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

Kazuki Motohashi† Michiyoshi Toya‡
Hitotsubashi University METI

Click here for the most recent version

This version: July 18, 2024

Abstract

Municipal mergers, aimed at improving local public services, can not only improve environmental quality by internalizing pollution spillovers, but also weaken pollution control due to coordination costs and political power imbalances. We examine the environmental effect of municipal mergers by exploiting the staggered implementation of Japan's mergers, which reduced municipalities by half. We find that municipal mergers increase river pollution by 5.5%, persisting for 14 years. These effects are driven by equal-footing mergers with high coordination costs and incorporated municipalities with little political power. We find no evidence supporting alternative mechanisms, including changes in pollution spillover patterns and land use.

JEL: D73, Q52, Q53, R11, R58

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

*For helpful comments, we thank Shunichiro Bessho, Ujjayant Chakravorty, Molly Elder, Kyle Emerick, Tsuyoshi Goto, Haruaki Hirota, Takatoshi Ito, Marc Jeuland, Cynthia Kinnan, Yoshifumi Konishi, Etienne Makdissi, Nobuhiko Nakazawa, Fumio Ohtake, Shinsuke Tanaka, Takanao Tanaka, Kensuke Teshima, Duc Anh Tran, Ulrich Volz, Akio Yamazaki, and Jie Yang; the seminar participants at J-TREE/Aoyama Gakuin University, Tufts University, Hitotsubashi University, Musashi University, and Kansai Labor Workshop; the conference participants at 2020 Berkeley/Sloan Summer School in Environmental and Energy Economics, 2020 SEEPS Annual Conference, 2022 AAEA Annual Meeting, Fifth Annual Conference of the Japan Economy Network, LSE Environment Day, 2023 JEA Autumn Meeting, and 2024 AERE Summer Conference. We also thank many local government officers for helpful discussions on the consequences of municipal mergers in Japan. This study is supported by Grants-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (grant JP24K16353). The views expressed in this paper are those of the authors and should not be attributed to the Ministry of Economy, Trade and Industry, Japan.

†Hitotsubashi Institute for Advanced Study, Hitotsubashi University (e-mail: kazuki.motohashi@r.hit-u.ac.jp).

‡Ministry of Economy, Trade and Industry, Japan (e-mail: toya-michiyoshi@meti.go.jp).

1 Introduction

The optimal level of decentralization, i.e., power distribution between local and central governments, has long been debated in academics (Tiebout, 1956; Oates, 1972; Besley and Coate, 2003). Under decentralized governance, competition among municipalities is expected to ensure Pareto-efficient allocation of local public services. However, this allocation can become inefficient when local public services have spatial spillover effects on neighboring municipalities without inter-jurisdictional coordination (Tiebout, 1956; Oates, 1972; Jannin and Sotura, 2020). One key example is the negative externality of weakened pollution control on neighboring municipalities' environmental quality. In accordance with this argument, an increase in local jurisdictions under decentralized governance has recently been shown to degrade environmental quality in developing countries (Burgess et al., 2012; Lipscomb and Mobarak, 2016). However, there is little research on the effect of the opposite scenario—a decrease in local jurisdictions, which is more prevalent in developed countries—on environmental quality.

We examine how municipal mergers, in which 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 approximately 20 developed countries (including Germany, France, Japan, and the United States) and are expected to increase in the future due to declining birth rates and aging populations, especially in rural areas. The aims of municipal mergers are 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 that exist across pre-merger municipalities. However, coordination costs and unbalanced political power among pre-merger municipalities can hamper the pollution control efforts of merged municipalities, leading to the deterioration of environmental quality. The relationship between municipal mergers and environmental quality seems ambiguous and deserves careful empirical examination.

We test the relationship between municipal mergers and river water quality in the context of Japan's municipal mergers from the late 1990s to the 2000s during the "Heisei" era. These "Great Heisei Mergers" in Japan have unique characteristics that allow us to investigate their environmental effect effectively. First, municipal mergers are implemented over time. We exploit this staggered implementation of municipal mergers as the setting of a quasi-natural experiment to examine the causal effects of mergers on river pollution. Second, these mergers drastically reduced the number of municipalities by approximately 50%, from 3,238 in 1998 to 1,725 in 2012 across Japan. The setting of these large-scale, nationwide municipal mergers increases the external validity of our results. Third, the primary objective of these municipal mergers was to strengthen the administrative and financial foundations of municipalities for local public service provision, rather than being driven by specific policy agendas like pollution control. This context allows us to examine the unintended consequences of mergers on water pollution with less concern about the endogenous timings of municipal mergers. We use 30 years of water quality panel data from 3,000 monitoring stations to examine the effect on water quality.

Exploiting the staggered implementation of municipal mergers, we investigate the causal effects of municipal mergers on river water quality. We adopt difference-in-differences (DiD) and event study designs, comparing the outcomes of municipalities that merged and never-merged municipalities, 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 bias from the bad comparison between municipalities that merged early and late (Goodman-Bacon, 2021). Thus, we adopt recently developed alternative estimators (Callaway and Sant'Anna, 2021; Sun and Abraham, 2021) that are robust to this concern as a baseline specification.

Contrary to the negative externality narrative, we find that municipal mergers increase river pollution, with this negative effect lasting for 14 years. Specifically, the mergers result in a 5.5% increase in the Biochemical Oxygen Demand (BOD) value, a key indicator of water pollution. Although BOD levels have generally declined across Japan, our findings suggest that municipal mergers offset this trend of water quality improvement by 12.5%. This pollution effect translates into an increase in narrow compliance cases of environmental standards by 10% without increasing the violations, suggesting weaker pollution control efforts.

The causality of our DiD results hinges on the assumption that treated and untreated municipalities would move in parallel in the absence of mergers. The plot of water quality trends for merged and never-merged municipalities shows that they appear to move in parallel during the pre-merger period. The event study analysis also shows no differential effects on water quality before the mergers. The baseline results remain robust across alternative specifications that limit our sample to comparable municipalities. This includes a specification that uses only the variation in merger timings among merged municipalities, and another using a subset of municipalities matched by industry compositions and financial conditions.

Heterogeneity analyses suggest that the mechanisms driving the negative effect 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 river pollution because the poorer integration of local public services following mergers can weaken pollution control efforts (coordination costs mechanism). We find that pollution increases for "equal-footing" mergers that entail higher coordination costs, but not for "incorporating" mergers with lower coordination costs.[1] Second, in the case of incorporating mergers, we examine whether the smaller, incorporated municipalities with less political power experience a greater increase in river pollution than the larger, incorporating municipalities with greater political power. The mayor of the larger, incorporating municipality retains her position post-merger and may prioritize pollution control in her original area, weakening pollution control in the areas of smaller, incorporated municipalities (political economy mechanism). We find that incorporated municipalities experience increased river pollution, while incorporating municipalities do not experience a change in river pollution.

As for the source of river pollution, we find suggestive evidence that a slowdown in sewer investments following mergers increases untreated domestic wastewater from households. Municipalities are primarily responsible for controlling sewage by constructing and operating sewage treatment plants. By conducting the same DiD analysis on the municipality-level panel of sewer coverage, we find that municipal mergers decelerate sewer investments for up to five years following the mergers. This negative effect on sewer coverage is primarily observed in "equal-footing" mergers, which is consistent with our baseline results. These findings suggest that a greater volume of domestic wastewater remains untreated in municipalities that have undergone mergers, consequently leading to heightened river pollution.

Consistent with the baseline results, we do not find spatial patterns supporting the negative externality theory, which would predict the internalization of pollution spillovers. The negative externality theory predicts that pollution increases as a river approaches the downstream border of a municipality because there is less harm caused to people within that municipality by polluting farther downstream (Lipscomb and Mobarak, 2016). We test this theory by examining how changes in the distance from water quality monitoring stations to their closest municipality borders affect the water quality at these stations. We find that pollution levels do not change as a river flows downstream within a municipality, a pattern inconsistent with the negative externality theory.

We do not find evidence supporting another alternative mechanism, namely changes in land use, which can lead to increased river pollution by generating new pollution sources without altering pollution control efforts. Municipal mergers can change land use patterns,

[1] "Equal-footing" mergers involve creating new cities between municipalities of similar size and electing a new mayor, where coordination among pre-merger municipalities is more challenging. Conversely, "incorporating" mergers involve a larger municipality incorporating smaller municipalities, where the larger municipality typically takes the lead in policy-making, leading to smoother coordination.

such as expanding industrial and residential areas through increased economic activities. This shift in land use could generate industrial and domestic wastewater, thereby escalating river pollution. However, we do not find effects on various land use classifications near water quality monitoring stations, including agriculture areas, built-up areas, and forests.

Our findings highlight that municipal mergers can have unintended negative effects on environmental quality due to coordination costs and political power imbalances. With the expectation of increased mergers due to population decline in many countries, the potential for such negative effects should be carefully considered. Moreover, weakened local public service provision, resulting from coordination costs and political economy mechanisms, could extend to other policies, highlighting the importance of careful consideration of these mechanisms in future mergers.

Our paper makes three contributions. First, we contribute to the literature on decentralization and fiscal federalism by showing that consolidations of local jurisdictions may not mitigate pollution spillovers, 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; instead, mergers increase river pollution in Japan. We show alternative underlying mechanisms, i.e., weaker pollution control due to coordination costs and political power imbalances, which should be newly considered in the discussion of decentralization.

Second, we contribute to the literature on municipal mergers by showing longer-run negative environmental effects. Most previous studies investigate the fiscal and macroeconomic effects of municipal mergers on local public finance (Hinnerich, 2009; Reingewertz, 2012; Moisio and Uusitalo, 2013; Blesse and Baskaran, 2016; Hirota and Yunoue, 2017; Miyazaki, 2018; Pickering et al., 2020), economic activity (Egger et al., 2018), and infrastructure expenditure (Li and Takeuchi, 2023), as well as determinants of municipal mergers (Weese, 2015). Instead, we focus on the environmental effects 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 firms' emissions. We complement this paper in two ways: (i) we show that municipal mergers can instead 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 longer-run effects of municipal mergers, revealing that their negative effect persists for up to 14 years.[2]

[2] Another relevant paper is Mizunoya et al. (2021), which examined the effect of municipal mergers

Third, we contribute to the literature on water pollution by providing the first causal estimates of the effects of municipal mergers on water quality. Past studies show that water pollution levels are affected by political boundaries (Sigman, 2002; Helland and Whitford, 2003; Sigman, 2005; Kahn et al., 2015; Lipscomb and Mobarak, 2016), political incentives (Kahn et al., 2015; He et al., 2020), and sanitation investments (Motohashi, 2023). 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., municipal mergers, can also cause water pollution due to weaker control efforts.

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 Mergers" in Japan

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

The primary objective of the "Great Heisei Mergers" was to strengthen the administrative and financial foundations of municipalities for local public service provision. Municipalities, especially those in rural areas, were grappling with challenges such as dwindling birth rates, aging and declining populations, and fiscal difficulties following the burst of the bubble economy in the early 1990s. Municipal mergers were envisaged as a means to rejuvenate these struggling municipalities. Since these mergers were not implemented to address specific policy agendas like water pollution control, our study reveals an unintended effect of municipal mergers on pollution.

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 municipal mergers.[3] The 1995 revision announced that the purpose of the Act was to push municipal mergers

on watershed management of the Lake Kasumigaura Basin in Japan using the simulation of a dynamic expanded input-output model. This paper is a case study of a specific 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.

[3] The Act had been in place since 1965, originally focusing on facilitating merger procedures.

forward and introduced a five-year preferential treatment in local tax allocation for merged municipalities. The 1999 revision further strengthened these financial incentives by extending the period of preferential treatment in local tax allocation to 10 years. Furthermore, merged municipalities were allowed to issue "Special Provision Bonds" for up to 10 years after the mergers to fund public projects included in their merger proposals. These municipalities were required to pay back only 30 percent of the amount borrowed for these bonds, and the central government paid the remaining 70 percent. Thus, the bonds effectively acted as a 70 percent public project subsidy for merged municipalities. The government initially announced that, to be eligible for these benefits, municipalities had to complete merges by March 2005. However, this was extended by one year to March 2006. providing additional time for municipalities struggling to complete mergers by the original deadline.

Thanks to the strong push from these financial incentives, the number of municipal mergers in Japan increased over time, starting in the late 1990s. As illustrated in Figure 2, the "Great Heisei Mergers" were implemented in a staggered manner. The first merger occurred in 1999, coinciding with the strengthening of financial incentives. However, the number of mergers remained low for the next few years. The vast majority of mergers took place between 2004 and 2006. This not only reflects the time required to complete the merger process but also indicates a bunching behavior by municipalities to meet the initial and final deadlines of 2005 and 2006, respectively. Municipal mergers then continued until 2011. Moreover, the "Great Heisei Mergers" were not a forced policy by the central government, leading to a variation between municipalities that underwent municipal mergers and those that did not.[4] We exploit the staggered implementation of municipal mergers in our DiD and event study analyses.

Municipal mergers are officially categorized into two types: "equal-footing" mergers and "incorporating" mergers. The former type involves mergers on an equal-footing, typically between municipalities of similar size, with a new name assigned to the merged municipality. Following the completion of the merger, a mayor for the new municipality is newly elected in the subsequent election. In our sample, 74% of the total mergers are classified as "equal-footing" mergers. Conversely, "incorporating" mergers involve a larger municipality incorporating smaller ones, with the resulting municipality retaining the name of the larger, incorporating municipality. The mayor of the incorporated municipality continues as the

[4] The autonomy of municipalities was respected. Municipalities had a choice to negotiate mergers and select their negotiation partners. The merger process involved several 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 following final voting by the involved municipalities and administrative approval by the prefectural governor and the Minister of Internal Affairs and Communications.

mayor of the newly created municipality, while mayors of the incorporated municipalities lose their positions post-merger. These “incorporating” mergers account for 26% of the total mergers in our sample.

2.2 Water Quality and Pollution Control in Japan

Ambient water quality in Japan is monitored under the Environmental Quality Standards for Water Pollution. These standards serve as non-mandatory policy targets, which means that municipalities can weaken pollution control following municipal mergers with less concern about the consequences of violation.[5] Among the multiple water quality indicators monitored in these standards, we focus on BOD as the primary outcome, although we also adopt other indicators, including dissolved oxygen and suspended solids, as robustness checks. BOD measures the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present, capturing the overall level of water contamination from various sources such as domestic, agricultural, and industrial wastewater. A higher level of BOD values indicates a higher level of water pollution. The Environmental Quality Standards set BOD limit values for river water quality from 1 to 10 mg/L, differentiated by the designated usage categories assigned to each river location.[6] The designation of usage categories is carried out by the Minister of the Environment and prefectural governors, rather than by municipal mayors.

Under these environmental quality standards, water quality in Japan has generally improved over time. The average BOD values in rivers declined from 3.6 mg/L to 1.4 mg/L from 1990 to 2018 in our sample. Therefore, 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 types: (i) domestic wastewater (sewage), (ii) industrial wastewater, and (iii) agricultural wastewater. Our conversations with local government officers in Japan indicate that municipalities primarily control pollution from domestic wastewater. Domestic wastewater is typically treated in sewage treatment plants, which are constructed and operated by the municipalities themselves. Conversely, municipalities have limited roles in controlling industrial and agricultural

[5] The average violation rate is approximately 20% during the pre-merger period, indicating that violations are not rare (Table 1). The Environmental Quality Standards for Water Pollution differ from effluent standards under the Water Pollution Prevention Act. The latter are mandatory requirements imposed on factories and sewage treatment plants to regulate the quality of their effluents.

[6] There are six designated usage categories, each with specific BOD limit values: AA, A, B, C, D, and E, requiring limits of 1, 2, 3, 5, 8, and 10 mg/L, respectively. The categories with lower limit values are defined as areas where water can be supplied as drinking water after treatment and is clean enough to support fish. In contrast, the categories with higher limit values are defined as areas where the water is only suitable for industrial and agricultural use.

wastewater. In the case of industrial wastewater, effluent standards for factories are enforced at the prefectural level through reporting and inspections. While designated municipalities under the Water Pollution Prevention Act are entitled to enforce these standards on behalf of prefectures, as of 2018, only 111 municipalities have this designation.[7] Therefore, most municipalities do not play a significant role in controlling industrial wastewater. Furthermore, agricultural wastewater is a non-point source, diffused over large areas due to factors such as precipitation. This diffusion makes it more challenging for municipalities to control agricultural wastewater through their policies.

2.3 How Do Municipal Mergers Affect Water Quality?

Municipal mergers, and more broadly, changes in the number of local jurisdictions, can affect water quality through three main mechanisms. First, past studies emphasize the role of pollution spillovers across jurisdictions, which would predict an improvement in environmental quality post-merger (Lipscomb and Mobarak, 2016; Wang and Wang, 2021). Second, in contrast, coordination costs and unbalanced political power among pre-merger municipalities may hamper the pollution control efforts of merged municipalities, leading to the deterioration of environmental quality. Third, changes in land use could lead to increased water pollution by generating new pollution sources.

