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

Kazuki Motohashi[†] Michiyoshi Toya[‡]

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Abstract

Municipal mergers that consolidate multiple municipalities can improve environmental quality by internalizing pollution spillovers but may also weaken pollution control due to coordination costs and political power imbalances between participating municipalities. We examine the environmental effect of municipal mergers by exploiting their staggered implementation in Japan, which halved the number of municipalities. We find that municipal mergers increase river pollution by 5.4%, 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: H73, Q52, Q53, R11

Keywords: Municipal mergers, Water pollution, Coordination costs, Political economy, Negative externality

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[†]Graduate School of Economics, 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, that is, the distribution of power between local and central governments, has long been debated among academics and policymakers. The decentralized provision of local public services can be more efficient than centralized, uniform provision, as it fosters competition among local jurisdictions and allows services to be better tailored to local needs (Tiebout, 1956; Oates, 1972). However, decentralization may lead to inefficient outcomes when local public services generate spatial spillover effects across jurisdictions without inter-jurisdictional coordination (Oates, 1972; Sigman, 2005; Solé-Ollé, 2006). A notable example is the negative externality of weakened pollution control on the environmental quality of neighboring jurisdictions. In accordance with this argument, an increase in the number of local jurisdictions under decentralized governance has been shown to degrade environmental quality in developing countries (Burgess et al., 2012; Lipscomb and Mobarak, 2016). However, there is limited research on the effects of the opposite scenario (i.e., a decrease in the number of local jurisdictions, which is more prevalent in developed countries) that could potentially internalize negative externalities.

We examine how municipal mergers that consolidate two or more municipalities affect environmental quality by changing their pollution control efforts. Municipal mergers have been widely adopted in approximately 20 developed countries and are expected to increase in the future due to their declining and aging populations, especially in rural areas. Municipal mergers aim to improve cost efficiency in the provision of local public services by leveraging economies of scale (OECD, 2014). Consistent with this aim, a negative externality theory suggests that municipal mergers can improve environmental quality by internalizing pollution spillovers across pre-merger municipalities. However, poor integration of local public services across participating municipalities following the merger can hamper pollution control efforts, leading to degraded environmental quality. Furthermore, areas absorbed in municipal mergers may be overlooked in post-merger pollution-control efforts, raising equity concerns within the merged municipality. Overall, the relationship between municipal mergers and environmental quality seems ambiguous and deserves careful empirical examination.

We evaluate the relationship between municipal mergers and river water quality within the context of Japan's "Great Heisei Mergers" from the late 1990s to the 2000s. The unique characteristics of these mergers allow us to effectively investigate their environmental effects. First, the municipal mergers were implemented in a staggered manner, which offers a quasi-experimental setting to examine their causal effects. Second, the mergers drastically reduced the number of municipalities by approximately 50% across Japan, from 3,238 in 1998 to 1,725 in 2012. These large-scale nationwide municipal mergers enhance the external validity of our findings within the country because they occurred across a wide range of local contexts, covering municipalities with diverse geographic, industrial, and infrastructure characteristics. Third, the primary objective of these mergers was to strengthen the municipalities' administrative and financial foundations, instead of addressing specific policy agendas, such as pollution control. This context allows us to examine the unintended consequences of municipal mergers on water quality with less concern about the endogenous implementations of the mergers. Finally, the availability of extensive water quality data from approximately 3,000 monitoring stations over 29 years enables us to examine the long-term environmental effects of the mergers. This geocoded dataset also enables an analysis of how the effects vary across different types of mergers and municipalities with differing levels of political power.

By exploiting the staggered implementation of municipal mergers, we investigate their causal effects on river water quality. We adopt a difference-in-differences (DiD) design to compare the outcomes of municipalities that merged with municipalities that never merged, in addition to comparing the outcomes of municipalities that merged earlier or later. In this staggered DiD design, a two-way fixed effects estimator may be subject to bias from the bad comparison between municipalities that merged earlier or later (Goodman-Bacon, 2021). Thus, we adopt the recently developed alternative estimator from Callaway and Sant'Anna (2021), which is robust to this concern, as our main specification.

In contrast to the narrative of negative externalities, we find that municipal mergers increased river pollution, with this negative effect lasting for 14 years. Specifically, mergers result in a 5.4% increase in biochemical oxygen demand (BOD), a key indicator of water pollution. Although BOD levels have generally declined across Japan, our findings suggest that municipal mergers offset this trend of improving water quality by 12.3%. This pollution effect translates into an 8% increase in cases where water quality remains just below regulatory limits, without increasing violations, suggesting weaker pollution control efforts.

The causality of our DiD results hinges on the assumption that the water quality levels in merged and non-merged municipalities would move in parallel in the absence of mergers. Our data indicate that water quality trends for merged and never-merged municipalities were indeed parallel during the pre-merger period. The event study analysis also shows no differential effects on water quality before the mergers, further supporting the parallel trends assumption. Our results remain robust across alternative specifications, including analyses of comparable municipalities matched by industry composition and financial conditions and the consideration of spillover effects, and are further supported by a falsification test.

Heterogeneity analyses suggest that the mechanisms driving the negative effect of municipal mergers are coordination costs and unbalanced political power between participating municipalities. First, we investigate 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 (i.e., 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. Equal-footing mergers involve creating new municipalities, typically between municipalities of comparable size, and electing a new mayor, where integration of services across participating municipalities is more challenging. Conversely, incorporating mergers involve a larger municipality that incorporates smaller municipalities, where the larger municipality takes the lead in policy-making, leading to smoother integration. These heterogeneity results are robust to using a more direct measure of coordination costs based on pre-merger population disparities.

