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Abstract

The management of common-pool resources requires collective action and cooperation, especially when resource users face extreme weather events. This study examines collective decision making in water resource management during droughts. By focusing on the drought response by groups of water users in river basin communities in Japan, we investigate the determinants of collective decisions on water withdrawal restrictions. Our results show that water user groups are more willing to cooperate for water conservation when other water user groups in a community also cooperate. This suggests that the level of cooperation in drought management depends on other water user groups' cooperation. The findings contribute to a better understanding of collective action in water management, which is also informative to improve adaptive capacity to climate change.

Keywords: Common-pool resource, Collective decision making, Cooperation, Drought, Water conservation, Japan

1. Introduction

Researchers have shown that groups of individuals are capable of overcoming social dilemmas and maintaining common-pool resources (CPRs). Traditional economic theory predicts that, without government intervention or privatization, resource users who face collective action problems overuse or even exhaust their common resources. This situation eventually leads to what Hardin [12] describes as "the tragedy of the commons." Many studies have challenged this assumption and found evidence of cooperation in the management of CPRs [19, 22]. Such evidence suggests that individuals can sustain collective action and self-organize CPRs over time. For example, theoretical work and laboratory experiments have provided explanations for cooperative action and other-regarding behavior from the viewpoint of social preferences [6, 7, 9, 10, 24]. Field studies from many parts of the world have also identified a variety of social, economic, and ecological factors that are likely to affect successful or unsuccessful CPR management [2, 3, 5, 8, 30, 33].

This paper presents an example of CPR management by focusing on river basin communities under drought conditions in Japan. Although Japan receives relatively abundant precipitation, droughts occur regionally almost every year. In the event of a drought, water users in river basin communities organize their councils to coordinate water use and impose joint water restrictions. This unique, user-based management system for drought response in Japan provides an opportunity to explore an interesting case of CPR management.

The objectives of this study are to examine which factors affect collective decision making in water resource management during a drought. While most previous CPR studies have explored the behavior of individuals to explain its impact on community resource management, our study focuses on interactions among groups of resource users in a community and the collective decisions these groups make for drought management. Water resource management involves several different groups of stakeholders that most likely face a dilemma in using their water resources. Given this feature of CPR management, our particular interest in this study is related to the ways in which cooperation is enhanced among water user groups that jointly implement water restrictions during a drought. Thus, we investigate the characteristics associated with CPR that may affect collective decisions and promote cooperation in community drought management.

The main result of this study shows that water user groups are more likely to cooperate with regard to water conservation when other water user groups also cooperate. Thus, the finding suggests that the coordination of water use through the drought council may promote mutual cooperation among water user groups and further help adaptation to extreme weather events. As climate change becomes a growing concern, all levels of government have been implementing adaptation strategies to reduce vulnerability and build adaptive capacity to climate change [14]. In November 2015, the Japanese government released the *National Plan for Adaptation to the Impacts of Climate Change*, otherwise know as the *National Adaptation Plan*, to address a wide range of environmental and socioeconomic issues associated with climate change [15]. In this report, droughts are raised as a major concern for the country's water resource management. Because of climate change, the frequency, intensity, and duration of droughts are projected to increase.

Therefore, it is important to consider how water users with different interests can be coordinated to address droughts.

The remainder of the paper is organized as follows. The next section presents an overview of the drought situation in Japan and the responses of local communities during a drought. The hypotheses of this study are also presented in this section. Section 3 describes the model and data used in our empirical analysis. Section 4 shows the results, and Section 5 concludes.

2. Background

2.1. Drought in Japan

Despite relatively abundant rainfall and annual typhoons, Japan experiences droughts, similar to many other parts of the world. Almost every year, droughts occur in various parts of Japan, resulting in water shortages in local communities. Drought-vulnerable areas are located mostly in the central and western parts of the country, including Tokyo and many other cities with large populations and economic power. Table 1 provides details of the most severe droughts that have occurred in Japan during the past 50 years. The table shows droughts by year, together with the names of the most affected cities. The right-hand columns present details of the mandatory restrictions on domestic water use implemented by water supply utilities. As shown in Table 1, droughts occurred locally in most cases and had severe impacts on the affected regions.

Among these extreme events, Japan suffered its worst drought in 1994. Because of the record-breaking high temperature and low precipitation, the 1994 drought caused widespread damage across the country. As a result of the restrictions placed on domestic water use, approximately 16 million people experienced mandatory cutbacks of water use [13]. The drought conditions were more severe and persisted for months in some regions, including the cities listed in Table 1. For example, the cities of Sasebo and Fukuoka in the western part of Japan adopted water use restrictions for 213 days and 295 days, respectively. The drought also had negative effects on the country's economy. In the agricultural sector, crop damage amounted to approximately 138 billion yen.[1] In the industrial sector, 77 industrial water utilities, which comprised one-third of all such utilities, curtailed water use during the drought. As a consequence of water shortages, firms experienced a temporary shutdown and decline in production. Furthermore, the drought caused environmental damage to the water system such as water quality degradation in rivers and land subsidence caused by excessive groundwater pumping. The experience in 1994 shows that droughts can have significant social, economic, and environmental impacts.

2.2. Drought response

In terms of drought response, local communities in Japan address the issues in a unique way. When a drought occurs, the members of river basin communities bring themselves together to implement a user-based drought response. Water users, together with river administrators and government agencies, form a drought coordination council, at which they discuss water use among different user groups within the river basin. Among the actions

[1] One billion yen was approximately US$9.35 million at the end of 1994. Thus, 138 billion yen was approximately US$1.29 billion.

taken in response to a drought, the council implements water restrictions to reduce water use. The interesting feature of such drought management in Japan lies in the coordination role the council plays during a drought. The council encourages water users to engage in the decision-making process for drought management. This also means that the water restrictions implemented by the council are associated with collective action by water users in river basin communities.

The implementation of a council for drought response dates back to the 1970s. In 1974, the former Japanese Ministry of Construction issued a notification about drought management [17].[2] The notification promoted the implementation of drought coordination councils in river basin communities facing the risk of drought. Since then, communities have begun to organize councils in response to droughts. Such councils play an important role in drought management by facilitating communication and information sharing through interactions among multiple stakeholders. Although participation in the council depends on the community in question, councils generally consist of stakeholders such as water user groups (e.g., domestic and industrial water utilities; groups of farmers; and electric power companies), river administrators (the Ministry of Land, Infrastructure, Transport, and Tourism; prefectures; and municipalities), local prefectures and municipalities, and other related administrative agencies (Japan Water Agency; the Ministry of Agriculture, Forestry, and Fisheries; and the Ministry of Economy, Trade,

[2]The Ministry of Construction, together with the National Land Agency, the Hokkaido Development Bureau, and the Ministry of Transport, was reorganized into the current Ministry of Land, Infrastructure, Transport, and Tourism in 2001.

and Industry).

