The Impact of Municipal Mergers on Pollution Control: Evidence of River Pollution in Japan

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Abstract

Municipal mergers are widely adopted by policymakers to improve local public services, including pollution control. Municipal mergers can improve environmental quality by internalizing pollution spillovers to neighboring municipalities, but the associated coordination costs and unbalanced political power can weaken pollution control. Using the staggered implementation of Japan's mergers that halved the number of municipalities, we find that municipal mergers increase river pollution by 5.5%, and the effect persists for about 15 years. These negative effects are concentrated in mergers entailing high coordination costs and in pre-merger municipalities with small political power. We do not find spatial patterns of river pollution suggested by the negative externality theory.

JEL: D73, Q52, Q53, R11, R58

Keywords: Municipal Mergers, Water Pollution, Negative Externality, Political Economy

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1 Introduction

The optimal level of decentralization and centralization, i.e., distribution of power between local and central governments, has been long debated in academics (Tiebout, 1956; Oates, 1972; Besley and Coate, 2003). Under decentralized governance, competition among municipalities is hypothesized to ensure Pareto-efficient allocation of local public services, but the allocation can become inefficient when local public services within a jurisdiction have spatial spillover effects on neighbors without inter-jurisdictional coordination (Tiebout, 1956; Oates, 1972; Jannin and Sotura, 2020). One key example of this type of spillover is a negative externality of weak pollution control that affects the environmental quality of neighboring municipalities. In accordance with this argument, an increase in local jurisdictions under decentralized governance has been recently shown to negatively affect environmental quality in developing countries (Burgess et al., 2012; Lipscomb and Mobarak, 2016). However, there is little research on the opposite scenario, the effect of a decrease in local jurisdictions, which is more prevalent in developed countries, on environmental quality. Do fewer larger-sized municipalities facilitate the internalization of negative externalities, thus improving environmental quality?

In this paper, we examine how municipal mergers, where two or more municipalities combine to form a new municipality, affect environmental quality by changing pollution control efforts. Municipal mergers have been widely adopted in 20 developed countries, including Germany, France, Japan, and the United States, and are expected to increase in the future due to the declining birthrate and aging population, especially in rural areas. This policy aims to provide local public services with higher quality at a lower cost based on economies of scale — a larger municipality can provide local public services at lower unit costs (OECD, 2014). Consistent with this aim, a negative externality theory suggests that municipal mergers can improve environmental quality by internalizing pollution spillovers, which exist across pre-merger municipalities before the mergers. On the other hand, coordination costs and unbalanced political power among pre-merger municipalities may hamper the pollution control effort of merged municipalities, leading to the deterioration of environmental quality. The relationship between municipal mergers and environmental quality appears ambiguous and deserves careful empirical examination.

We test this relationship between municipal mergers and environmental quality in the context of Japan's municipal mergers and river pollution in the late 1990s to 2000s. The municipal mergers in Japan have unique characteristics to effectively investigate our research question. First, this policy drastically reduced the number of municipalities by about 50%, from 3,238 in 1998 to 1,725 by 2012. This large-scale and nationwide occurrence of municipal mergers in all prefectures in Japan increases the external validity of our results. Second, the universal occurrence of municipal mergers allows us to use water quality data from 3,000 monitoring stations across Japan. We use rich water quality data over 30 years to examine the long-run impact of municipal mergers on water quality. Lastly, municipal mergers occurred over time from 1999 to 2011. Thus, we exploit the staggered implementation of municipal mergers as a setting of a quasi-natural experiment to examine the causal effects of mergers on river pollution.

We investigate the effects of municipal mergers on river water quality by exploiting the staggered implementation of municipal mergers. The existence of both merged municipalities and never-merged municipalities and the variation in the timing of municipal mergers among merged municipalities allow us to adopt difference-in-differences (DID) and event study specifications. Here, we compare the outcomes of municipalities that merged and municipalities that did not merge, as well as comparing the outcomes of municipalities that merged earlier and municipalities that merged later. In this staggered-adoption DID design, a two-way fixed effects estimator may be subject to the bias which comes from the bad comparison between early merged municipalities and late merged municipalities (Goodman-Bacon, 2021). Thus, we adopt recently-developed alternative estimators (Sun and Abraham, 2021; Callaway and Sant'Anna, 2021) that are robust to this concern as the baseline specification.

Contrary to the narrative of the negative externality theory, we find that municipal mergers increase river pollution on average by 5.5%. This negative effect persists for about 15 years in the event study specification. The causality of this effect hinges on the assumption that the treated municipalities and untreated municipalities would move in parallel in the absence of municipal mergers. A plot comparing the raw water quality of never-merged versus merged municipalities supports the parallel pre-trends, and event study plots do not show differential effects on water quality before the mergers. Moreover, the results are robust to an alternative specification that only uses variation in merger timings among municipalities that have ever experienced mergers.

Consistent with the negative effect of municipal mergers on water quality, we do not find spatial patterns of the negative externality theory that would predict the internalization of pollution spillovers. The negative externality theory predicts that pollution increases as the river travels towards the downstream border of a municipality because there is less harm caused to people in that municipality by polluting farther downstream (Lipscomb and Mobarak, 2016). We directly test this negative externality theory by using the river distance specification of Lipscomb and Mobarak (2016). Specifically, we examine how river distances from monitoring stations to their closest upstream and downstream municipality borders affect the water quality by exploiting the changes in distances after the municipal mergers. We find that pollution levels do not change as a river flows downstream within a municipality, a pattern inconsistent with the negative externality theory. Without the evidence of the negative externality theory, municipal mergers are unlikely to internalize pollution spillovers and improve water quality.

Heterogeneity analysis by merger types and involved municipalities suggests that the mechanisms behind the negative effects of municipal mergers are coordination costs and unbalanced political power among pre-merger municipalities. We first test whether municipal mergers with higher coordination costs lead to larger water pollution because insufficient coordination of public services after mergers can weaken pollution control. We show that pollution increases for "equal-footing" mergers that entail higher coordination costs but not for "incorporating" mergers with lower coordination costs (coordination cost channel).[1] Second, we examine whether incorporated municipalities with less political power experience more water pollution than incorporating municipalities with greater political power, where mayors continue to hold the same position after municipal mergers and can reduce pollution control efforts in incorporated municipalities (political economy channel). We find that incorporated municipalities experience increased water pollution while incorporating municipalities do not experience a change in water pollution.

We do not find evidence of an alternative explanation, a change in land use, which could lead to increased water pollution without changing the pollution control. Municipal mergers can increase economic activities (Egger et al., 2018), which leads to changes in land use, e.g., increased industrial and residential areas. This increase in new water pollution sources may drive the river pollution after the mergers. To test this alternative explanation, we examine the impacts of municipal merges on land use near water quality monitoring stations. We do not find effects on any land use classifications, including agriculture, built-up, and forest.

Taken together, our analysis shows that municipal mergers can have unintended negative effects on environmental quality when coordination costs and unbalanced political power among pre-merger municipalities weaken pollution control. Future municipal mergers, which are expected to increase due to population decline in many countries, should take these negative effects into account in the cost-benefit analyses. Moreover, the coordination costs and unbalanced political power among pre-merger municipalities may similarly weaken the implementation of other policies managed by municipalities, so the careful consideration of these underlying mechanisms will be important in future municipal mergers across a range of policies.

[1] Equal-footing mergers involve mergers between municipalities of similar size, with a new municipality name given after the merger. On the other hand, incorporating mergers involves a larger municipality incorporating other smaller municipalities, with the resulting municipality inheriting the name of the incorporating municipality.

Our paper makes three contributions. First, we contribute to the literature on decentralization and fiscal federalism by showing that spillovers across jurisdictions may not be resolved by consolidations of municipalities, and coordination costs and balance of political powers matter. Previous studies show that splits of local jurisdictions exacerbate pollution spillovers along rivers in Brazil (Lipscomb and Mobarak, 2016), and conversely, mergers internalize spillovers of air pollution in China (Wang and Wang, 2021), which are consistent with the negative externality theory. However, we find no evidence of the negative externality theory, and instead, mergers increase river pollution in Japan. We show alternative underlying mechanisms, i.e., weaker pollution control due to coordination costs and unbalanced political power among pre-merger municipalities, which should be newly considered in the discussion of decentralization.

Second, we contribute to the literature on the impacts of municipal mergers by showing negative effects on the environment. Most previous studies investigate the fiscal and macroeconomic effects of municipal mergers on local public finance (Hinnerich, 2009; Reingewertz, 2012; Moisio and Uusitalo, 2013; Hirota and Yunoue, 2017; Miyazaki, 2018; Pickering et al., 2020) and economic activity (Egger et al., 2018), as well as determinants of municipal mergers (Weese, 2015). We instead focus on the environmental impacts of municipal mergers, where only a little evidence exists. A particularly relevant paper is Wang and Wang (2021), which showed that township mergers in China internalized the negative externalities of air pollution by reducing emissions by firms. We complement this paper in two ways: (i) we show that municipal mergers can increase pollution and that negative externality theory may not hold in a developed country context; (ii) our 30-year panel data on water quality enables us to examine the long-term impacts of municipal mergers, and we show that the negative impacts of municipal mergers persist for about 15 years.[2]

Third, we broadly contribute to the literature on the causes of and measures against water pollution by providing first causal estimates of the effects of municipal mergers on water quality. Past studies show that water pollution increases with political boundaries (Sigman, 2002; Kahn et al., 2015; Lipscomb and Mobarak, 2016) and sanitation investment without complementary investment in the treatment of fecal sludge (Motohashi, 2022). Another set of studies has examined the effectiveness of interventions in reducing pollution, including water pollution regulations (Greenstone and Hanna, 2014; Keiser and Shapiro, 2019) and court rulings (Do et al., 2018). This paper shows that a decrease in political boundaries, i.e.,

[2] Another relevant paper is Mizunoya et al. (2021), which examined the impacts of municipal mergers on watershed management of the Lake Kasumigaura Basin using the simulation of a dynamic expanded input-output model. This paper is a case study of one water body and relies on a simulation based on the model. Instead, we examine the causal effects of municipal mergers across Japan adopting a quasi-experimental design.

municipal mergers, can also cause water pollution due to weaker pollution control.

The rest of the paper is organized as follows. Section 2 provides background information on municipal mergers and water quality in Japan. In Sections 3 and 4, we explain the data and empirical strategy, respectively. Section 5 discusses the results. In Section 6, we analyze the underlying mechanisms behind our results. Section 7 concludes.

2 Background

2.1 The "Great Heisei Municipal Mergers" in Japan

The "Great Heisei municipal mergers" took place in Japan predominantly in the late 1990s to 2000s. They are large-scale municipal mergers that occurred in all prefectures in Japan (Figure 1). The number of municipalities in Japan drastically decreased by about 50% from 3,238 in 1998 to 1,725 by 2012.

The financial incentives under the revisions of the "Act on Special Provisions of the Merger of Municipalities" in 1995 and 1999 played a key role in fostering these municipal mergers.[3] The 1995 revision announced that the purpose of the Act was to push forward municipal mergers and introduced five-year preferential treatment in local tax allocation for merging municipalities. Municipalities, especially those in rural areas, were experiencing dwindling birth rates, aging, and declining population, as well as increasingly difficult fiscal conditions following the burst of the bubble economy in the early 1990s. Municipal mergers were seen as a tool to rejuvenate such municipalities.

The 1999 revision further strengthened financial incentives. The above preferential treatment in local tax allocation was extended to 10 years. Furthermore, merged municipalities were now allowed to issue "Special Provision Bonds" for up to 10 years after merging to fund public projects included in their merger proposals. These municipalities were only asked to pay back 30 percent of what they borrowed using these bonds, and the central government paid the remaining 70 percent. Thus, the bonds were essentially a 70 percent public project subsidy for merging municipalities. The government initially announced that, in order to be eligible for these benefits, municipalities had to merge by March 2005. However, this was later extended by one year to March 2006 in order to provide more time for municipalities that were struggling to complete mergers by the original deadline.

Thanks to the strong push by these financial incentives, the number of municipal mergers in Japan increased over time from the late 1990s. Figure 2 illustrates the frequency of municipality mergers since 1995. The first merger occurred in 1999 when financial incentives

[3] The Act had been in place since 1965. The focus of the Act was originally on facilitating merger procedures.

were strengthened. However, merger counts remained low for the next few years. The vast majority of mergers took place between 2004 and 2006. This not only reflects the fact that it can take several years to complete the merger process but also indicates bunching behavior by municipalities to meet the initial and final deadlines of 2005 and 2006, respectively. Municipal mergers continued even after 2006 until 2011. As discussed here, there is a variation in the timings of municipal mergers. Also, the "Great Heisei municipal mergers" were not mandatory for municipalities, so we have a variation between municipalities that experienced municipal mergers and those that did not. We use these variations in the difference-in-differences and event-study specification as explained in Section 4.1.