As a second mechanism, we examine how differences in political power across participating municipalities lead to differential pollution effects (i.e., political economy mechanism). This analysis reveals heterogeneity within incorporating mergers that is masked by the null average effect. In the case of incorporating mergers, the mayor of the larger, incorporating municipality retains her position post-merger and may prioritize pollution control in her original jurisdiction, which weakens pollution control in the areas of smaller, incorporated municipalities. We find that incorporated municipalities with less political power experience increases in river pollution, while incorporating municipalities with greater political power experience limited changes in river pollution levels.

Considering the source of river pollution, we find evidence suggesting that a slowdown in sewerage investments following mergers increases the amount of untreated domestic wastewater. Municipalities are primarily responsible for controlling domestic wastewater by constructing and operating sewerage systems, including sewers and sewage treatment plants. Using the same DiD analysis on the municipality-level panel of sewerage expenditure and coverage, we find that municipal mergers reduce sewerage construction expenditure by 13% and slow the expansion of coverage. These findings suggest that mergers lead to a larger volume of untreated domestic wastewater, thereby exacerbating river pollution.

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

We do not find evidence supporting another alternative mechanism, that is, 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, such as expanding industrial and residential areas through increased economic activities. This change in land use could generate industrial and domestic wastewater, thereby escalating river pollution. However, we find no significant effects of mergers on land-use types near water quality monitoring stations, including agricultural, built-up, and forest areas.

Our findings highlight that municipal mergers can have unintended negative effects on environmental quality due to coordination costs and political power imbalances between participating municipalities. With the expected increase in municipal mergers driven by declining and aging populations in developed 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 to the literature. First, we contribute to the literature on decentralization by presenting the mechanisms of coordination costs and political power imbalances.[1] Previous studies have shown that splits in local jurisdictions exacerbated pollution spillovers along rivers in Brazil (Lipscomb and Mobarak, 2016), while mergers instead internalized air pollution spillovers in China (Wang and Wang, 2021), aligning with the negative externality theory. However, our paper finds no evidence supporting the negative externality theory; instead, municipal mergers in Japan increase river pollution. We show that alternative mechanisms (i.e., weaker pollution controls due to coordination costs and political power imbalances) merit greater attention in discussions of decentralization.

Second, we contribute to the literature on municipal mergers by showing their negative long-term environmental effects. Most previous studies have investigated the fiscal and macroeconomic effects of municipal mergers on local public finance (Hinnerich, 2009; Reingewertz, 2012; Blesse and Baskaran, 2016; Hirota and Yunoue, 2017; Miyazaki, 2018), economic growth (Egger et al., 2022; Han and Wu, 2024), and infrastructure expenditure (Li and Takeuchi, 2023).[2] In contrast, we focus on the effects of municipal mergers at the level of local public services—specifically pollution control—where evidence remains scarce. A particularly relevant study by Wang and Wang (2021) showed that township mergers in China internalized the negative externalities of air pollution by controlling firms' emissions.

[1] This paper broadly relates to fiscal federalism within the context of environmental policies, including the interactions of environmental policies across local jurisdictions (Fredriksson and Millimet, 2002) and Tiebout sorting influenced by environmental quality (Banzhaf and Walsh, 2008).

[2] Another strand of literature has examined the decision-making processes and associated costs of municipal mergers and inter-municipal cooperation (Weese, 2015; Tricaud, 2025).

We complement their findings in two ways: (i) we show that municipal mergers can instead have negative environmental effects, which necessitates alternative explanations beyond the negative externality theory, and (ii) our 29-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.

Third, we contribute to the literature on water pollution by providing the first causal estimates of the effects of municipal mergers on water quality. Earlier studies have shown 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; Chen et al., 2025), political incentives (Kahn et al., 2015; He et al., 2020), and infrastructure investments (Motohashi, 2023). Another strand of literature has examined the effectiveness of interventions in reducing pollution, including water quality regulations (Greenstone and Hanna, 2014; Keiser and Shapiro, 2019) and court rulings (Do et al., 2018). This paper shows that a decrease in the number of political boundaries, such as 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 the paper.

2 Background

2.1 The Great Heisei Mergers in Japan

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

The primary objective of the Great Heisei Mergers was to strengthen municipalities' administrative and financial foundations to sustain their provision of local public services. Municipalities, especially those in rural areas, were grappling with various challenges, such as dwindling birth rates, declining and aging populations, and fiscal difficulties following the burst of the Bubble Economy in the early 1990s. Hence, municipal mergers were envisaged as a means to rejuvenate these struggling municipalities. As these mergers were not implemented to address specific policy agendas, such as water pollution control, this paper

[3] Local governments in Japan operate through a two-tiered system, comprising prefectures as the upper level and the municipalities that fall under their jurisdiction as the lower level.

examines the unintended effect of municipal mergers on water quality with less concern about the endogenous implementations of these municipal mergers.

The financial incentives established with the revisions of the Act on Special Provisions of the Merger of Municipalities in 1995 and 1999 played a key role in fostering the Great Heisei Mergers.[4] The 1995 revision announced that the purpose of the Act was to promote municipal mergers and introduced preferential treatment in local allocation tax grants—that is, a fiscal transfer from the central government to local governments—to ensure that the transfer amount would not decrease for 5 years following a merger. The 1999 revision further strengthened this financial incentive by extending the period of preferential treatment in local allocation tax grants 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, while the central government paid the remaining 70 percent. Thus, the bonds effectively acted as a 70 percent public project subsidy for merged municipalities. The central government initially announced that municipalities had to complete their mergers by March 2005 to be eligible for these benefits; however, this deadline was later extended by 1 year to March 2006.