The origin of drought coordination councils may also date back to the River Act established in 1964.[3] Article 53 of the River Act provides for the coordination of water use during a drought. According to Article 53, water users shall hold consultations in order to coordinate water use among users in circumstances whereby a drought hinders water utilization. Water users are also required to respect each other's water use with regard to water use coordination. Thus, the law not only encourages collective action but also promotes a specific attitude among water users toward drought management. Further, Article 53 specifies the roles of water users and river administrators in drought management. While water users coordinate water use during a drought, river administrators may assist water users in reaching agreements as necessary. This implies that water users should play a major role in the decision-making process, whereas river administrators should act as mediators. Based on these provisions in the River Act, river basin communities can conduct self-organized drought management.

In the drought coordination council, participants make collective decisions on water restrictions as an important component of their drought response actions.[4] More specifically, water users impose rates of reduction on

[3]The former River Act, which had lasted since 1896, was replaced by the 1964 River Act. A major amendment was made in 1997.

[4]Note that the water restrictions introduced in this section are different from the mandatory restrictions on domestic water use mentioned in Section 2.1, which were adopted by domestic water supply utilities. The restrictions explained here apply to water withdrawals from dams and rivers.

water withdrawals from upstream dams. In cases of multipurpose dams that provide water for domestic, agricultural, and industrial water uses, these restriction rates are implemented simultaneously for each type of water use. Although the level of water restrictions imposed may also depend on the types of water rights each water sector holds, we do not address this aspect of structural difference in this paper.[5] Figures 1a and 1b present the restriction rates of the water withdrawals associated with domestic, agricultural, and industrial water in each drought that occurred in Japan between 1987 and 2013. Figure 1a compares the water restriction rates for domestic and agricultural water. In some cases, the same restriction rates are applied to these water uses. In other cases, however, different restriction rates are applied to each type of water use. A similar tendency is observed when comparing domestic and industrial water restriction rates, as shown in Figure 1b. These restriction rates do not originate from individual decisions by each water user group, but from the collective decisions of the drought coordination council. In other words, water user groups act together to curtail water use as part of their response to a drought. Hence, the drought coordination council implements water restrictions as a result of collective decision making by

[5]From the standpoint of stability, water rights are classified into three types: stable water right, affluent water right, and provisional affluent water right. The stable water right is the most basic right that permits water right holders to intake river water constantly. The affluent water right allows right holders to intake river water only when the flow rate is abundant. The provisional affluent water right is a temporary right permitted in case that there is an urgent water demand even if water resources are not already developed by the completion of a dam.

water user groups.

2.3. Hypotheses

Our study focuses on water restrictions during a drought. We examine the collective action of water user groups in river basin communities when they impose restrictions on water withdrawals from upstream dams. As mentioned in Section 2.2, water user groups from different sectors jointly implement water withdrawal restrictions. In such situations, collective action for drought management should require cooperation among water user groups. In this study, we assume that water restrictions reflect the level of cooperation for water conservation, given that the severity of the drought is controlled for. Building upon this assumption, we analyze the factors related to the resource systems that may affect the implementation of water restrictions. Thus, the hypotheses of this study are as follows:

H1. A water user group cooperates more for water conservation when other water user groups sharing water resources in their river basin community also cooperate.

H2. Higher level of cooperation is demanded during droughts when water is provided for a larger variety of purposes in a community.

H3. The experiences of droughts improve cooperation in the water resource management during droughts.

H4. Larger reservoir storage capacities induce cooperation toward water conservation.

H1 is based on previous research on participants' behavior in CPR management [4, 8]. Cavalcanti et al. [4], for instance, examine the effect of contributions by others on one's willingness to contribute to the management of more sustainable fisheries. They find that participants are more willing to contribute to the implementation of management proposals when they believe that others also contribute. This finding suggests that many fishers are conditionally cooperative; in other words, people increase their level of cooperation as others cooperate more [11]. Evidence of such behavior is also shown in the study by Fehr and Leibbrandt [8], who conduct field experiments in fishing communities. Their results, derived from public goods games, suggest that the level of contribution depends on how much a fisher expects other fishers to contribute. In the context of our study, evidence of conditional cooperation should be found if a water user group cooperates with other water user groups, provided that these groups also cooperate.

H2 addresses the role of heterogeneity in collective action. Heterogeneity in the context of this study refers to the different uses of water resources, reflecting the difference in economic interests derived from the resources [29]. Water resources are provided for various uses through the management of multipurpose dams. In the event of a drought, each water user group in a community must consider other groups in regard to water use. The greater the variety of purposes is, the more efforts for water conservation are demanded. Because the existence of drought coordination council can promote cooperation among heterogeneous water users, free-riding is less likely to occur. Given this institutional scheme that might encourage the cooperation under repeated games, we hypothesize that cooperation improves with heterogeneity in the use of water resources. As Varughese and Ostrom [28] point out, problems arising from heterogeneity can be overcome by designing institutional arrangements that encourage cooperation [23]. Other researchers have also found that heterogeneity does not always hinder CPR management and that there is a positive association with collective action [1, 23, 29]. However, we should note that there is no consensus on the effect of heterogeneity on the likelihood of successful CPR management. Some researchers have asserted that differences in many aspects, such as political heterogeneity, inequality in wealth and endowments, cultural diversity, and economic interests, cause conflicts among resource users [29]. There has been a great deal of debate over the impact of heterogeneity on collective action in CPR settings [1].

H3 focuses on interactions among water user groups through drought experiences in the past. The experiences of droughts are associated with the experiences of holding drought coordination councils. The council provides water user groups with opportunities for communication and discussion to coordinate water use during a drought. In the context of CPR management, face-to-face communication affects collective action in a way that enhances cooperation among resource users [20]. This is because such interactions enable resource users to adopt joint strategies to pursue the optimal outcomes. Communication also helps resource users develop norms that induce cooperative behavior [21]. Moreover, past experiences of drought may improve cooperation because resource users can learn how to work with each other from repeated interactions [20].

H4 investigates the physical characteristics of the resource system that may affect water resource management. We expect the reservoir capacity to have a positive effect on cooperation in the drought management. Schlager et al. [25] describe the storage capacity of a resource system as one of the physical characteristics of CPRs that induces cooperation among resource users when managing their resources.[6] The presence of storage capacity helps mitigate the problems that arise in CPR settings. For example, storage capacity restrains the overconsumption of resources when users attempt to withdraw or harvest the resources before others do. This means that resource users' incentives for overuse become lower because they can reserve their resources. Taking the example of an irrigation system, Schlager et al. [25] point out that larger storage capacities enhance users' ability to control water. They further argue that users who have more ability to control water through storage capacity are more cooperative in managing water resources.