The municipal mergers under the 1995 and 1999 revisions were not a forced policy. The autonomy of municipalities was respected, and municipalities could choose whether or not to negotiate mergers and which municipalities to negotiate with. The merger process took the following steps. Firstly, interested municipalities were to form a panel to discuss potential mergers. Secondly, the panel was to negotiate and formulate merger proposals. Finally, a merger was formally announced and implemented after final voting by the municipalities involved and administrative approval by the prefectural governor and the Minister of Internal Affairs and Communications.

Municipal mergers can be categorized into two types: "equal-footing" mergers and "incorporating" mergers. The former type involves mergers between municipalities of similar size, with a new municipality name given after the merger. A mayor of the new municipality will be newly elected in the election held after the completion of the municipal merger. On the other hand, "incorporating" mergers involve a larger municipality incorporating other smaller municipalities, with the resulting municipality inheriting the name of the incorporating municipality. A mayor of an incorporating municipality continues to be the mayor of the newly created municipality, while mayors of incorporated municipalities lose their jobs after municipal mergers.

2.2 Water Quality and Pollution Control in Japan

Water quality in Japan is regulated by the Environmental Quality Standards for Water Pollution. One important regulated indicator of water quality is BOD (Biochemical oxygen demand). BOD is the amount of dissolved oxygen needed by aerobic biological organisms to break down the organic material present, which captures the overall level of water contamination from various sources such as domestic, agricultural, and industrial wastewater. These standards set the limit values of BOD to be from 1 up to 10 mg/L in rivers, which depends on the usage of water in a given location.

Under these environmental standards, water quality in Japan has generally improved over time. The average BOD of rivers declined from about 3.5 to 1.5 mg/L from 1979 to 2018 (Ministry of the Environment, Government of Japan, 2019), which is within the range of limit values of BOD. Our analysis examines whether municipal mergers alter the existing positive trend of river water quality.

The main sources of water pollution can be categorized into three sources: (i) domestic wastewater (sewage), (ii) industrial wastewater, and (iii) agricultural wastewater. Municipalities in Japan are responsible for controlling pollution from domestic wastewater and industrial wastewater. Domestic wastewater is usually treated in sewage treatment plants which are managed by municipalities. Effluent standards on industrial wastewater are enforced through reporting and inspections by prefectures and designated cities.[4] On the other hand, agricultural wastewater is a non-point source that is diffused over a wide area as a result of factors such as precipitation, and thus it is more difficult to control this source.

2.3 How Do Municipal Mergers Affect Water Quality?

Municipal mergers can affect water quality through several channels. One channel which has been examined in the past literature is negative externalities along rivers (Lipscomb and Mobarak, 2016). Lipscomb and Mobarak (2016) develop a theoretical framework where pollution within a municipality located higher upstream on a river adversely affects other municipalities located downstream. They showed that an increase in the number of municipalities along a river path worsens water pollution. Based on their model, we may expect that municipal mergers, which decrease the number of municipalities along a river path, would improve water quality in rivers.

The key to the negative externality theory is the spatial pattern of river pollution within a municipality. Following Lipscomb and Mobarak (2016), consider a municipality, which spans an area from 0 to 1 on the horizontal axis and is located along a river with a population uniformly distributed in this area (Appendix Figure A1). The river flows from 0 to 1, and thus 0 and 1 are the upstream and downstream municipality borders, respectively. A local governor chooses how much economic activity to pursue and hence how many pollutants to emit at each point within her municipality. Because the local governor wishes to minimize the negative effect of emissions on her population and does not care about people living in other municipalities, including those downstream, she will choose to focus most of the economic activity and emissions near the downstream border, 1. Most of her municipality's population would be living upstream of this point and would not be adversely affected by

[4] A designated city is a city that has a population greater than 500,000 and has been designated by the ordinance of the Japanese government under the Local Autonomy Law. A designated city is delegated many of the functions normally performed by prefectural governments.

emissions that take place at this point.

Thus, the Lipscomb and Mobarak (2016) model predicts, among others, that pollution will increase exponentially as the river flows downstream within a municipality and that there will be a structural break in the slope of the pollution function at the municipality border. The latter prediction follows from the fact that emissions are high just upstream of a municipality border but are low just downstream of a municipality border. We test the presence of such spatial patterns by using specifications in the spirit of Lipscomb and Mobarak (2016).

Contrary to the negative externality channel, two additional channels, namely the coordination cost channel and the political economy channel, can weaken the pollution control of municipalities and consequently increase water pollution. First, for the coordination cost channel, post-merger surveys indicate a lack of organization and solidarity among municipality officials, including difficulty and delay in policy coordination, as negative consequences of the "Great Heisei Municipal Mergers" (National Association of Towns and Villages, 2008; Nakazawa and Miyashita, 2016). If coordination costs among merging municipalities are high, a newly created municipality will have difficulties in reformulating public services, which were separated by each pre-merger municipality, into newly coherent public services. Thus, the quality of pollution control in merged municipalities with higher coordination costs may deteriorate. In terms of the types of municipal mergers, "equal-footing" mergers between municipalities of similar size are expected to have higher coordination costs than "incorporating" mergers when a large municipality will incorporate other small municipalities. Therefore, we expect that water pollution increases more substantially in the case of "equal-footing" mergers with higher coordination costs.

Second, for the political economy channel, municipal mergers can cause unbalanced political power between incorporating and incorporated municipalities in the case of "incorporating" mergers. A mayor of an incorporating municipality continues to be the mayor of the newly created municipality, while mayors of incorporated municipalities lose their jobs after municipal mergers. Because the mayor of the newly created municipality has an electoral base in the former incorporating municipality, he or she may prioritize pollution control in that area. Similarly, post-merger, council members of the new municipality may consist mainly of members from the incorporating municipality. Indeed, reports by the National Association of Towns and Villages note that the voices of people living in incorporated municipalities were not adequately reflected after mergers took place (National Association of Towns and Villages, 2008). As a result, pollution control of incorporated municipalities may be weakened. Thus, we may expect that incorporated municipalities experience larger water pollution due to weaker efforts to control water pollution.

Finally, another channel could be the change in land use, which results from increases in economic activity as suggested by Egger et al. (2018). For example, if enhanced economic activity leads to deforestation and increases in built-up areas, river pollution may increase after mergers due to an increase in industrial wastewater.

3 Data

In this paper, we combine novel datasets on ambient water quality and detailed information on municipal mergers to examine the effects of municipal mergers on water quality. We also use geospatial data, including municipality boundaries and river lines, to identify the changes in distances between monitoring stations and municipality borders and test the negative externality theory.

3.1 Water Quality

The main outcome variable is water quality. We use data from water quality monitoring stations, which are provided by the Ministry of Environment, Government of Japan. These water quality data are originally collected by each prefecture in Japan under Article 15 of the Water Pollution Prevention Act and reported to the Minister of the Environment. Then, the Ministry of Environment publicizes these reported data on its website. These data include yearly average indicators of water quality, which are measured at monitoring stations in Japan. Among multiple water quality indicators, we use the yearly average BOD (Biochemical oxygen demand) as a representative indicator in the analysis. As explained in Section 2.2, BOD is a standard measure of water quality that is being monitored under the "Environmental Water-Quality Standard" in Japan. A higher level of BOD values means a higher level of water pollution.

In our analysis, we use balanced panel data of 3,309 water quality monitoring stations along rivers in Japan from 1990 to 2018 (Figure 3). We drop stations whose water quality data are only partially available during this period to address the concern of endogenous construction of monitoring stations. Thanks to the large panel of thousands of stations across Japan over 30 years, we are able to assess the dynamic effects of municipal mergers on water quality over a long period.

We complement this dataset with geospatial data of water basins in Japan, provided by the Ministry of Land, Infrastructure, Transport, and Tourism, to identify the basin where a given monitoring station is situated.

3.2 Municipal Merger

The key treatment variable in our analysis is an indicator of whether a municipal merger occurred in the municipality where a given monitoring station is located in a given year. We obtain data on the timing of municipal mergers and on the involved municipalities from the Ministry of Internal Affairs and Communications. The data allow us to compare the change in water quality between merged municipalities and non-merged municipalities, as well as between municipalities that merged earlier and those that merged later.

This dataset also includes information on the types of municipal mergers ("equal-footing" mergers versus "incorporating" mergers) and whether the municipality is incorporating municipality or incorporated municipality in the case of "incorporating" mergers. We use this information to examine the heterogeneous effects of municipal mergers by merger types in the analysis of the coordination cost channel and political economy channel.

3.3 River Distance

To test the negative externality theory as in Lipscomb and Mobarak (2016), we calculate the changes in distances between monitoring stations and new versus old municipality borders.

As for data sources, we obtain pre-merger (1984) and post-merger (2018) municipality boundary data provided by Kirimura et al. (2011). We also obtain detailed river node data with elevation information, as well as river line data, provided by the Ministry of Land, Infrastructure, Transport, and Tourism. Lastly, we use the locations of water monitoring stations in the water quality data.

In the analysis of negative externality theory, we construct two distance variables, U and D, in the spirit of Lipscomb and Mobarak (2016). U refers to the distance along the river from a monitoring station to its closest upstream municipality border. Likewise, D indicates the river distance between a monitoring station and its closest downstream border. U and D require calculating distances along rivers instead of Euclidean distance and judging flow direction.

For constructing U and D, we use the river node data, which contains elevation information, to compute fine-resolution elevation raster data. Based on this elevation data, we identify the upstream-downstream relationships among monitoring stations and municipality borders. Then, we calculate these two distance variables along rivers.[5]

[5] Detailed steps are written in the Appendix C.1.

3.4 Other Municipality Characteristics

We supplement the above information with further data to account for municipality characteristics that might affect both water quality and the likelihood of municipal mergers. Specifically, we use an economic indicator and population.

As an economic indicator, we use "Product shipment values" in the manufacturing sector from 1990 to 2018 from the Census of Manufacture provided by the Ministry of Economy, Trade, and Industry.

We use population data from the Census. Because the Census is conducted every five years, we compute the yearly population from 1990 to 2015 based on the linear interpolation of the reported population in 1990, 1995, 2000, 2005, 2010, and 2015.

For a balance check of municipality characteristics in the pre-merger period, we use (i) agricultural output values from the Statistics of Agricultural Income Produced provided by the Ministry of Agriculture, Forestry and Fisheries and (ii) financial capability index from the Annual Statistics on Local Public Finance provided by the Ministry of Internal Affairs and Communications.[6]

3.5 Data Matching and Sample Construction

For matching water quality data with municipal merger data, we use municipality boundary GIS data provided by the Ministry of Land, Infrastructure, Transport, and Tourism. We first use this boundary data and the GPS coordinates of monitoring stations to identify the most recent prefecture and city names of these stations. Then, we match both data based on these prefecture and city names. All other data, including water basins and other municipality characteristics, are similarly merged based on the latest prefecture and city names.

After data matching, we construct a balanced panel of 3,309 water quality monitoring stations in 983 municipalities from 1990 to 2018 for the difference-in-differences specification. The baseline specification in the analysis uses panel data starting in 1996, five years before the first municipal merger was observed in our dataset in 2001. We also conduct robustness checks by using alternative sample periods, (i) 1990-2018 and (ii) 1999-2018, as discussed in Section 5.2.

In the specification that uses river distance to test the negative externality theory, we only use monitoring stations that are situated along the river lines used in our data construction. We also exclude monitoring stations that are situated either in uppermost municipalities or furthest-downstream municipalities because one of the distance measures (U or D) cannot

[6] Financial capability index is computed by dividing basic financial revenues by basic financial needs and averaging these values over the past three years. A higher financial capability index means a better financial condition of the local government.

be calculated. We use observations until 2015 since we use population as a control, and population data are available until 2015. With these restrictions, the final sample for the river distance specification becomes 700 monitoring stations in 382 municipalities from 1996 to 2015.

3.6 Summary Statistics

Summary statistics of all variables in the pre-merger period (before 2001 in our sample) are shown in Table 1. In the pre-merger period, merged municipalities (treatment group) are different from non-merged municipalities (control group) in BOD level, product shipment values, agricultural output values, financial capability index, and land use. Specifically, the differences in means of these variables suggest that merged municipalities focus more on the agricultural sector than the manufacturing sector, and they had weaker financial conditions and better water quality before the mergers. Although level differences in outcomes and municipality characteristics are observed, we rely on the assumption of parallel trends in the difference-in-differences specification to derive causal estimates. We test this assumption later in Section 4.1 and Section 5.1.

Moreover, as shown in Figure 4, BOD levels decrease in the post-merger period both in the treatment and control groups. However, the magnitude of the decrease in BOD level is smaller in the treatment group, which implies that municipal mergers cause water pollution. A formal econometric analysis of this effect is conducted in the following sections.