Driven by these strong financial incentives, the Great Heisei Mergers were implemented over time in a staggered manner. As illustrated in Figure 2, the first merger occurred in 1999, which coincided with the strengthening of financial incentives. While the number of mergers remained low for the next few years, the vast majority took place between 2004 and 2006. This pattern not only reflects the time required to complete the merger process but also indicates bunching behavior by municipalities aiming to meet their initial and final deadlines for financial incentives in 2005 and 2006, respectively. These municipal mergers continued until 2011. Moreover, the central government did not force the Great Heisei Mergers policy on municipalities, leading to variations between municipalities that underwent municipal mergers and those that did not.[5]

These municipal mergers were officially categorized into two types: equal-footing mergers and incorporating mergers (as illustrated in Appendix Figure A1). The former involves mergers on an equal footing, typically between municipalities of comparable size, resulting in the creation of a new municipality with a newly assigned name. Following the completion

[4] Promulgated in 1965, the Act originally focused on facilitating merger procedures.

[5] Hence, municipalities' autonomy was respected by enabling them to decide whether to merge and, if so, to choose their preferred merger partners. The merger process involved several steps. First, interested municipalities formed a panel to discuss potential mergers. Second, the panel negotiated and formulated the merger proposals. Finally, the merger was formally announced and implemented following a final voting process by the participating municipalities and administrative approval by the prefectural governor and the Minister of Internal Affairs and Communications.

of the merger, the mayor of the new municipality is newly elected in the subsequent election. In our sample, 73% of the total mergers are classified as equal-footing mergers. Conversely, incorporating mergers involve a larger municipality incorporating smaller ones, with the resulting municipality keeping the name of the larger, incorporating municipality. The mayor of the incorporating municipality continues as the mayor of the post-merger municipality, while the mayors of the smaller incorporated municipalities lose their positions. These incorporating mergers account for 27% of the total mergers in our sample. Both types of mergers were implemented in a staggered manner, with no noticeable differences in timing, as shown in Appendix Figure A2.

2.2 Water Quality and Pollution Control in Japan

Ambient water quality in Japan is monitored under the Environmental Quality Standards for Water Pollution, which serve as non-mandatory policy targets. Therefore, municipalities can weaken their pollution controls following municipal mergers, with little concern about the consequences of violating these environmental standards.[6] Among the multiple water quality indicators monitored under these standards, we focus on BOD levels as the primary outcome. BOD levels measure the amount of dissolved oxygen (DO) needed by aerobic biological organisms to break down organic material present. Thus, they capture the overall level of water contamination from various pollution sources, where a higher BOD level indicates a higher level of water pollution. The environmental quality standards set BOD limits for river water quality from 1 to 10 mg/L, as differentiated by the designated usage categories assigned to each river location.[7] The Minister of the Environment and prefectural governors, not municipal mayors, are responsible for designating usage categories.

Under these environmental quality standards, the quality of river water in Japan has generally improved over time. From 1990 to 2018, the average BOD levels in our sample declined from 3.6 to 1.4 mg/L. Correspondingly, the violation rates of environmental quality standards decreased from over 20% to 10% during the same period. Therefore, we examine whether municipal mergers changed the existing positive trend of river water quality.

The main sources of water pollution can be categorized into three types: (i) domestic

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

[7] 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 (i.e., 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, which is typically treated in sewerage infrastructure constructed and operated by the municipalities themselves.[8] Domestic wastewater is typically the primary source of river pollution in Japan, suggesting that municipalities play an important role in addressing it.[9] Conversely, municipalities have limited roles in controlling industrial and agricultural wastewater. In the case of industrial wastewater, effluent standards for factories are mostly 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.[10] 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 several factors, such as precipitation. This diffusion makes it more challenging for municipalities to establish policies for controlling agricultural wastewater.

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, earlier studies have emphasized the role of negative externalities across jurisdictions, which suggests that mergers internalize pollution spillovers. Second, in contrast, the coordination costs and unbalanced political power between participating municipalities may subsequently hamper the merged municipalities' pollution control efforts. Third, changes in land use driven by mergers could generate new sources of pollution.

Negative Externality Theory.—One mechanism often emphasized in the literature is the role of negative externalities or pollution spillovers across jurisdictions, which suggests a positive effect of municipal mergers on water quality. Lipscomb and Mobarak (2016) developed

[8] In Japan, most sewerage services are directly operated by municipalities, except in certain cases such as prefecture-led sewerage systems that serve multiple municipalities. This direct involvement of municipalities in mitigating water pollution represents a distinctive aspect that does not apply to other types of pollution, such as air pollution, where governments primarily focus on enforcing emission standards for emitters.

[9] Prefecture-level estimates in Japan indicate that domestic wastewater is a major contributor to river pollution, even though no nationwide data exist on the contribution of each pollution source. For example, in Saitama Prefecture, the estimated contribution of domestic wastewater to BOD was 73.5% in 2001 (according to the 2004 Master Plan for Development of Domestic Wastewater Treatment Facilities). In Niigata Prefecture, a more rural region, the estimated contribution was 59.5% in 2001, based on a pollution load survey.

[10] The designated municipalities tend to be large municipalities that did not undergo municipal mergers.

a conceptual framework based on negative externality theory, in which pollution from an upstream municipality adversely affects other downstream municipalities. Using this conceptual framework, they showed that an increase in the number of districts along a river course due to district splits in Brazil worsens water pollution. Building on their model, we may expect that municipal mergers, which conversely decrease the number of municipalities along a river course, improve water quality in rivers by internalizing pollution spillovers.[11]

A key assumption behind this negative externality mechanism is that municipal mergers occur along the same rivers, with upstream–downstream relationships among participating municipalities. Our GIS data supports this assumption: in 71% of merged municipalities, at least 75% of the post-merger municipal area lies within the same river basin. This concentration of mergers within the same basin is visually observed in Appendix Figure A3.

