates for each utility in 2043 (the rate and timing of increases necessary to avoid running in the red) are calculated. As shown in Figure 5, this estimation model assumes a one-time rate increase to prevent accumulated deficits by 2043 at a certain point in the future when a certain utility is estimated to be in the red, and it should be noted that this is not strictly consistent with the rate calculation method for water utilities.

Figure 6. Composition of charge increases required in 2043



Note 1: Reprinted from Ernst & Young ShinNihon LLC and the Secretariat of the Organization for Water Security Strategy (2021).

[10] Assumptions are made based on the fact that waterworks projects should originally be managed based on the principle of independent profitability and the severe financial situation of the national treasury and general account.

The results of this estimation indicate that 1,162 entities, or approximately 94% of the total 1,232 entities analyzed, will be required to raise their water rates by FY2043. Of these, 648 entities, accounting for about 50% of the total, are estimated to require a rate increase of 30% or more. The national average rate increases estimated for 2015 (starting from 2013) and 2018 (starting from 2015) were 34% and 36%, respectively, while the estimated rate increase for the current year (starting from 2018) is 43%. Averaged across all projects, the water rate level is estimated to be 3,225 yen/month in 2018 to 4,642 yen/month in 2043 for average water consumption (20 m^3/month).[11] The gap in water rates among individual entities is estimated to widen from 9.1 times today to 24.9 times by 2043. The entities with the highest rate of rate hikes are located in the Hokkaido, Tohoku, and Hokuriku regions, and it is estimated that more than 30% of the entities in each of these regions have rate hikes of 50% or more. Thus, it can be said that water rate hikes are inevitable throughout the country.

III-3. Water Charge System and Revision Cases

III-3-1. Overview of the Water Rate System

The charges for water services operated by local governments are based on the total cost method under the Local Public Enterprise Law and the Waterworks Law, and the three elements of “appropriate cost under efficient management,” “fair and reasonable” and “sound management” are stipulated in Article 21 of the Local Public Enterprise Law and Article 14 of the Waterworks Law, respectively. The three elements are stipulated in Article 21 of the Local Public Enterprise Law and Article 14 of the Waterworks Law, respectively. In the 2018 revision of the Waterworks Law, “ensuring sound management” was added to the Waterworks Law as well. In addition, under the Local Public Enterprise Law, waterworks projects are obliged to establish public enterprise accounting, and in principle, they are supposed to be managed on a self-financing basis based on the water charges paid by the beneficiaries.

Furthermore, in the 2018 revision of the Waterworks Law, the following amendments were made in relation to the management of water supply services, and the related ministerial ordinance (Waterworks Law Enforcement Regulations) came into effect in October 2019 accordingly. Specifically, in paragraph 2 of Article 22-4 (Systematic Renewal of Water Supply Facilities, etc.) of the Waterworks Law, it is stipulated that “Water service providers shall prepare and endeavour to publicize, as specified by an Ordinance of the Ministry of Health, Labour and Welfare, a forecast of income and expenditure for their business, including costs required for the renewal of water supply facilities”.

In addition, the revision of the Ministerial Ordinance stipulates the following in Article 17-4 (Preparation and Publication of Income and Expenditure Forecasts for Water Supply Business) of the Ordinance for Enforcement of the Water Supply Law.

[11] This estimation assumes a one-time price increase in the year in which the deficit is incurred, but in reality the price increase will be phased in, so the price increase is expected to be gradual.

In preparing the income/expenditure projection set forth in paragraph (2) of Article 22-4 of the Act, the Water Utility shall establish a period of not less than 30 years (referred to as the "Calculation Period" in the following paragraph) and estimate the long-term income/expenditure for its business.

(2) The estimation set forth in the preceding paragraph shall be based on an appropriate forecast of water supply revenues during the calculation period, as well as an appropriate understanding or forecast of the status of damage, corrosion and other deterioration of water supply facilities, and calculation of the demand for new installation, expansion or alteration of water supply facilities (limited to those related to renewal of water supply facilities required by the said status). The demand for new water supply facilities shall be calculated.

(3) In calculating the demand set forth in the preceding paragraph, consideration shall be given to the appropriate size and layout of water supply facilities, cost leveling, and water supply capacity in the event of a disaster or other emergency.