4 Empirical Strategy

We examine the impact of municipal mergers on water pollution in two ways. First, we directly assess the impact of municipal mergers on water pollution by adopting a difference-in-differences model with two-way fixed effects. Simple ordinary least squares (OLS) estimates are subject to bias due to potential endogeneity through potential reverse causality and omitted variables. Municipal mergers could be implemented to better mitigate the water pollution in those municipalities, although this would be highly implausible because the decisions of municipal mergers are primarily based on the condition of local public finance. Also, spurious correlations may be caused by omitted unobservables, such as different priorities on water pollution control across municipalities. Thus, we adopt a difference-in-differences model to deal with potential endogeneity. By including monitoring station fixed effects and basin-year fixed effects, we control for the time-invariant unobservable differences across monitoring stations and secular time trends, which may vary across river basins.

Second, using a specification similar to Lipscomb and Mobarak (2016), we test whether relationships between locations along the river and pollution predicted by the negative externality theory hold in the case of Japan. Similar to the difference in difference specification, we include station-fixed effects and basin-year fixed effects to control for station-specific characteristics that are constant over time and annual trends that vary across river basins.

4.1 Difference-in-Differences Specification

We first adopt a difference-in-differences model with two-way fixed effects:

$$Log(BOD_{i,t}) = \alpha + \beta_{DID} Merger_{i,t} + \lambda X_{i,t} + \delta_i + \theta_{b,t} + \varepsilon_{i,t} \tag{1}$$

where the dependent variable, $Log(BOD_{i,t})$, is a logarithm of BOD at monitoring station i in year t. $Merger_{i,t}$ is an indicator variable that switches on and stays on for all subsequent years when a merger takes place in the municipality associated with station i. $X_{i,t}$ is a vector of time-varying control variables, including a municipality-level economic indicator (product shipment values) and population. Given the "bad control" concerns of these variables, which may be affected by municipal mergers, we only include them as a robustness check. We include monitoring station fixed effects (δ_i), which control for time-invariant characteristics of each monitoring station, including positions (downstreamness) along rivers. To account for any secular trends in water quality across years, which may vary across river basins, we include year dummies interacted with indicators for each of the river basins b ($\theta_{b,t}$). Lastly, standard errors are clustered at the municipality level because the variation in municipal mergers is observed at the municipality level.

The coefficient of particular interest is β_{DID}. If municipal mergers decrease river pollution, as negative externality theory would suggest, then β_{DID} should be negative. On the other hand, β_{DID} could be positive if the negative externality theory does not hold, and high coordination costs and unbalanced political power among pre-merger municipalities cause an increase in river pollution.

Note that we examine a staggered policy: municipal mergers took place in different years. Thus, the estimate of β_{DID} in the regression (1) is a weighted average of all possible two-group/ two-period difference-in-differences estimators (Goodman-Bacon, 2021). In other words, the estimate reflects all possible cases with different definitions of treatment and control groups. One case could be comparing monitoring stations in municipalities that experienced mergers (treatment group) with monitoring stations in municipalities that never experienced mergers (control group). Another case could be comparing monitoring stations in municipalities that experienced mergers in the early years (treatment group) with monitoring stations in municipalities that experienced mergers in later years (control group).

The difference-in-differences specification hinges on the parallel trend assumption between treatment and control groups. A simple comparison of the evolution of BOD values between the merged and not merged municipalities encouragingly shows signs of parallel pre-trends (Figure 4).[7] To empirically test the parallel trend assumption, we adopt the following event-study specification. This specification also allows us to examine the long-run dynamic impacts of municipal mergers up to 17 years.

$$Log(BOD_{i,t}) = \alpha + \sum_{\tau=-14}^{17} \beta_\tau Merger_{\tau,i} + \lambda X_{i,t} + \delta_i + \theta_{b,t} + \varepsilon_{i,t} \quad (2)$$

where $Merger_{\tau,i}$ is an indicator for each year τ relative to the municipal merger, where τ is zero in the year that the municipal merger was implemented. τ ranges from -14 to 17 in our sample years. For monitoring stations where municipal mergers did not take place, all $Merger_{\tau,i}$'s are set equal to zero. $\tau = -1$ is set as a reference year.

The β_τ's are the parameters of interest. β_τ's should be around zero and statistically insignificant from $\tau = -14$ to $\tau = -2$ to satisfy parallel pre-trends. After $\tau = 0$, β_τ's capture the dynamic treatment effects in the short and long runs.

Recent literature indicates that, in the case of staggered difference-in-differences designs where treatment effects vary over time, standard two-way fixed effect regression estimates and event study estimates are subject to bias. As mentioned above, two-way fixed effect estimates are weighted averages of all possible two-group/ two-period difference-in-differences estimators. However, comparisons between the early merger group (as a control group) and the late merger group (as a treatment group) become problematic if treatment effects vary over time, i.e., when we have a trend break rather than a level shift. This comparison leads to bias from negative weights (Goodman-Bacon, 2021; Callaway and Sant'Anna, 2021; Sun and Abraham, 2021). To overcome this issue and obtain unbiased estimates, we apply an alternative estimator of Callaway and Sant'Anna (2021) that is robust to negative weights as the baseline specification throughout this paper.[8] We present the results of Callaway and Sant'Anna (2021) estimator together with the results of two-way-fixed effects specification of the regressions (1) and (2).

4.2 River Distance Specification

To formally test the negative externality theory predictions, we investigate spatial patterns of pollution using the following specification:

[7] The same pattern is also observed when we plot the trends of logarithms of BOD values that are used for the analysis (Appendix Figure A2).

[8] We also adopt estimator of Sun and Abraham (2021) as a robustness check, as discussed in Section 5.2.

$$Log(BOD_{i,t}) = \alpha + \eta_1 Downstream_{i,t} + \eta_2 Downstream^2_{i,t} + \lambda X_{i,t} + \delta_i + \theta_{b,t} + \varepsilon_{i,t} \tag{3}$$

We first obtain distances along the river from monitoring station i to its closest upstream municipality border in year t ($U_{i,t}$) and to its closest downstream municipality border ($D_{i,t}$), as outlined in Section 3.3. We then construct a variable $Downstream_{i,t} = U_{i,t}/(U_{i,t} + D_{i,t})$. $Downstream_{i,t}$ takes a value between 0 and 1 and measures the relative "downstreamness" of a monitoring station within its municipality. The closer the value is to 1, the more downstream a station is within its municipality. As before, $X_{i,t}$ is a vector of control variables consisting of a municipality-level economic indicator (product shipment values) and population. Likewise, δ_i and $\theta_{b,t}$ are station fixed effects and basin-year fixed effects, respectively. Standard errors are clustered at the station level to address the serial correlation.

The coefficients of prime interest here are η_1 and η_2. Negative externality theory predicts that pollution rises at an increasing rate as we go downstream along a municipality, as illustrated in Appendix Figure A1. In such a case, the first and second derivatives with respect to "downstreamness" would both be positive, and we expect a convex relationship with $\eta_1 > 0$ and $\eta_2 > 0$.

A specification following Lipscomb and Mobarak (2016) is also considered:

$$Log(BOD_{i,t}) = \alpha + \gamma_1 U_{i,t} + \gamma_2 U^2_{i,t} + \gamma_3 D_{i,t} + \gamma_4 D^2_{i,t} + \lambda X_{i,t} + \delta_i + \theta_{b,t} + \varepsilon_{i,t} \tag{4}$$

where the variables are as explained above. According to the negative externality theory in Lipscomb and Mobarak (2016), pollution should increase exponentially as the distance from the downstream border gets smaller (i.e., the further downstream within the municipality), so we expect $\gamma_3 < 0$ and $\gamma_4 > 0$. Also, the existence of a structural break in the pollution function at the municipality border implies that γ_1 should be different from γ_3.

5 Results

5.1 Difference-in-Differences Specification

The results of the difference-in-differences specification are reported in Table 2. Panel A uses the Callaway & Sant'Anna estimator, and it is our preferred specification. The results for the two-way fixed effect specification are provided for reference in Panel B. Looking at our baseline specification (Column 1) for Panel A, we find that municipal mergers do not improve water quality but rather increase water pollution on average by 5.5%. This is in stark contrast to what the negative externality theory and results of Lipscomb and Mobarak (2016) would suggest. These negative effects on water quality are robust when we include product shipment values and population as controls in the regression, although these variables can be "bad controls" that are affected by the treatment (Column 2).

The result of the event study specification, using the Callaway and Sant'Anna (2021) estimator, is shown in Figure 5. The estimates for pre-merger years are largely insignificant, which suggests that parallel pre-trends hold. After period 0, which corresponds to the beginning of municipal mergers, statistically significant impacts of increased water pollution are observed. The effects become larger over time and remain statistically significant for about 15 years, which suggests that the negative impacts on water quality exacerbate in short to medium run after mergers. After 15 years, the effects become smaller and statistically insignificant, which suggests that the increase in pollution is being mitigated in the long term. However, it should be noted that estimates become imprecise over time with larger standard errors, which is due to the smaller sample sizes that consist of only municipalities that merged very early.

5.2 Robustness Checks: Difference-in-Differences Specification

The results of the difference-in-differences specification are robust to alternative estimators and sample periods, as well as to analysis that only uses variation in merger timings among merged municipalities.

Alternative estimators and sample periods.—The negative effects of municipal mergers on water quality are similarly found when we adopt alternative estimators, including the Sun and Abraham (2021) estimator, although the magnitude of the effects is slightly smaller in alternative estimators (Appendix Figure A4).

Moreover, the results are robust to the adoption of alternative sample periods, including (i) 1990-2018 (longer period) and (ii) 1999-2018 (shorter period), as shown in Appendix Figure A5. The negative effects of municipal mergers are consistently found, and the magnitude of the effects is similar.

Analysis comparing early versus late mergers.—The baseline specification relies on the comparison between merged municipalities and never-merged municipalities, which are different in the shares of manufacturing and agricultural sectors and financial conditions as discussed in Section 3.6. This difference can lead to the concern of selection bias, although the evidence on parallel pre-trends supports the causal interpretation of the baseline results. However, as a robustness check to address the concern of selection bias, we run the regressions (1) and (2) by restricting our sample to municipalities that have experienced mergers. This analysis relied on the comparison between municipalities that merged earlier (treatment group) and those that merged later (control group), which are expected to be more similar and balanced in characteristics.

As shown in an event study plot (Appendix Figure A3) of this specification, we similarly find that municipal mergers increase water pollution, especially six years after municipal mergers. The DID results show the negative effects on water quality in our preferred specification without controls, although the estimate becomes imprecise, possibly because of insignificant short-run effects (Column 1 of Appendix Table B1).

5.3 River Distance Specification

Table 3 reports the results of the spatial analysis that uses the changes in river distances between monitoring stations and municipality borders. First, the results on the relative downstreamness (regression (3)) are provided in Columns 1 and 2. The coefficients on both the downstream indicator and its squared term are both statistically insignificant. Also, the sign of the coefficient for the downstream indicator is positive, which is contrary to the prediction by the negative externality theory.

Second, results for the Lipscomb and Mobarak (2016) specification (regression (4)) in Columns 3 and 4 are not supportive of the negative externality channel either. In our preferred specification with basin-year fixed effects (Column 4), the coefficient of D is again positive and not statistically significant. Furthermore, we cannot reject the equality of the coefficients of U and D when we test the structural break in the pollution function at the municipality border.

In sum, the negative externality channel of Lipscomb and Mobarak (2016) does not hold true in the case of municipal mergers in Japan. This may be partly due to differences between developing/emerging countries (Lipscomb and Mobarak, 2016) and developed countries like Japan. In a developed country case, it may be more difficult or costly to relocate polluting sources (to internalize any externality) after municipal mergers, where for instance, property rights are more rigid, and there is less available land area for relocation. Null effects of municipal mergers on land use in Section 6.4 are consistent with this explanation.

6 Mechanisms

The negative effects of municipal mergers on water quality and the lack of supporting evidence for the negative externality theory show that the negative externality channel does not apply in our setting of municipal mergers in Japan. As the main mechanisms, heterogeneity analysis by merger types and involved municipalities suggests that municipal mergers weaken pollution control due to coordination costs and unbalanced political power among pre-merger municipalities. We do not find evidence of an alternative explanation, which is a change in land use (e.g., increased industrial and residential areas), which could lead to increased water pollution without changing the pollution control.

6.1 Coordination Costs

We test the coordination cost channel by comparing the case of "equal-footing" mergers which entail higher coordination costs, with "incorporating" mergers which have lower coordination costs. We expect that "equal-footing" mergers result in larger water pollution because of higher coordination costs. We estimate the impacts of "equal-footing" mergers by the regression (1) after only keeping the municipalities that have experienced "equal-footing" mergers and never-merged municipalities. The same procedure is repeated for the case of "incorporating" mergers.