One mechanism often emphasized in the past literature is the role of pollution spillovers or negative externalities across jurisdictions, which would predict a positive effect of municipal mergers on water quality. Lipscomb and Mobarak (2016) developed a framework of negative externality theory, where pollution within a municipality located higher upstream on a river adversely affects other municipalities located downstream. Based on this framework, they showed that an increase in the number of districts along a river path, due to district splits, worsens water pollution. Based on their model, we may expect that municipal mergers, which conversely decrease the number of municipalities along a river path, would improve water quality in rivers by internalizing pollution spillovers.[8]

One of the key predictions of the negative externality theory in Lipscomb and Mobarak (2016) is that pollution increases exponentially as the river flows downstream within a municipality. Following Lipscomb and Mobarak (2016), consider a municipality that 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; thus, 0 and 1 are the upstream and downstream municipality borders, respectively. A local governor

[7] The designated municipalities tend to be large municipalities that have not undergone municipal mergers.

[8] Wang and Wang (2021) shows results consistent with this prediction in the case of air pollution, demonstrating that township mergers reduce firm-level emissions in China.

chooses how much economic activity to pursue and, consequently, how many pollutants to emit at each point within her municipality. Because the local governor aims to minimize the negative effect of emissions on her population and does not consider the effect on people living in other municipalities, including those downstream, she would choose to focus most of the economic activity and emissions near the downstream border, at point 1. Most of her municipality's population, living upstream of this point, would not be adversely affected by emissions occurring near the downstream border. We examine the presence of such spatial patterns to test the validity of the negative externality mechanism in Section 6.4.[9]

Contrary to the negative externality mechanism, two additional mechanisms, namely the coordination cost and political economy mechanisms, can increase water pollution by weakening municipalities' pollution control efforts.

First, municipal mergers with high coordination costs can weaken pollution control efforts, resulting in increased water pollution (coordination costs mechanism). This mechanism is suggested by the post-merger survey indicating difficulties and delays in policy coordination as negative consequences of the "Great Heisei Mergers" (NATV, 2008). According to a JMRC (2008) survey, which surveyed 416 municipalities, 44% pointed out that the continuation and coordination of projects among pre-merger municipalities remained an issue. If coordination costs among pre-merger municipalities are high, a newly created municipality faces difficulties in reformulating local public services, which were previously managed separately by each pre-merger municipality, into coherent new services. Therefore, the pollution control efforts in merged municipalities with higher coordination costs may be weakened. The levels of these coordination costs can differ by the types of municipal mergers. "Equal-footing" mergers, which involve creating new cities typically between municipalities of similar size and electing a new mayor, are expected to face greater challenges in coordinating services. Conversely, "incorporating" mergers, where the mayor of the larger, incorporating municipality retains her position and takes the lead in policy-making, are expected to have limited coordination costs. Therefore, the coordination costs mechanism suggests that water pollution increases more substantially in the case of "equal-footing" mergers with higher coordination costs than in "incorporating" mergers with lower coordination costs due to the weaker pollution control.

Second, municipal mergers can have differential effects on water pollution depending on the political power of the involved municipalities, especially in the case of incorporating mergers (political economy mechanism). In such mergers, the mayor of the larger, incorporating

[9] Another associated prediction is that there is a structural break in the slope of the pollution function at the municipality border. This prediction means that emissions are high just upstream of a municipality border but are low just downstream of a municipality border.

municipality retains her position, while the mayors of smaller, incorporated municipalities lose their positions. Post-merger, the mayor of the incorporating municipality may prioritize pollution control in her original area because she has an electoral base there. Similarly, the council members of the new municipality are likely to consist mainly of members from the incorporating municipality. Indeed, the post-merger survey notes that the voices of people living in incorporated municipalities were not adequately reflected after mergers (NATV, 2008). According to a JMRC (2008) survey, 54% of the 416 municipalities surveyed pointed out that the widening disparity between central and peripheral areas is a concern resulting from municipal mergers. Consequently, pollution control efforts in the areas of incorporated municipalities may be weakened post-merger. Thus, the political economy channel suggests that incorporated municipalities can experience larger water pollution than incorporating municipalities.

Another mechanism could be changes in land use, which might lead to increased water pollution by generating new pollution sources without altering pollution control efforts. Municipal mergers can increase economic activities, as shown by Egger et al. (2018), potentially leading to changes in land use. Such changes might involve converting forest and agricultural areas near rivers into industrial and residential areas. Consequently, this shift in land use could result in an increase in sources of water pollution, namely industrial and domestic wastewater, thereby escalating river pollution.

3 Data

We combine administrative datasets on ambient water quality and municipal mergers to examine the effects of municipal mergers on water quality.

3.1 Water Quality

The main outcome variable is water quality. We use data from water quality monitoring stations provided by the Ministry of Environment, Government of Japan.[10] These data include yearly average water quality indicators, measured at monitoring stations across Japan. As explained in Section 2.2, we use the yearly average BOD as a representative water quality outcome in the analysis. BOD is a standard water quality measure monitored under the Environmental Quality Standards for Water Pollution in Japan.

Our analysis uses balanced panel data from 3,309 water quality monitoring stations along

[10] 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 compiles and publicizes these reported data.

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. Exploiting the long panel of thousands of stations 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 each monitoring station is located.

3.2 Municipal Merger

The key treatment variable in our analysis is an indicator of whether a municipal merger occurred each year in the municipality where each monitoring station is located. We obtain data on the timing of municipal mergers and on the involved municipalities from the Ministry of Internal Affairs and Communications.

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 in the analysis of coordination costs and political economy mechanisms.

3.3 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 also 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.[11]

3.4 Data Matching and Sample Construction

We match water quality and municipal merger datasets by using the post-merger municipality boundary data in 2020 provided by the Ministry of Land, Infrastructure, Transport, and Tourism. We first use this boundary data alongside the GPS coordinates of monitoring stations to identify the names of the post-merger prefectures and cities where these stations are located. Subsequently, we match water quality and municipal merger data based on the names of these prefectures and cities. Similarly, all other data, including information on water basins and various municipality characteristics, are merged based on the post-merger names of prefectures and cities.

After data matching, we construct a balanced panel of approximately 3,000 water quality monitoring stations in approximately 1,000 municipalities from 1990 to 2018. The baseline specification uses panel data starting in 1996, five years before the first municipal merger, observed in 2001 in our dataset. However, we also conduct robustness checks by using alternative sample periods, (i) 1990-2018 and (ii) 1999-2018, as discussed in Section 5.2.

3.5 Summary Statistics and Water Quality Trends

Summary statistics of all variables in the pre-merger period (before 2001 in our sample) are shown in Table 1. In this period, merged municipalities (treatment group) differed from never-merged municipalities (control group) in BOD levels, product shipment values, agricultural output values, financial capability index, sewer coverage, and land use. Specifically, these differences show that merged municipalities were more focused on the agricultural sector than the manufacturing sector and had weaker financial conditions and better water quality before the mergers.

Although the baseline level differences are observed, we rely on the assumption of parallel trends in our DiD design to derive causal estimates. A comparison of the trends of BOD values between the merged and never-merged municipalities encouragingly shows signs of parallel pre-trends (Figure 4).[12] These parallel pre-trends are formally tested in the event study design in Sections 4.1 and 5.1.

Moreover, as shown in Figure 4, BOD levels decreased in both the merged and never-merged municipalities in the post-merger period. However, the observed smaller decrease in

[11] The 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 better financial conditions for a local government.

[12] The same pattern is also observed when plotting the trends of logarithms of BOD values, which are used as outcomes in the analysis (Appendix Figure A2).

BOD levels in the merged municipalities suggests a negative effect of municipal mergers on water pollution. This differential decrease in BOD levels is examined in our DiD analysis in subsequent sections.[13]

4 Empirical Strategy

We examine the causal effect of municipal mergers on water quality by adopting a DiD design that exploits variations in merger timings. Simple ordinary least squares (OLS) estimates are subject to bias due to potential endogeneity that comes from reverse causality and omitted variables. Municipal mergers could be implemented to reduce water pollution in these municipalities.[14] Additionally, spurious correlations may arise from omitted unobservables, such as different priorities on water pollution control across municipalities. To address this potential endogeneity, we adopt a DiD design, as explained in the next section.

4.1 Difference-in-Differences Design

We adopt the following DiD regression with two-way fixed effects:

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

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 where station i is located. $X_{i,t}$ is a vector of control variables, including a municipality-level economic indicator (product shipment values) and population, that can affect both water quality and the likelihood of municipal mergers. Given the "bad control" concerns of these variables, which may be affected by municipal mergers, we control for their baseline values by interacting them with year dummies as a robustness check.[15] 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 potentially influenced by changes in regulations, which may vary across river basins, we include basin-by-year fixed effects ($\theta_{b,t}$). Lastly, standard errors are clustered at the municipality level because the

[13] The water quality trends appear to be converging towards a value of 1. This convergence might introduce contamination in the effects, especially in later periods. Nonetheless, in the short term, where convergence poses less of an issue, we find significant effects, as demonstrated by the event study results in Section 5.

[14] However, this is highly implausible, as municipal mergers are not implemented to address specific policy agendas, including water pollution control, as discussed in Section 2.1.

[15] Specifically, we use the average of these values in the pre-merger periods (from 1996 to 2000).

variation in municipal mergers is observed at the municipality level.

The coefficient of interest is β_{DID}. β_{DID} could be negative if municipal mergers decrease river pollution by internalizing pollution spillovers, as the negative externality theory would predict. Conversely, β_{DID} could be positive if municipal mergers increase river pollution due to coordination costs and unbalanced political power among pre-merger municipalities.

To examine pre-trends and the dynamic evolution of the treatment effects, we also adopt the event study design. The DiD analysis hinges on the parallel trends assumption between treated and untreated municipalities. We empirically test this parallel trends assumption in the following event study regression. This regression also allows us to examine the long-run dynamic effects of municipal mergers.

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

where $Merger_{\tau,i}$ is an indicator for each year τ relative to the timings of municipal mergers, where τ is zero in the year that the municipal merger was implemented. τ ranges from -14 to 17 in our baseline sample. For monitoring stations located in never-merged municipalities, all $Merger_{\tau,i}$'s are set equal to zero. $\tau = -1$ is set as a reference year.

The coefficients of interest are β_τ's. β_τ's from $\tau = -14$ to $\tau = -2$ are examined to test the parallel pre-trends. From $\tau = 0$ to $\tau = 17$, β_τ's capture the dynamic evolution of the treatment effects in the short and long runs for up to 17 years.

In our analysis, we exploit the staggered implementation of municipal mergers. Thus, the estimates of β_{DID} and β_τ's in the regressions 1 and 2 are weighted averages of all possible two-group/two-period DiD estimates (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 the late years (control group).

Recent literature indicates that standard two-way fixed effect estimates can be subject to bias in the case of the staggered DiD design. The comparison between the early and late merger municipalities becomes problematic in the presence of heterogeneous treatment effects across treatment cohorts and time. This comparison leads to negative weights, thus causing bias (Goodman-Bacon, 2021).

To obtain unbiased estimates, we adopt alternative estimators that are robust to negative weights as the baseline specification. Specifically, we adopt the Callaway and Sant'Anna

(2021) estimator, where we essentially include year fixed effects instead of basin-by-year fixed effects.[16] We also use the Sun and Abraham (2021) estimator, which is another alternative estimator robust to negative weights, for a robustness check in Section 5.2, and to analyze the effects on land use in Section 6.5.

5 Results

5.1 Baseline Results: Water Quality

We find that municipal mergers increase river pollution, contradicting the negative externality narrative that mergers can internalize pollution spillovers. Table 2 shows that municipal mergers increase water pollution by 5.5% when adopting the Callaway & Sant'Anna estimator (column 1 of Panel A). This effect size is larger than the 3.6% increase estimated using a two-way fixed effects specification, which suggests the presence of negative weights in this latter specification when applied in a staggered DiD design. Considering that the BOD value decreased by 44% on average in never-merged municipalities in our sample, our result suggests that municipal mergers offset this trend of water quality improvement by 12.5% ($5.5 \div 44 \times 100$). Our result is robust to clustering standard errors at the more conservative basin level, accounting for the possibility of spatial dependence in water pollution that extends beyond the municipality level (column 2). Furthermore, it is robust to controlling for a municipality-level economic indicator and population (column 3).

We also find that the negative effects of municipal mergers on water quality persist for 14 years. Figure 5 shows these results in the event study design of the Callaway and Sant'Anna (2021) estimator. First, we find no differential pre-trends for most pre-merger periods, reinforcing the validity of the parallel trends assumption. Second, the negative effects on water quality intensify over time and remain statistically significant for up to 14 years, indicating the sustained, adverse effect of municipal mergers in the short to medium run. However, beyond 15 years post-merger, the effects diminish and become statistically insignificant, suggesting that issues with weaker pollution control were eventually addressed in the long run. It is important to note, though, that these insignificant estimates, accompanied by large confidence intervals, may also be driven by the smaller sample sizes consisting of only those municipalities that merged very early.

[16] The event study results of the Callaway and Sant'Anna (2021) estimator from Section 5 include the coefficients for event time -1. This is because a varying base period is used for estimating the pseudo-effects in pre-treatment periods, aligning with the parallel trends assumptions outlined in Callaway and Sant'Anna (2021). Specifically, the base (reference) period is the immediately preceding period. For example, for event time -1, the base period is -2.

5.2 Robustness Checks

The results remain robust across various analyses, including analysis comparing early versus late mergers, analysis on matched municipalities, consideration of spillover effects from upstream and border municipalities, the adoption of alternative estimators, sample periods, and alternative water quality indicators.

Difference-in-Differences Analysis Comparing Early versus Late Mergers.—The baseline specification relies on the comparison between merged and never-merged municipalities, which differ in terms of industry compositions and financial conditions, as discussed in Section 3.5. This difference may raise concern about selection bias, although the evidence of parallel pre-trends supports a causal interpretation of the baseline results. However, as a robustness check, we conduct a DiD analysis, restricting our sample to municipalities that have undergone mergers. This robustness check compares municipalities that merged earlier (treatment group) and those that merged later (control group), which are expected to be more similar and balanced in characteristics. Appendix Figure A3 shows that, consistent with our baseline findings, municipal mergers increase water pollution, especially six years after municipal mergers.

Difference-in-Differences Analysis on Matched Municipalities.—To address the concern of selection bias in comparing merged and never-merged municipalities, we also conduct a DiD analysis only on municipalities that are matched based on their imbalanced municipality characteristics prior to the mergers. We specifically adopt Mahalanobis distance matching for product shipment values, agricultural output values, and the financial capability index.[17] The matched samples exhibit balanced characteristics between merged and never-merged municipalities (Appendix Table B1). Appendix Figure A4 shows that the result for these matched municipalities is similar to that of the baseline specification, although the coefficients are imprecise beginning six years after the merger.

Spillovers from Upstream and Border Municipalities.— Our baseline analysis relies on the stable unit treatment value assumption (SUTVA). However, there is a potential for spillovers from upstream merged municipalities to downstream never-merger municipalities along rivers. To test this, we compare never-merged municipalities located within 25, 50, or 100 kilometers of upstream merged municipalities (control group subject to spillovers) to those located further away from upstream merged municipalities (pure control group).[18] However, Appendix

[17] In the matching process, we use the average of these values in the pre-merger periods (from 1996 to 2000).

[18] We identify upstream municipalities for each station by using elevation raster data and river line data,

Figure A5 shows that these spillover effects are statistically insignificant in most event years, regardless of the chosen distance cutoffs.

As a robustness check to enhance the validity of the SUTVA, we run an analysis by directly removing the spillovers from upstream merged municipalities. Here, we only use monitoring stations that do not have upstream merged municipalities located within 25, 50, or 100 kilometers. Appendix Figure A6 shows that the results in this specification are similar to those in the baseline specification, where the average treatment effects on the treated (ATT) are 0.047-0.055, with p-values of 0.009-0.024.

We also consider another type of spillover effect, originating from border municipalities. Our baseline analysis assumes that water quality at a given monitoring station is affected only by the merger of the municipality where it is located. However, monitoring stations can be situated on rivers that flow along the border of multiple municipalities. In this case, water quality at these stations is likely to be affected by the mergers of multiple border municipalities. To account for this spillover effect, we conduct an analysis where the treatment indicator is set to one once at least one border municipality begins to undergo mergers, specifically for stations located on municipality borders.[19] As shown in Appendix Figure A7, this analysis yields results consistent with the baseline results, where ATT is 0.053, with a p-value of 0.003.

Alternative Estimators and Sample Periods.—We find a similar negative effect of municipal mergers on water quality using alternative estimators, such as the one proposed by Sun and Abraham (2021), although the effect is slightly less pronounced (Appendix Figure A8).