(4) Based on the estimation under paragraph (1), the Waterworks Utility shall prepare and endeavor to publicize a forecast of income and expenditure for a reasonable period of time based on a standard of 10 years or longer.

(5) When the Waterworks Utility has prepared a forecast of income and expenditure, it shall endeavor to review it approximately every three to five years.

Furthermore, Article 12 (Item 2 and Item 3) of the said Enforcement Regulations stipulates that

In the case of a long-term estimate of income and expenditure, water rates are set for a period of approximately three to five years from the time of the calculation based on the estimate, and reviewed at appropriate times (every three to five years).

Thus, although the provision of Article 22-4 of the law is only an effort provision, it is significant that the law stipulates that a systematic renewal plan, a financial plan, and a trial calculation of water rates to finance the plan be conducted on a regular basis.

However, when a local public entity operates a water service, water rates are determined by an ordinance passed by the local public entity's assembly, and under the Waterworks Law, it is sufficient to notify the Minister of Health, Labour and Welfare of any changes in rates, so ultimately the determination of water rates depends on the policy direction of the local public entity's head of government and the judgment of the assembly. Ultimately, the decision on water rates depends on the policy direction of the head of the local government and the judgment of the local assembly.

III-3-2. From the Case Study on Water Rate Revision

While there have been cases in which the council and the head of the city have disagreed on the revision of water rates, there have also been cases in which municipalities have steadily implemented necessary revisions of water rates.

For example, the water rates in Nobeoka City, Miyazaki Prefecture, were reportedly "at odds" between the mayor and the city council regarding water rates. Before the current mayor took office, a proposal to raise water rates by 14.9% was passed at the December 2017 council meeting. However, the mayor, who was elected in the January 2018 mayoral election with a pledge to freeze the price increase, proposed a freeze on the price increase to the council in March of the same year, which was rejected, and the price increase was implemented starting in July 2018. Subsequently, in 2019, a proposal to lower the rates was submitted to the September council meeting but was rejected twice, and after holding a citizens' briefing session, the November council meeting finally approved a price revision to lower the basic rates by an average of 2.53%. According to media reports, there was a continuing disagreement between the mayor, who believed that the reduction could be financed by a government subsidy for earthquake-proofing projects, and the council, which believed that the city should promote earthquake-proofing of pipelines in anticipation of the Nankai Trough earthquake and other disasters.

On the other hand, Iizuka City in Fukuoka Prefecture revised its rates by an average of 35% from January 2022. This is the first rate revision in about 20 years since the former Iizuka City revised its rates in April 2001 (at the time of the merger in March 2006, the rates were unified with those of the former Iizuka City, which was the cheapest at the time). While the waterworks business has been in the red since FY2018, it was necessary to address the aging of facilities, which were progressively deteriorating compared to other organizations of the same size. In light of this situation, the "Iizuka City Waterworks Management Strategy" established an investment plan (including the standard years for renewal and selection and concentration of investment targets) and a financial plan (including financial targets), and estimated a minimum rate revision of 35% as a means of both making the necessary investments and ensuring financial soundness. The proposed rate revision based on such a plan is "a minimum of 35%". The proposed rate revision based on this plan was discussed at the "Iizuka City Waterworks and Sewerage Management Council," and the city's website has a "Frequently Asked Questions" section with about 20 questions and answers on matters that would generally be of interest to the public. The questions include "Why this time of year?" "Why this range of price increase?" "What will happen if the price is not raised?" and "Can't the taxpayers compensate for the increase?" In this way, we believe that this case study provides suggestions for appropriate rate revisions in terms of formulating an objective rate revision plan after establishing an investment and financial plan through the formulation of a "management strategy," engaging in discussions with outside experts such as the management council, and publicizing the plan to the public and fostering understanding.