Columns 1 and 2 in Table 4 reports the effects of municipal mergers of both types. We find a statistically significant negative effect in the case of "equal-footing" mergers. "Equal-footing" mergers increase water pollution by 6.7% (Column 1 of Panel A), but the effect becomes insignificant in the case of "incorporating" mergers (Column 2). As expected, the negative effects are more substantial in the case of "equal-footing" mergers, which entail higher coordination costs among pre-merger municipalities.

6.2 Political Economy

We also test the political economy channel by comparing the change in water quality of incorporating municipalities with that of incorporated municipalities. We expect that incorporated municipalities experience larger water pollution due to neglect by a mayor originally from the incorporating municipality. We estimate the impacts of municipal mergers in incorporating municipalities by the regression (1) after only keeping the incorporating municipalities and never-merged municipalities. The same procedure is repeated for the case of incorporated municipalities.

Columns 3 and 4 in Table 4 report the results. Incorporated municipalities experience a large increase in water pollution by 8.5% (Column 3 of Panel A). But we find no effect for the incorporating municipalities (Column 4). This difference in results aligns with the argument of the political economy channel, where incorporated municipalities with less political power incur negative effects.

6.3 Pollution Sources Subject to Weaker Control

In the coordination cost and political channels, we show that municipal mergers can weaken water pollution control. Concretely, this could take the form of insufficient treatment of domestic wastewater in sewage treatment plants and industrial wastewater in factories, which are under the responsibility of municipalities (Section 2.2). In an effort to explicitly test the change in pollution control, we examine the change in the quality of treatment of domestic wastewater at sewage treatment plants.

Treated wastewater from sewage treatment plants is discharged into rivers. Hence, if merged municipalities reduce their efforts to treat wastewater, water quality in rivers may deteriorate. This weaker pollution control can occur in the form of delaying the renewal of aging sewage treatment plants, which can inhibit sufficient wastewater treatment at these plants.[9]

To test this possibility, we compute the BOD values of effluent and influent[10] of sewage treatment plants from 1996 to 2017 in Japan. We use the Sewage Statistics compiled by the Japan Sewage Works Association and aggregate plant-level data into municipality-level data by computing the mean of BOD values. In this analysis, we adopt the difference-in-differences specification that is similar to the baseline specification in Section 4.1, although we include municipality fixed effects and cluster the standard errors at the municipality level.

Appendix Table B3 and Appendix Figure A7 report the results of this analysis. We do not find statistically significant effects of municipal mergers on effluent water quality, which suggest that pollution control efforts are not weakened by delaying renewal. The placebo check, which looks at the effect on influent water quality, also shows null effects, as expected. These null results of sewage treatment plants suggest that municipal mergers may cause weaker pollution control on other pollution sources, i.e., either industrial wastewater or agricultural wastewater. However, as discussed in Section 2.2, agricultural wastewater is a non-point source that is not well controlled by the municipality's policy.

Hence, the results from this analysis on sewage treatment plants, combined with the characteristics of agricultural wastewater as well as the relevance of the coordination cost and political economy channels, offer indirect and suggestive evidence that the most likely source of weaker pollution control is industrial wastewater.

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[9] The aging of sewage treatment plants is a growing issue in Japan. More than 80% sewage treatment plants have been operating for 15 years since their inception and need to be renewed to maintain the quality of wastewater treatment.

[10] Effluent is wastewater flowing out of a sewage treatment plant, while influent is wastewater entering a sewage treatment plant.

6.4 Alternative Explanation: Change in Land Use

We do not find evidence of an alternative explanation, which is a change in land use, which could lead to increased water pollution without changing the pollution control. Municipal mergers can increase economic activities (Egger et al., 2018), which leads to a change in land use. This may, for instance, involve turning forest areas near rivers into industrial and residential areas. This change in land use may lead to an increase in water pollution sources, i.e., industrial and domestic wastewater, which eventually increase river pollution.

To test this alternative explanation, we examine the impact of municipal mergers on land use patterns. This analysis uses the 100-meter raster data of land use over six periods in 1991, 1997, 2006, 2009, 2014, and 2016 from the dataset of the Ministry of Land, Infrastructure, Transport, and Tourism. We focus on the land use pattern within the 150-meter buffer from each monitoring station. Our analysis uses the following four classifications of land use: agriculture, forest, built-up, and non-use.[11] Then, we construct the share of each land use classification and the binary indicator of which land use classification is major for each monitoring station.[12]

Based on the constructed panel of land use patterns over six periods, we adopt the same difference-in-differences approach as the baseline specification in Section 4.1 with the shares and binary indicators of four land use classifications as the outcome variables. In this case, the panel data does not cover consecutive years, so we cannot use the Callaway and Sant'Anna (2021) estimator, which requires a balanced panel with consecutive years. Thus, we use the two-way fixed effects specification and Sun and Abraham (2021) estimator in this analysis.

As shown in Appendix Table B2 and Appendix Figure A6, we do not find statistically significant effects of municipal mergers on land use patterns (agriculture, built-up, forest, and non-use). Thus, the river pollution induced by municipal mergers cannot be explained by this land use channel.

7 Conclusion

We document that municipal mergers, where two or more municipalities combine to form one municipality, increase river pollution. This result runs counter to the prediction of the negative externality theory emphasized in past studies, i.e., municipal mergers can facilitate the internalization of pollution spillovers across pre-merger municipalities.

[11] Built-up areas include residential or urban areas where buildings are densely built up, and athletic fields, airports, racetracks, baseball fields, schools, and harbor areas. Non-use areas include wasteland, wasteland, cliffs, rocks, perennial snow, wetlands, and mined land.

[12] Detailed steps are written in the Appendix C.2.

Specifically, we investigate the case of Japan's large-scale municipal mergers in the late 1990s to 2000s, which drastically reduced the number of municipalities by about 50%. Based on 30-year water quality data on more than 3,000 monitoring stations and detailed information on municipal mergers, we investigate the long-run impacts of municipal mergers on water quality across Japan.

To examine the effects of municipal mergers on river water quality, we adopt two main identification strategies. First, we adopt the difference-and-differences and event study specifications by using variations in the occurrence and timings of municipal mergers. Second, we adopt the river distance specification in Lipscomb and Mobarak (2016), which directly tests the negative externality theory by examining how pollution levels change as a river flows downstream within a municipality. Here, we exploit the change in distances from monitoring stations to their closest upstream and downstream municipality borders along rivers after the mergers.

Contrary to the prediction of the negative externality theory, we find that municipal mergers increase river pollution by 5.5% percent, and this negative effect persists for about 15 years. We also find no evidence of negative externality theory in the river distance specification.

As alternative mechanisms, heterogeneity analysis by merger types and involved municipalities suggests that pollution control becomes weaker after mergers due to coordination costs and unbalanced political power among pre-merger municipalities. We find that pollution increases in "equal-footing" mergers with higher coordination costs but not in "incorporating" mergers with lower coordination costs. We further show that in the case of "incorporating" mergers, incorporated municipalities experience a larger increase in water pollution than incorporating municipalities, whose political power is higher because a mayor there continues to hold the same position after municipal mergers.

Our results have several implications for policy and research direction on municipal mergers. First, while proponents emphasize positive impacts on fiscal outcomes such as local public finance, municipal mergers can have unintended negative effects on environmental outcomes. These negative effects should be carefully considered in the cost-benefit analysis of future municipal mergers.

Second, the negative externality narrative of pollution may not be as relevant in a developed country's case as in a developing country's case of splits in municipalities. Our results point to the relative significance of coordination cost and political economy channels in the case of Japan's municipal mergers. Conducting careful pre-analysis of likely relevant channels and designing relevant countermeasures on a country-by-country basis would be important in mitigating the negative effects of municipal mergers on environmental quality.

Finally, the negative effects of municipal mergers we observed in the case of pollution control can extend to other policies managed by municipalities, including educational investment and healthcare. The coordination cost and political economy channels may also play a role in weakening the implementation of these policies. Investigating these potential negative effects in other policies may be a fruitful area for future research.

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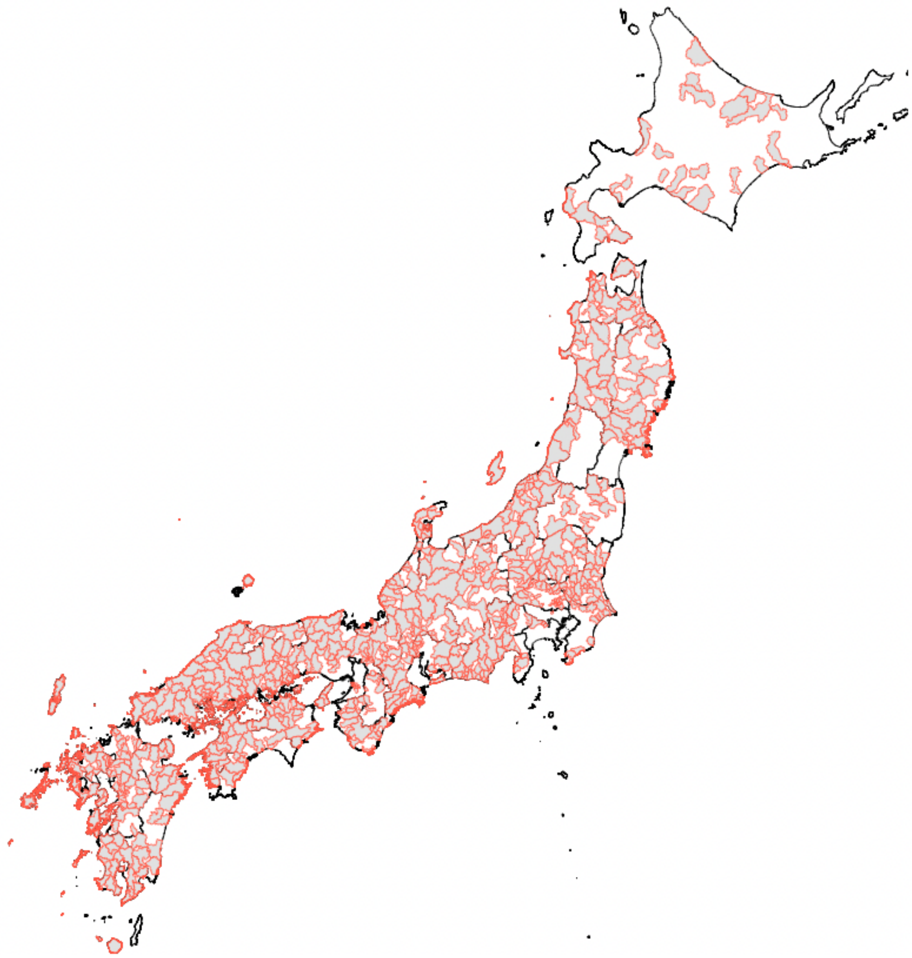

Figure 1: Locations of Municipal Mergers in Japan

Notes: This figure shows the boundaries of municipalities that experienced municipal mergers (red lines surrounding grey areas) and the boundaries of prefectures in Japan (in black).

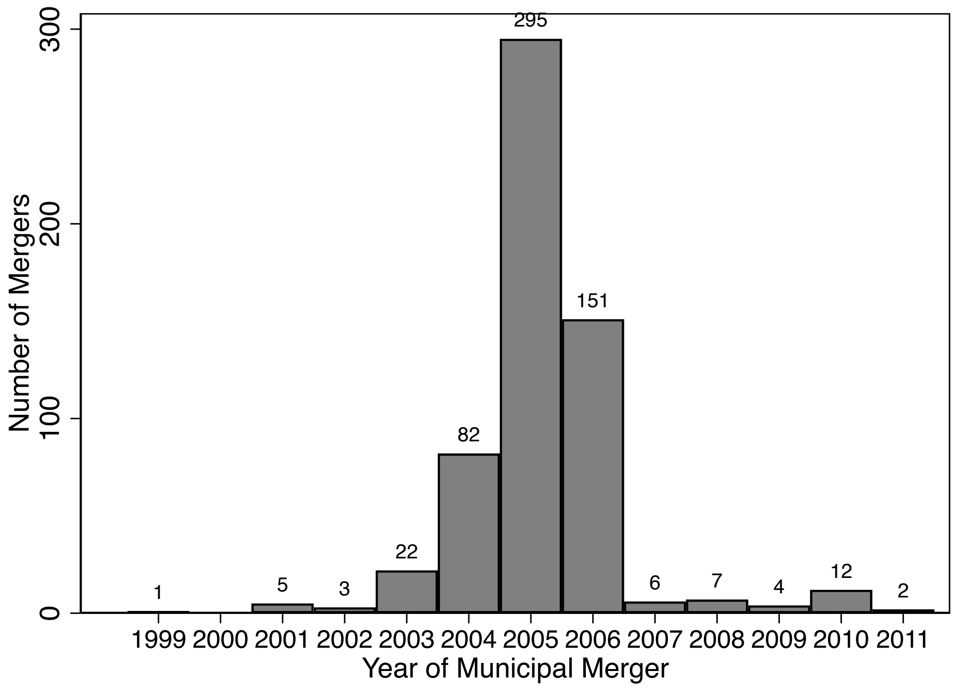

Figure 2: Timing of Municipal Mergers in Japan

Notes: This figure shows the number of municipal mergers by year in Japan based on the merger data of the Ministry of Internal Affairs and Communications. In our analysis, we only use variation of merger years from 2001 to 2011 based on our sample of municipalities along rivers.