Moreover, our findings demonstrate robustness when adopting alternative sample periods. This includes both a longer period from 1990 to 2018 and a shorter period from 1999 to 2018, as shown in Appendix Figure A9. Across these different sample periods, the negative effect of municipal mergers on water quality is consistently observed, with the magnitudes of these effects being the same as those found in the baseline specification (ATT being 0.055).

Alternative Water Quality Indicators.—We find a similar negative effect of municipal mergers on water quality when adopting alternative indicators, including the 75 percentile value of BOD (BOD 75) and the mean dissolved oxygen (DO) level (Panels A and B of Appendix Figure A10). Both indicators capture the overall level of water contamination from various pollution sources. However, lower DO levels indicate higher water pollution, which is the

which are explained in Section 6.4. Specifically, we select upstream municipalities that intersect with river segments at elevations higher than that of a given station, following the approach in Motohashi (2023).

[19] We identify stations situated on municipality borders by selecting those located within 2 kilometers of more than one municipality.

opposite of the relationship seen with BOD values. The ATT for logarithms of BOD 75 and DO is 0.064 and -0.013, with a p-value of 0.001 and 0.008, respectively, These results show that municipal mergers increase BOD 75 by 6.4% and decrease DO by 1.3%.

Conversely, we find no effects of municipal mergers on suspended solids (SS), as shown in Panel C of Appendix Figure A10. SS measures soil erosion, which is closely related to agricultural wastewater, as discussed in Lipscomb and Mobarak (2016). Therefore, this result suggests that agricultural wastewater is unlikely to be the primary source of pollution.

5.3 Compliance with Environmental Standards

As we observe that municipal mergers increase water pollution, we investigate whether this pollution increase ultimately impacts compliance with Environmental Quality Standards for Water Quality. We find that while municipal mergers do not increase the number of violation cases, they do lead to more cases of narrow compliance. These findings suggest that merged municipalities weaken their pollution control efforts just enough to avoid violating environmental standards.

We investigate the effects of municipal mergers on compliance with environmental standards by adopting the baseline DID design. Compliance is evaluated by comparing BOD values with the limit values set under the Environmental Quality Standards for Water Pollution.[20] This analysis focuses on 2,027 criteria stations out of a total of 3,285 stations, whose water quality data are officially used to assess compliance with environmental standards.[21] Instead of using average BOD values, we utilize BOD 75 values to assess compliance, following the official practice that aims to remove the influence of abnormal weather on water quality measures.[22] Based on these data, we construct a violation indicator that equals one if the BOD values exceed the limit values. Additionally, we measure narrow compliance by creating a binary indicator that equals one if the BOD values are within the range of 75-100% of the limit values among non-violation observations. For a continuous measure of narrow compliance, we also calculate the percentage of BOD values relative to the limit values, where a higher percentage closer to 100% suggests narrow compliance. We use the DiD specification outlined in Section 4.1 to analyze the effects of municipal mergers on these three compliance outcomes.

[20] Limit values vary according to the designated usage categories for each river location, which can be revised over time. Typically, these categories become more stringent, resulting in lower limit values, which aligns with observed improvements in water quality, as illustrated in Figure 4. Compliance is checked according to the designated usage categories applicable for each location each year.

[21] The baseline result remains robust in the DiD analysis focusing on criteria stations, as shown in Appendix Figure A11. The ATT is 0.047, with a p-value of 0.007.

[22] Our baseline result, based on average BOD values, remains robust when adopting BOD 75 as an outcome, as shown in Section 5.2.

We find that municipal mergers increase narrow compliance without increasing the violations. As shown in Panel A of Figure 6, we generally do not find an increase in violation cases, except for statistically significant positive effects 16-17 years after the mergers. However, we find a statistically significant effect of increased narrow compliance cases among non-violation cases (Panel B). The ATT is 0.032, with a p-value of 0.049, showing that the mergers increase the non-compliance by 3.2 percentage points. Given that the average pre-merger narrow compliance rate is 30%, this effect represents an approximately 10% increase in narrow compliance cases. Furthermore, we find that municipal mergers increase the percentage of BOD values relative to the limit values, suggesting an increase in narrower compliance (Panel C). The ATT is 1.69, with a p-value of 0.089, indicating that municipal mergers increase this measure by 1.69 percentage points from the pre-merger average of approximately 60%.[23]

6 Mechanisms

Heterogeneity analysis by merger types and involved municipalities suggests that the mechanisms driving the negative effects of municipal mergers are coordination costs and unbalanced political power among pre-merger municipalities, which can weaken pollution control. We also find suggestive evidence that municipal mergers decelerate the expansion of sewer coverage, which increases the volume of untreated domestic wastewater from households. Conversely, we find no evidence of alternative mechanisms, including the negative externality theory and land use changes.

6.1 Coordination Costs

We examine the coordination costs mechanism by investigating how the effects of municipal mergers vary by merger type. Specifically, we compare the effect of equal-footing mergers, which entail higher coordination costs, with that of incorporating mergers, which entail lower coordination costs.[24] In this mechanism, we hypothesize that equal-footing mergers result in larger increases in water pollution due to weaker pollution control under higher coordination costs. To analyze the effect of equal-footing mergers, we conduct a DiD analysis, restricting our sample to municipalities that have undergone equal-footing mergers (treatment group)

[23] Municipalities cannot avoid violations or narrow compliance by just changing the designated usage categories because these categories are determined at the central and prefectural levels. Therefore, our results shed more light on the weaker pollution control by municipalities.

[24] Different levels of coordination costs between equal-footing and incorporating mergers are discussed in Section 2.3.

and never-merged municipalities (control group). We repeat a similar analysis to examine the effect of incorporating mergers.

We find that the negative effect of municipal mergers on water quality is concentrated in equal-footing mergers, which entails high coordination costs. As shown in Table 3, equal-footing mergers increase water pollution by 6.7% (column 1 of Panel A), whereas the effect is insignificant in the case of incorporating mergers (column 2). These differential effects between different types of mergers suggest that coordination costs can weaken pollution control efforts. The event study results, presented in Figure 7, corroborate these findings. Equal-footing mergers increase river pollution for up to 14 years, although this negative effect is mitigated in the long run, possibly as municipalities eventually overcome initial coordination challenges (Panel A). In contrast, incorporating mergers have limited effects on river pollution except for a temporal negative effect around 3-5 years post-merger (Panel B).

6.2 Political Economy

We also examine the political economy mechanism by examining the differential effects on incorporating and incorporated municipalities. In this mechanism, we hypothesize that the negative effect on water quality is more pronounced in incorporated municipalities with little political power, compared to incorporating municipalities with larger political power.[25] We analyze the effect of municipal mergers on incorporated (incorporating) municipalities by conducting a DiD analysis, restricting our sample to incorporated (incorporating) and never-merged municipalities.

We find that the negative effect of municipal mergers on water quality is concentrated in incorporated municipalities with little political power. As shown in Table 3, incorporated municipalities experience a significant increase in water pollution post-merger by 8.6% (column 3 of Panel A), while the effect is insignificant in incorporating municipalities (column 4). This difference in results supports the argument of the political economy mechanism, suggesting that incorporated municipalities with less political power incur weaker pollution control relative to incorporating municipalities. The event study results, presented in Figure 8, show the same findings. Specifically, we find a rise in river pollution at an increasing rate in incorporated municipalities for up to 17 years post-merger (Panel A). Conversely, we observe limited effects on river pollution in incorporating municipalities, with the exception of a temporary negative effect observed around 3-5 years post-merger (Panel B).

[25] Different levels of political power between incorporated and incorporating municipalities are discussed in Section 2.3.

6.3 Pollution Sources Subject to Weaker Control

We investigate sources of pollution that increase following mergers due to weaker control. Municipalities are primarily responsible for controlling domestic wastewater, but their role in controlling industrial and agricultural wastewater is limited, as discussed in Section 2.2.[26] The primary approach for controlling domestic wastewater is to construct and operate sewage treatment plants.[27] Therefore, we examine the effect of municipal mergers on sewer investment levels. Our analysis shows suggestive evidence that municipal mergers decelerate the expansion of sewer coverage, especially in the case of equal-footing mergers. This finding suggests that, post-mergers, a larger volume of domestic wastewater remains untreated in merged municipalities.

To investigate the effect of mergers on domestic wastewater control, we conduct a DiD analysis using municipality-level panel data on sewer coverage. This analysis uses sewer coverage data from the Sewage Statistics, spanning from 1996 to 2018, provided by the Japan Sewage Works Association. We calculate the proportion of sewer coverage, which ranges from 0 to 1, by dividing the population served by the sewer system by the total population of each municipality in each year. To accommodate the changes in municipalities post-mergers, we aggregate the data at the post-merger municipality level.[28] Moreover, this analysis focuses on municipalities that maintained sewer infrastructure up to 2018 to ensure a balanced panel. Using the constructed panel data, we adopt the same DiD design as outlined in our baseline specification in Section 4.1, employing municipality-fixed effects instead of monitoring station-fixed effects.

As shown in Panel A of Figure 9, we find suggestive evidence that municipal mergers decelerate sewer investments for up to 5 years following the mergers. However, it is important to note that the anticipation effect is observed one year prior to the mergers, despite the presence of parallel pre-trends in other periods. This anticipation effect could be attributed to the possibility of sewer projects being suspended or canceled just before the mergers, during the negotiation phase. The negative effect on sewer coverage is primarily observed in equal-footing mergers, which is consistent with the baseline heterogeneity results (Appendix Figure A12).[29]

[26] The insignificant effect of municipal mergers on suspended solids, predominantly associated with agricultural wastewater, further indicates that agricultural wastewater is unlikely to be the pollution source (shown in Section 5.2).

[27] Another approach could be to subsidize the construction of "Johkasou", a decentralized wastewater treatment system installed at the household level. However, we could not test the effect of mergers on Johkso coverage, as the municipality-level coverage data is available only from 2013 onwards.

[28] For example, if municipalities A and B merged into a new municipality C in year X, the sewer coverage for C before X is derived from the total populations served by sewers in A and B.

[29] We are unable to conduct a heterogeneity analysis comparing the effects on incorporated and incorpo-

Conversely, we do not observe a negative effect on the operation of sewage treatment plants. Specifically, we investigate whether the water quality of the effluent from these plants changes following mergers, potentially due to deteriorating operation. We utilize BOD values of sewage treatment plant effluent from 1996 to 2017, provided as plant-level data in the Sewage Statistics. After aggregating this plant-level data into municipality-level panel data on average BOD values of effluent, we conduct the same DiD analysis. As demonstrated in Panel B of Figure 9, we do not find a statistically significant effect of municipal mergers on effluent water quality. This suggests that pollution control efforts are not weakened through changes in operation. This result is plausible given the existence of mandatory effluent regulations for sewage treatment plants, which municipalities must adhere to.

In summary, while municipal mergers did not alter the operation of sewage treatment plants, they slowed the expansion of sewer coverage. This suggests that a greater volume of domestic wastewater remains untreated in municipalities that have undergone mergers, consequently leading to heightened pollution in rivers following the mergers.

6.4 Alternative Mechanism 1: Negative Externality Theory

We test the negative externality theory as an alternative mechanism, which predicts that municipal mergers improve environmental quality by internalizing pollution spillovers. Consistent with the DiD analysis showing a negative effect of municipal mergers on water quality, we do not observe the spatial patterns predicted by the negative externality theory.

To investigate the negative externality theory, we conduct a river distance analysis, similar to that of Lipscomb and Mobarak (2016). Specifically, we examine how river distances from monitoring stations to their closest upstream and downstream municipality borders affect water quality, exploiting changes in these distances following municipal mergers. For this analysis, we construct two distance variables, U and D. U refers to the distance along the river from a monitoring station to its closest upstream municipality border, while D indicates the distance to the closest downstream border. These distances are calculated along rivers, taking into account the flow direction. To calculate U and D, we use the river node data with elevation information, along with river line data provided by the Ministry of Land, Infrastructure, Transport, and Tourism. This data allowed us to construct fine-resolution elevation raster data, from which we determined the upstream-downstream relationships among monitoring stations and municipality borders.[30] Then, we calculate the two distance

rating municipalities, as the panel data has been constructed at the level of post-merger municipalities.

[30] We use pre-merger (1984) and post-merger (2018) municipality boundary data, as provided by Kirimura et al. (2011).

variables along the river.[31]

We adopt the following regression to test the negative externality theory:[32]

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

where $Downstream_{i,t}$ is a relative "downstreamness" indicator of a monitoring station within its municipality, calculated as $U_{i,t}/(U_{i,t} + D_{i,t})$. Here, $U_{i,t}$ and $D_{i,t}$ represent distances along the river from monitoring station i to its closest upstream municipality border and its closest downstream municipality border, respectively, in year t. $Downstream_{i,t}$ ranges from 0 to 1, with values closer to 1 indicating a station's more downstream position within its municipality. $X_{i,t}$ is a vector of time-varying control variables consisting of a municipality-level economic indicator (product shipment values) and population. δ_i and $\theta_{b,t}$ are monitoring station fixed effects and basin-by-year fixed effects, respectively. Standard errors are clustered at the monitoring station level to address serial correlation.

The coefficients of primary interest are η_1 and η_2. According to the negative externality theory, as detailed in Section 2.3, pollution levels are expected to rise at an increasing rate as one moves downstream within a municipality. This predicts a convex relationship, with both η_1 and η_2 (representing the first and second derivatives with respect to "downstreamness") expected to be positive.

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

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

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

Table 4 presents the results of the river distance analysis, where we do not find spatial patterns consistent with the negative externality theory. First, the results of the specification

[31] Detailed steps are described in Appendix C.1.

[32] In this river distance analysis, we use water quality data from monitoring stations located along the river lines used in our data construction. We exclude stations located in either the uppermost or furthest-downstream municipalities, as one of the distance measures (U or D) cannot be calculated for these locations. Our observations extend until 2015, as we include population as a control variable, and population data is available only up to that year. With these criteria, our final sample for the river distance analysis comprises 700 monitoring stations in 382 municipalities, spanning from 1996 to 2015.

using relative downstreamness (regression 3) are provided in columns 1 and 2. We do not find the effects of either the downstreamness indicator or its squared term on water quality. Also, the coefficient of the downstreamness indicator (η_1) is negative, contradicting the predictions of the negative externality theory. Second, the results of the Lipscomb and Mobarak (2016) specification (regression 4) in columns 3 and 4 also fail to support the negative externality theory. We do not find significant effects of D and D^2 on water quality. Furthermore, the equality of the coefficients of U and D cannot be rejected when testing for a structural break in the pollution function at the municipality border.

In summary, the negative externality theory of Lipscomb and Mobarak (2016) does not hold true in the case of municipal mergers in Japan. This discrepancy may be partly attributed to the differences between the developing countries studied in Lipscomb and Mobarak (2016) and developed countries like Japan. In the context of developing countries, as discussed in Lipscomb and Mobarak (2016), the mechanism focuses on how local politicians permit slum areas with inadequate water and sanitation infrastructure. In such a case, it could be easier to restrict or relocate these informal settlements, which often have weaker property rights. Additionally, the relocation of slums might be more feasible when nearby cities are expanding. However, in developed countries, local governments are likely to face the challenge of relocating established formal polluting sources such as residences and factories to internalize negative externalities following municipal mergers. This can be more difficult or costly due to more stringent property rights and limited available land for relocation in developed countries. The null effects of municipal mergers on land use in Section 6.5 are consistent with this explanation.

6.5 Alternative Mechanism 2: Land Use

We test another alternative mechanism, namely changes in land use, which can lead to increased water pollution by generating new pollution sources without altering pollution control efforts. However, we do not find the effects of municipal mergers on various land use types, including agriculture, built-up areas, and forests.

As discussed in Section 2.3, municipal mergers can cause changes in land use, such as expanding industrial and residential areas, by increasing economic activities, as demonstrated by Egger et al. (2018). This shift in land use could result in an increase in sources of water pollution, namely industrial and domestic wastewater, thereby escalating river pollution.

To investigate this alternative mechanism, we examine the effect of municipal mergers on land use patterns. Our analysis uses 100-meter raster data of land use for six periods (1991, 1997, 2006, 2009, 2014, and 2016), provided by the Ministry of Land, Infrastructure, Transport, and Tourism. We specifically focus on land use patterns within 150 meters, 1 kilometer, or 5 kilometers from water quality monitoring stations. The analysis categorizes land use into three main classifications: agriculture, built-up areas, and forests.[33] Subsequently, we construct a binary indicator that identifies the major land use classification for each monitoring station.[34]

Based on the panel of land use patterns over six periods, we apply the same DiD approach as in our baseline specification in Section 4.1, using binary indicators of the three land use classifications as outcome variables. Due to the non-consecutive nature of our panel data, we are unable to employ the Callaway and Sant'Anna (2021) estimator, which works with a balanced panel with consecutive years. Therefore, we instead use the Sun and Abraham (2021) estimator in this analysis.