To examine the hypotheses above, we should control for the severity of drought in the estimation. Therefore, we include one of the following climate variables related to drought: number of dry days, annual precipitation, and ratio of annual precipitation to average precipitation. The coefficients of these meteorological variables can be interpreted as how communities respond to climate variability in water resource management under drought

[6] According to Schlager et al. [25], *storage* is defined by the availability of storage capacity (e.g., reservoirs, irrigation canals, and groundwater basins) that is able to keep resource units (e.g., water in stream, fish, and wildlife) in stock. The other physical aspect, *stationarity* or *mobility*, is defined by whether unharvested resource units (e.g. water, shellfish, and timber) remain spatially for a longer time or migrate inside and/or outside the resource system.

conditions. Climate variability and further climate change alter global and regional weather patterns, causing more frequent and severe droughts. In particular, changes in precipitation patterns directly affect drought conditions. Figure 2 gives an example of such changes in Japan. The figure shows that the annual number of rainy days, which are days with a precipitation amount of more than 1 mm, has decreased in recent decades. In other words, the number of dry days is increasing over time, implying that the duration of dry periods is also increasing. The current trend is likely to continue because the number of dry days in Japan is projected to increase. The Japanese Ministry of the Environment and the Japan Meteorological Agency have jointly reported climate change projections for assessing the impact of climate change on the country in order to develop the *National Adaptation Plan* [16]. According to their report, the number of dry days in Japan is projected to increase by 1.1 days (RCP2.6) to 10.7 days (RCP8.5) based on representative concentration pathways (RCPs).[7] Indeed, Japan may face more severe droughts in the coming years.

3. Empirical Analysis

3.1. Empirical strategy

We examine the extent to which collective decision-making affects water withdrawal restrictions during a drought. The specification for the regression

[7]RCPs are the climate scenarios adopted in the IPCC Fifth Assessment Report. Four RCPs are commonly used and defined by the total radiative forcing by 2100. RCP2.6 represents the least radiative forcing level pathway, and RCP8.5 represents the highest level pathway.

model is as follows:

$$WaterRestrictions_{ij} = \beta_0 + \beta_1\, Rate_{ij} + \beta_2\, Dam_{ij} + \beta_3\, Climate_{ij} + \beta_4\, C_{ij} + \delta_{ij} + \gamma_{ij} + \varepsilon_{ij}, \quad (1)$$

where $WaterRestrictions_{ij}$ is the maximum water restriction rate for domestic water, which is applied to dam j during drought i.[8] $Rate_{ij}$ is the restriction rate of either one of the other water user groups (*agricultural water restriction rate* and *industrial water restriction rate*). Dam_{ij} is the set of characteristics related to dam and drought management (*purposes of dam*, *drought experience*, and *reservoir capacity*). $Climate_{ij}$ is the set of climate variability (*dry days*, *precipitation*, and *precipitation ratio*). C_{ij} is the set of control variables (*previous restriction rate*, *domestic water distribution*, *domestic water price*, *multiple dams*, and *Full Plan*). In addition to these variables, two types of fixed effects are included in our analysis: year fixed effects δ_{ij} and region fixed effects γ_{ij}. For region fixed effects, we divide the country into eight areas, which are commonly used for geographical classification in Japan. Finally, ε_{ij} is an error term.

One important aspect of drought management implemented in Japanese river basins is that groups of water users collectively implement water restrictions. As mentioned in Section 2.2, water restrictions for each water supply are jointly determined through the water coordination council. While this shows an interesting feature of drought response in Japan, the situation implies the potential simultaneity problem for the estimation that includes these

[8]Note that the water restriction rate is applied to "a group of dams j," when the restrictions involve multiple dams, as described in the following section.

water user groups. That is, restriction rates of all three water supply types in the regression model may be endogenous variables. In this case, regressing domestic water restriction rate by using ordinary least squares (OLS) yields inconsistent parameter estimates. To address this issue, we adopt the method of instrumental variables (IV) and estimate the models with the two-stage least squares (2SLS) procedure. In our model, there are two potential endogenous variables included as independent variables, namely, agricultural water restriction rate and industrial water restriction rate. We instrument agricultural water restriction rate with agricultural outputs and industrial water restriction rate with the value of manufactured goods shipments. These instruments should affect domestic water restriction rate only through changes in each potential endogenous variable. We assume agricultural outputs and the value of manufactured goods shipments to have direct impacts on the restriction rates of each relevant sector, thereby indirectly affecting the domestic water restriction rate. Data on agricultural outputs are taken from the Japanese Ministry of Agriculture, Forestry, and Fisheries, whereas data on the value of manufactured goods shipments are taken from the Japanese Ministry of Economy, Trade, and Industry. Since the data are provided at the prefecture level, we construct each instrument variable by calculating the aggregate amount for a river basin, as some river basins are spread across several prefectures.

3.2. Data description

This section presents the variables used in our empirical analysis. To test the hypotheses, we use the water restriction rate for domestic water as the dependent variable. The independent variables and corresponding hypotheses are as follows: water restriction rates of other two types of water uses (H1), number of purposes of a dam (H2), experiences of droughts (H3), and reservoir capacity of a dam (H4). We also include climate variability and other factors related to the characteristics of domestic water user groups and dam management as control variables. Table 2 describes the variables used in our analysis and summarizes the expected effect of each variable on the domestic water restriction rate. Table 3 provides descriptive statistics of these variables. Overall, we have 165 cases of water restrictions implemented on 50 dams during the data period from 1987 to 2013.[9] This means that a dam in our sample experiences water restrictions approximately three times on average, ranging from one to 25 times depending on the dam. Our dataset includes seven out of eight classified regions, in which droughts occurred during the sample period. Thus, there are about seven dams in each region in the sample. On average, each region experienced droughts approximately 23.6 times, and 6.1 drought incidents occurred every year.

The primary variables of interest in this study relate to collective decisions on water restrictions during droughts. These variables are the *domestic water restriction rate*, *agricultural water restriction rate*, and *industrial water restriction rate*. As described in Section 2.2, water user groups jointly implement restrictions by imposing rates of reduction on water withdrawals from dams. Therefore, imposition of water restrictions indicates how much percentage of water is curtailed during a drought. In reality, council members

[9]Note that 50 dams are the total number of dams included in the sample. As explained later in this section, some cases involve multiple dams for the joint implementation of water restrictions.

hold multiple meetings in which the restriction rates are adjusted over time as a drought continues. Figure 3 illustrates how water restrictions are implemented by taking the example of Mastuyama city in 2008. The figure shows the water restriction rates implemented via the Ishitegawa Drought Coordination Council and daily rainfall in the city. In summer of 2008, the council set water restrictions on August 4. At the early stages, they usually impose restrictions with relatively lower rates of reduction. The council gradually tightened the restriction rates as the drought persisted. After the restriction rate reached the highest in late September, the council relaxed the restrictions until they were lifted in early October. Because of data availability, our study uses the maximum rate of water restrictions for each observation, which is 25% in this example.