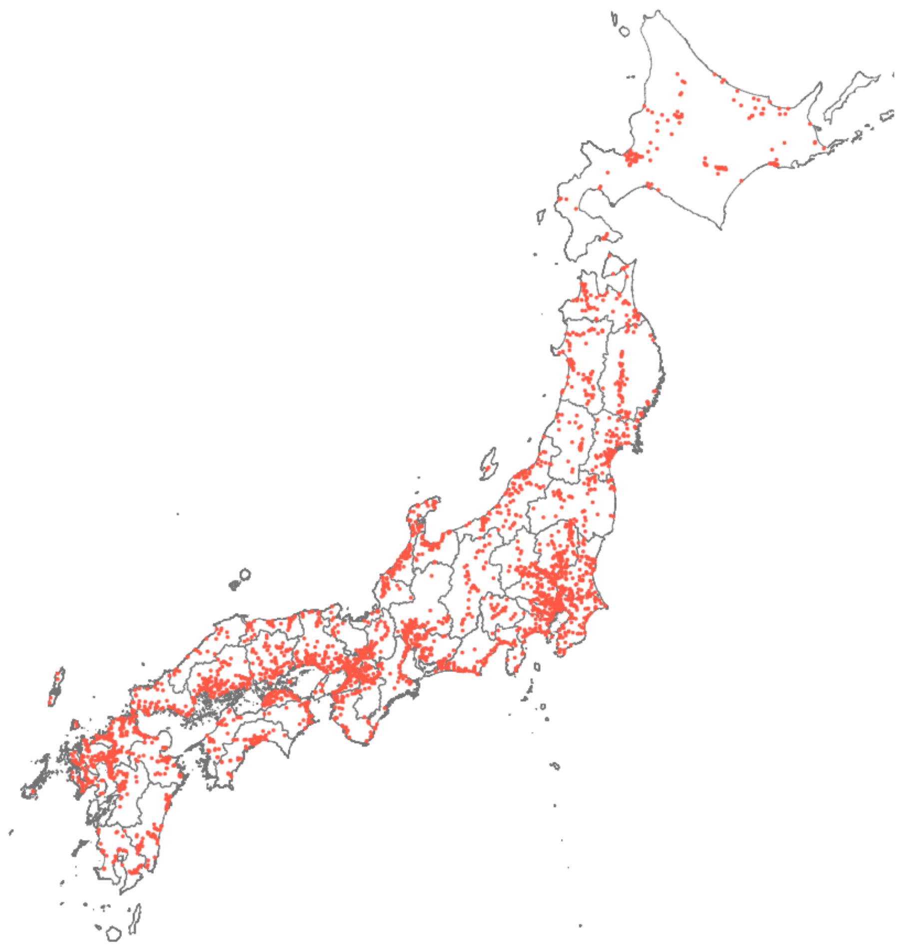

Figure 3: Locations of Water Quality Monitoring Stations in Japan

Notes: This figure shows the locations of water quality monitoring stations (in red) that are included in our sample along rivers based on the data of the Ministry of Environment. Boundaries of prefectures in Japan are also shown (in black).

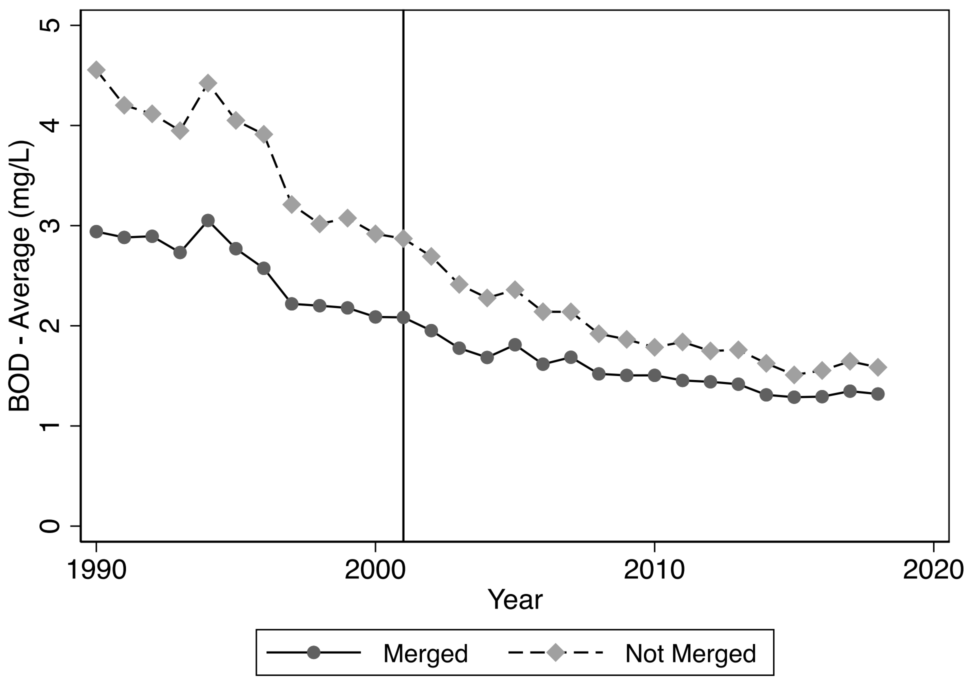

Figure 4: Trends of BOD Values in Merged and Not Merged Municipalities

Notes: This figure compares the changes in average BOD values (mg/L) from 1990 to 2018 between the municipalities which experienced municipal mergers (Merged) and the municipalities which did not experience the mergers (Not Merged). The vertical in 2001 shows the year when the first municipal mergers took place in our sample.

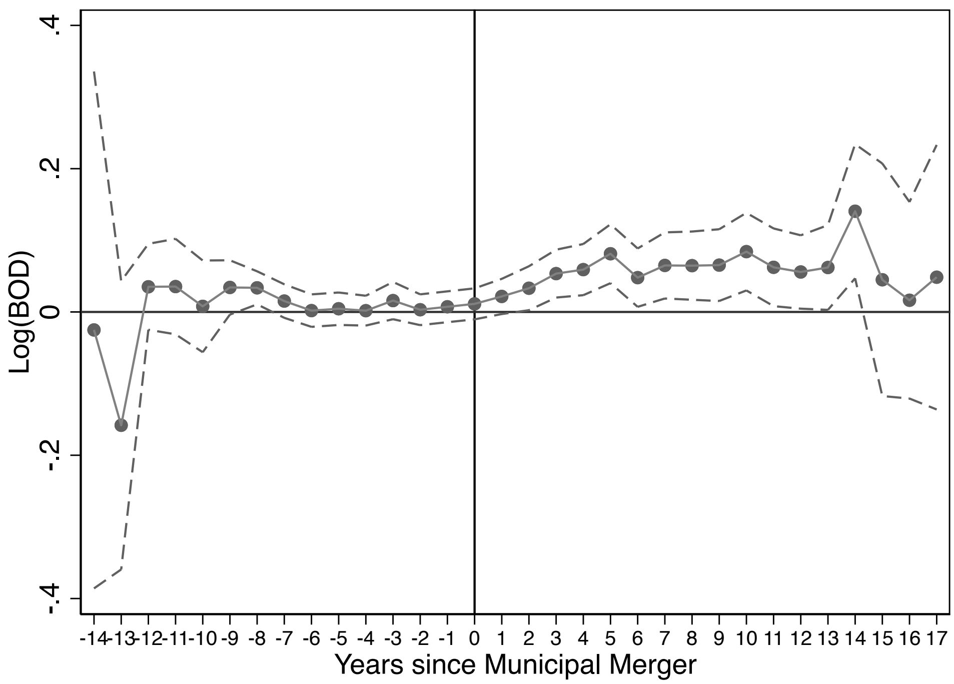

Figure 5: The Dynamic Effect of Municipal Mergers on Water Pollution

Notes: This figure shows the coefficients of the Callaway and Sant'Anna (2021) estimator. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level. This specification includes monitoring station fixed effects and year fixed effects.

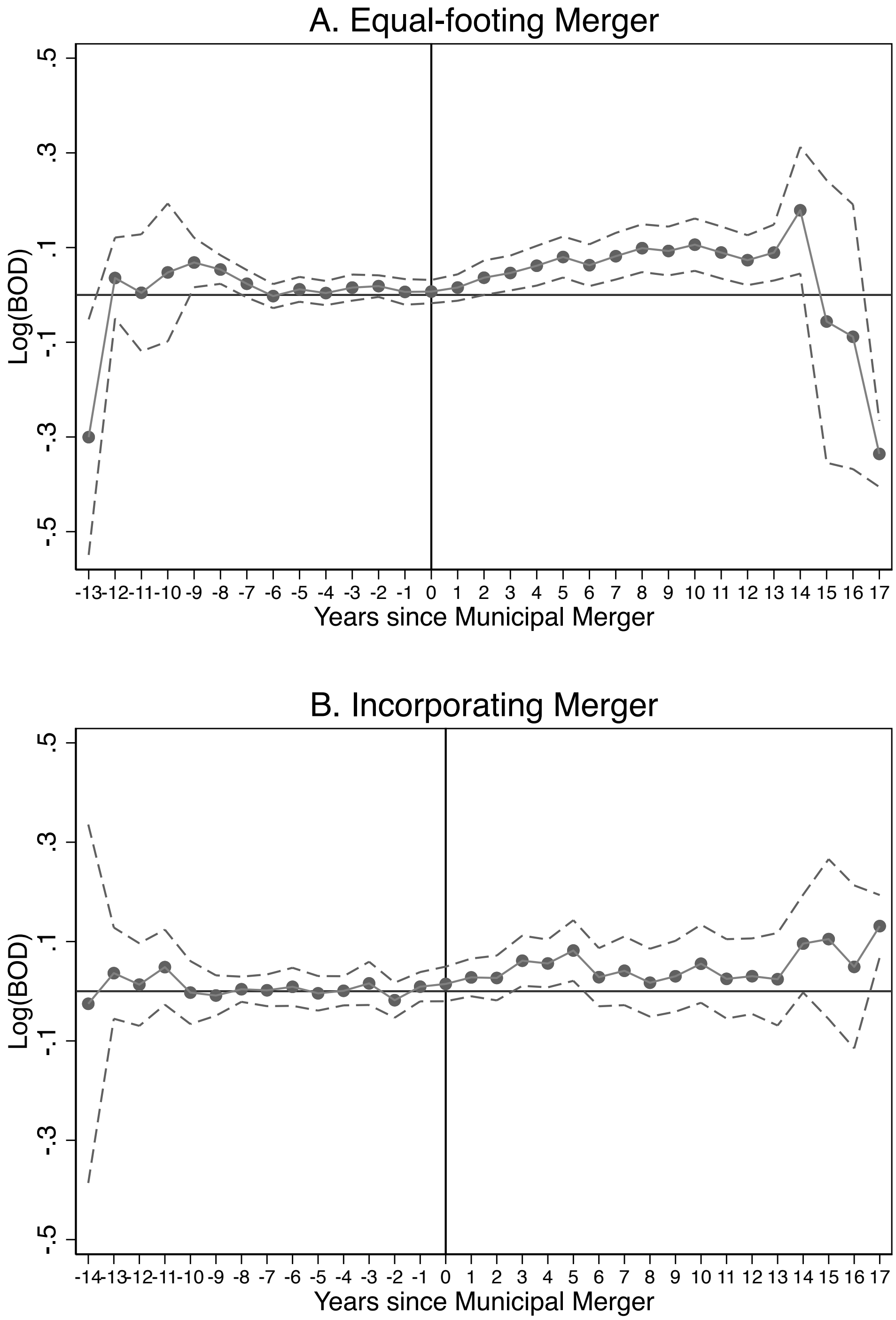

Figure 6: Event Study Results: Mechanism on Coordination Cost

Notes: These figures show the coefficients of the Callaway and Sant'Anna (2021) estimator. Panel A shows the effects of equal-footing mergers based on the data of these municipalities and never-merged municipalities, while Panel B similarly shows the effects of incorporating mergers. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level. Both panels include monitoring station fixed effects and year fixed effects.