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 their model, consider a municipality that spans an area from 0 to 1 on the horizontal axis and is located along a river (Appendix Figure A4). The river flows from 0 to 1; thus, 0 and 1 are the upstream and downstream municipality borders, respectively. A mayor chooses how much economic activity to pursue and, consequently, how many pollutants to emit at each point within the municipality. Because the mayor aims to minimize the negative effect of emissions on the population and does not consider the effect on people living in other municipalities, they would choose to focus most of the economic activity and emissions near the downstream border at point 1. Most of the municipality's population living upstream of this point would not be adversely affected by any emissions occurring near the downstream border. We examine the presence of these spatial patterns to test the validity of the negative externality theory later in Section 6.4.[12]

Coordination Costs and Political Economy.—In contrast to the negative externality mechanism, two additional mechanisms (i.e., coordination costs and political economy) can worsen water quality by weakening municipalities' pollution control efforts.

First, municipal mergers with high coordination costs can weaken pollution control efforts, leading to increased water pollution (i.e., the coordination costs mechanism). This mechanism is suggested by responses to the post-merger survey indicating difficulties and delays in policy coordination as a negative consequence of the Great Heisei Mergers (NATV,

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

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

2008). According to a survey conducted by the Japan Municipal Research Center of 416 municipalities, 44% reported that the continuation and coordination of projects between participating municipalities remained an issue (JMRC, 2008). If coordination costs between participating municipalities are high, a post-merger municipality faces difficulties in reformulating its local public services, which were previously managed separately by each participating municipality, into coherent new services. These difficulties in policy integration are closely related to challenges in merging administrative departments and staff into a unified system. As a result, pollution control efforts in merged municipalities with higher coordination costs may be weakened. The levels of these coordination costs can differ according to the type of municipal merger. Equal-footing mergers, which involve creating new municipalities, typically between municipalities of comparable size, and electing a new mayor, are expected to experience greater challenges in integrating services. Conversely, incorporating mergers—where the mayor of the larger, incorporating municipality retains their position and leads policy decisions—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 the case of incorporating mergers with lower coordination costs.

Second, municipal mergers can have differential effects on water pollution depending on the relative political power of the participating municipalities in the case of incorporating mergers (i.e., the political economy mechanism). In such mergers, the mayor of the larger, incorporating municipality retains her position, while the mayors of smaller, incorporated municipalities lose their positions. After the merger, the mayor of the incorporating municipality may prioritize pollution control in her original jurisdiction within the merged municipality, as her electoral base is concentrated there. In addition, the council members in the new municipality are likely to include a higher proportion of representatives from the incorporating municipality, further reinforcing its priority in this area. Conversely, the areas of incorporated municipalities, which have lost their own decision-making power, may be overlooked in post-merger pollution control efforts, raising equity concerns within the post-merger municipality. Indeed, the responses to the post-merger survey note that the voices of people living in incorporated municipalities were not adequately reflected following the merger (NATV, 2008). A JMRC (2008) survey also revealed that 54% of the surveyed municipalities expressed concerns about the widening disparities between central and peripheral areas following mergers.[13] This political economy mechanism suggests that incorporated

[13] Additional supporting evidence from the political science literature suggests that politicians reallocate public spending away from areas with smaller populations (or fewer voters) toward those with larger populations following municipal mergers in Japan (Pickering et al., 2020). Egger et al. (2022) similarly found widening economic disparities between absorbed and absorbing municipalities in the German context,

municipalities can experience more water pollution than incorporating municipalities do.

Land Use.—Another mechanism could be changes in land use, which might generate new pollution sources without altering pollution control efforts. Municipal mergers can reshape economic activities, as shown by Egger et al. (2022), potentially leading to land use changes, such as converting forest and agricultural areas near rivers into industrial and residential areas. Consequently, these land use changes could increase 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 construct a panel dataset covering 3,285 monitoring stations over a span of 29 years.

3.1 Water Quality

The main outcome variable is water quality. We use monitoring station-level data provided by the Japanese Ministry of the Environment, which includes annual average water quality indicators measured at monitoring stations, alongside their global positioning system (GPS) locations.[14] As discussed in Section 2.2, we mainly use BOD levels as a representative water quality outcome in our analysis.

Specifically, our analysis uses balanced panel data covering the period from 1990 to 2018 from 3,285 water quality monitoring stations along rivers across Japan (Figure 3). To address concerns about the potential endogenous placement of monitoring stations during this period, we restrict the sample to stations with complete observations for all years in the study period.[15] Our extensive panel dataset, covering thousands of stations over a 29-year span, allows us to examine the long-term effects of municipal mergers on water quality. Furthermore, the geocoded station-level data enable us to investigate heterogeneity across merger types and participating municipalities with different levels of political power.

although these disparities were already evident in the pre-policy period.

[14] To identify the river basin of each monitoring station, we spatially merge the dataset with river basin boundaries for Japan from the Ministry of Land, Infrastructure, Transport, and Tourism.

[15] Although the placement of monitoring stations is determined at the prefectural level (or by designated cities), rather than at the municipality level, stations may still be newly established or discontinued in ways that are correlated with underlying local water quality conditions. Moreover, our DiD analysis with monitoring station fixed effects, which examines changes in water quality within the same station over time, further mitigates concerns about the endogenous selection of monitoring stations.

3.2 Municipal Mergers

The key treatment variable in our DiD design is an indicator of whether a municipal merger occurred each year in the municipality where each monitoring station is located. To construct this treatment variable, we obtain data for the timing of municipal mergers and the participating municipalities from the Ministry of Internal Affairs and Communications.

This dataset also provides information about the types of municipal mergers (i.e., equal-footing versus incorporating mergers) and whether each participating municipality is the incorporating or incorporated municipality in the case of incorporating mergers. This information is used to examine the heterogeneous effects of municipal mergers in our analysis of coordination costs and political economy mechanisms.