As shown in Figure 10, we do not find any statistically significant effects of municipal mergers on land use classifications near monitoring stations, including agriculture areas, built-up areas, and forests, across various distance cutoffs. This finding suggests that river pollution resulting from municipal mergers cannot be explained by the changes in land use.

7 Conclusion

We document that municipal mergers, in which two or more municipalities combine, increase environmental 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.

Specifically, we investigate the case of Japan's nationwide municipal mergers in the late 1990s to 2000s, which drastically reduced the number of municipalities by approximately 50%. We exploit the staggered implementation of mergers across Japan to estimate the causal effects of municipal mergers on river water quality in the difference-and-differences analysis.

Contrary to the prediction of the negative externality theory, we find that municipal mergers increase river pollution by 5.5%, and this negative effect persists for 14 years. We also find that the mergers ultimately increase narrow compliance with environmental standards without increasing the violations. Consistent with these results, we do not find evidence supporting the negative externality theory in the river distance analysis that examines how river distances from monitoring stations to their closest upstream and downstream municipality borders affect the water quality.

[33] 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.

[34] Detailed steps are described in the Appendix C.2.

As for mechanisms, heterogeneity analyses suggest that municipal mergers weaken pollution control 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. In the case of incorporating mergers, we further show that smaller, incorporated municipalities experience a larger increase in river pollution than larger, incorporating municipalities. This is likely due to the higher political power of incorporating municipalities, where the mayor retains her position post-merger. Moreover, we find suggestive evidence that municipal mergers decelerate sewage investments for up to five years post-merger, especially in equal-footing mergers. This suggests that the increase in water pollution is driven by domestic wastewater not treated in sewage treatment plants.

Our results have several implications for policy and research directions on decentralization. First, while proponents of mergers emphasize positive effects on fiscal outcomes such as local public finance, these mergers can have an unintended negative effect on environmental quality. This negative effect should be carefully considered in future municipal mergers.

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

Finally, the negative effects of municipal mergers we observe in the case of pollution control can extend to other policies implemented at the municipality level, including those related to education and healthcare. The coordination cost and political economy channels may similarly weaken the implementation of these policies. Investigating these potential negative effects in other policies may be a fruitful area for future research.

References

Besley, Timothy, and Stephen Coate. 2003. "Centralized versus decentralized provision of local public goods: a political economy approach." *Journal of Public Economics*, 87(12): 2611–2637.

Blesse, Sebastian, and Thushyanthan Baskaran. 2016. "Do municipal mergers reduce costs? Evidence from a German federal state." *Regional Science and Urban Economics*, 59 54–74.

Burgess, Robin, Matthew Hansen, Benjamin A Olken, Peter Potapov, and Stefanie Sieber. 2012. "The political economy of deforestation in the tropics." *The Quarterly Journal of Economics*, 127(4): 1707–1754.

Callaway, Brantly, and Pedro HC Sant'Anna. 2021. "Difference-in-differences with multiple time periods." *Journal of Econometrics*, 225(2): 200–230.

Do, Quy-Toan, Shareen Joshi, and Samuel Stolper. 2018. "Can environmental policy reduce infant mortality? Evidence from the Ganga Pollution Cases." *Journal of Development Economics*, 133 306–325.

Egger, Peter H, Marko Koethenbuerger, and Gabriel Loumeau. 2018. "Municipal mergers and economic activity." Mimeo.

Goodman-Bacon, Andrew. 2021. "Difference-in-differences with variation in treatment timing." *Journal of Econometrics*, 225(2): 254–277.

Greenstone, Michael, and Rema Hanna. 2014. "Environmental regulations, air and water pollution, and infant mortality in India." *American Economic Review*, 104(10): 3038–72.

He, Guojun, Shaoda Wang, and Bing Zhang. 2020. "Watering down environmental regulation in China." *The Quarterly Journal of Economics*, 135(4): 2135–2185.

Helland, Eric, and Andrew B Whitford. 2003. "Pollution incidence and political jurisdiction: evidence from the TRI." *Journal of Environmental Economics and Management*, 46(3): 403–424.

Hinnerich, Björn Tyrefors. 2009. "Do merging local governments free ride on their counterparts when facing boundary reform?" *Journal of Public Economics*, 93(5-6): 721–728.

Hirota, Haruaki, and Hideo Yunoue. 2017. "Evaluation of the fiscal effect on municipal mergers: Quasi-experimental evidence from Japanese municipal data." *Regional Science and Urban Economics*, 66 132–149.

Jannin, Nicolas, and Aurélie Sotura. 2020. "This town ain't big enough? Quantifying public good spillovers." Banque de France Working Paper 796.

JMRC. 2008. "Great Heisei Mergers: City Handbook (*Heisei no daigappei toshi yoran*)." Japan Municipal Research Center (JMRC).

Kahn, Matthew E, Pei Li, and Daxuan Zhao. 2015. "Water pollution progress at borders: the role of changes in China's political promotion incentives." *American Economic Journal: Economic Policy*, 7(4): 223–42.

Keiser, David A, and Joseph S Shapiro. 2019. "Consequences of the Clean Water Act and the demand for water quality." *The Quarterly Journal of Economics*, 134(1): 349–396.

Kirimura, T, T Nakaya, and K Yano. 2011. "Building a spatio-temporal GIS database about boundaries of municipalities: Municipality map maker for web." *Theory and Applications of GIS*, 19 83–92.

Li, Jinsong, and Kenji Takeuchi. 2023. "Do municipal mergers reduce the cost of waste management? Evidence from Japan." *Regional Science and Urban Economics*, 103, p. 103939.

Lipscomb, Molly, and Ahmed Mushfiq Mobarak. 2016. "Decentralization and pollution spillovers: evidence from the re-drawing of county borders in Brazil." *The Review of Economic Studies*, 84(1): 464–502.

Miyazaki, Takeshi. 2018. "Examining the relationship between municipal consolidation and cost reduction: an instrumental variable approach." *Applied Economics*, 50(10): 1108–1121.

Mizunoya, Takeshi, Noriko Nozaki, and Rajeev Kumar Singh. 2021. "Impact of the municipal merger on watershed management: a study of Lake Kasumigaura, Japan." *Asia-Pacific Journal of Regional Science*, 5(2): 673–704.

Moisio, Antti, and Roope Uusitalo. 2013. "The impact of municipal mergers on local public expenditures in Finland." *Public Finance and Management*, 13(3): 148–166.

Motohashi, Kazuki. 2023. "Unintended consequences of sanitation investment: Negative externalities on water quality and health in India." ISER Discussion Paper No. 1210.

NATV. 2008. "Status and Evaluation of the Heisei Mergers (*Heisei no gappei wo meguru jittai to hyoka*)." National Association of Towns and Villages (NATV).

Oates, Wallace E. 1972. *Fiscal federalism.*: Edward Elgar Publishing.

OECD. 2014. *OECD Regional Outlook 2014: Regions and Cities: Where Policies and People Meet.*: OECD Publishing.

Pickering, Steve, Seiki Tanaka, and Kyohei Yamada. 2020. "The Impact of Municipal Mergers on Local Public Spending: Evidence from Remote-Sensing Data." *Journal of East Asian Studies*, 20(2): 243–266.

Reingewertz, Yaniv. 2012. "Do municipal amalgamations work? Evidence from municipalities in Israel." *Journal of Urban Economics*, 72(2-3): 240–251.

Sigman, Hilary. 2002. "International spillovers and water quality in rivers: do countries free ride?" *American Economic Review*, 92(4): 1152–1159.

Sigman, Hilary. 2005. "Transboundary spillovers and decentralization of environmental policies." *Journal of Environmental Economics and Management*, 50(1): 82–101.

Sun, Liyang, and Sarah Abraham. 2021. "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects." *Journal of Econometrics*, 225(2): 175–199.

Tiebout, Charles M. 1956. "A pure theory of local expenditures." *Journal of Political Economy*, 64(5): 416–424.

Wang, Shaoda, and Zenan Wang. 2021. "The environmental and economic consequences of internalizing border spillovers." Mimeo.

Weese, Eric. 2015. "Political mergers as coalition formation: An analysis of the Heisei municipal amalgamations." *Quantitative Economics*, 6(2): 257–307.

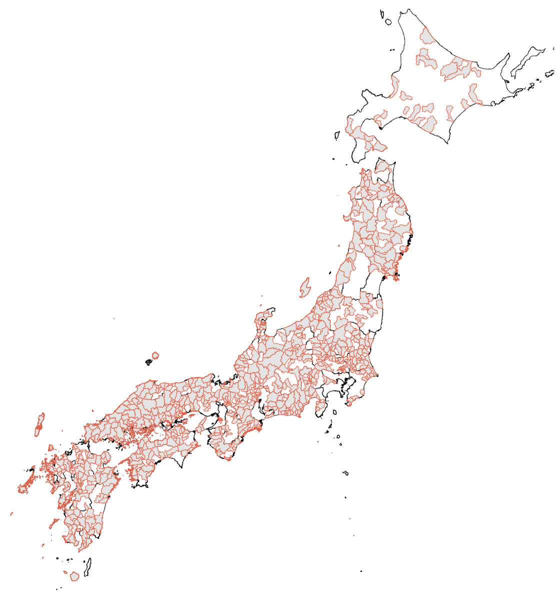

Figure 1: Locations of Municipal Mergers in Japan

Notes: This figure shows the boundaries of municipalities in Japan that underwent municipal mergers, marked by red lines surrounding grey areas. Additionally, it shows the boundaries of prefectures in black.

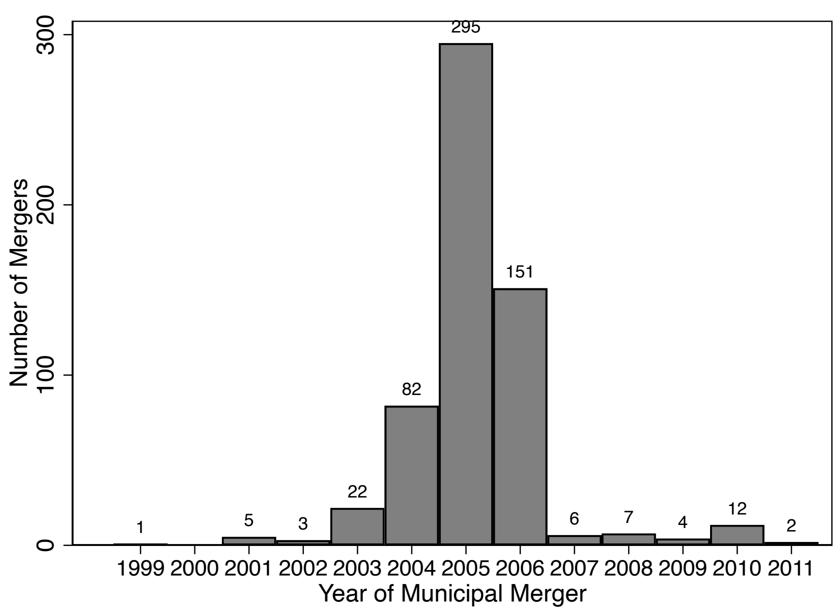

Figure 2: Timing of Municipal Mergers in Japan

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

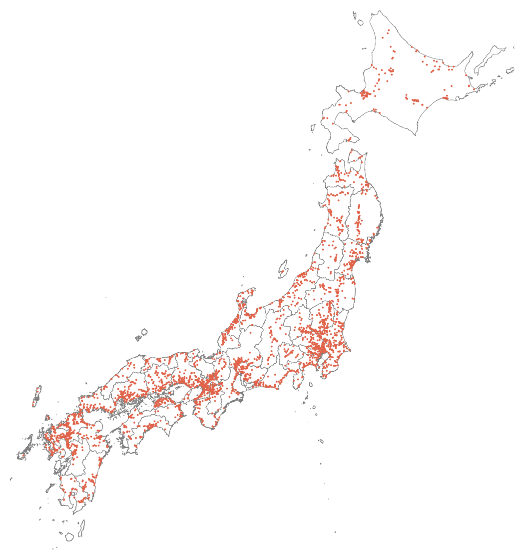

Figure 3: Locations of Water Quality Monitoring Stations in Japan

Notes: This figure shows the locations of water quality monitoring stations, marked in red, which are included in our sample along rivers. This is based on data from the Ministry of Environment. Additionally, the boundaries of prefectures in Japan are also shown in black.

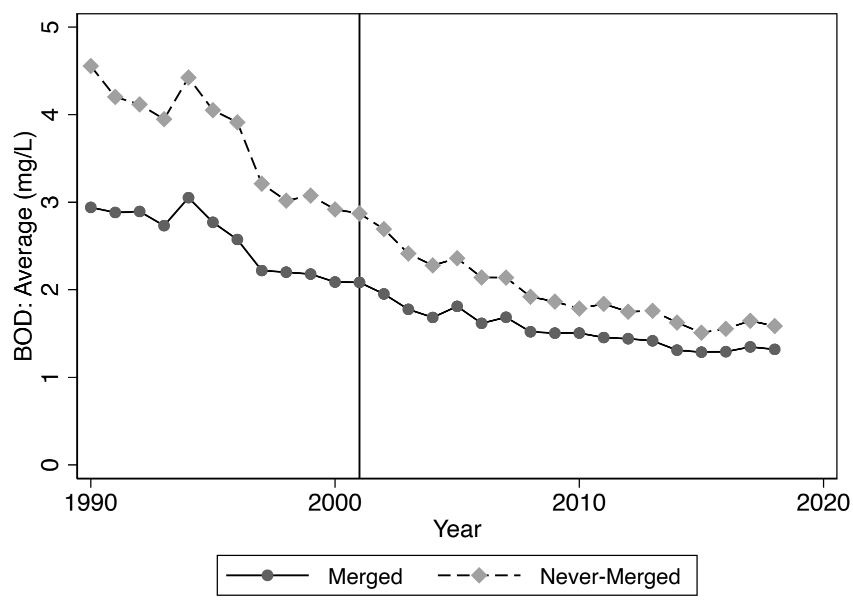

Figure 4: Trends of BOD Values in Merged and Never-Merged Municipalities

Notes: This figure compares the changes in average BOD values from 1990 to 2018 between municipalities that experienced municipal mergers (labeled "Merged") and municipalities that did not (labeled "Never-Merged"). The vertical line in 2001 marks the year when the first municipal mergers took place in our sample.

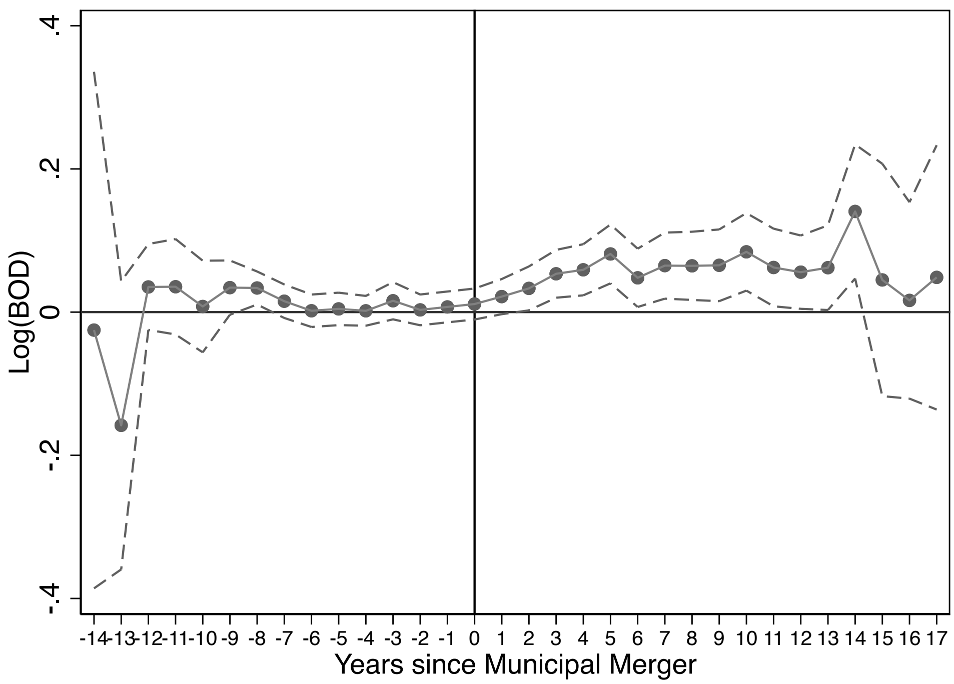

Figure 5: The Dynamic Effect of Municipal Mergers on Water Pollution

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.