The data on water restrictions were collected from the annual report, *Water Resources in Japan*, published by the Japanese Ministry of Land, Infrastructure, Transport, and Tourism. From this data source, we were able to obtain the data on more than 400 cases of regional droughts in Japan from 1983 to 2013. From these data, we take water restrictions for multipurpose dams that supply water for domestic, agricultural, and industrial uses. We also use the information on past droughts for some independent variables. As a result, our dataset consists of 165 cases of water restrictions from 1987 to 2013. The descriptive statistics in Table 3 show that the mean restriction rate for domestic water is 17%. The mean restriction rates for agricultural and industrial water are greater than those for domestic water at 26% and 28%, respectively.

The variables used to test H2–H4 are related to the characteristics of resource systems. Data on variables for H2 and H4 were obtained from the *Dam Yearbook*, published by the Japan Dam Foundation. The official websites of the dams were also used as supplementary data sources. *Purposes of dam* for testing H2 indicates the number of purposes for which a dam provides water resources. There are eight categories for the purposes of dams in Japan, including the three types of water supplies mentioned above.[10] We use multipurpose dams that have these three types of water supplies to test H1 in this study. Therefore, the minimum number of purposes is three, while the maximum number is six. On average, the dams in our sample have approximately five purposes for their water use.

We use *drought experience* to test H3. This is a dummy variable indicating whether a river basin had a drought within three years prior to the present drought. With this variable, we examine if the decisions on water restriction rates are affected by the drought experiences in the past. Having experienced droughts means that a river basin community has had the experience of holding a coordination council prior to the present drought. Therefore, water user groups with drought experiences must have had similar interactions quite recently, not to mention decisions on water restrictions. In our sample, the mean value of drought experience is 0.79. This means that, in almost 80% of the drought events, river basin communities have past experience of a drought and the associated council meetings.

The variable that relates to H4 is *reservoir capacity.* This represents the

[10]Besides domestic, agricultural, and industrial water supplies, other purposes of dams in Japan are controlling floods, generating hydroelectric power, stabilizing water flow, supplying water for snowmelt control, and providing facilities for recreation.

volume of water a reservoir can hold for operating purposes. Reservoir capacity varies widely from 9 million m^3 to 1,900 million m^3, depending on the dam. This is because some cases of water restrictions involve more than one dam. We calculate the total reservoir capacity in cases when water restrictions were applied to multiple dams. This difference in water management between cases that involve multiple dams and those with a single dam is also examined in the analysis, as we explain in more detail later in this section.

With regard to climate variability, we examine three alternative variables associated with the severity of drought: *dry days*, *precipitation*, and *precipitation ratio*. The variable *dry days* is defined as the number of days with precipitation of less than 1 mm. A situation in which there are many days without rain is likely to cause a drought and may even lead to severe conditions. Therefore, this precipitation pattern may be relevant to the level of water restrictions. We expect that more dry days exacerbate a drought, thereby resulting in the implementation of a higher water restriction rate.

Another weather-related variable is *precipitation*. Since precipitation such as rain and snow contributes to the recharging of reservoirs, the amount of precipitation is likely to affect the occurrence of drought. We use annual precipitation in order to capture the overall tendency for drought severity throughout a year. We expect higher precipitation to mitigate a drought, thereby reducing the water restriction rate.

The other variable is *precipitation ratio*. We define precipitation ratio as the ratio of annual precipitation to the mean annual precipitation between 1981 and 2010. The long-term mean value represents the average weather conditions in a region. Thus, by considering relative conditions of precipitation that vary with years in a particular area, this variable explains how much precipitation in a given year differs from its average conditions. In other words, the precipitation ratio considers the relative value of precipitation, whereas the annual precipitation above considers the absolute value. When there is higher precipitation compared with the average year, droughts are likely to be less severe. Thus, we expect the precipitation ratio to be negatively related to the water restriction rate. The data on these meteorological variables were taken from the online database of the Japan Meteorological Agency.[11] From this database, we collected data from the available weather stations that are geographically closest to each dam's location.

Our analysis includes five control variables: *previous restriction rate*, *domestic water distribution*, *domestic water price*, *multiple dams*, and *Full Plan*. The first three variables belong to domestic water user group characteristics, and the remaining variables belong to dam management. *Previous restriction rate* is one of the variables related to domestic water user groups. It indicates the restriction rate of domestic water user groups in the previous drought. The information on the restriction rate from past drought may be used as reference so that domestic water user groups and council members can better manage the current drought. Similar to the variable *drought experience*, the council members may learn from the level of restriction rates they imposed in the past. In such a case, the observed restriction rate may be affected by the previous rate. Yet, its impact can be positive or negative, depending on how the council members respond to the past information.

[11] http://www.jma.go.jp/jma/indexe.html.

The data on the following two variables of domestic water user groups were obtained from the *Local Public Enterprise Yearbook*, published by the Japanese Ministry of Internal Affairs and Communications.[12] *Domestic water distribution* is the average amount of domestic water distribution by water utilities per day. A larger amount of water use may lead to a lower water restriction rate because of higher opportunity costs. The opportunity costs of water savings may be relatively high when the domestic water supply supports people and businesses that consume larger amounts of water. They may include various private and public service sectors such as offices, hospitals, and schools. Thus, such larger communities may prioritize domestic water by relaxing the water restrictions.

The variable *domestic water price* is measured by the price of water charged per 10 m^3 for bore diameters of 13 mm. We expect higher water prices to have a negative impact on the water restriction rate. People respond to the level of water price and reduce their daily water usage as prices rise [26]. Under such circumstances, a strict water restriction may not be implemented because water use is already restrained.

The dummy variable *multiple dams* distinguishes joint water restrictions on multiple dams from water restrictions on individual dams. In some regions, several dams in the same river basin are managed together regularly or only during a drought. Communities in these regions convene the drought

[12]In Japan, water utilities are run by municipalities (cities, towns, and villages), prefectures, or joint public entities consisting of municipalities and prefectures. The latter two supply water to lower-tier municipalities as wholesalers. Municipal water utilities then supply this water or water from their water sources to households.

coordination council and implement joint water restrictions on their dams. We use this variable to examine the systematic difference in the collective decisions applied to multiple dams and a single dam. If water restriction rates are jointly implemented on multiple dams, the value is one; otherwise, the value is zero. The variable implies that some regions have more complex management systems in terms of collective action. Assuming that the joint implementation of water restrictions reflects the higher level of cooperation in a river basin community, we can expect a higher water restriction rate to be imposed in cases that involve multiple dams.