IV. Empirical Analysis

IV-1. Related Literature on Water Utilities

Previous research on water utilities in Japan has focused on examining economies of scale and management efficiency. An analysis focusing on proper water charges from the perspective of the sustainability of water utilities was Nagamine (2015). Using a case study of a water project in Nishiwaki, Hyogo Prefecture, it was found that the current water charges and revenue structure would result in a shortage of financial resources. The specific procedure is (1) to estimate the amount of past infrastructure investment in Nishiwaki. (2) Organize water supply facilities into five categories: pipelines, water treatment facilities, water intake facilities, water distribution facilities, and pumping stations, and estimate in which years and to what extent renewal investment for the maintenance of the facilities will be required, taking into account the service life of each category. (3) Based on the amount of renewal investment, the revenue and expenditure of the water utility accounting for each fiscal year is projected. In conclusion, they point out that a renewal investment between 900 million and 1 billion yen is required every fiscal year, and since the recent investment in Nishiwaki is around 300 million yen, the current revenue must be tripled, that is, the water charges must be tripled. Yane (2012) used data from "Water Statistics of Japan" (Japan Water Works Association) to easily calculate the amount needed for renewal and found that the average amount of investment required by each utility for the next 50 years will be 900 million yen per year. In conclusion, it points out that in order to secure the cost of renewal, water charges for each utility must be doubled on average, and quadrupled for those with aging facilities that have exceeded their useful life.

Also, there is Tashiro (2017) as a previous study on water charges revision. According to "Guidelines for Calculating Water Charges", water charges are to be calculated by forecasting water demand for three to five years and estimating costs. In practice, there are many utilities that do not implement charges revisions for a long period of time. This study analyzes the determinants of the charge revision as an explained variable. Estimates based on binary logistic regression analysis reveal that the amount of operating income has a significant negative effect on charge revisions, merger dummies have a significant positive effect, and third-party consignment dummies have no significant effect. Furthermore, they point out that while municipal mergers can trigger rate revisions, they tend not to do so as long as the self-supporting accounting system is maintained. Kuramoto (2021) examines strategic interaction among local governments, focusing on the reduction or exemption of water charges. This study examines the determinants of the presence or absence of water charge exemptions as the explained variable. According to the estimated results using monthly pooling data of 26 municipalities in Kyoto Prefecture, it is clear that whether or not a neighbouring local government is implementing a reduction or exemption (weighting 25 municipalities other than their own by distance) has an impact on the local government's implementation of a water charge reduction or exemption. That is, they point out that the determination of water charges is mutually strategic. In addition, Adachi, Shinozaki and Saito (2022) point out that the yardstick factor has an impact on the setting of water charges for the own utility and neighbouring utilities. At the same time, it has been clarified that water charges are kept at a certain level relative to cost in efficiently managed entities. Thus, in recent years, an increasing number of studies have taken water rates as an object of analysis in the context of strategic interdependencies.

Finally, Toyama (1994) is an example of a study focusing on charge systems. The study points out that increases in water charges are not only about the average revision rate, but also about the content. In other words, it is important to pay attention to the range of increase in basic charges and metered charges, as well as the charge system, etc., and clarified that the range of increase in basic charges is relatively large in large cities such as Tokyo and Osaka. They also argued that in urban areas, small users may be given consideration at the expense of large users, and that in order to avoid political factors in water supply, the entity should be reformed into an organization that is more independent of local councils. However, Toyama (1994) is not an approach based on data analysis, and there is no data analysis that explicitly deals with the water charge system, as in our study.

IV-2. Verification Hypothesis on Setting and Revising Water Charges

The management of a water supply industry is strongly influenced by unique factors such as the type of water source and its acquisition conditions, population density and industrial structure. Therefore, in this paper, we use panel data to control the individual effects of water utilities and then test the following three hypotheses.

The percentage of pipeline extensions that have reached the end of their legal service life has increased dramatically from 8.9% in 2011 to 20.7% in 2020 (see Table 1). If there is a mechanism to determine water charges in view of the aging of pipelines, the number of water utilities that set or revise rates should increase. In reality, however, the percentage of entities raising rates has not shown an upward trend since 2010 (see Table 3). Furthermore, when we check the trends of individual entities whose percentage of pipeline extensions past their statutory useful lives exceeds 50%, we do not observe a high rate of rate revision in those entities (see Table 4). In addition, population decline is one of the factors that reduces the sustainability of the water supply industry, as well as aging pipelines. A possible solution to the decline in water supply revenues due to lower water demand is to raise water rates. In Japan, many regions have already experienced a decline in population, but the percentage of water utilities that have decided to raise water charges remains low. Therefore, the mechanism by which water charges are determined to accommodate a declining population may not be working. Therefore, the first hypothesis of this paper is as follows.