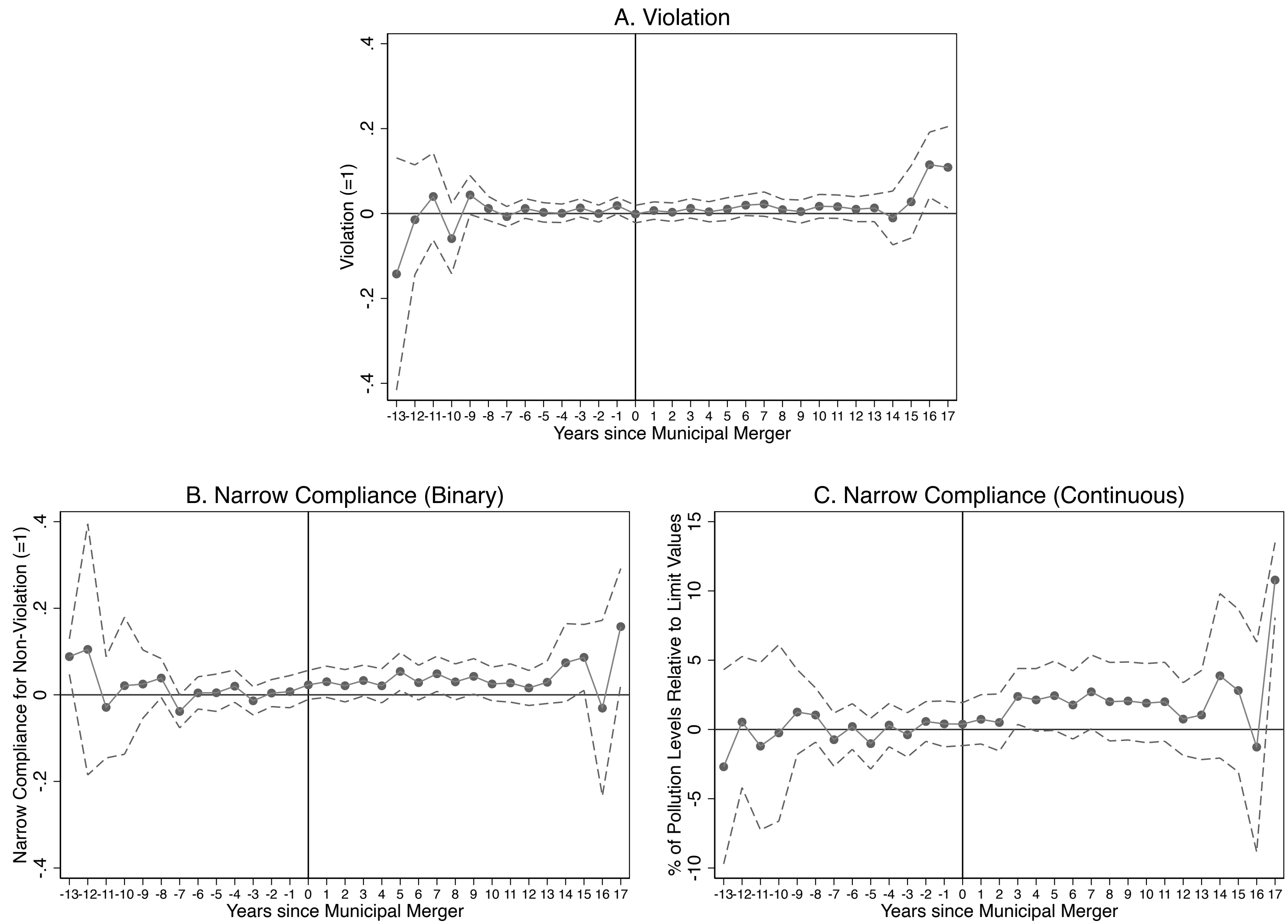

Figure 6: The Effect of Municipal Mergers on Compliance with Environmental Standards

Notes: This figure shows the coefficients of the Callaway and Sant'Anna (2021) estimator. Panel A shows the effect of municipal mergers on violations in criteria stations, while Panels B and C show the effects of municipal mergers on narrow compliance measures in the same stations for non-violation cases. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level.

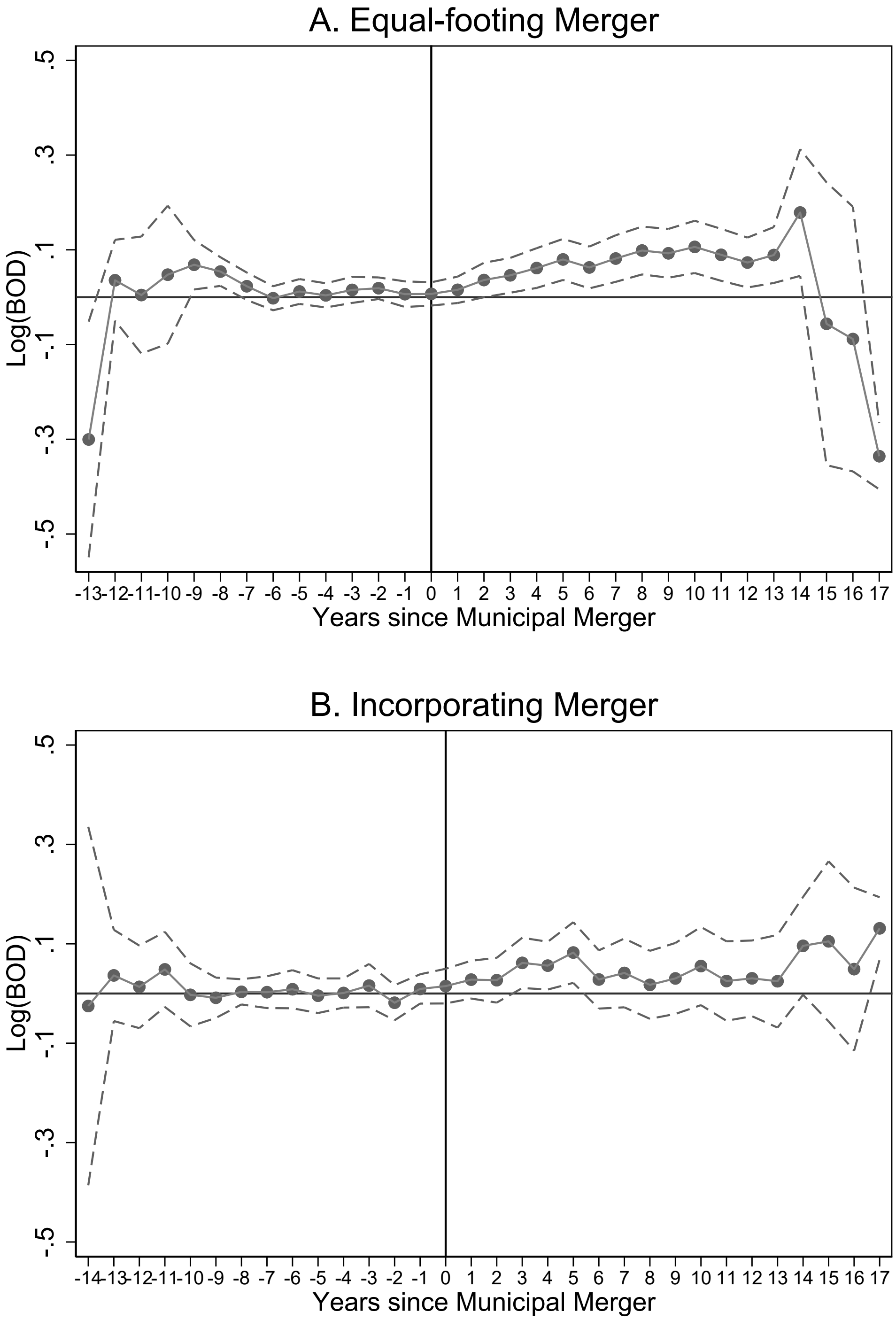

Figure 7: Event Study Results: Mechanism of Coordination Costs

Notes: This figure shows the coefficients of the Callaway and Sant'Anna (2021) estimator. Panel A shows the effect of equal-footing mergers by using data from municipalities that underwent such mergers and never-merged municipalities. Panel B, in a similar manner, shows the effect of incorporating mergers. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level.

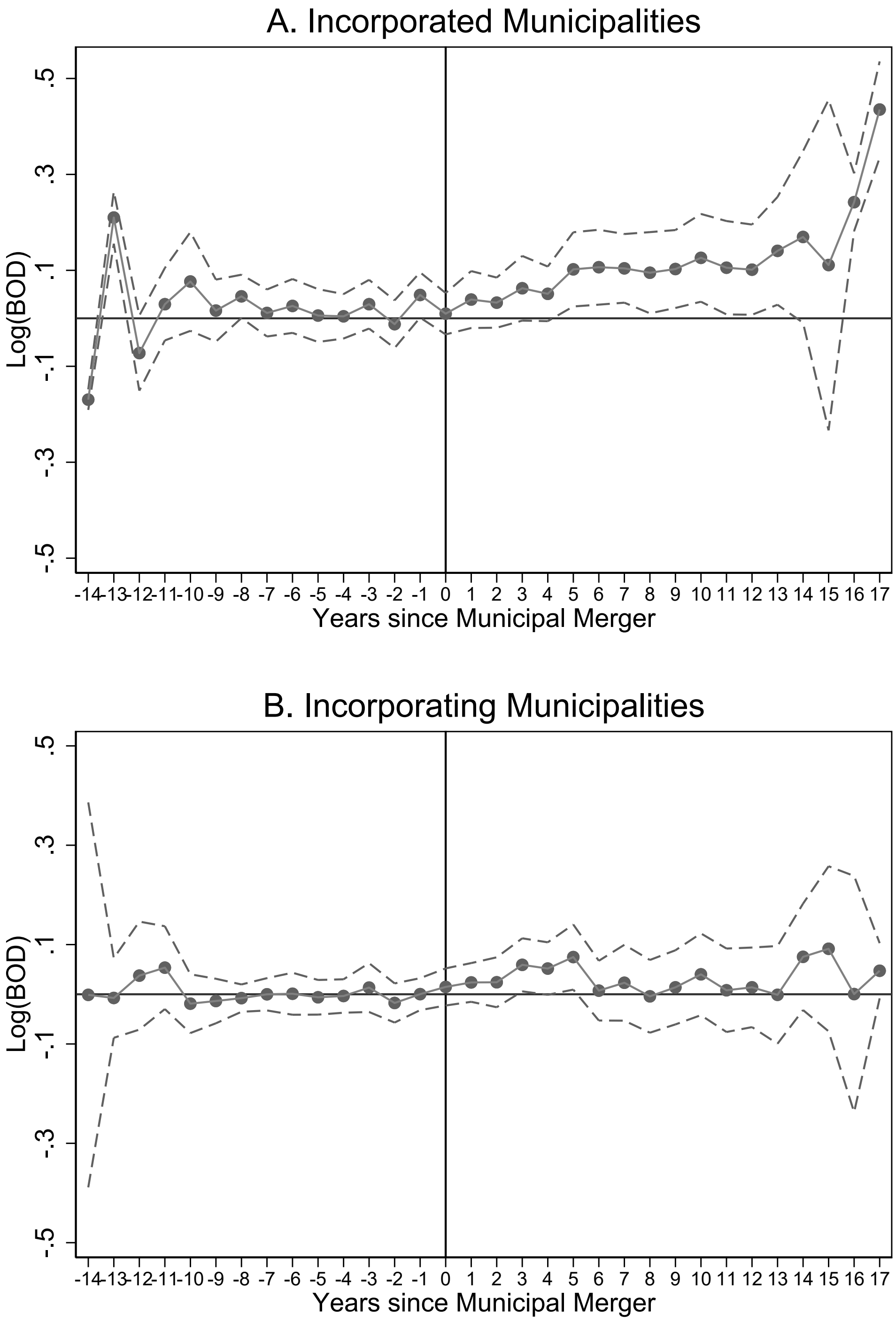

Figure 8: Event Study Results: Mechanism of Political Economy

Notes: This figure shows the coefficients of the Callaway and Sant'Anna (2021) estimator. Panel A shows the effect of mergers in incorporated municipalities by using the data of these municipalities and never-merged municipalities. Panel B, in a similar manner, shows the effect of mergers in incorporating municipalities. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level.

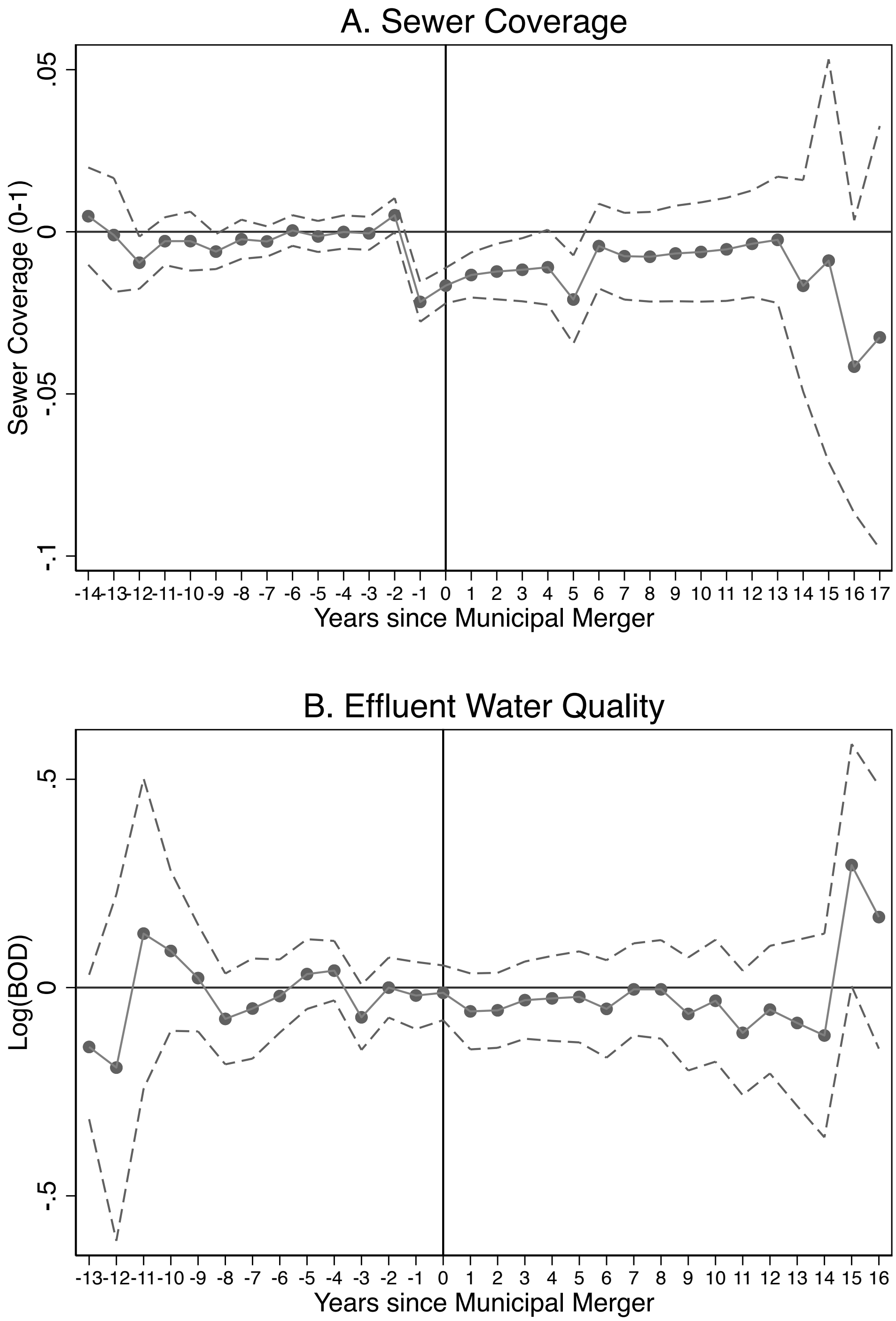

Figure 9: Pollution Source: The Effect on Sewer Coverage and Effluent Water Quality from Sewage Treatment Plants