3.3 Other Municipality Characteristics

We supplement the above information with further data on municipality characteristics that could affect both water quality and the likelihood of municipal mergers. Specifically, our empirical analyses use an economic indicator and population as controls. As the economic indicator, we use product shipment values in the manufacturing sector from 1990 to 2015 from the Census of Manufacture provided by the Ministry of Economy, Trade, and Industry. We also use population data from the Japanese Census. Because the census is conducted every 5 years, we compute the annual 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 for the pre-merger period (i.e., 1990–2000), we also use (i) agricultural output values from the Statistics of Agricultural Income Produced provided by the Ministry of Agriculture, Forestry and Fisheries and (ii) the financial capability index from the Annual Statistics on Local Public Finance provided by the Ministry of Internal Affairs and Communications.[16]

3.4 Data Matching and Sample Construction

We match water quality and municipal merger datasets 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 municipalities where these stations are located. Subsequently, we match water quality and municipal merger data based on the names of these

[16] The financial capability index is computed by dividing basic financial revenues by basic financial needs and averaging these values over the past 3 years. A higher financial capability index indicates better financial conditions in a municipality.

municipalities. Similarly, we merge all other data, including information on river basins and other municipality characteristics, based on the post-merger names of these municipalities. Moreover, we use the pre-merger municipality boundary data from 1995 alongside municipal merger data to differentiate between stations located within incorporating and incorporated municipalities to analyze the political economy mechanism.

After matching these data, we construct a balanced panel of 3,285 water quality monitoring stations within 971 post-merger municipalities from 1990 to 2018.[17]

3.5 Summary Statistics and Water Quality Trends

The summary statistics for the main variables during the pre-merger period (before 2001 in our sample) are shown in Table 1. During this pre-policy period, merged municipalities differ from never-merged municipalities in several aspects, including water quality levels, agricultural output values, and the financial capability index. Merged municipalities were more focused on the agricultural sector in their economy and had poorer financial conditions and better water quality before their mergers.

These baseline differences between merged and never-merged municipalities may raise concerns about selection bias in merger decisions, even if the mergers themselves were not implemented with the explicit objective of improving environmental quality. For instance, municipalities with weaker financial conditions may be more likely to merge and, at the same time, may reduce pollution control efforts (e.g., sewerage investments) after the merger to prioritize other local public services over environmental protection. Alternatively, these municipalities may merge to leverage final incentives, such as special provision bonds, to expand and maintain sewerage infrastructure, thereby strengthening pollution control.

To assess and address concerns about selection bias, we test the parallel trends assumption and conduct DiD analyses using a matched sample. A comparison of the trends in BOD levels between the merged and never-merged municipalities encouragingly shows signs of parallel pre-trends (Figure 4).[18] These parallel pre-trends are formally tested and found in the event study design that we describe in Sections 4.1 and 5.1. Moreover, we obtain similar results when conducting DiD analysis on a matched sample of more comparable municipalities, matched on agricultural sector intensity and financial conditions, as shown in Section 5.2.

Since BOD levels decreased in both merged and never-merged municipalities during the post-merger period (Figure 4), our DiD analyses examine the differential decrease in BOD levels. The smaller observed decrease in merged municipalities suggests a negative effect

[17] The average number of stations per post-merger municipality is 3.38, with a standard deviation of 4.05.

[18] The same pattern is also observed when plotting the trends of logarithms of BOD levels, which are used in the empirical analyses (Appendix Figure A5).

of municipal mergers on water quality, a hypothesis we test in subsequent sections. One potential concern is that water quality trends appear to converge toward a BOD level of 1 mg/L, which may represent a floor due to technological limitations or limited incentives to reduce BOD levels further. This convergence could introduce a mechanical floor effect, as merged municipalities with lower baseline BOD levels may have had less room for improvement, particularly in later periods. However, our raw water quality data do not show clear evidence of such a floor: 37% of BOD observations are below 1 mg/L. Moreover, we observe significant effects in the short term, when the floor effect is less likely to be a concern, as shown in the event study results in Section 5.1.[19]

4 Empirical Strategy

We identify the causal effect of municipal mergers on water quality by adopting a DiD design that exploits staggered implementation of municipal mergers. Simple ordinary least squares estimates may be subject to bias due to the potential endogeneity that comes from reverse causality and omitted variables. Municipal mergers could be implemented to address water pollution.[20] Additionally, spurious correlations may arise from omitted unobservables, such as differences in time-varying policy priorities for water pollution control across municipalities. To address this potential endogeneity, we adopt the following DiD design.

4.1 Difference-in-Differences Design

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

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

where the dependent variable, $Log(BOD_{i,m,t})$, is a logarithm of BOD levels at monitoring station i located in municipality m in year t. We use a logarithmic transformation because BOD levels are right-skewed and approximately follow a log-normal distribution. $Merger_{m,t}$ is an indicator variable that switches to 1 and remains 1 for all subsequent years once a merger takes place in the municipality m where station i is located.[21] $X_{m,t}$ is a vector of

[19] The convergence to a floor is also not evident in the trends of the logarithm of BOD levels (Appendix Figure A5).

[20] However, this concern is highly implausible, as municipal mergers are not implemented to address specific policy agendas, including water pollution control (see Section 2.1).

[21] When municipal mergers are implemented in multiple stages, treatment timings are assigned based on the specific stage of implementation. For example, if municipality A incorporates municipality B in year X and subsequently incorporates municipality C in year Y, the treatment timing for stations within municipalities A and B is year X, whereas it is year Y for stations within municipality C.

municipality-level control variables for a robustness check, including an economic indicator (i.e., product shipment values) and population, both of which can affect both water quality and the likelihood of municipal mergers.[22] 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.[23] Monitoring station fixed effects (δ_i) are included to control for the time-invariant characteristics of each monitoring station (and more broadly of each municipality), including the relative positions of stations along rivers and socioeconomic disparities across municipalities. To account for trends in water quality that may potentially be influenced by changes in environmental regulations, which may vary across river basins, we also include basin-by-year fixed effects ($\theta_{b,t}$). Last, standard errors are clustered at the post-merger municipality level because this is where the variation in mergers is observed.