Hypothesis 1: Setting and revising water charges in consideration of aging and declining population are not functioning.

The charge system for the water supply industry can be broadly classified into two categories: those based on use and those based on caliber. In Japan, the use-based charge system initially became popular due to the need to control water charges for public bathhouses, etc. In recent years, there has been a shift to a charge system based on caliber, but as of 2021, about 30% of entities have adopted a system based on usage (see Table 2). The explicit category of “household use” in the use-based charge system is considered to be a factor that prevents raising water charges for household use. In fact, there exist cases in Toyama City and Yokohama City where water charges are raised on the occasion of shifting from by-use to by-caliber. Therefore, the second hypothesis of this paper is as follows.

Hypothesis 2: Water utilities with a charge system based on caliber of pipelines have higher domestic water charges than those with a charge system based on purpose of water use.

Furthermore, in relation to hypothesis 2 above, if it is easier for entities with a caliber charge system to make the decision to raise water charges, there may be a disparity in profitability between entities with a charge system based on caliber and a charge system based on use. In other words, entities by caliber may tend to be more profitable than entities by use. Therefore, the third hypothesis of this paper is as follows.

Hypothesis 3: Water utilities with a charge system based on caliber of pipelines are more profitable than those with a charge system based on purpose of water use.

If hypothesis 2 holds and hypothesis 3 does not hold as a result of the verification, it suggests that use-based entities may maintain profitability by keeping water charges for household use low while setting higher charges for commercial and industrial use.

IV-3. Hypothesis Test

IV-3-1. Testing Hypothesis 1 and Hypothesis 2: Water Charges

In this paper, the dependent variable periods are 2016 and 2020, using two periods of panel data[12]. In principle, the explanatory variables are one period earlier than the dependent variables, 2015 and 2019. The formulation of the verification of hypothesis 1 and hypothesis 2 is as shown in formula (1), where β is the parameter to be estimated. The dependent variable $\ln Y_{it}$ is the natural logarithm of the household water charge per 10 m^3. X_{it-1} is the explanatory variable vector. μ_i is an entity-specific individual effect that does not vary over time, and ϵ_{it} is the normal error term, assumed to be $\epsilon_{it} \sim i.i.d.N\ (0, \sigma_2)$. In panel analysis, time-specific effects are sometimes set in order to control for impacts such as economic fluctuations. However, in this paper, the explained variable the water charges set by the water utilities and is not an economic variable influenced by economic fluctuations, so time-specific effects are not considered.

$$\ln Y_{it} = \beta_1 D_{it} + \beta_2 X_{it-1} + \mu_i + \epsilon_{it} \tag{1}$$

The explanatory variables X_{it-1} are the ratio of aging pipelines and the population growth rate to test Hypothesis 1 and the charge system dummy to test Hypothesis 2. In addition, by

12 However, as will be pointed out later, there are some explanatory variables (specifically, the population growth rate at time 2) that cannot be analyzed one period earlier due to data constraints.

considering the intersection term of the charge system dummy by caliber and the ratio of aging pipelines, we examine the possibility of adopting a charge system by caliber and at the same time setting and revising charges according to the ratio of aging pipelines. Here, the ratio of aging pipelines is the ratio of the length of pipelines (raw water transmission main, treated water transmission main, and distribution main) that have passed the useful life designated by law to the total length of pipelines. In practice, by taking the natural logarithm, we clarify by what percentage the water charges increase if the ratio of aging pipelines increases by 1%[13]. The source of the data is the "Local Public Enterprise Yearbook" (annual edition). the population growth rate is a comparison with the census of the municipality five years ago. Specifically, at time 1 of the panel data, the dependent variable is the water charges for FY2016 and the explanatory variable, the population growth rate, is the FY2015 census population relative to the FY2010 population. At time 2, the dependent variable is water charges in FY2020, and the explanatory variable, the population growth rate, is the FY2020 census population relative to the FY2015 population. This is because at time 2, unlike at time 1, it is not possible to take a lag one period earlier due to data constraints. The charge system dummy D_{it} is an explanatory variable that is 1 when the charge system by caliber is adopted and 0 when the charge system by use or other is adopted. In the case of utilities that adopt a charge system by caliber, water charges are based on a caliber of 13 mm. For the charge system dummy, the data for period t is used, without taking the lag for period 1. The source of the data on the charge system, as well as the ratio of aging pipelines, is "Local Public Enterprise Yearbook" (annual edition).