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

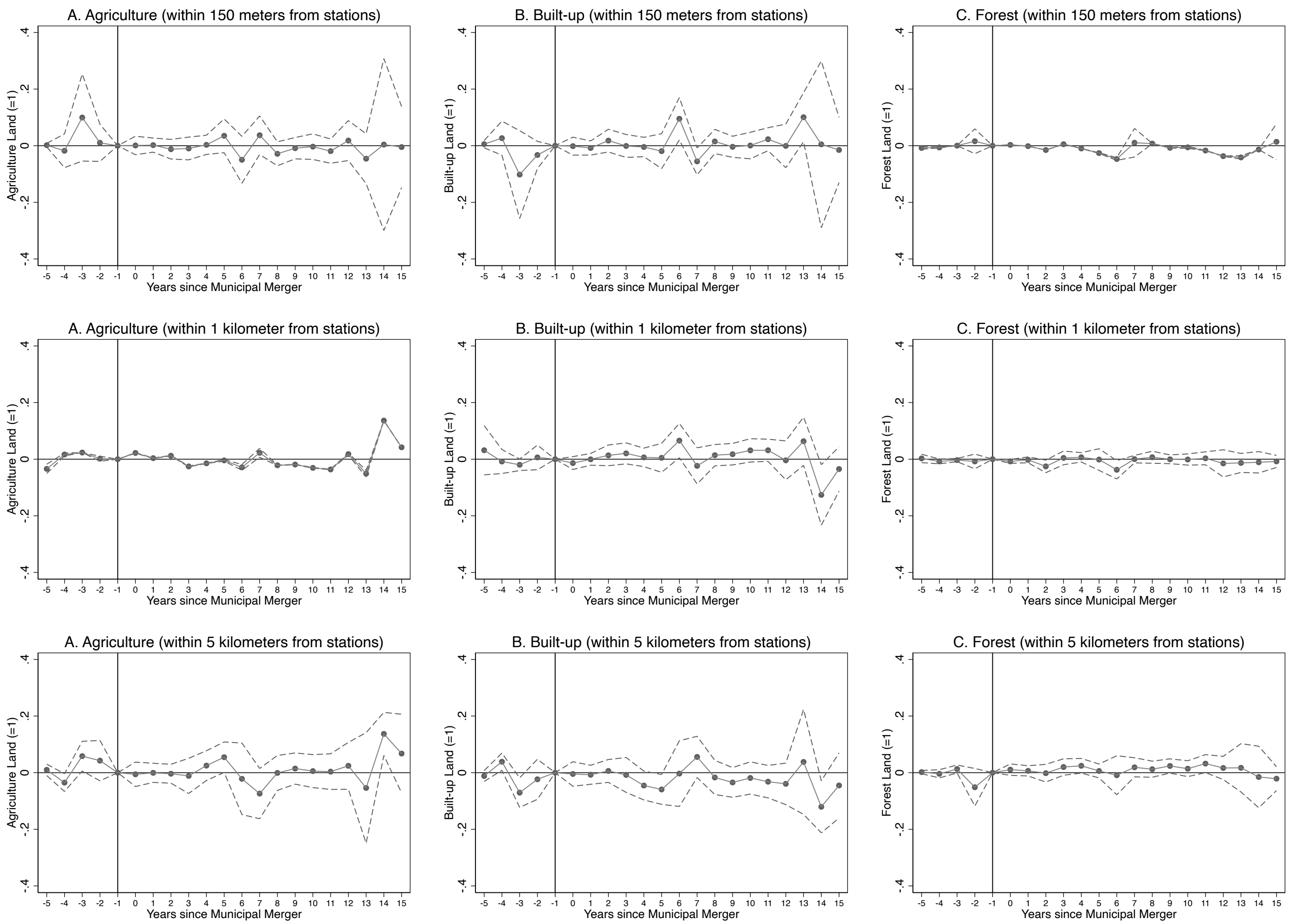

Figure 10: Alternative Mechanism 2: Effect on Land Use

Notes: This figure shows the coefficients of the Sun and Abraham (2021) estimator. The panels in each row show results for different dependent variables, specifically indicators that take the value of one if the majority of land use within 150 meters, 1 kilometer, or 5 kilometers from monitoring stations is of 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-by-year fixed effects. The coefficients for event time before -5 are not shown because most of them are omitted in the regressions.

Table 1: Summary Statistics in Pre-Merger Period

Variable	Means: Never-Merged	Means: Merged	Difference	Obs.
Panel A. Water Quality (Station-level)				
BOD: Average (mg/l)	3.240	2.254	-0.986***	3,285
	(3.725)	(2.665)	(0.207)	
BOD: 75 percentile (mg/l)	3.719	2.634	-1.085***	3,285
	(4.313)	(3.319)	(0.243)	
DO: Average (mg/l)	8.983	9.493	0.510***	3,280
	(2.107)	(1.502)	(0.145)	
SS: Average (mg/l)	11.144	12.300	1.156	3,278
	(10.664)	(62.925)	(1.601)	
Violation of Environmental Quality Standards (=1)	0.243	0.198	-0.046**	2,027
	(0.363)	(0.333)	(0.023)	
Narrow Compliance for Non-Violation (=1)	0.329	0.298	-0.031	1,807
	(0.379)	(0.354)	(0.023)	
% of Pollution Levels Relative to Limit Values	61.032	60.193	-0.839	1,807
	(20.703)	(19.023)	(1.270)	
Panel B. Municipality Characteristics (Municipality-level)				
Product shipment values (100 billion JPY)	2.321	3.037	0.716*	909
	(5.641)	(5.830)	(0.382)	
Population (thousand)	100.348	113.070	12.722	909
	(271.816)	(161.476)	(14.635)	
Agricultural output values (billion JPY)	4.116	11.608	7.492***	909
	(5.054)	(10.578)	(0.562)	
Financial capability index	0.609	0.493	-0.117***	909
	(0.311)	(0.229)	(0.018)	
Panel C. Sewage Treatment Plants (Municipality-level)				
Proportion of population connected to sewage treatment plants	0.540	0.394	-0.146***	706
	(0.276)	(0.221)	(0.019)	
BOD - Effluent from a sewage treatment plant (mg/l)	5.420	7.545	2.125	273
	(2.683)	(24.293)	(1.863)	
Panel D. 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 E. Land Use (Station-level)				
Major land use within 150 meters from stations: Agriculture (0/1)	0.342	0.412	0.070***	2,770
	(0.475)	(0.492)	(0.026)	
Major land use within 150 meters from stations: Forest (0/1)	0.137	0.213	0.076***	2,770
	(0.344)	(0.410)	(0.020)	
Major land use within 150 meters from stations: Built-up (0/1)	0.498	0.364	-0.134***	2,770
	(0.500)	(0.481)	(0.031)	

Notes: This table compares summary statistics between merged and never-merged municipalities before the commencement of municipal mergers in our sample. Specifically, it focuses on the period before 2001, when the first mergers were observed, and after 1996, following the baseline specification. The means are calculated by averaging the values for all years in that period. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The standard errors of the differences in means are clustered at the municipality level when variables are observed at the station level in Panels A, D, and E.

Table 2: DiD Results: The Effect on Water Quality

	Log(BOD)		
	(1)	(2)	(3)
Panel A: Callaway and Sant'Anna (2021) Estimator			
Merger (= 1)	0.055***	0.055***	0.049***
	(0.018)	(0.018)	(0.017)
Panel B: Two-way Fixed Effects			
Merger (= 1)	0.036*	0.036	0.036**
	(0.018)	(0.025)	(0.017)
Observations	75,555	75,555	73,738
Adjusted R^2	0.866	0.866	0.865
Number of Stations	3,285	3,285	3,206
Number of Municipalities	971	971	946
Controls	NO	NO	YES
Cluster SE at	Municipality level	Basin level	Municipality level
Mean of Dep. Variable	2.654	2.654	2.602

Notes: The regression coefficients are reported. Standard errors are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Panel B includes basin-by-year fixed effects and monitoring station fixed effects. In both Panels A and B, column 3 controls for pre-merger product shipment values and population after being interacted with year dummies. The mean of the dependent variable represents the average of BOD values before the commencement of municipal mergers in our sample.

Table 3: DiD Results: Mechanisms of Coordination Costs and Political Economy (Dependent Variable: Log(BOD))

	Coordination Costs		Political Economy	
	(1)	(2)	(3)	(4)
	Equal-footing	Incorporating	Incorporated	Incorporating
Panel A: Callaway and Sant'Anna (2021) Estimator				
Merger (= 1)	0.067***	0.039	0.086**	0.027
	(0.019)	(0.026)	(0.034)	(0.027)
Panel B: Two-way Fixed Effects				
Merger (= 1)	0.064***	0.004	0.098***	-0.018
	(0.022)	(0.027)	(0.029)	(0.029)
Observations	56,120	49,565	33,994	46,138
Adjusted R^2	0.868	0.871	0.874	0.871
Number of Stations	2,440	2,155	1,478	2,006
Number of Municipalities	849	629	572	625
Mean of Dep. Variable	2.664	3.018	3.104	3.129

Notes: The regression coefficients are reported. Standard errors, which are clustered at the municipality level, are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Panel B includes basin-by-year fixed effects and monitoring station fixed effects. The mean of the dependent variable represents the average of BOD values before the commencement of municipal mergers in our sample.

Table 4: Alternative Mechanism 1: Negative Externality Theory

	Log(BOD)			
	(1)	(2)	(3)	(4)
Downstreamness indicator ($U/(U+D)$)	-0.191	-0.215		
	(0.230)	(0.225)		
Squared downstreamness 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
Adjusted R^2	0.868	0.895	0.869	0.895
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
Equality Test: p-value for U = D	-	-	0.202	0.209
Mean of Dep. Variable	2.365	2.401	2.365	2.401

Notes: The regression coefficients are reported. Standard errors, which are clustered at station level, are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. This specification includes basin-by-year fixed effects and monitoring station fixed effects, as well as product shipment values and population as controls. The mean of the dependent variable represents the average of BOD values before the commencement of municipal mergers in our sample.

Online Appendix

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

Kazuki Motohashi Michiyoshi Toya

Contents

List of Figures

List of Tables

A Additional Figures

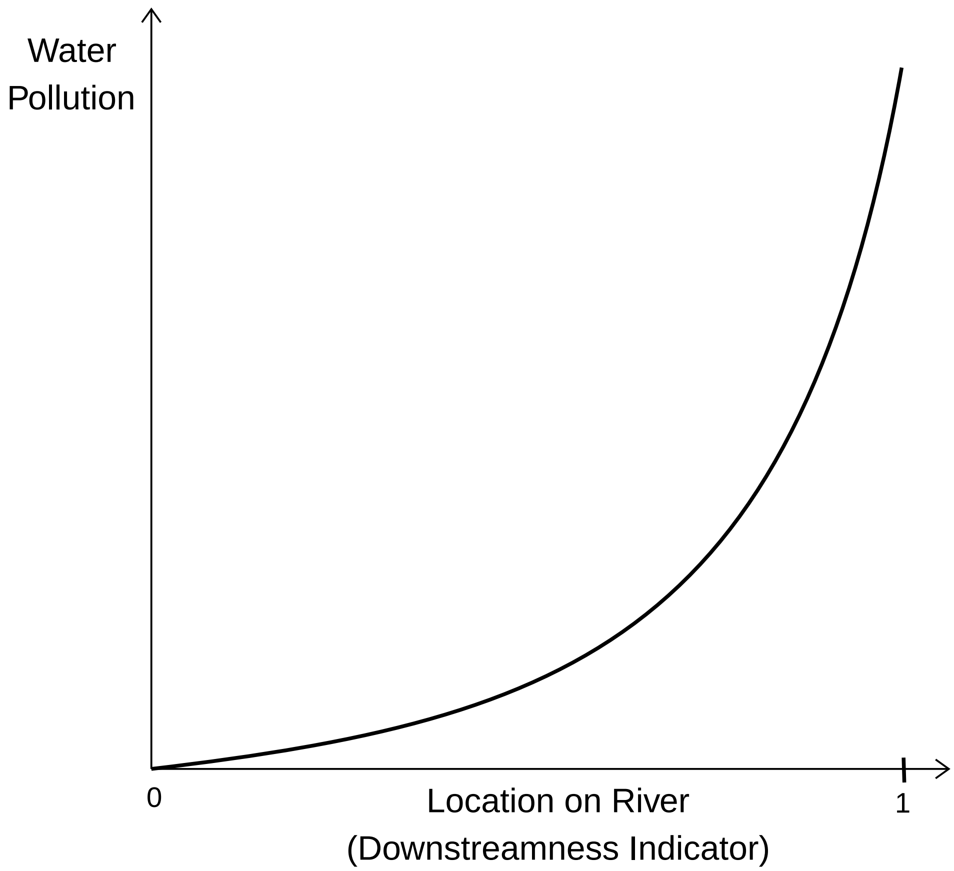

Figure A1: Prediction of Negative Externality Theory

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

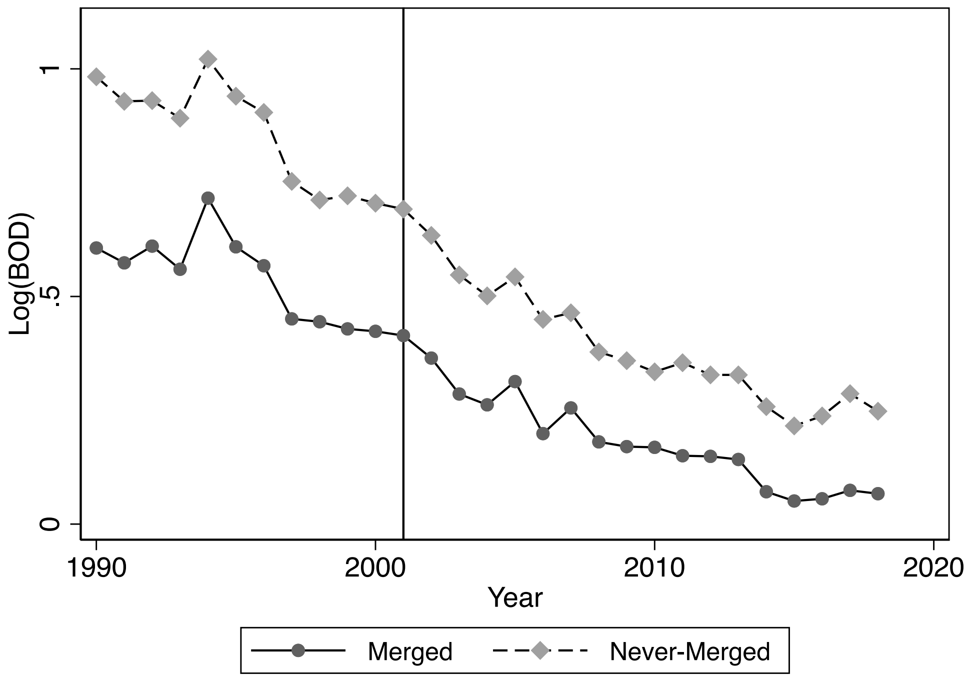

Figure A2: Trends of Logarithms of BOD Values in Merged and Never-Merged Municipalities

Notes: This figure compares the changes in the logarithms of average BOD values from 1990 to 2018 between municipalities that experienced municipal mergers (labeled "Merged") and municipalities that did not (labeled "Never-Merged"). The vertical line in 2001 marks the year when the first municipal mergers took place in our sample.

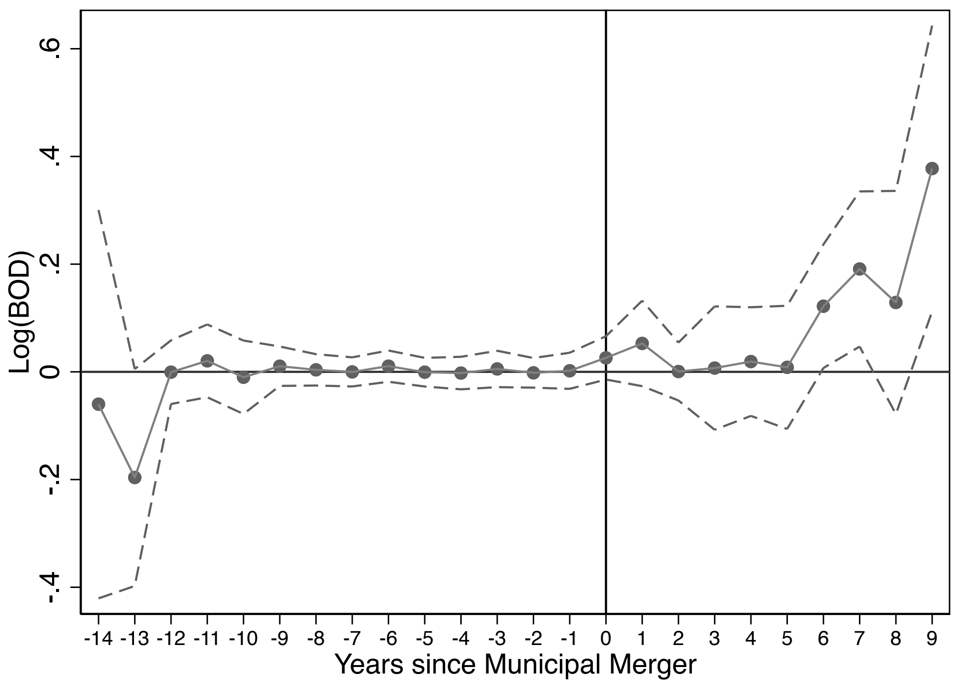

Figure A3: Robustness Check: Difference-in-Differences Analysis Comparing Early versus Late Mergers

Notes: This figure shows coefficients of the Callaway and Sant'Anna (2021) estimator. The sample is restricted to monitoring stations in municipalities that have undergone mergers, excluding those in municipalities that have never merged. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level.