We also examine a variable related to the national government policy for water resource use. Governmental organizations are an influential factor in CPR management. Contrary to the adverse impact of government interference often recognized in CPR studies, Zhang et al. [33] show the positive effects of a top-down approach on irrigation water productivity. They find that the involvement of an upper-tier water users association in farmers' crop choices leads to higher water productivity. In our study, the national government policy and related water resource plan may help enhance drought management and promote cooperation among water users. The Japanese Ministry of Land, Infrastructure, Transport, and Tourism has designated seven river basins as "river systems for water resources development" under the Water Resources Development Promotion Law.[13] These river basins have

[13]The seven designated river basins are the Tone River system, the Ara River system, the Toyo River system, the Kiso River system, the Yodo River system, the Yoshino River system, and the Chikugo River system. The designation was first applied to the Tone River system that drains in the Tokyo metropolitan area and the Yodo River system that

all implemented the master plan called "Water Resources Development Basic Plan (Full Plan)." The main objective of this plan is to promote the comprehensive development and rational use of water resources in each river basin. The master plan is developed for each river basin by committees and working groups that consider the risk of drought to set a target for water supplies. We use a dummy variable, *Full Plan*, equal to one if a river basin under water restrictions is a designated area, and zero otherwise. Our intention in using this variable is to investigate whether the national government policy influences drought management in local communities. We expect higher water restriction rates for areas that have implemented the master plan.

4. Results

The estimation results for the OLS and 2SLS models are presented in Tables 4 and 5. The models in Table 4 include the agricultural water restriction rate in the dependent variables, while the models in Table 5 include the industrial water restriction rate. One of the three climate variables is used in each model. All models include both year and region fixed effects.

The validity of the instruments is tested and reported for the 2SLS models in both Table 4 and 5. The F test in the first stage of the 2SLS model is used to test weak instruments. Although the test rejects the null hypothesis in most of the models, F statistic does not exceed the value of 10, which is

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drains in the Osaka metropolitan area, in 1962. Today, the seven river basin regions have a population of 67 million, or 52% of Japan's total population, and the value of the shipments of manufactured goods from these regions amounts to 11.1 billion yen, or 44.5% of the total value [31]. The term "river system" is used to refer to a river basin in Japan.

considered as a threshold for ruling out the weak instrument problem [27]. This suggests that the instrument may be only weakly correlated with the endogenous variable. The underidentification test is the Lagrange Multiplier (LM) test that checks whether the instrument variable is relevant to the endogenous regressor. The Kleibergen-Paap *rk* statistic is statistically significant at the 5% level in all the 2SLS models in Table 4 and at the 10% levels in two out of three 2SLS models in Table 5. Therefore, the LM test for underidentification suggests that the instrument is correlated with the endogenous variable.

To check endogeneity, we conduct the regression-based test because we use robust standard errors where the assumption of being independent and identically distributed (i.i.d.) for the error term is dropped. Under the null hypothesis that the variable being tested is exogenous, the OLS model should be used. If the null hypothesis is rejected, the variable tested should be treated as endogenous; thus the 2SLS model is more appropriate than the OLS model to yield consistent parameter estimates. In Table 4, the regression-based F statistic shows that the null hypothesis of exogeneity is not rejected in models 2 and 6, suggesting that the agricultural water restriction rate is exogenous. In model 4, however, the regression-based F statistic is statistically significant and suggests the variable is endogenous. In Table 5, the regression-based test shows that the industrial water restriction rate is an endogenous variable in models 2 and 4 but not in model 6.

In addition, we test the joint significance for the set of year and region fixed effects. The test reports F statistic for the OLS model and χ^2 statistic for the 2SLS model. The test statistics show that the set of fixed effects are jointly significant in all models with the agricultural water restriction rate, as shown in Table 4. In the case of the industrial water restriction rate in Table 5, only the OLS models show that the fixed effects are jointly significant.

The results in Table 4 show that *agricultural water restriction rate* is significantly related to the domestic water restriction rate. The coefficients are positive and statistically significant at the 1% level in all models. The coefficients for the OLS models are 0.53 to 0.54. The coefficients for the 2SLS models are slightly larger than those of the OLS model, ranging from 0.89 to 0.98. *Industrial water restriction rate* in Table 5 also shows the correlation with the domestic water restriction rate. The coefficients are positive and significant at the 1% level in the OLS models and at the 10% level in the 2SLS models. Similar to the agriculture water restriction rate, the magnitude of coefficients for the 2SLS model is larger than that for the OLS model. The positive sign of the coefficients suggests that a domestic water user group applies a higher water restriction rate as other water user groups, agricultural and industrial water user groups, increase their water restriction rates. This finding is in line with the first hypothesis, namely, a water user group is more willing to cooperate for water conservation when other water user groups also cooperate. We find that the level of cooperation in drought management, measured by the water restriction rate, is related to other groups' water conservation efforts.

Purposes of dam is positively correlated with the water restriction rate. The coefficients are statistically significant in models 5 and 6 in Table 4 and in models 1, 3, and 5 in Table 5. These results show that dams with more purposes tend to implement higher water restriction rates. Therefore, the findings support our second hypothesis: greater variety of purposes for water use leads to more cooperation. The number of purposes of a dam represents the heterogeneity defined by the different uses of water resources. In our study, we find that the heterogeneity in resource use may lead to cooperation toward water conservation. *Drought experience* is measured by the experiences of droughts in the past three years. The coefficients are not statistically significant in most of the models. From these estimation results, the impact on water restrictions is not robust. We do not find evidence for the third hypothesis that the experiences of droughts improve cooperation. We also do not find correlation between *reservoir capacity* and the water restriction rate. The coefficients for neither the OLS nor 2LSL models shows a significant effect. Therefore, the results do not support the fourth hypothesis about the relationship between reservoir capacity and cooperation in drought coordination.