Two data sets are used for hypothesis testing: the first, dataset A, samples 644 city-only entities, excluding ordinance-designated cities, and the second, dataset B, samples 1,157 city and town/village entities, including ordinance-designated cities. The sample excludes entities from the three disaster-hit prefectures that suffered particularly severe damage in the Great East Japan Earthquake: Iwate, Miyagi, and Fukushima. Missing values are also excluded from the sample, so the data set is an unbalanced panel. As a result, the total number of samples for the two periods is 1,217 for dataset A and 2,177 for dataset B. Their descriptive statistics are shown in Table 8.

First, we examine hypothesis 1. Table 9 shows the estimation results for dataset A, which uses samples from municipalities only, excluding ordinance-designated cities. According to the estimation result (a1), it can be confirmed that although the ratio of aging pipelines (= the rate of pipelines that have passed the useful life designated by law) has a significantly positive impact on the water charges for household use, the parameter is extremely small. That is, the elastic value is only 0.006%. Although this is a rough estimate, if the water charge is 5,000 yen, the average monthly water bill would increase by only 0.3 yen. An increase of 0.3 yen per month in water charges, on an annual basis, represents a 3.6 yen increase in the burden per household. Assuming a city with a population of 100,000 and

[13] Since samples with an aging rate of 0.0% cannot be logarithmically transformed, all samples are actually logarithmically transformed by adding 0.0015%, the minimum value excluding 0.0%.

Table 8. Summary statistics

Dataset A	Mean	SD	Max	Min	Number of observations
Household water charge	7.22	0.31	8.07	5.91	1217
the ratio of aging pipelines	-2.87	2.30	-0.24	-8.80	1217
the population growth rate	-3.20	3.96	14.60	-19.00	1217
the charge system dummy	0.73	0.44	1	0	1217
the current balance ratio	112.1	9.3	148.6	76.0	1217
Dataset B	**Mean**	**SD**	**Max**	**Min**	**Number of observations**
Household water charge	7.28	0.34	8.17	5.91	2177
the ratio of aging pipelines	-3.39	2.82	-0.09	-8.80	2177
the population growth rate	-4.09	4.53	23.00	-19.30	2177
the charge system dummy	0.68	0.47	1	0	2177
the current balance ratio	111.3	10.9	170.9	57.3	2177

Table 9. Estimation results A: Effect on household water charges
(Dataset A: Estimation using only municipal samples, excluding ordinance-designated cities)

	(a1)	(a2)	(a3)
the ratio of aging pipelines	0.006 *** (4.24)	0.003 (1.09)	
the population growth rate	-0.007 *** (3.31)	-0.007 *** (3.38)	
the charge system dummy	0.089 *** (4.61)	0.108 *** (4.82)	0.120 *** (5.92)
the intersection term		0.005 * (1.67)	0.008 *** (4.70)
R-squared	0.964	0.964	0.963
Observations	1217	1217	1217

Note 1: ***means that the parameter estimate is different from zero at 1%, ** means 5%, and * means 10% significance level. Also, the numbers in parentheses mean t-values.
Note 2: This is a one-way panel analysis considering individual effects. A fixed-effects model is adopted.

50,000 households, the increase in water supply revenue for the water utility would be only 180,000 yen (= Multiply 3.6 yen by 50,000 households). Next, Table 10 shows the estimation results using dataset B, which is a sample of city and town/village entities, including ordinance-designated cities. The small effect of the ratio of aging pipelines does not change in the estimated result (b1). These results suggest that water rates are not set and revised in view of the aging of the pipelines. That is, hypothesis (1) regarding aging of pipelines is considered to be valid. Then, to check the effect of population change, in Table 9 (a1) and (a2) using dataset A, it is found that when the population growth rate increases by one unit, the household water charges decrease by 0.007%. The average rate of population change in this sample (dataset A) is -3.2%, and about 80% of its 1,217 entities are in the 2% to -8% range. For example, if the rate of population change is -3% compared to the census population five years ago, and the level drops by 1% to -4%, the average water bill will be 0.007% higher. When applied to the same rough calculation as the ratio of aging pipelines, it is only an increase in water supply revenue of 210,000 yen per year for the water utility. Assuming 0.001% in Table 10 using dataset B, this increase in water revenue is even lower at 30,000 yen per year. Therefore, this result suggests that household water charges have not been set and revised to account for population decline as well as aging of pipelines. That is, hypothesis (1) regarding population decline is considered to be valid.