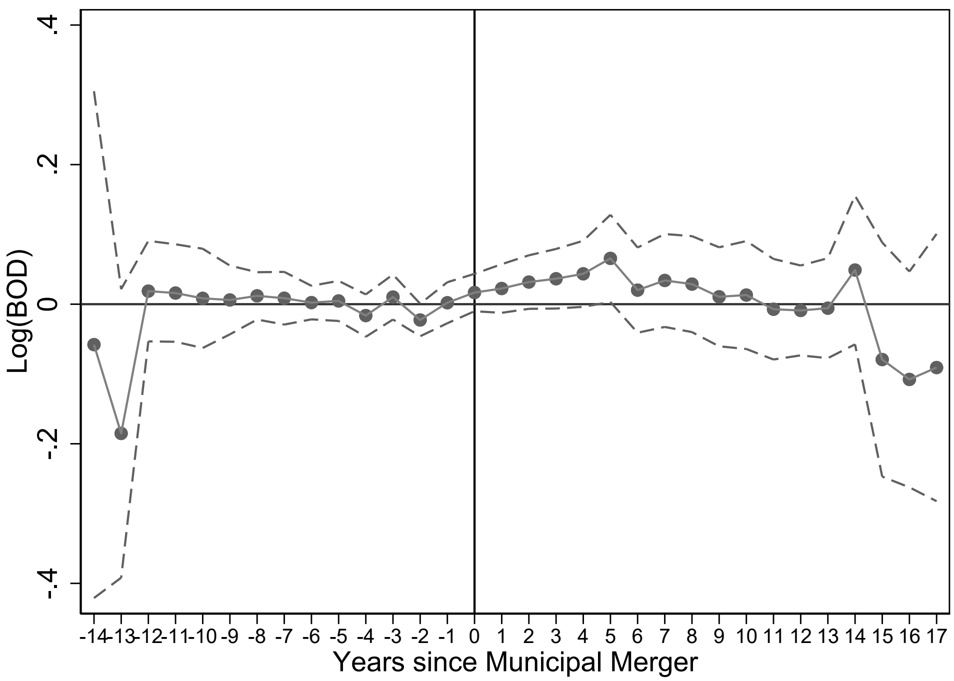

Figure A4: Robustness Check: Difference-in-Differences Analysis on Matched Municipalities

Notes: This figure shows coefficients of the Callaway and Sant'Anna (2021) estimator. The sample is limited to monitoring stations in matched municipalities. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level.

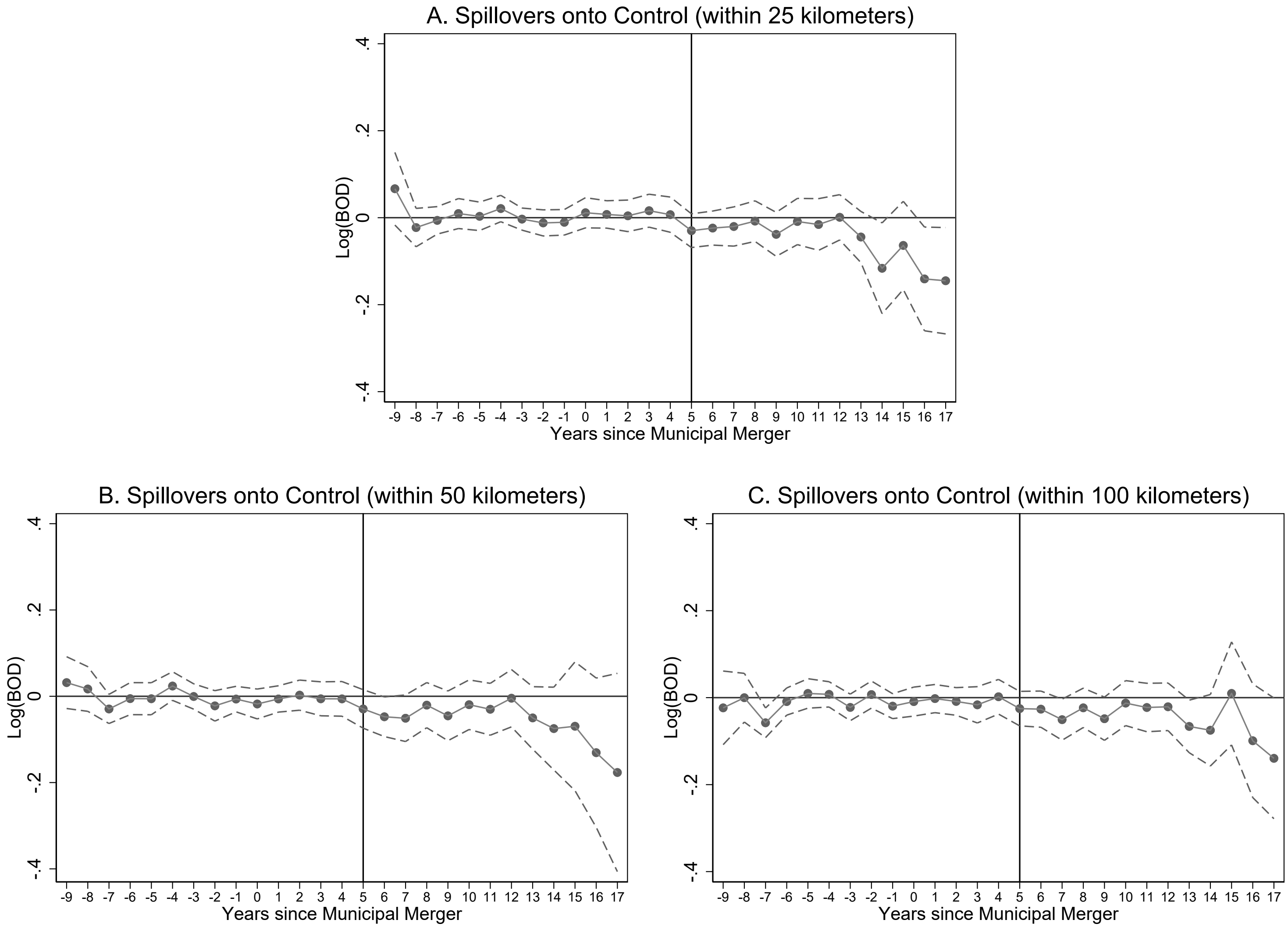

Figure A5: Robustness Check: Spillovers onto Control Municipalities

Notes: This figure shows the coefficients of the Callaway and Sant'Anna (2021) estimator. Panel A shows the spillover effect of upstream mergers on downstream, never-merged municipalities located within 25 kilometers of merged municipalities. Similarly, Panels B and C show the spillover effect of upstream mergers using cutoff distances of 50 and 100 kilometers, respectively. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level.

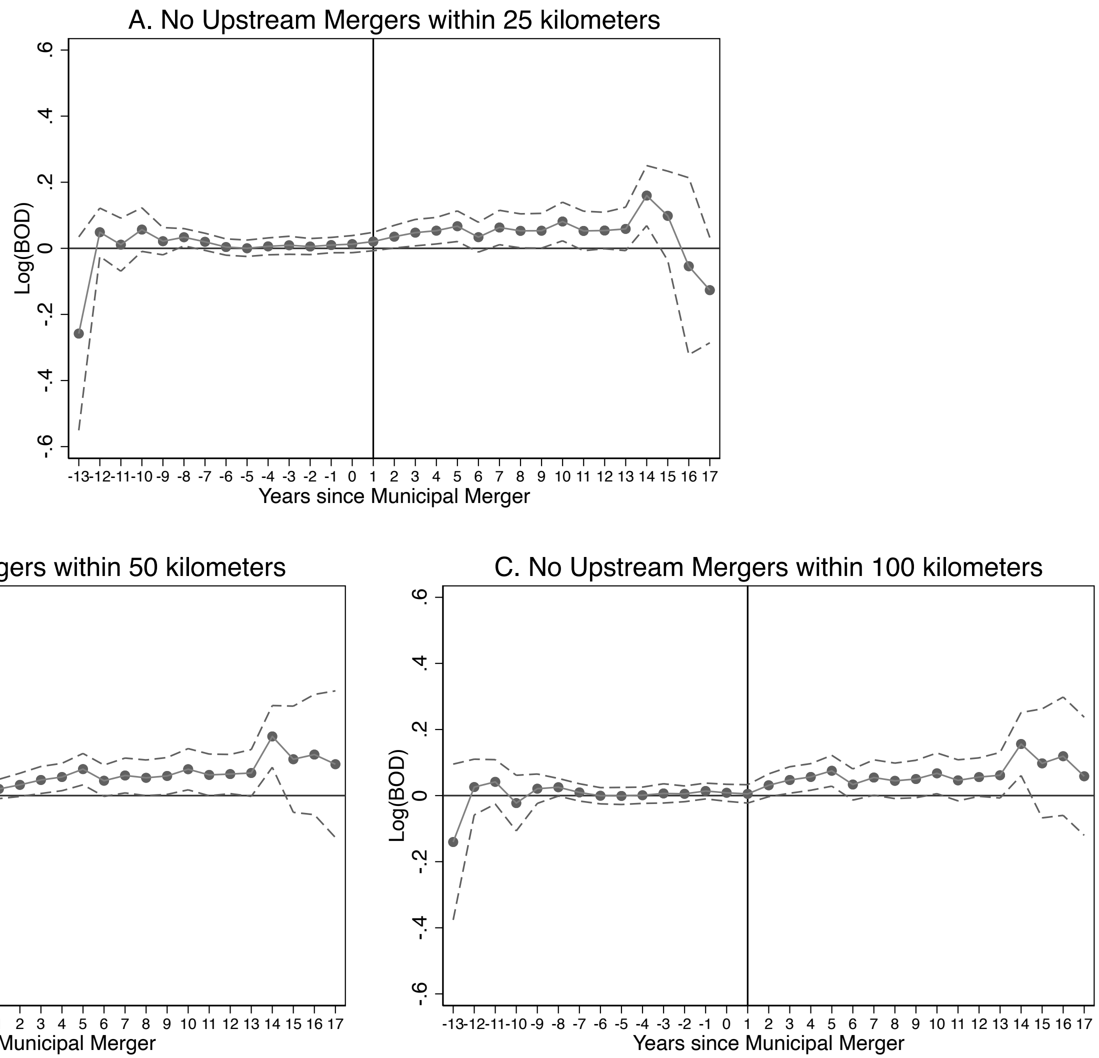

Figure A6: Robustness Check: Removing Spillovers from Upstream Merged Municipalities

Notes: This figure shows the coefficients of the Callaway and Sant'Anna (2021) estimator. Panel A shows a result using monitoring stations that do not have upstream merged municipalities within a 25-kilometer radius. Similarly, Panels B and C show results when using cutoff distances of 50 and 100 kilometers, respectively. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level.

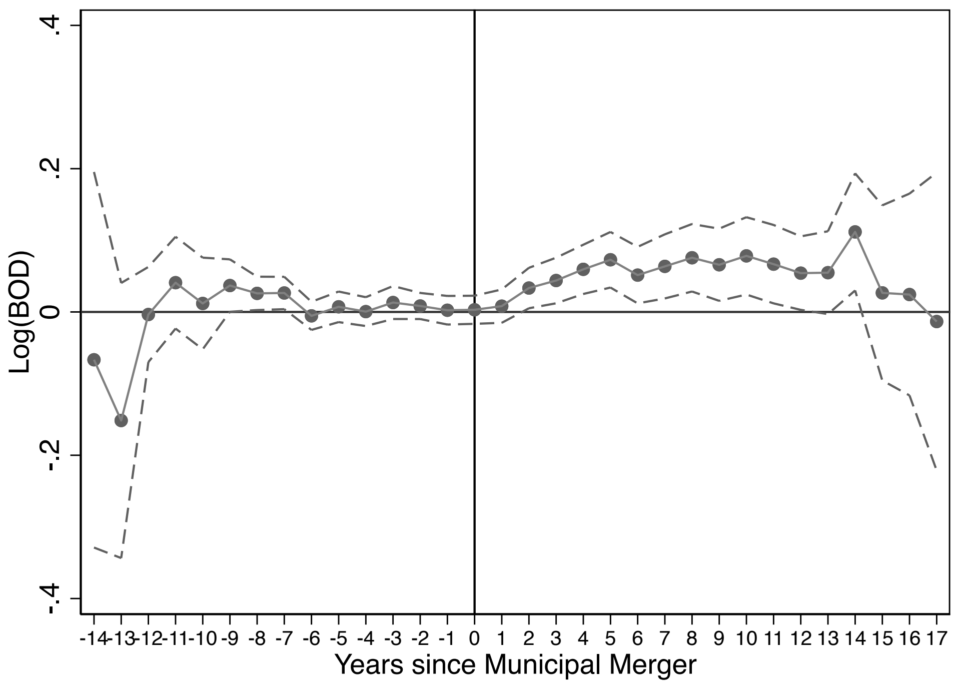

Figure A7: Robustness Check: Spillovers from Border Municipalities

Notes: This figure shows coefficients of the Callaway and Sant'Anna (2021) estimator. In this specification, the treatment indicator is set to one once at least one border municipality begins to undergo mergers for stations located at the borders of municipalities. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level.

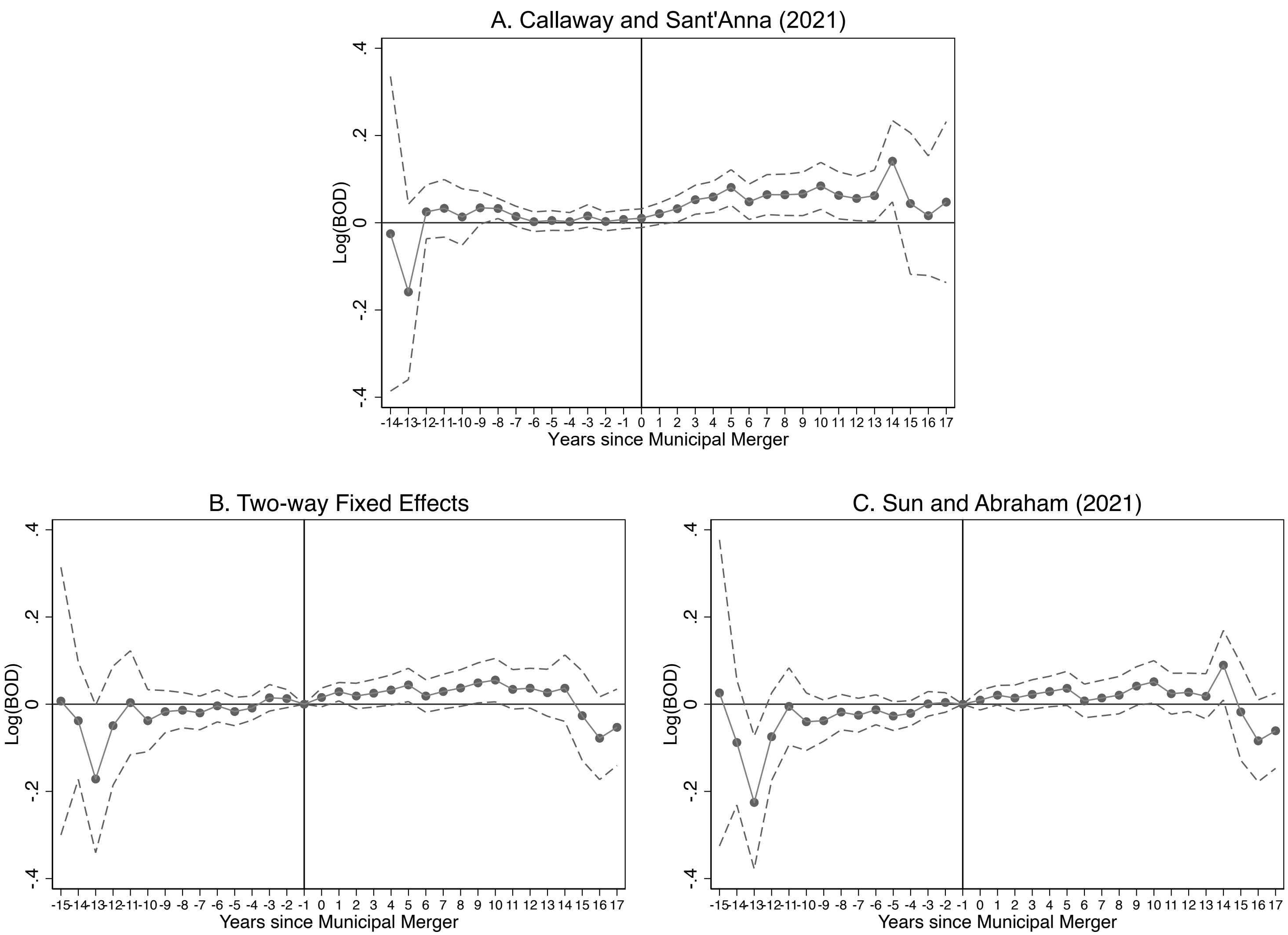

Figure A8: Robustness Check: Alternative Estimators

Notes: This figure compares the event study results among three alternative estimators. Panels A, B, and C show the coefficients of the Callaway and Sant'Anna (2021) estimator, two-way fixed effects estimator, 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. Panels B and C include monitoring station fixed effects and basin-by-year fixed effects.