The climate variables in our analysis represent precipitation conditions relevant to droughts. All the variables in the hypotheses are estimated, provided that drought severity is controlled for with the climate variable. Contrary to our expectation, the estimation results of *dry days* and *precipitation* are insignificant and/or inconsistent. The coefficients of *dry days* are negative and insignificant except in model 2 in Table 4, where the coefficients are significant but the sign is negative. The coefficients of *precipitation* show a significant effect but with unexpected positive signs. These results may be due to the unsuitability of using annual data to capture the impact on water restrictions that are usually implemented for only a short period of time. Although the duration of water restrictions for each drought varies, water restrictions in some cases last only a couple of days or weeks in our sample. Therefore, the annual data may not reflect weather shocks that affect such short-term droughts. Possibly, the relative measure of weather conditions, rather than the absolute measure, is more appropriate to estimate the impact of climate variability. The variable *precipitation ratio* indicates how precipitation deviates from the long-term mean precipitation. Thus, this variable can capture the precipitation anomaly in a region. We find that the coefficients of *precipitation ratio* are statistically significant at the 10% level in model 5 in Table 5. The coefficients and expected negative sign indicate that the restriction rate increases by approximately 0.1% when the precipitation ratio is 1% lower. The findings from the weather variables suggest that a relative measure may be a better indicator of climatic impact than an absolute measure.

Besides these variables above, we also include other characteristics associated with the resource system and test whether these variables affect collective decisions on water restrictions. We find that *previous restriction rate* is correlated with the water restriction rate. The coefficients are positive and statistically significant in models 1 and 5 in Table 4 and in all models in Table 5. The result suggests that the past restriction rate may influence the present rate. Furthermore, it is interesting to find that the restriction rate in the previous drought shows a significant effect on the water restriction rate, whereas the experiences of droughts alone do not. The coefficients of *domestic water distribution* show a negative but insignificant impact. We expect the amount of water distribution to have a negative effect on the water restriction rate because the domestic water sector may be prioritized to support communities with a larger amount of water use. Nevertheless, we do not find a significant effect of water distribution to the domestic sector. We find that *domestic water price* is statistically related to the water restriction rate. The coefficients are negative and significant in the models with the agricultural water restriction rate in Table 4. The negative sign is in line with our expectation, suggesting that water use may be already restrained because of the higher water prices. The variable *multiple dams* is insignificant in all models but model 4 in Table 4. Although the coefficients show expected positive signs, the results may not be robust. We do not find the impact of the joint implementation of water restrictions on multiple dams. The policy-related variable, *Full Plan*, is positive and significantly correlated with the water restriction rate. The result suggests that a higher water restriction rate tends to be implemented in river basins where the national government policy for water resources is applied. Thus, we find that the government policy for water resources is positively related with collective decision making in community drought management.

5. Conclusions

This study examines collective decision making in water resource management during droughts. The data used in the analysis include 165 cases of regional droughts that occurred in Japan from 1987 to 2013. In response to a drought, water users in river basin communities participate in drought management and take action to mitigate water shortages. By focusing on this community-based drought response, we examine which characteristics of the resource management affect collective decisions and contribute to cooperative actions for water conservation.

The regression results show cooperative collective action for water conservation among water user groups that jointly implement a drought response. We find that the level of water restrictions on domestic water user groups, measured by the rate of reductions in water withdrawals, is correlated with the level of water restrictions on other water user groups. Water user groups tend to impose higher water restriction rates when other water user groups also impose higher water restriction rates. This result suggests that the willingness to cooperate and save water depends on other water users' cooperativeness. This finding is in line with the results of laboratory experiments showing that people are conditionally cooperative; that is, they are willing to cooperate when others cooperate as well [11]. Thus, the result of our empirical study provides suggestive evidence regarding conditional cooperation in real-world settings.

While we should bear in mind that factors that induce successful or unsuccessful CPR management depend on the context, our findings may have important implications for policymakers, local governments, and managers. Because community-based management of water resources involves various groups of stakeholders, it is crucial to understand the behavioral mechanisms of these groups when they interact. Our findings suggest that reciprocal cooperation could lead to greater water conservation effort during a drought. Cooperation is a key element in community resource management. From this perspective, drought coordination councils in Japan may play an important role in providing opportunities for interaction to promote cooperation among water users. Working together probably makes resource users less competitive and helps them to act collectively [18]. Furthermore, a better understanding of CPR management mechanisms may be useful in terms of climate change adaptation. We can expect more serious droughts to occur in the coming decades because of climate change. Research on water resource management by communities facing droughts could contribute to the implementation of effective climate change adaptation strategies.

Nevertheless, a limitation of our study is that unobserved, yet important variables may affect collective action in the context of water resource management. Indeed, analyzing the interactions of resource users and the management mechanisms of resource systems is challenging because the management of CPRs includes multiple stakeholders who form extremely complex interrelations. For example, farmers in a community who cooperate with each other when confronting farmers in other communities may compete with each other for the allocation of water in their own community [32]. Future research should consider such interactions in multiple levels of complex systems to examine the reality of CPR management.

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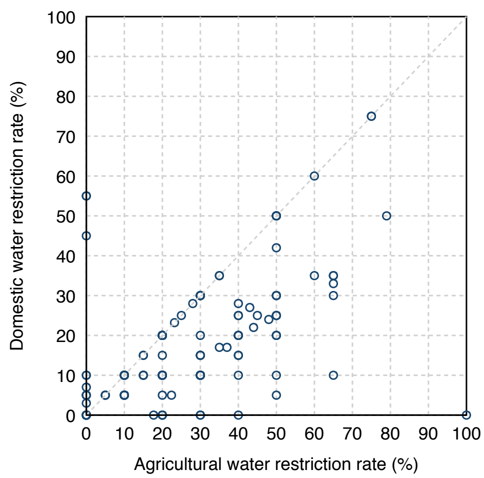
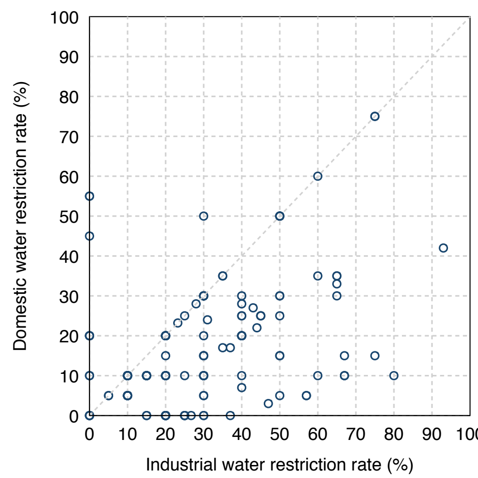