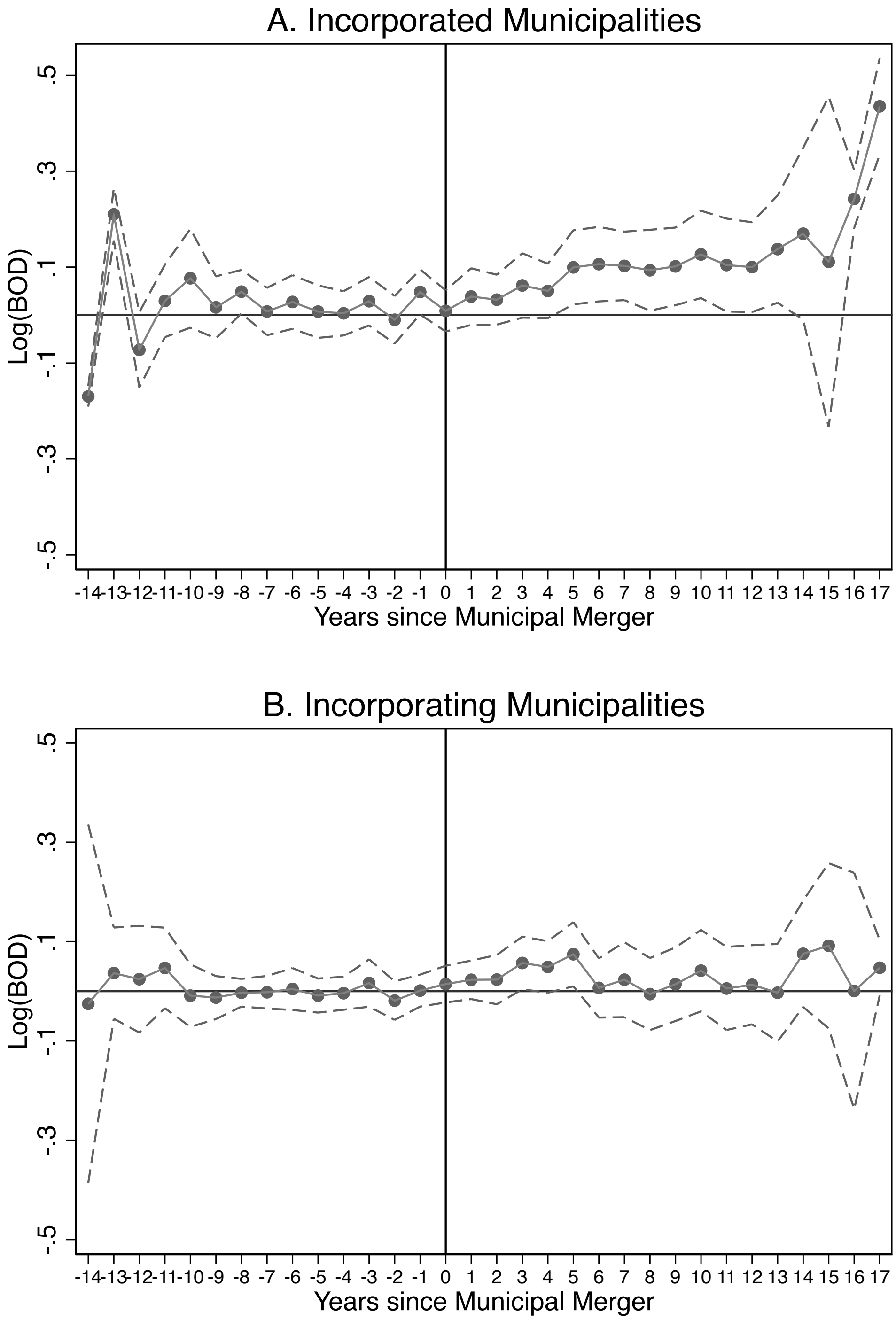

Figure 7: Event Study Results: Mechanism on Political Economy

Notes: These figures show the coefficients of the Callaway and Sant'Anna (2021) estimator. Panel A shows the effects of mergers in incorporated municipalities based on the data of these municipalities and never-merged municipalities, while Panel B similarly shows the effects of mergers in incorporating municipalities. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level. Both panels include monitoring station fixed effects and year fixed effects.

Table 1: Summary Statistics in Pre-Merger Period (Before 2001)

Variable	Means: Not Merged	Means: Merged	Difference	Obs.
Panel A. Water Quality (Station-level)				
BOD - Yearly average (mg/l)	3.227	2.252	-0.975***	3,309
	(3.716)	(2.672)	(0.206)	
Panel B. River Distance (Station-level)				
Distance from upstream border to station (km)	4.402	4.161	-0.241	700
	(4.746)	(4.906)	(0.461)	
Distance from station to downstream border (km)	3.518	3.914	0.396	700
	(4.179)	(4.293)	(0.430)	
Downstream indicator (0-1)	0.554	0.533	-0.021	700
	(0.278)	(0.272)	(0.022)	
Panel C. Municipality Characteristics (Municipality-level)				
Product shipment values (100 billion JPY)	2.272	2.954	0.682*	958
	(5.668)	(5.674)	(0.367)	
Population (thousand)	97.349	111.842	14.494	958
	(266.419)	(157.791)	(14.353)	
Agricultural output values (billion JPY)	4.128	11.665	7.536***	958
	(4.978)	(10.496)	(0.522)	
Financial Capability Index	0.601	0.488	-0.113***	958
	(0.315)	(0.226)	(0.018)	
Panel D. Land Use (Station-level)				
Major land use around stations: Agriculture (0/1)	0.342	0.412	0.070***	2,770
	(0.475)	(0.492)	(0.026)	
Major land use around stations: Forest (0/1)	0.137	0.213	0.076***	2,770
	(0.344)	(0.410)	(0.020)	
Major land use around stations: Buildup (0/1)	0.498	0.364	-0.134***	2,770
	(0.500)	(0.481)	(0.031)	
Panel E. Sewage Treatment Plants (Municipality-level)				
BOD - Effluent from Sewage Treatment Plants (mg/l)	5.420	7.537	2.118	273
	(2.683)	(24.294)	(2.452)	

Notes: This table compares the summary statistics between merged municipalities and non-merged municipalities before municipal mergers started in our sample, i.e., before 2001 when the first mergers were observed. The means are calculated by averaging the values of all years in the pre-merger period. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The standard errors of differences of means are clustered at the municipality level when variables are observed at the station level (Panels A, B, D).

Table 2: DID Results: The Effect on Water Quality

	Log(BOD)	
	(1)	(2)
Panel A: Callaway & Sant'Anna (2021) Estimator		
Merger (= 1)	0.055***	0.049***
	(0.018)	(0.015)
Panel B: Two-way Fixed Effects		
Merger (= 1)	0.036*	0.034**
	(0.018)	(0.017)
Observations	75,555	64,011
R^2	0.881	0.889
Number of Stations	3,285	3,206
Number of Municipalities	971	946
Product Shipment Values	NO	YES
Population	NO	YES
Mean of Dep. Variable	2.654	2.603

Notes: The coefficients are reported. Standard errors are in parentheses and clustered at the municipality level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Panel A includes year fixed effects and monitoring station fixed effects, while Panel B includes basin-year fixed effects and monitoring station fixed effects. Mean dependent variables are the mean of BOD values before municipal mergers started in our sample (before 2001) in each specification.

Table 3: Results of River Distance Specification

	Log(BOD)			
	(1)	(2)	(3)	(4)
Downstream indicator ($U/(U+D)$)	-0.191	-0.215		
	(0.230)	(0.225)		
Squared downstream indicator ($(U/(U+D))^2$)	0.273	0.334		
	(0.212)	(0.224)		
Distance from upstream border to station (U)			0.010***	0.004
			(0.003)	(0.003)
Squared distance from upstream bortder to station (U^2)			-0.000**	-0.000
			(0.000)	(0.000)
Distance from station to downstream border (D)			0.002	-0.003
			(0.004)	(0.005)
Squared distance from station to downstream border (D^2)			0.000	0.000
			(0.000)	(0.000)
Observations	14,000	13,360	14,000	13,360
R^2	0.875	0.915	0.876	0.915
Number of Stations	700	668	700	668
Number of Municipalities	382	354	382	354
Year FE	YES	NO	YES	NO
Basin-Year FE	NO	YES	NO	YES
F-stat for U = D	-	-	1.631	1.578
p-value for U = D	-	-	0.202	0.209
Mean of Dep. Variable	2.365	2.401	2.365	2.401

Notes: The coefficients are reported. Standard errors, clustered at station level, are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. This specification includes monitoring station fixed effects, as well as product shipment values and population as controls. Mean dependent variables are the mean of BOD values before municipal mergers started in our sample (before 2001) in each specification.

Table 4: DID Results: Mechanisms on Coordination Cost and Political Economy (Dependent Variable: Log of BOD)

	Coordination Cost		Political Economy	
	(1) Equal-footing	(2) Incorporating	(3) Incorporated	(4) Incorporating
Panel A: Callaway & Sant'Anna (2021) Estimator				
Merger (= 1)	0.067***	0.039	0.085**	0.026
	(0.019)	(0.026)	(0.033)	(0.027)
Panel B: Two-way Fixed Effects				
Merger (= 1)	0.064***	0.005	0.100***	-0.019
	(0.022)	(0.027)	(0.029)	(0.029)
Observations	56,097	49,588	34,017	46,437
R^2	0.885	0.886	0.891	0.887
Number of Stations	2,439	2,156	1,479	2,019
Number of Municipalities	848	630	573	625
Mean of Dep. Variable	2.665	3.017	3.103	3.124

Notes: The coefficients are reported. Standard errors, clustered at the municipality level, are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Panel A includes year fixed effects and monitoring station fixed effects, while Panel B includes basin-year fixed effects and monitoring station fixed effects. Mean dependent variables are the mean of BOD values before municipal mergers started in our sample (before 2001) in each specification.

Appendix

Impact of Municipal Mergers on Pollution Control:
Evidence of River Pollution in Japan

Kazuki Motohashi   Michiyoshi Toya

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A Additional Figures

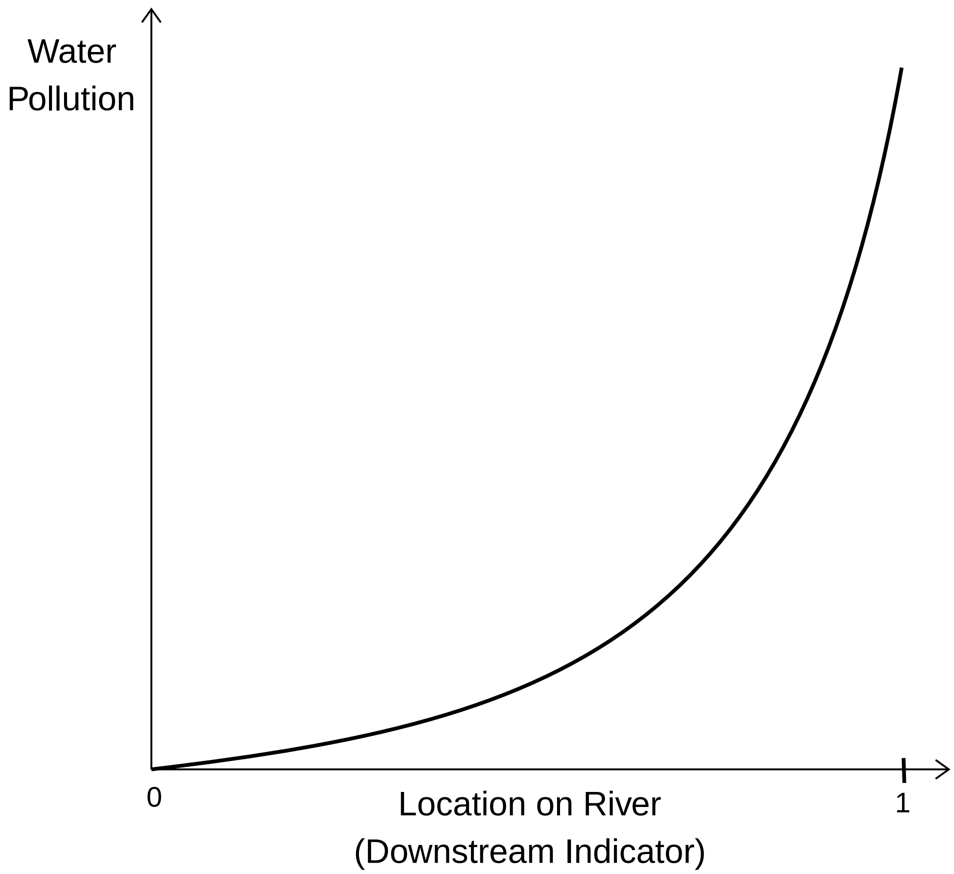

Figure A1: Prediction of Negative Externality Theory

Notes: This figure shows a convex relationship between a downstream indicator and water pollution implied by the negative externality theory of Lipscomb and Mobarak (2016).