The coefficient of interest is β_{DID}, which could be negative if municipal mergers decrease river pollution by internalizing pollution spillovers, as suggested by the negative externality theory. Conversely, β_{DID} could be positive if municipal mergers increase river pollution due to the coordination costs and unbalanced political power between participating municipalities.

We also adopt an event study specification to examine the pre-trends and the dynamic evolution of the treatment effects. The DiD design hinges on the parallel trends assumption between merged and non-merged municipalities. We empirically test this parallel trends assumption in the following event study regression, which also allows us to examine the long-run dynamic effects of municipal mergers.

$$Log(BOD_{i,m,t}) = \delta_i + \theta_{b,t} + \sum_{\tau=-10}^{15} \beta_\tau Merger_{\tau,m} + \lambda X_{m,t} + \varepsilon_{i,t} \tag{2}$$

where $Merger_{\tau,m}$ serves as a treatment indicator for each year τ relative to the timing of the merger for municipality m. Although the event time τ in our sample potentially ranges from -15 to 19, our baseline analysis focuses on the effects within the range of $-10 < \tau < 15$, where water quality data are available from a substantial number of monitoring stations.[24] For monitoring stations located in never-merged municipalities, $Merger_{\tau,i}$ is set to 0 for all

[22] We focus on these two control variables to maintain consistency with the river distance specification in Section 6.4. Although we do not control for other municipality characteristics here, specifically agricultural output values and the financial capability index, these characteristics are effectively controlled for in the DiD analysis of matched municipalities in Section 5.2.

[23] Specifically, we use the average values of these variables during the pre-merger period (i.e., 1990–2000).

[24] The number of monitoring stations in merged municipalities falls below 50 for $\tau \geq 16$, as the sample includes only a small number of municipalities with very early mergers, resulting in larger confidence intervals. Although the number of monitoring stations exceeds 1,900 for $\tau = -10$, we present results only for $\tau > -10$ for readability. However, full estimates across the entire range of τ are provided in Appendix Figure A6.

periods. In this two-way fixed effects regression, $\tau = -1$ is set as a reference year.

The coefficients of interest in the event study specification are β_τ. We examine β_τ from $\tau = -10$ to $\tau = -2$ to test the parallel pre-trends. From $\tau = 0$ to $\tau = 15$, β_τ captures the dynamic evolution of the treatment effects in the short and long runs for up to 15 years.

Our DiD design exploits the staggered implementation of municipal mergers. Thus, the estimates of β_{DID} and β_τ 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 (i.e., the treatment group) with those in municipalities that never experienced mergers (i.e., the control group). Another case could be comparing monitoring stations in municipalities that experienced mergers in the early years (i.e., the treatment group) with those in municipalities that experienced mergers in later years (i.e., the control group).

The recent econometrics literature has shown that the two-way fixed effect estimator can be subject to bias in the case of the staggered DiD design. The comparison between early and late merger municipalities can become problematic in the presence of heterogeneous treatment effects across treatment cohorts and time, which leads to negative weights and thus causes bias (Goodman-Bacon, 2021).

To obtain unbiased estimates, we adopt alternative estimators that are robust to negative weights as our main specification. Specifically, we adopt the Callaway and Sant'Anna (2021) estimator.[25] In this estimator, common year shocks are effectively differenced out, thereby serving the role of year fixed effects; accordingly, we do not include basin-by-year fixed effects in this specification. As a robustness check, we also use the Sun and Abraham (2021) estimator, which is likewise robust to negative weights. In both estimators, we set never-merged municipalities as the control group.

5 Results

5.1 Baseline Results: Water Quality

We find that municipal mergers increase river pollution, which contradicts the negative externality narrative that mergers can internalize pollution spillovers. Table 2 shows that municipal mergers increase water pollution by 5.4% when adopting the Callaway and Sant'Anna

[25] The event study results for the Callaway and Sant'Anna (2021) estimator include the coefficients for event time -1 because a varying base period is used for estimating the pseudo-effects in pre-treatment periods in alignment with their parallel trends assumption. Specifically, the base (i.e., reference) period is set to the immediately preceding period. For example, for event time -1, the base period is -2.

(2021) estimator (Column 1 of Panel A). This effect size is larger than the 4.4% increase estimated using the two-way fixed effects specification, which suggests bias from negative weights in this latter specification. Overall, these results show that water quality improvements become slower following municipal mergers than in the absence of mergers. Considering that the BOD level decreased by 44% on average in never-merged municipalities in our sample, our estimate suggests that municipal mergers offset this trend of water quality improvement by 12.3% ($5.4 \div 44 \times 100$). These results are based on our preferred specification, which does not include controls and which clusters standard errors at the municipality level, and all subsequent sections rely on this specification. Our result remains robust when clustering standard errors at the 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 have persisted for 14 years. Figure 5 shows the event study results for the Callaway and Sant'Anna (2021) estimator.[26] First, we find no differential pre-trends for most pre-merger periods, which reinforces 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 long term. However, the effects become statistically insignificant 15 years after the merger, which is likely due to the smaller sample sizes including only municipalities that merged at earlier stages.

5.2 Robustness Checks

The results remain robust across alternative specifications, including the analysis of matched municipalities, the consideration of spillover effects from upstream and border municipalities, and the adoption of alternative water quality indicators. They are further supported by a falsification test using an unrelated water quality indicator.

DiD Analysis of Matched Municipalities.—The baseline DiD specification relies on a comparison between merged and never-merged municipalities, which differ in agricultural sector intensity and financial conditions prior to the mergers. These differences raise concerns about selection bias in merger decisions, as discussed in Section 3.5.