a. Agricultural and domestic water restriction rates



b. Industrial and domestic water restriction rates

Figure 1 Water withdrawal restriction rates

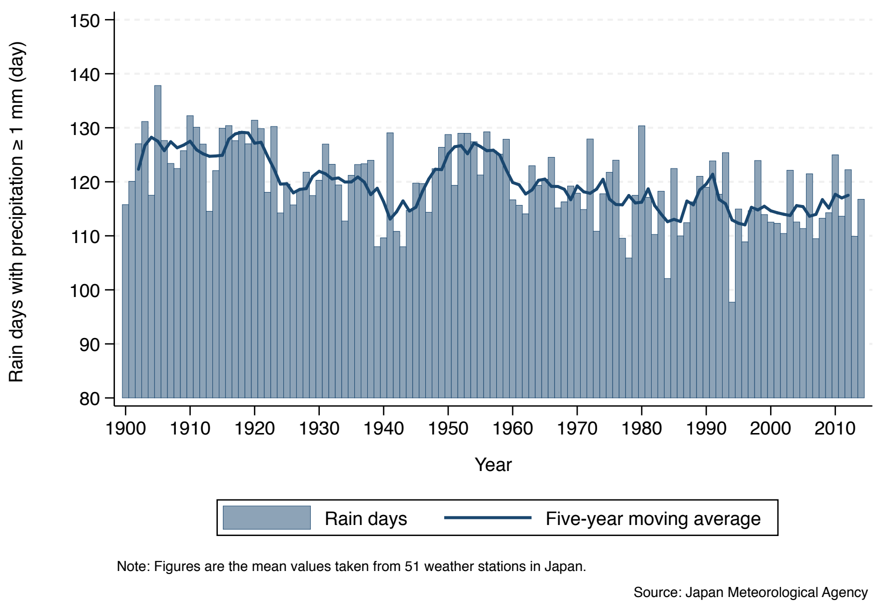
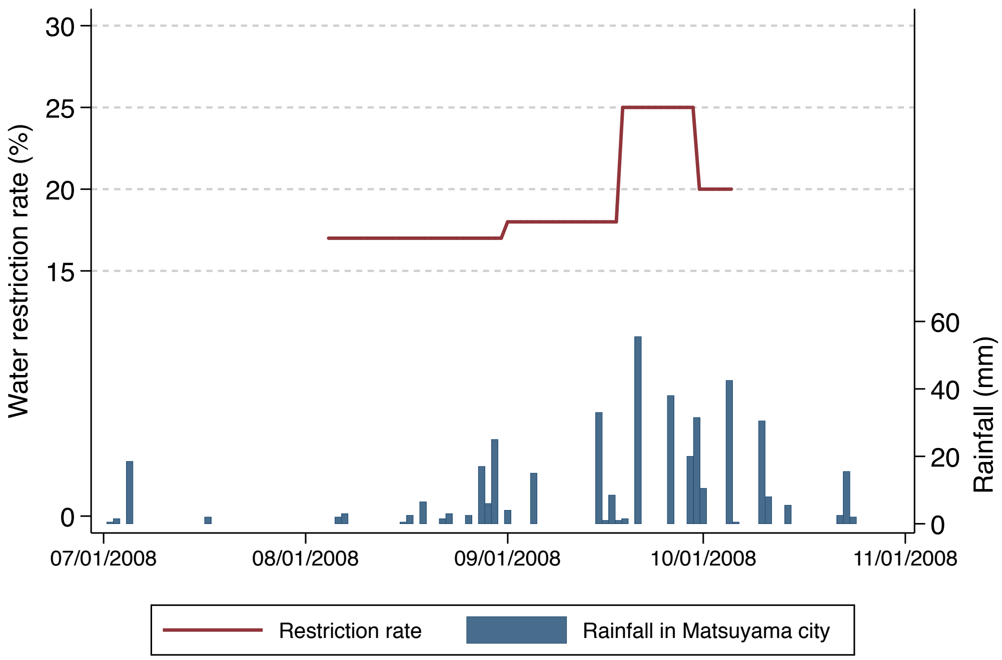


Figure 2 Annual days of rain in Japan



Source: Matsuyama city, http://www.city.matsuyama.ehime.jp/kurashi/kurashi/josuido/keikaku/kassuikiroku/tyouseikyougikai_H20.html

Figure 3 Water restrictions during the 2008 drought in Matsuyama city

Table 1 Major severe droughts in Japan

Year	City	Mandatory restrictions on domestic water use			
		Duration (day)	Period		
1964	Tokyo	84	July 10	-	Oct. 1
1967	Kitakyushu	130	June 19	-	Oct. 26
	Chikushino	22	Sept. 5	-	Sept. 26
	Nagasaki	72	Sept. 25	-	Dec. 5
1973	Matsue	135	June 20	-	Nov. 1
	Otake	49	July 27	-	Sept. 13
	Takamatsu	58	July 13	-	Sept. 8
	Naha, etc.	239	Nov. 21	-	Sept. 24, 1974
1978	Osaka, etc.	161	Sept. 1	-	Feb. 8, 1979
	Kitakyushu	173	June 8	-	Dec. 11
	Fukuoka	287	May 20	-	Mar. 24, 1979
1987	Tokyo, etc.	71	June 16	-	Aug. 25
	Gamagori, etc.	274	Aug. 24	-	May 23, 1988
	Tokai, etc.	188	Sept. 12	-	Mar. 17, 1988
1994	Takamatsu	67	July 11	-	Sept. 30
	Matsuyama	123	July 26	-	Nov. 25
	Sasebo	213	Aug. 1	-	Mar. 5, 1995
	Fukuoka	295	Aug. 4	-	May 31, 1995
2005	Anan, etc.	77	Apr. 26	-	July 12
		33	Aug. 3	-	Sept. 4
	Toyohashi	72	June 15	-	Aug. 25
	Takamatsu, etc.	78	June 22	-	Sept. 7
	Yamatokoriyama	61	June 27	-	Aug. 26

Source: Japanese Ministry of Land, Infrastructure, Transport, and Tourism, 2014 [31]

Table 2 Variable descriptions and expected effects

Variable	Description	Expected effect
Domestic water restriction rate	Water withdrawal restriction rate for domestic water	N/A
Agricultural water restriction rate	Water withdrawal restriction rate for agricultural water	+
Industrial water restriction rate	Water withdrawal restriction rate for industrial water	+
Purposes of dam	Number of purposes for which a dam provides water resources	+
Drought experience	Dummy variable, the experiences of droughts in the past three years: 0 = no, 1 = yes	+
Reservoir capacity	Reservoir capacity for operating purposes	+
Dry days	Annual number of days with precipitation of less than 1 mm	+
Precipitation ratio	Ratio of annual precipitation to the mean annual precipitation from 1981 to 2010	-
Precipitation	Amount of annual precipitation	-
Previous restriction rate	Water withdrawal restriction rate for domestic water in the previous drought	+/-
Domestic water distribution	Average daily amount of water distribution among domestic water users	-
Domestic water price	Price of domestic water charged per 10 m^3 for bore diameters of 13 mm	-
Multiple dams	Dummy variable, water restrictions are jointly implemented on water withdrawals from multiple dams: 0 = no, 1 = yes	+
Full Plan	Dummy variable, the river basin in which a dam is located is subject to the national government policy for water resources: 0 = no, 1 = yes	+