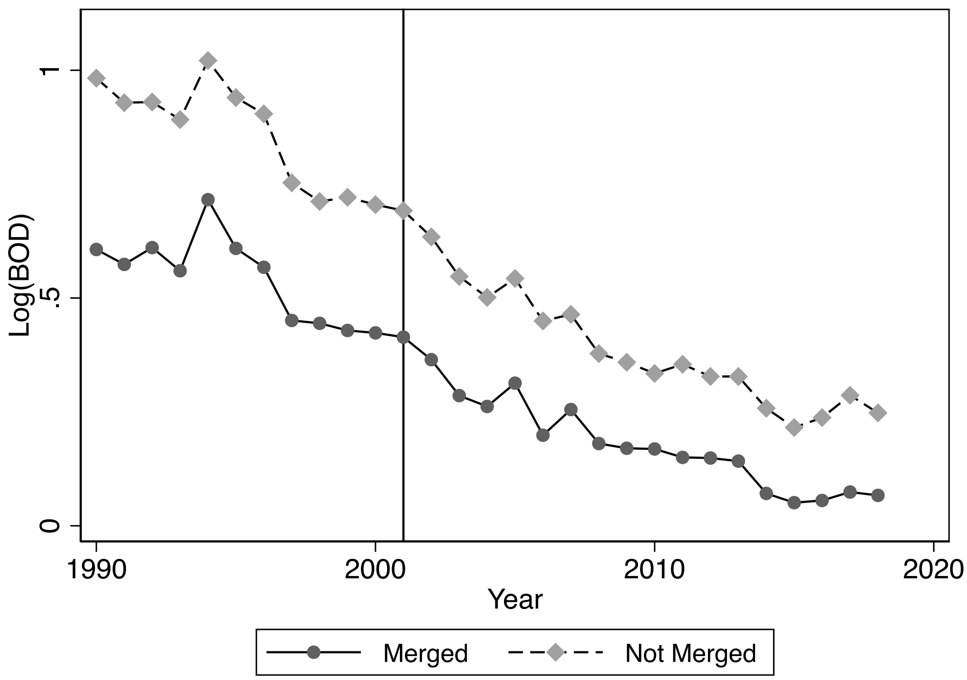

Figure A2: Trends of Logarithms of BOD Values in Merged and Not Merged Municipalities

Notes: This figure compares the changes in the logarithms of average BOD values (mg/L) from 1990 to 2018 between the municipalities which experienced municipal mergers (Merged) and the municipalities which did not experience the mergers (Not Merged). The vertical in 2001 shows the year when the first municipal mergers took place in our sample.

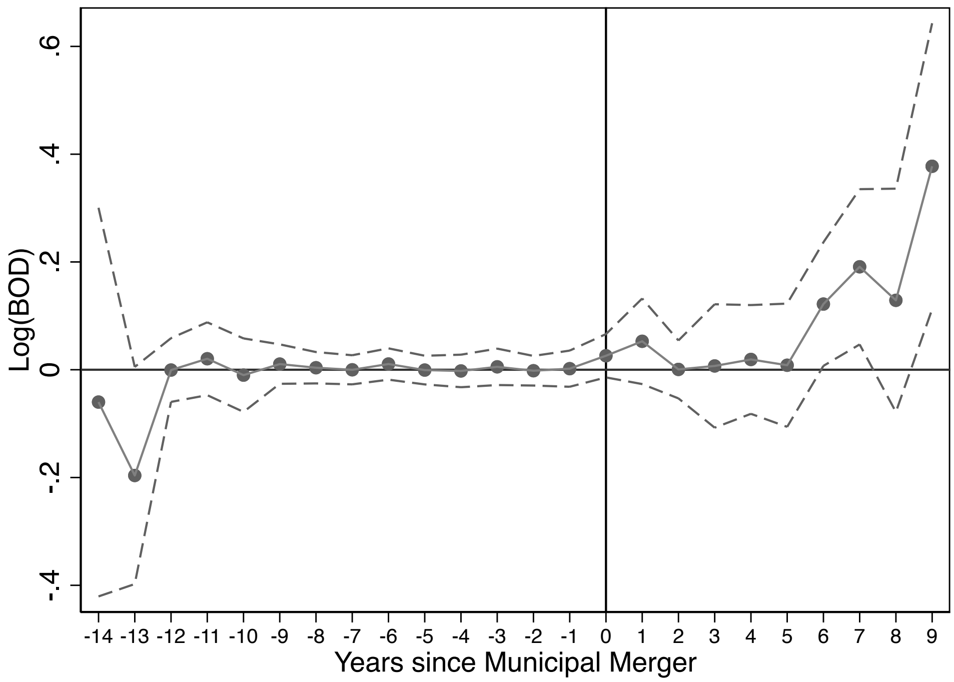

Figure A3: Event Study Results (Early Mergers versus Late Merger)

Notes: The sample is limited to monitoring stations in municipalities that have experienced mergers by dropping monitoring stations in municipalities that have never merged. This figure shows coefficients of the Callaway and Sant'Anna (2021) estimator. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level. This specification includes monitoring station fixed effects and year fixed effects.

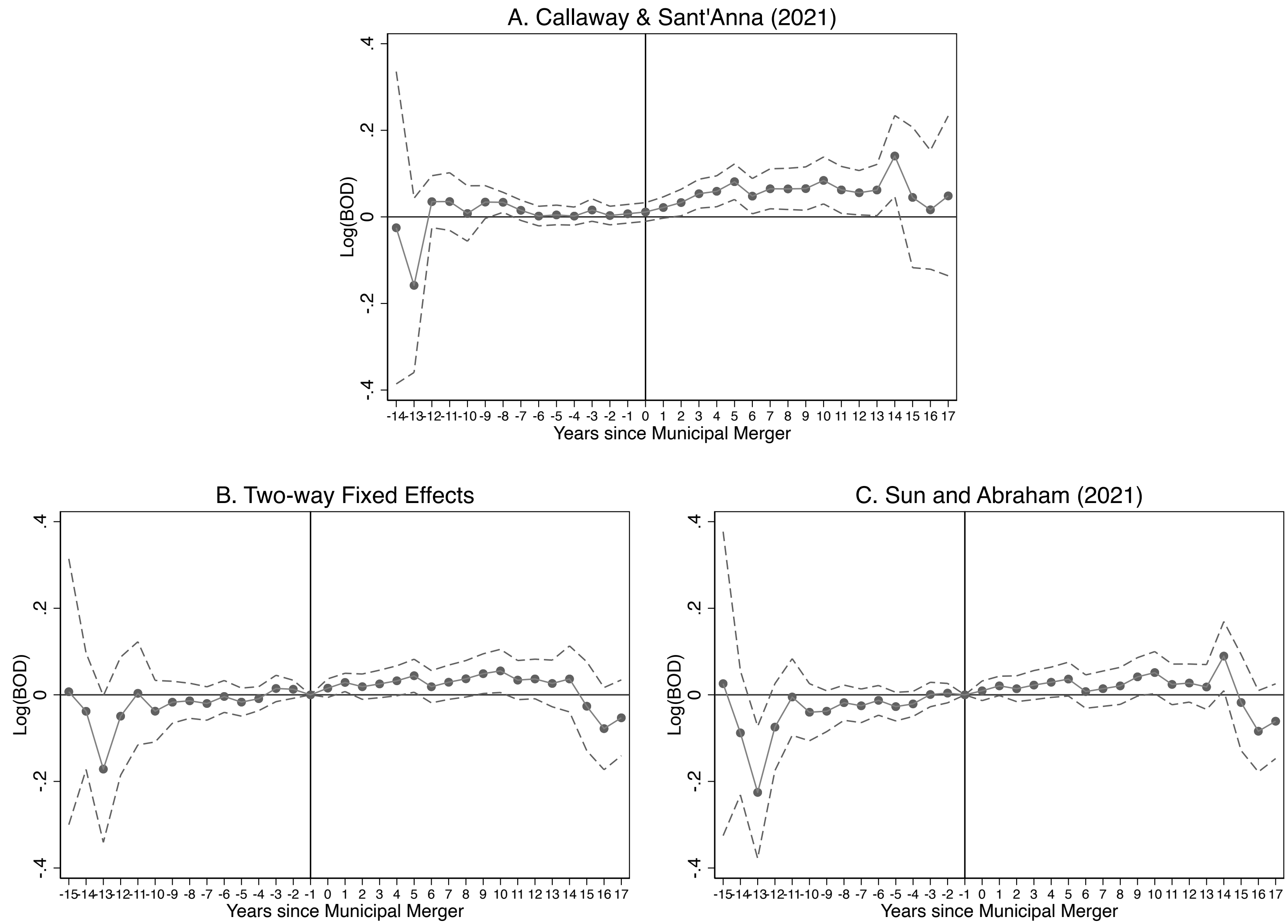

Figure A4: Event Study Results with Alternative Estimators

Notes: These figures compare the event study results among 3 alternative estimators. Panels A, B, and C show the coefficients of the Callaway and Sant'Anna (2021) estimator, two-way fixed effects specification, and the Sun and Abraham (2021) estimator, respectively. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level. Panel A includes monitoring station fixed effects and year fixed effects, while Panels B and C include monitoring station fixed effects and basin-year fixed effects.

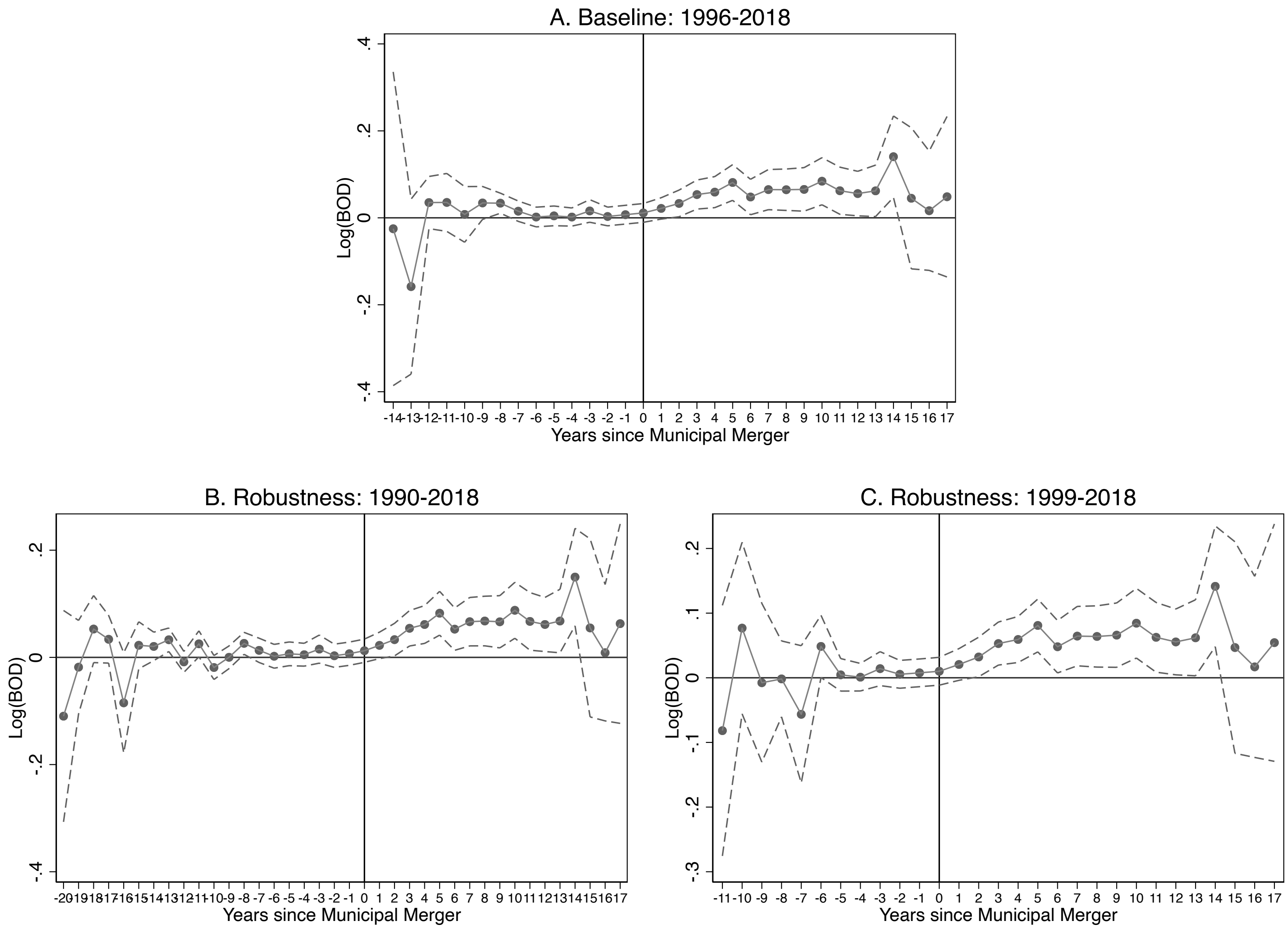

Figure A5: Event Study Results with Alternative Sample Periods

Notes: These figures show the coefficients of the Callaway and Sant'Anna (2021) estimator. Panel A is the baseline specification when the sample years are 1996-2018, while Panels B and C are shown for robustness checks when the sample years are 1990-2018 and 1999-2018, respectively. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level. All panels include monitoring station fixed effects and year fixed effects.