To address these selection bias concerns, we conduct a DiD analysis on a sample of more comparable municipalities matched on their pre-merger imbalanced characteristics. Specifically, we adopt Mahalanobis distance matching using two variables: agricultural output val-

[26] We find similar results when using alternative estimators, such as the one proposed by Sun and Abraham (2021) (see Appendix Figure A7).

ues (capturing the agricultural sector intensity) and the financial capability index (capturing financial conditions).[27] The matched samples exhibit balanced characteristics between the merged and never-merged municipalities (Appendix Table B1). Consistent with the baseline results, Appendix Figure A8 shows that municipal mergers have negative effects on water quality, particularly in the short term up to 5 years post-merger. The aggregate average treatment effects on the treated (ATT) for event years 0–5 is 0.047, with a p-value of 0.009 (Appendix Table B2). This result indicates a 4.7% increase in BOD values, which is slightly smaller but still comparable in magnitude to the baseline results.

The similar results obtained from the DiD analysis of municipalities matched on financial conditions suggest that the negative environmental effects are unlikely to be driven by poorer financial conditions that could weaken pollution control. This finding is consistent with the merger policy, which ensured that municipal revenues would remain stable for 5 to 10 years due to preferential treatment in central government transfers to merged municipalities (see Section 2.1).[28] Differential effects by merger type and participating municipalities, where the negative effects become insignificant in incorporating mergers and incorporating municipalities, further suggest that the underlying mechanisms are coordination costs and political economy rather than the municipality's general financial conditions (see Section 6).

Spillovers from Upstream and Border Municipalities.— Our DiD analysis relies on the stable unit treatment value assumption (SUTVA). However, there is potential for spillovers from upstream merged municipalities to downstream never-merged municipalities along river courses. To test this spillover effect, we compare never-merged municipalities located within 25, 50, or 100 kilometers of upstream merged municipalities (i.e., the control group subject to spillovers) to those located further away from upstream merged municipalities (i.e., the pure control group).[29] However, we find that the spillover effects are statistically insignificant in most event years, regardless of the chosen distance cutoffs (Appendix Figure A9 and Columns 1–3 of Appendix Table B3).

As a robustness check to enhance the validity of the SUTVA, we run an analysis designed to mitigate the influence of spillovers from upstream merged municipalities. In this analysis,

[27] For the matching process, we use the average values for these variables during the pre-merger period (i.e., 1990–2000). Furthermore, we weight observations by the Mahalanobis matching frequency (i.e., the number of times each municipality is used as a match) when conducting balance checks and the DiD analysis.

[28] Merged municipalities with previously weak financial conditions can leverage special provision bonds to finance sewerage infrastructure, as explained in Section 2.1. However, we find no corresponding improvements in water quality, suggesting these financial incentives are used for purposes other than pollution control.

[29] We identify upstream municipalities for each monitoring station using elevation raster data and river line data, which we explain in Section 6.4. Specifically, we select upstream municipalities that intersect with river segments at elevations higher than that of a given monitoring station, following the approach by Motohashi (2023).

we restrict the sample to monitoring stations without upstream merged municipalities located within 25, 50, or 100 kilometers, where spillovers are expected to be minimal. The DiD results from this specification are similar to the baseline results, with ATT ranging from 0.045 to 0.052 (Appendix Figure A10 and Columns 4–6 of Appendix Table B3).

We also address another type of spillover effect originating from border municipalities. While our baseline analysis assumes that water quality at a certain monitoring station is influenced only by the merger of the municipality where it is located, stations located on rivers at municipal borders may also be affected by mergers in neighboring municipalities. To account for this spillover effect, we conduct a DiD analysis in which the treatment indicator is set to 1 once at least one border municipality begins a merger, specifically for stations located on municipality borders.[30] This analysis yields results consistent with the baseline results, with an ATT of 0.053 (Appendix Figure A11 and Column 7 of Appendix Table B3).

Alternative Water Quality Indicators and Falsification Test.—We find similar negative effects of municipal mergers on water quality when adopting alternative indicators, including the 75th percentile value of BOD (BOD-75) and the mean DO level (Panels A and B in Appendix Figure A12). Both BOD and DO capture the overall level of water contamination from various sources of pollution. However, lower DO levels indicate higher water pollution, which is the opposite of the relationship seen with BOD values. We specifically find that municipal mergers increase BOD-75 by 6.2% and decrease DO by 1.3% (Columns 1–2 of Appendix Table B4).

We also conduct a falsification test using an alternative water quality indicator unrelated to municipal mergers. As discussed in Section 2.2, agricultural wastewater is unlikely to be affected by municipal mergers because it is a non-point source that is difficult for municipalities to regulate. Consistent with this expectation, we find an insignificant effect of municipal mergers on suspended solids (see Panel C of Appendix Figure A12 and Column 3 of Appendix Table B4), which measures soil erosion and is closely related to agricultural wastewater, as discussed by Lipscomb and Mobarak (2016). This result provides further evidence against concerns about selection bias in merger decisions.

5.3 Compliance with Environmental Standards

As we observe that municipal mergers increase water pollution, we investigate whether this increase ultimately impacts compliance with the Environmental Quality Standards for Water Quality. We find that while municipal mergers do not increase the number of violation cases,

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

they lead to more cases in which water quality remains just below the regulatory limits.

We evaluate municipalities' compliance with environmental standards by comparing their BOD levels with the limit values set under these standards.[31] This analysis focuses on 2,027 criteria stations, whose water quality data are officially used to assess compliance with environmental standards, out of a total of 3,285 monitoring stations.[32] Instead of using average BOD values, we use BOD-75 values to assess compliance, following the official practice that aims to remove the potential influence of abnormal weather on water quality measures. Based on these data, we construct a violation indicator that equals 1 if the BOD values exceed the limit values. Additionally, we measure narrow compliance by creating a binary indicator that equals 1 if the BOD values are within the range of 75–100% of the limit values among compliant cases. 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 then use the same DiD specification outlined in Section 4.1 to analyze the effects of municipal mergers on these three compliance outcomes.