Table 3 Descriptive statistics

Variable	Unit	Mean	Std. Dev.	Min	Max
Domestic water restriction rate	%	16.52	14.84	0	75
Agricultural water restriction rate	%	25.29	19.78	0	100
Industrial water restriction rate	%	27.70	19.39	0	93
Purposes of dam	-	4.98	1.02	3	6
Drought experience	dummy	0.79	0.41	0	1
Reservoir capacity	100 million m^3	1.40	1.87	0.09	19
Dry days	day	244.65	16.41	154	278
Precipitation ratio	%	92.96	19.95	58.59	206.73
Precipitation	mm	1,753.60	570.18	828	3,912
Previous restriction rate	%	16.72	14.34	0	75
Domestic water distribution	1,000 m^3	1,404.16	1,988.49	6	7,962
Domestic water price	yen	1,288.30	195.04	770	1,899
Multiple dams	dummy	0.38	0.49	0	1
Full Plan	dummy	0.73	0.44	0	1

Table 4 Regression results (agricultural water restriction rate in independent variables)

	1	2	3	4	5	6
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Agricultural water restriction rate	0.543***	0.968***	0.543***	0.977***	0.531***	0.889***
	(0.086)	(0.263)	(0.084)	(0.223)	(0.088)	(0.252)
Purposes of dam	1.808	1.549	1.742	1.673	2.387*	2.314*
	(1.251)	(1.420)	(1.058)	(1.273)	(1.207)	(1.269)
Drought experience	-3.045	-6.187*	-3.406	-6.421**	-2.283	-4.912
	(2.536)	(3.594)	(2.344)	(3.153)	(2.394)	(3.142)
Reservoir capacity	0.253	-0.186	0.092	-0.262	0.579	0.249
	(0.681)	(0.557)	(0.534)	(0.450)	(0.673)	(0.524)
Dry days	-0.122	-0.177*				
	(0.074)	(0.100)				
Precipitation			0.008***	0.008***		
			(0.002)	(0.002)		
Precipitation ratio					-0.018	0.059
					(0.046)	(0.076)
Previous restriction rate	0.207**	0.067	0.149	0.003	0.215**	0.104
	(0.092)	(0.149)	(0.092)	(0.146)	(0.095)	(0.142)
Domestic water distribution	-0.002	-0.001	-0.001	-0.001	-0.002	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Domestic water price	-0.013*	-0.020**	-0.012**	-0.017***	-0.010	-0.014**
	(0.007)	(0.008)	(0.006)	(0.006)	(0.007)	(0.006)
Multiple dams	-0.376	4.239	2.520	7.552*	-0.374	3.470
	(3.034)	(4.172)	(3.060)	(4.118)	(3.068)	(3.883)
Full Plan	10.954***	14.105***	10.878***	14.085***	10.895***	13.398***
	(3.243)	(3.796)	(2.987)	(3.410)	(3.237)	(3.584)
Constant	32.124	44.909	-17.828**	-21.247**	0.058	-15.828
	(22.668)	(32.217)	(8.253)	(8.449)	(11.369)	(13.570)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observation	165	165	165	165	165	165
F test in the first stage[a]		3.234*		3.495*		3.594*
Underidentification test[b]		5.970**		6.492**		6.641**
Endogeneity test[c]		1.862		3.700*		1.216
Test of joint significance[d]	1.765**	55.139***	1.635**	48.409**	1.557**	59.085***

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[a] Kleibergen-Paap Wald *rk* F statistic is reported to test weak instruments.

[b] Kleibergen-Paap *rk* LM statistic is reported to test the relevance of excluded instruments.

[c] Regression-based F statistic is reported since the i.i.d. assumption for the error term is relaxed.

[d] F statistic is reported for the OLS model and χ^2 statistic is reported for the 2SLS model to test the joint significance of year and region fixed effects.

Table 5 Regression results (industrial water restriction rate in independent variables)

	1	2	3	4	5	6
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Industrial water restriction rate	0.323***	1.289*	0.362***	1.574*	0.315***	1.253*
	(0.085)	(0.683)	(0.081)	(0.827)	(0.082)	(0.718)
Purposes of dam	2.916*	5.234	2.437*	4.477	3.191**	5.261
	(1.524)	(3.594)	(1.283)	(3.385)	(1.449)	(3.399)
Drought experience	-0.801	-6.073	-2.007	-9.945	-0.234	-5.760
	(3.003)	(5.876)	(2.797)	(7.109)	(2.864)	(5.846)
Reservoir capacity	0.296	-1.247	-0.225	-2.776	0.517	-1.132
	(1.004)	(1.578)	(0.780)	(1.956)	(0.941)	(1.605)
Dry days	-0.045	-0.025				
	(0.078)	(0.130)				
Precipitation			0.009***	0.018**		
			(0.003)	(0.007)		
Precipitation ratio					-0.099*	0.006
					(0.058)	(0.114)
Previous restriction rate	0.411***	0.487***	0.338***	0.357*	0.406***	0.486***
	(0.099)	(0.169)	(0.097)	(0.198)	(0.100)	(0.167)
Domestic water distribution	-0.002	-0.002	-0.001	-0.001	-0.002	-0.002
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
Domestic water price	-0.008	-0.016	-0.009	-0.023	-0.007	-0.015
	(0.009)	(0.013)	(0.008)	(0.017)	(0.009)	(0.012)
Multiple dams	-4.339	1.415	-0.625	9.906	-4.248	1.216
	(2.656)	(5.772)	(2.803)	(9.091)	(2.633)	(5.691)
Full Plan	11.020***	23.223*	11.420***	26.664*	11.092***	22.753*
	(4.177)	(12.730)	(3.784)	(14.273)	(4.160)	(13.023)
Constant	1.712	-32.952	-29.603**	-73.558*	1.320	-40.308
	(25.129)	(57.493)	(12.015)	(42.199)	(14.026)	(42.235)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observation	165	165	165	165	165	165
F test in the first stage[a]		2.960*		1.946		2.692
Underidentification test[b]		3.260*		2.456		2.934*
Endogeneity test[c]		2.967*		4.902**		2.486
Test of joint significance[d]	1.995***	20.985	2.789***	19.066	1.607**	23.768

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[a] Kleibergen-Paap Wald *rk F* statistic is reported to test weak instruments.

[b] Kleibergen-Paap *rk* LM statistic is reported to test the relevance of excluded instruments.

[c] Regression-based F statistic is reported since the i.i.d. assumption for the error term is relaxed.

[d] F statistic is reported for the OLS model and χ^2 statistic is reported for the 2SLS model to test the joint significance of year and region fixed effects.