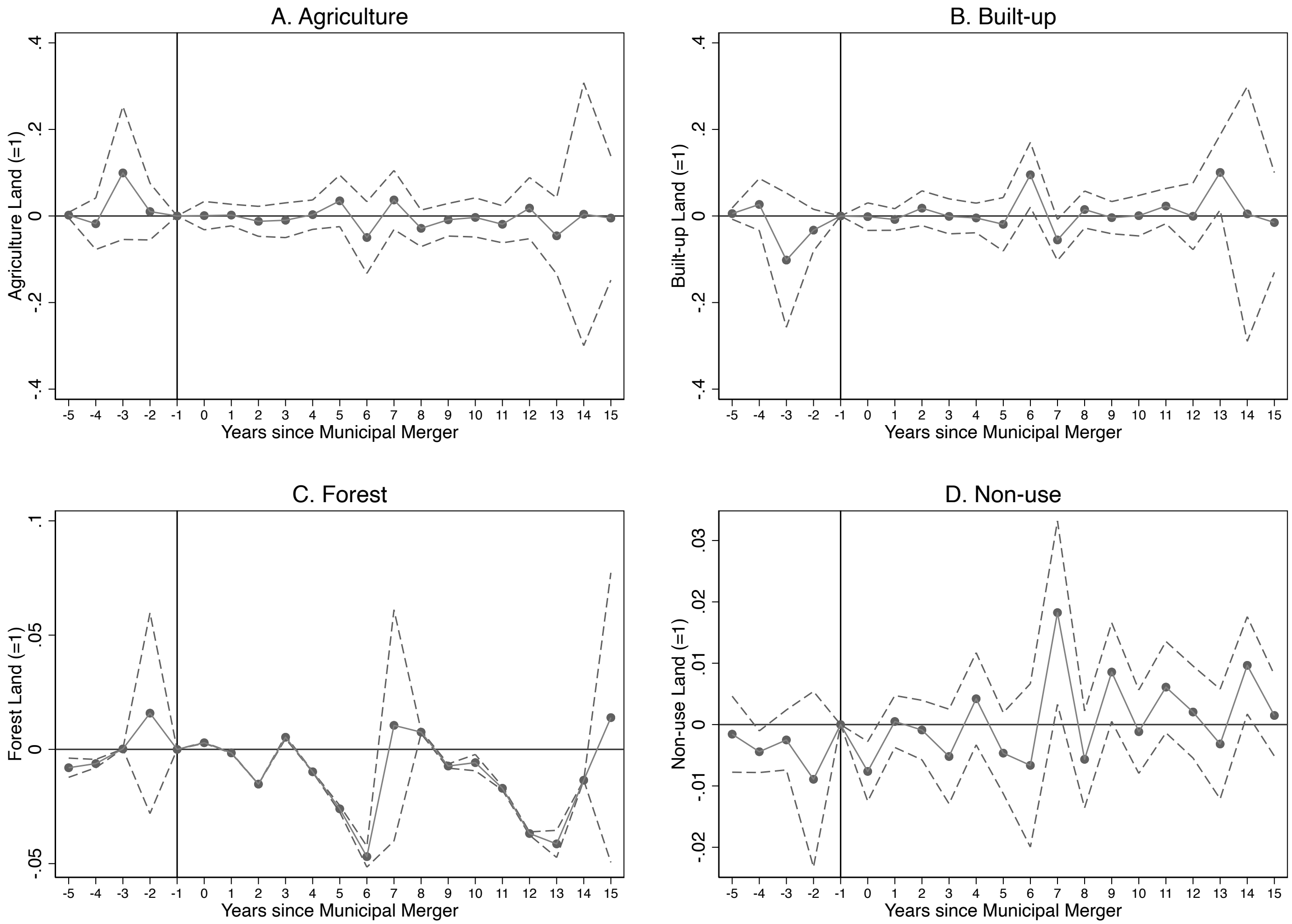

Figure A6: Event Study Results: Change in Land Use

Notes: These figures show the coefficients of the Sun and Abraham (2021) estimator. Four panels show results when the dependent variables are the indicator which takes one if the majority of land use within 150 meters from monitoring stations is the corresponding type. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level. All specifications include monitoring station fixed effects and basin-year fixed effects as a control. The coefficients of event time before -5 are not shown because most of them are dropped in the regressions.

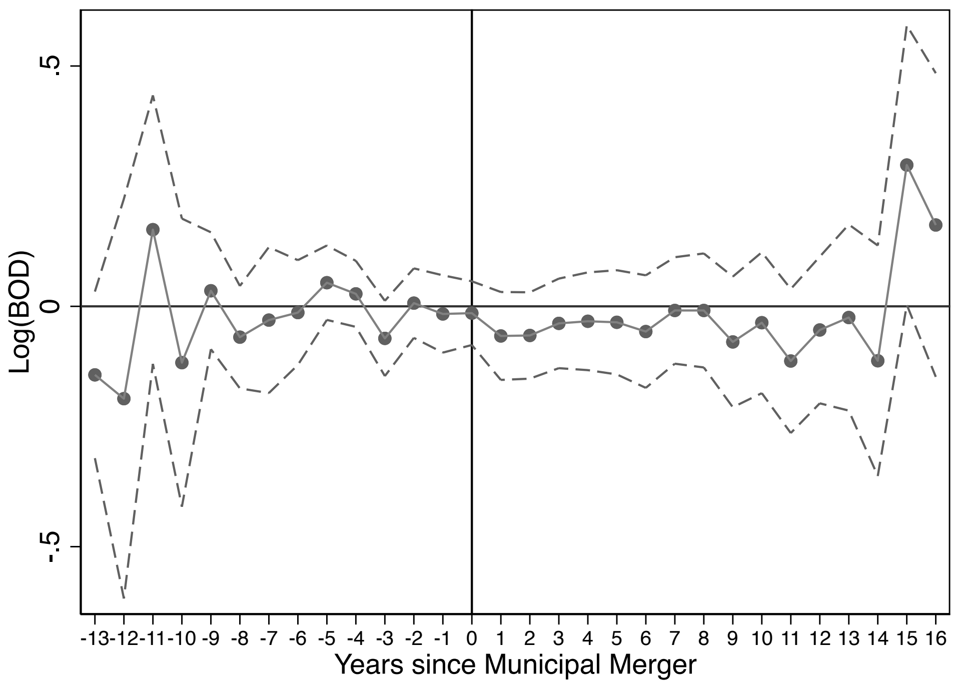

Figure A7: Event Study Results: Wastewater Treatment in Sewage Treatment Plants

Notes: This figure shows the coefficients of the Callaway and Sant'Anna (2021) estimator. The 95% confidence intervals are shown with dashed lines. This specification includes municipality fixed effects and year fixed effects.

B Additional Tables

Table B1: DID Results: The Effect on Water Quality (Early Mergers versus Late Mergers)

	Log(BOD)	
	(1)	(2)
Panel A: Callaway & Sant'Anna (2021) Estimator		
Merger (= 1)	0.026	-0.005
	(0.030)	(0.030)
Panel B: Two-way Fixed Effects		
Merger (= 1)	0.009	0.009
	(0.013)	(0.012)
Observations	44,689	38,856
R^2	0.879	0.885
Number of Stations	1,943	1,943
Number of Municipalities	443	443
Product Shipment Values	NO	YES
Population	NO	YES
Mean of Dep. Variable	2.259	2.259

Notes: The sample is limited to monitoring stations in municipalities that have ever merged. The coefficients are reported. Standard errors are in parentheses and clustered at the municipality level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Panel A includes year fixed effects and monitoring station fixed effects, while Panel B includes basin-year fixed effects and monitoring station fixed effects. Mean dependent variables are the mean of BOD values before municipal mergers started in our sample (before 2001) in each specification.

Table B2: DID Results: Change in Land Use

	Agriculture		Built-up		Forest		Non-use	
	(1) Dummy	(2) Share	(3) Dummy	(4) Share	(5) Dummy	(6) Share	(7) Dummy	(8) Share
Merger (= 1)	-0.009	-0.003	0.007	-0.002	-0.008	0.000	0.004	0.001
	(0.012)	(0.006)	(0.012)	(0.006)	(0.006)	(0.003)	(0.003)	(0.002)
Observations	13,738	13,738	13,738	13,738	13,738	13,738	13,738	13,738
R^2	0.866	0.953	0.884	0.955	0.920	0.976	0.689	0.763
Number of Stations	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829
Number of Municipalities	900	900	900	900	900	900	900	900
Mean of Dep. Variable	0.382	0.376	0.421	0.409	0.181	0.173	0.006	0.015

Notes: The coefficients are reported. Standard errors, clustered at the municipality level, are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Columns 1, 3, 5, 7 report results when the dependent variables are the indicator which takes one if the majority of land use within 150 meters from monitoring stations is the corresponding type. Columns 2, 4, 6, 8 report results when the dependent variables are the shares of the area of the corresponding type within 150 meters from monitoring stations. All regressions are based on two-way fixed effects specification, which include both basin-year fixed effects and monitoring station fixed effects. Mean dependent variables are the mean of dependent variables before municipal mergers started in our sample (before 2001) in each specification.

Table B3: DID Results: Wastewater Treatment in Sewage Treatment Plants

	Effluent Water Quality	Influent Water Quality (Placebo)
	(1)	(2)
	Log(BOD)	Log(BOD)
Panel A: Callaway & Sant'Anna (2021) Estimator		
Merger (= 1)	-0.043	0.039
	(0.047)	(0.034)
Panel B: Two-way Fixed Effects		
Merger (= 1)	-0.061	0.022
	(0.043)	(0.027)
Observations	5,733	5,733
R^2	0.577	0.541
Number of Municipalities	273	273
Mean of Dep. Variable	6.769	195.029

Notes: The coefficients are reported. Standard errors, clustered at the municipality level in Panel A, are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. This specification includes municipality fixed effects and year fixed effects. Mean dependent variables are the mean of BOD values before municipal mergers started in our sample (before 2001) in each specification.

C Data Appendix

C.1 Construction of River Distance

We construct two distance variables, U and D, based on the following steps.

1. We perform inverse distance weighting (IDW) interpolation on the river node point layer to create a 300-meter raster elevation layer, which is at a finer resolution than readily available Digital Elevation Models (DEMs) and is highly accurate along river paths.
2. We use the river polyline layer and the municipality boundaries layer and intersect them by point to obtain municipality entry/exit points of rivers.
3. We attach elevation information to both the "entry/exit point" layer and the monitoring station layer using the raster feature to point tool.
4. To reduce margins for error, we only focus on monitoring stations that are located within 2km of the river polyline by conducting spatial queries.
5. We build a network based on the river polyline layer and perform a "find the closest facility" analysis to pick the six closest border boundary points along the river for each monitoring station and obtain distances for these routes.
6. We use the elevation information to determine whether each selected border boundary points are upstream or downstream of the monitoring station, after which we find the closest upstream and downstream border boundaries for each monitoring station and finally obtain values for U and D.

C.2 Construction of Land Use Measures

We compute the numbers of pixels corresponding to the following four land use classifications within the 150-meter buffer of each monitoring station.[13] Then, we compute the share of pixels for each classification and the binary land use indicator of whether each classification has the largest number of pixels.

1. Agriculture: rice paddies and other agricultural land
2. Forest: areas with dense perennial vegetation
3. Built-up: residential or urban areas where buildings are densely built up, and athletic fields, airports, racetracks, baseball fields, schools, and harbor areas
4. Non-use: wasteland, wasteland, cliffs, rocks, perennial snow, wetlands, and mined land

[13] Although the original data have finer land use classifications, we regrouped them into four classifications for analysis. We also dropped the pixels corresponding to sea and river water, road, railroad, and golf course.