Next, we examine hypothesis (2). In the use-based charge system, the explicit "household use" category may cause water utilities to face decision-making difficulties, such as residents' opposition to setting or revising water charges for household use to a higher level. In such a case, there could be a charge disparity between entities that adopt a charge system by caliber and those that adopt a charge system by use. According to the estimation results (a2) and (a3) in Table 9, it can be confirmed that the charge system dummy (by caliber = 1) is significantly positive. It can be seen that water charges for entities that adopt a charge system by caliber are 0.11% to 0.12% higher than those that adopt a charge system by use. That is, hypothesis (2) is considered to be valid. In addition, the intersection term between the charge system dummy and the ratio of aging pipelines is also significantly positive, suggesting that entities adopting a charge system by caliber may have set or revised their water charges to a higher level in view of the aging of their pipelines. However, in the estimation results in Table 10, the parameter of the intersection term in (b3) is significant, but (b2) is not significant, indicating that the estimation is somewhat less robust. The estimates in Table 10 include samples from ordinance-designated cities to towns and villages, so it may be necessary to make improvements such as controlling the size of the population.

Table 10. Estimation results B: Effect on household water charges
(Dataset B: Estimation using city and town/village samples, including ordinance-designated cities)

	(b1)	(b2)	(b3)
the ratio of aging pipelines	0.006 *** (6.58)	0.004 (3.24)	
the population growth rate	-0.001 (1.14)	-0.001 *** (1.19)	
the charge system dummy	0.041 *** (3.03)	0.030 *** (3.28)	0.073 *** (5.17)
the intersection term		0.002 (1.30)	0.007 *** (6.00)
R-squared	0.973	0.973	0.972
Observations	2177	2177	2177

Note 1: *** means that the parameter estimate is different from zero at 1%, ** means 5%, and * means 10% significance level. Also, the numbers in parentheses mean t-values.
Note 2: This is a one-way panel analysis considering individual effects. A fixed-effects model is adopted.

IV-3-2 Testing Hypothesis 3: Profitability of Entities

The above verification reveals that household water charges are higher when the charge system by caliber is adopted and lower when the charge system by use is adopted. Then, are there differences in profitability among these entities with different water charge systems? If entities by caliber are setting and revising water charges appropriately in line with cost, the profitability of entities by use is declining. Or, if entities by use keep their water charges low for household use, and set relatively high charges for commercial and industrial use, then overall, there is no overall difference in profitability between entities by caliber and those by use.

$$Z_{it} = \beta X_{it} + \mu_i + \theta_t + \epsilon_{it} \tag{2}$$

Therefore, to verify hypothesis 3, we formulate the dependent variable Z_{it} as the current balance ratio of the water utility, as shown in equation (2). The current balance ratio of a water utility measures the extent to which current expenses are covered by current revenues, and means the profitability of the business. X_{it} is the explanatory variable vector. μ_i is an entity-specific individual effect that does not vary over time, and ϵ_{it} is the normal error term, assumed to be $\epsilon_{it} \sim i.i.d.N(0, \sigma_2)$. In this estimation, the current balance ratio, which is the dependent variable, is affected by water demand through economic fluctuations, so this is a two-way panel analysis that also considers the time effect θ_t. The explanatory variables, the charge system dummy and the population growth rate, are the same as the previous datasets. Descriptive statistics for the current balance ratio are shown in Table 8 above.

The estimation results are shown in Table 11. In all estimations from (c1) to (c4), we find that the charges structure dummy is positive at the 1% or 5% significance level. Tables 9 and 10 show that household water charges are set and revised at a high level among entities adopting charge system based on caliber of pipelines. As a result, Table 11 confirms that the profitability of entities by caliber is also high. That is, hypothesis 3 is considered to be valid. Since it is clear that entities that adopt the charge system by use are less profitable than those that adopt the charge system by caliber, the estimation results do not suggest the possibility that, while keeping household water charges low, they ensure the overall profitability of business entities by setting higher charges for commercial and industrial water to compensate for this. The fact that there is a charge category of "household use" makes it difficult to make decisions to set or revise water charges for household use to a high level. As a result, entities that adopt the charge system by use also have low profitability.