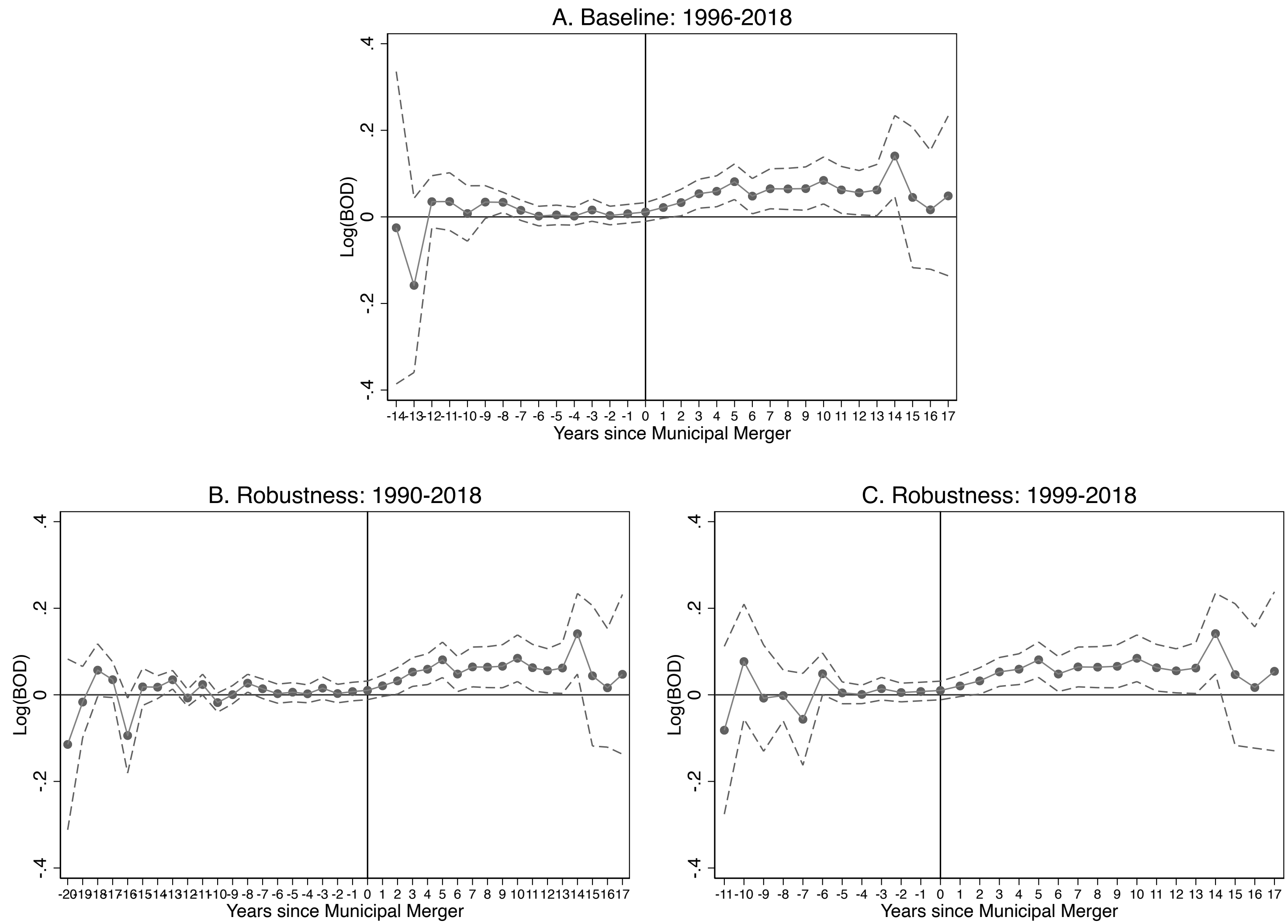

Figure A9: Robustness Check: Alternative Sample Periods

Notes: This figure shows 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.

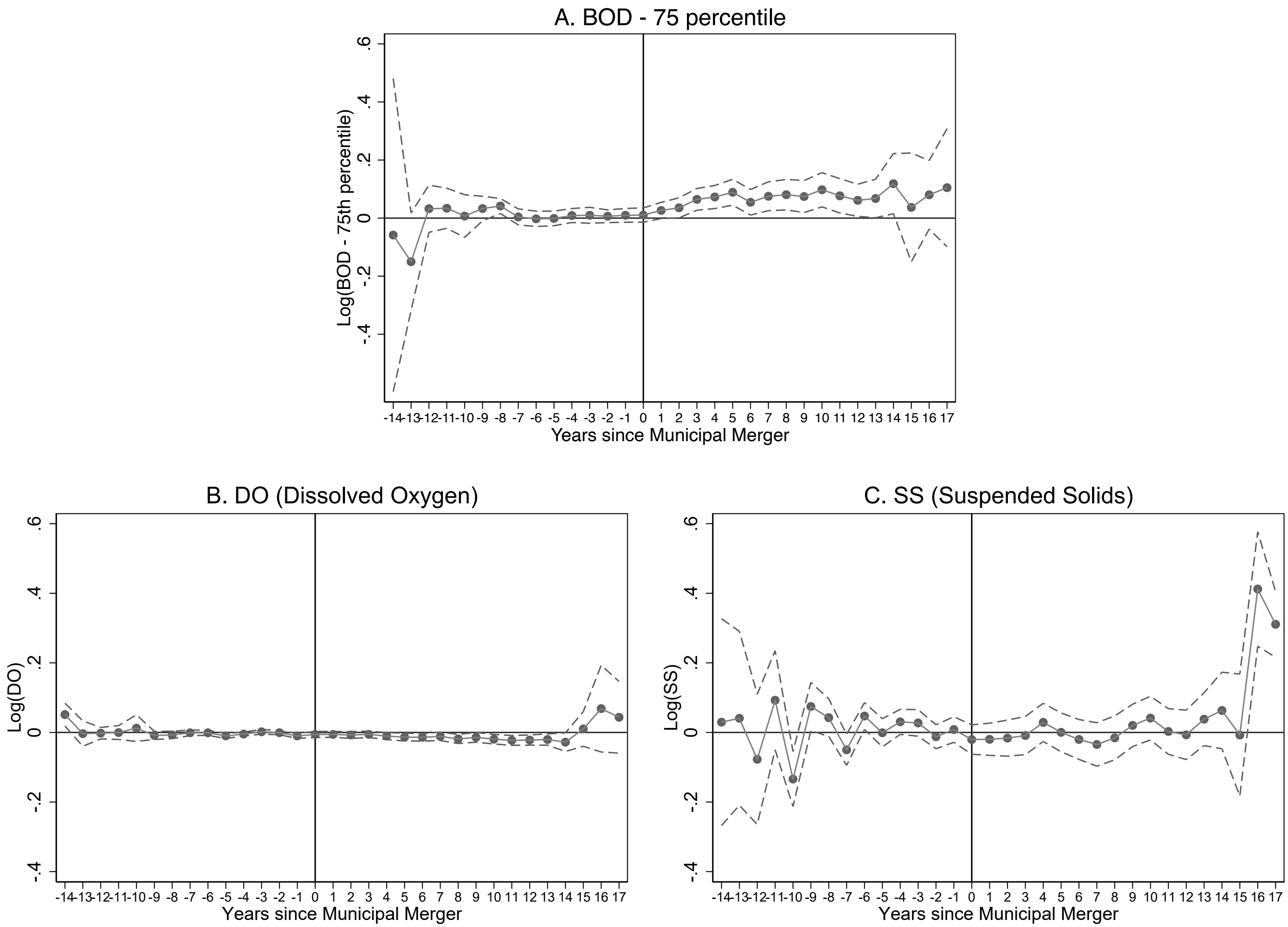

Figure A10: Robustness Check: Alternative Water Quality Indicators

Notes: 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.

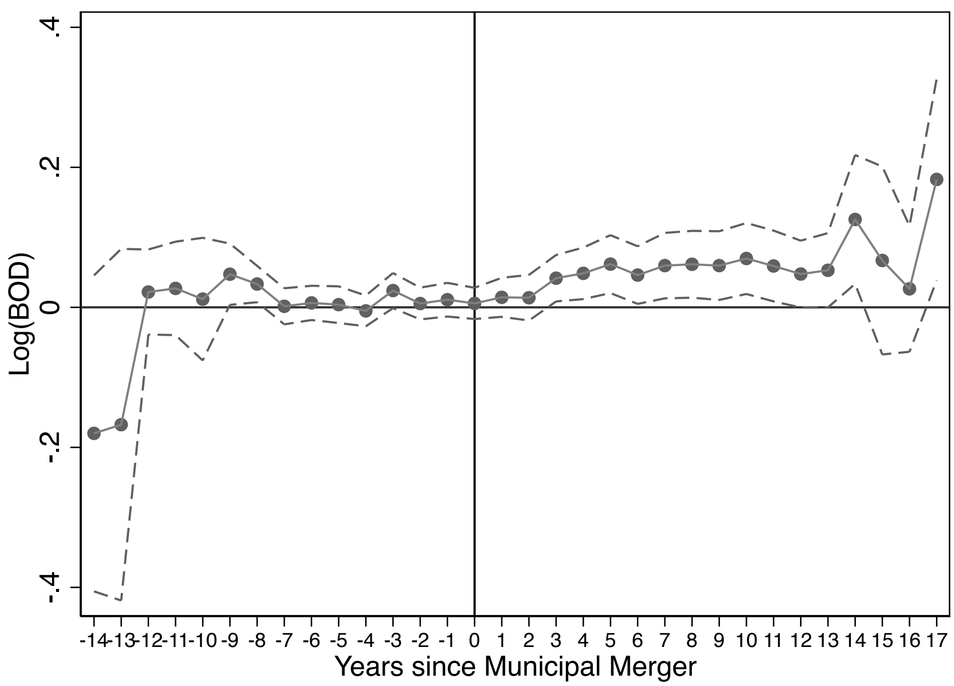

Figure A11: Robustness Check: Difference-in-Differences Analysis for Criteria Stations

Notes: This figure shows coefficients of the Callaway and Sant'Anna (2021) estimator. The sample is limited to criteria stations. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level.

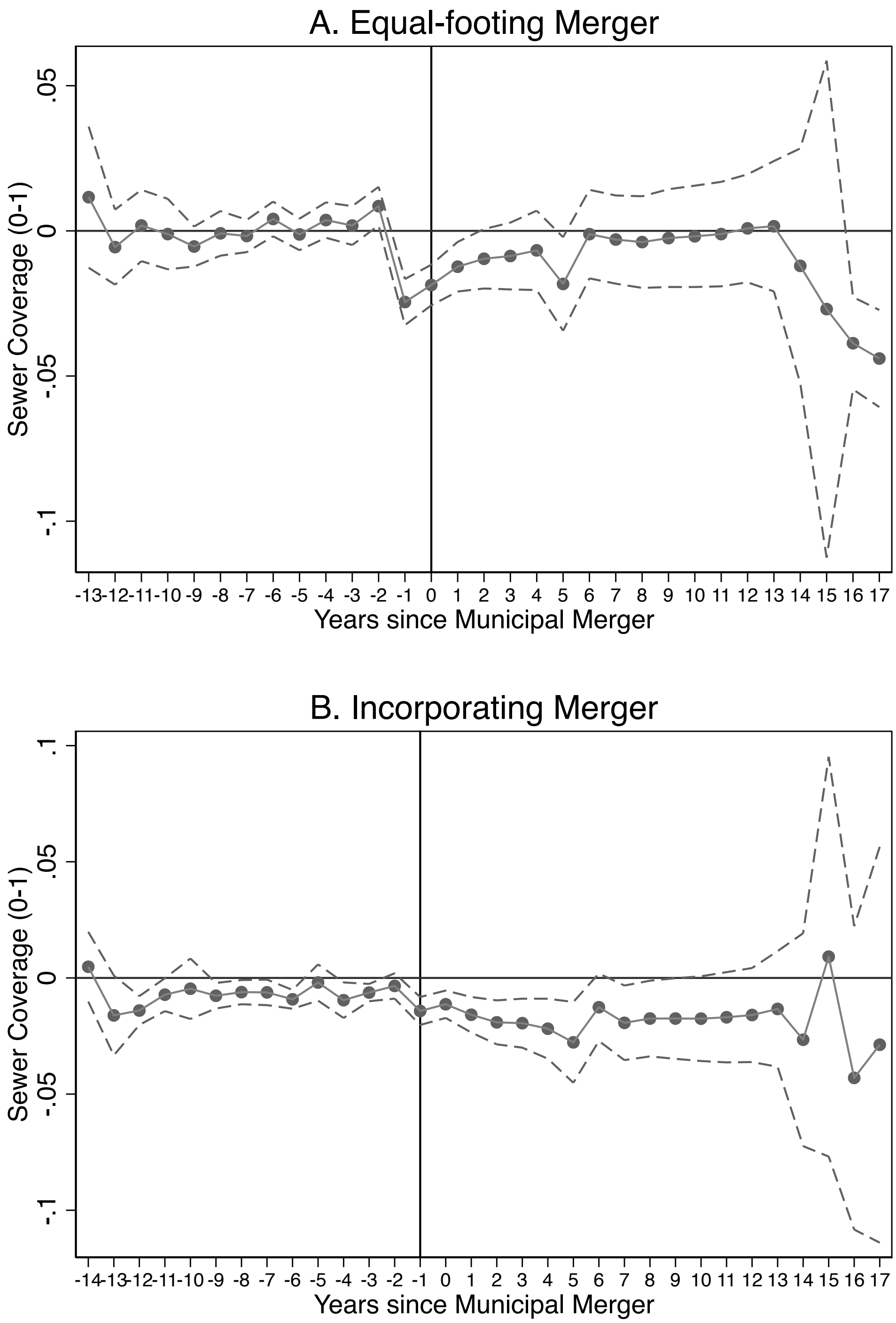

Figure A12: Pollution Source: Heterogeneous Effects on Sewer Coverage by Merger Types

Notes: This figure shows the coefficients of the Callaway and Sant'Anna (2021) estimator. Panel A shows the effect of equal-footing mergers by using data from municipalities that underwent such mergers and never-merged municipalities. Panel B, in a similar manner, shows the effect of incorporating mergers. The 95% confidence intervals are shown with dashed lines. Standard errors are clustered at the municipality level.

B Additional Tables

Table B1: Balance Checks of Matched Municipalities (Pre-Merger Period)

	Means		Difference	Obs.
Variable	Never-Merged	Merged		
Product shipment values (100 billion JPY)	2.391	2.954	0.563	643
	(4.822)	(5.674)	(0.459)	
Population (thousand)	101.865	111.842	9.977	643
	(224.588)	(157.791)	(16.906)	
Agricultural output values (billion JPY)	10.858	11.665	0.807	643
	(9.222)	(10.496)	(1.228)	
Financial capability index	0.483	0.488	0.005	643
	(0.231)	(0.226)	(0.022)	

Notes: This table compares summary statistics between matched merged and never-merged municipalities before the commencement of municipal mergers in our sample. Specifically, it focuses on the period before 2001, when the first mergers were observed, and after 1996, following the baseline specification. The means are calculated by averaging the values for all years in that period. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

C Data Appendix

C.1 Construction of River Distance

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

1. We apply inverse distance weighting (IDW) interpolation to the river node point layer to generate a 300-meter raster elevation layer. This layer offers a finer resolution compared to readily available Digital Elevation Models and provides high accuracy along river paths.
2. We use the river polyline layer and the municipality boundaries layer and intersect them by point to obtain the municipality entry/exit points of rivers.
3. We then append elevation information to both the "entry/exit point" layer and the monitoring station layer.
4. To minimize error, we only focus on monitoring stations that are located within 2 kilometers of the river polyline.
5. We build a network based on the river polyline layer and perform a "find the closest facility" analysis in ArcGIS. This allows us to pick the six closest municipality border points along the river for each monitoring station and calculate distances between each station and border points.
6. We use the elevation information to determine whether each selected municipality boundary point is upstream or downstream of the monitoring station. Then, we identify the closest upstream and downstream border points for each monitoring station and finally obtain values for U and D.

C.2 Construction of Land Use Measures

We calculate the numbers of raster pixels corresponding to the following three land use classifications within 150 meters, 1 kilometer, and 5 kilometers from water quality monitoring stations.[35] Following this, we construct a binary indicator of major land use by identifying the classification that represents the majority of pixels in each specified area.

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

[35] While the original data contained finer land use classifications, we consolidated them into three major classifications for our analysis. We also excluded pixels representing sea and river water, roads, railroads, and golf courses.