Finally, the population growth rate controls the fluctuation of water demand in the region, and the sign condition of its effect is consistent. In other words, it can be confirmed that population growth has a positive effect on the profitability of entities[14].

V. Conclusion

The purpose of this paper is to obtain fact-finding on charges setting and revision in water utilities. Specifically, we set three hypotheses and empirically examined how the aging of water pipelines and the declining population would be reflected in household water

Table 11. Estimation results C: Effect on the profitability of the entity

	only municipal samples, excluding ordinance-designated cities (Dataset A)		city and town/village samples, including ordinance-designated cities (Dataset B)	
	(c1)	(c2)	(c3)	(c4)
Const.	107.2 *** (72.6)	108.5 *** (68.0)	108.9 *** (92.8)	110.8 *** (87.8)
the charge system dummy	6.57 *** (3.26)	6.64 *** (3.30)	3.47 ** (2.03)	3.79 *** (2.22)
the population growth rate		0.39 * (1.94)		0.51 *** (3.87)
R-squared	0.598	0.600	0.657	0.662
Observations	1217	1217	2177	2177

Note 1: *** means that the parameter estimate is different from zero at 1%, ** means 5%, and * means 10% significance level. Also, the numbers in parentheses mean t-values.
Note 2: This is a two-way panel analysis considering individual and time effects. A fixed-effects model is adopted.

charges, and whether differences in the charge system would lead to differences in water charge and profitability. The estimation results suggest that the setting and revision of water charges that take into account aging pipelines and population decline may not be working. Therefore, hypothesis 1 is considered to hold. That is, it should be noted that there may be a reverse causal relationship to the model estimated in this paper. Although the estimation in this paper addresses this reverse causality problem by setting the timing of the explanatory variable, the percentage of aging, one period earlier than the dependent variable, it is important to interpret the results with caution. This will be an issue for the future.

Hypothesis 2 can be confirmed because water charges for household use are at a higher level in utilities that adopt a charge system based by caliber than in utilities by use. At the same time, it is confirmed that entities by caliber are also highly profitable, and hypothesis 3 is also established. In water entities by use, the explicit classification of “household use” may cause some decision-making difficulties, such as residents’ opposition to setting or revising water charges for household use to a higher level. In other words, the charge system by use seems to be an institutional factor preventing the setting and revision of appropriate water charges based on the aging of facilities and the balance of business. Generally, the more water available, the higher the investment and maintenance costs for facilities and equipment. Therefore, from the point of view of the fairness of the burden, it is said that the system of charging by caliber is more desirable. Furthermore, from the standpoint of sys-

[14] In recent years, in the wake of COVID-19, a number of entities have taken measures such as reducing or exempting water charges and extending payment deadlines in order to take into account households facing difficult economic conditions. Since time 2 of the data set in this paper is FY2020, it is possible that these measures have had an effect on the profitability of entities at time 2. Of course, if this effect is uniform for all entities, it can be controlled by the time effect of the panel analysis, but in fact, there are some entities for which the extraordinary subsidy from the national government is not enough and the special account for the water utility is forced to bear the burden. Originally, these factors should be carefully addressed, but since it is not easy to construct a database, a more precise examination of profitability is an issue to be addressed in the future.

tematic improvement and renewal, it is desirable to shift the water charges from a usage-based charge system to a caliber-based charge system.

Of course, in a society with a declining population, there is no need to replace all the aging water facilities. Discussions are also needed to limit the infrastructure to be updated, such as aiming for a compact city. In addition, attempts to introduce cutting-edge technology for maintenance, inspection, and operation management of water utilities have also begun. The environment surrounding the water supply system is changing dramatically, and a framework is needed to maintain the sustainability of the water supply system while incorporating such changes in the environment. In addition to measures for aging water facilities, efforts are also being made to make them earthquake-resistant. The verification of this paper did not allow us to consider the data related to them, but that is something we will address in the future. This paper did not take into account the data related to these efforts, but this will be an issue for the future.

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