We find that municipal mergers do not increase violation cases (Panel A of Figure 6 and Column 1 of Appendix Table B5). However, we find a significant effect of increased narrow compliance cases among compliant cases (Panels B and C of Figure 6). Although the event-study estimates are relatively noisy, Column 2 of Appendix Table B5 shows that the mergers increase the probability of narrow compliance by 2.7 percentage points (an 8% increase relative to the pre-merger level). Municipal mergers also increase the percentage of BOD values relative to the limit values by 1.6 percentage points during event years 0–7, further suggesting an increase in narrower compliance (Column 3 of Appendix Table B5).[33] These findings suggest that merged municipalities weaken their pollution control efforts, allowing water quality to deteriorate toward, but not beyond, the standards.

6 Mechanisms

Heterogeneity analyses by merger types and participating municipalities suggest that the negative environmental effects of municipal mergers are driven by coordination costs and

[31] Limit values vary by designated usage category for each river location, which can be revised over time. Typically, these categories become more stringent, resulting in lower limit values, which aligns with the water quality improvement shown in Figure 4. The increasing stringency of categories over time suggests that the estimated river pollution is unlikely to be driven by the relaxation of limit values by merged municipalities. Compliance is checked according to the designated usage categories applicable for each location each year.

[32] Our DiD result remains unchanged when we restrict our sample to criteria stations, with an ATT of 0.045 (Appendix Figure A13 and Column 4 of Appendix Table B4).

[33] Municipalities cannot avoid violations or narrow compliance by adjusting the designated usage categories because these categories are determined at the central and prefectural levels (see Section 2.2). Therefore, our results shed more light on municipalities' weaker pollution control.

imbalances in political power between participating municipalities, which weaken pollution control. We also find that municipal mergers decelerate investments in sewerage infrastructure, which suggests an increase in the volume of untreated domestic wastewater from households. Conversely, we find no evidence supporting alternative mechanisms, including the negative externality theory and changes in land use.

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.[34] 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 after restricting our sample to monitoring stations located in municipalities that have undergone equal-footing mergers (i.e., the treatment group) and those in never-merged municipalities (i.e., the control group). When examining the effect of incorporating mergers, the treatment group becomes municipalities that experienced this type of merger, while the control group still comprises never-merged municipalities (see Appendix Figure A1).

We find that the negative effect of municipal mergers on water quality is concentrated in equal-footing mergers, which entail high coordination costs. Table 3 shows that equal-footing mergers increase water pollution by 6.6% (Column 1 of Panel A), whereas the effect is insignificant in the case of incorporating mergers (Column 2). These differential effects between different merger types suggest that coordination costs weaken municipalities' pollution control efforts.

The event study results in Figure 7 corroborate these heterogeneous effects. We find that equal-footing mergers increase river pollution for up to 14 years, as observed in the baseline result (Panel A). Although coordination frictions are expected to diminish over time, short-term disruptions to investments in pollution control infrastructure (i.e., sewerage systems, as shown in Section 6.3), which are long-lived assets, can generate persistent effects on water quality. In other words, even temporary coordination failures following the merger can slow infrastructure investment, with lasting consequences for environmental outcomes due to the durable and cumulative nature of such capital. In contrast, we find that incorporating mergers have limited effects on river pollution except for a temporary negative effect around 3–5 years post-merger (Panel B). However, this result masks the substantial heterogeneous

[34] The differing levels of coordination costs between equal-footing and incorporating mergers are discussed in Section 2.3.

effects between incorporating and incorporated municipalities (see Section 6.2).

One may be concerned that merger types serve only as an indirect proxy for coordination costs and may vary along other dimensions, making the observed heterogeneous effects only suggestive of the coordination costs mechanism. To more directly measure coordination costs, we construct a measure based on the relative sizes of the participating municipalities, using pre-merger population data. Specifically, we calculate the coefficient of variation (CV), defined as the standard deviation divided by the mean, of the population across participating municipalities for each merger, using 1998 data from the Basic Resident Register. Mergers among similarly sized municipalities, indicated by a lower CV, are expected to face greater coordination challenges (i.e., higher coordination costs), as discussed in the context of equal-footing mergers.[35] We then compare the effects of mergers with a CV below the median to those with a CV above the median.[36] We find that the negative effect on water quality is concentrated in mergers with lower CVs, which are expected to entail higher coordination costs (Columns 3–4 of Table 3 and Panels C and D of Figure 7). The magnitude of this negative effect is a 6% increase in BOD, which is similar to that observed for equal-footing mergers (Column 3 of Panel A of Table 3). These findings provide further support for the coordination costs mechanism.

6.2 Political Economy

We also examine the political economy mechanism by investigating the differential effects of municipal mergers on incorporating and incorporated municipalities with differing levels of political power, thereby revealing heterogeneity within incorporating mergers that is masked by the null average effect. We hypothesize that the negative effect on water quality is more pronounced in incorporated municipalities with smaller political power than in incorporating municipalities with larger political power.[37] This political power asymmetry is further indicated by the pre-merger population data: incorporated municipalities in our final sample have, on average, only 8.8% of the population of incorporating municipalities, based on the 1998 data used in the coordination cost analysis.

To analyze the effect of municipal mergers in incorporated (or incorporating) municipalities, we conduct a DiD analysis, which designates incorporated (or incorporating) municipalities as the treatment group and never-merged municipalities as the control group (see

[35] The population CV is highly correlated with merger type. The mean CV for equal-footing mergers in our final sample is 0.78, which is statistically significantly lower than that for incorporating mergers by 0.61 (with a p-value of 0.000).

[36] As in the merger-type analysis, we conduct a DiD analysis comparing monitoring stations in municipalities that underwent low- or high-CV mergers to those in never-merged municipalities.

[37] The differing levels of political power between incorporated and incorporating municipalities are discussed in Section 2.3.

Appendix Figure A1). In this analysis, we focus on the heterogeneous effects of incorporated and incorporating municipalities, rather than examining the average impacts of both types in the case of incorporating mergers, as conducted in Section 6.1.

We find that the negative effect of municipal mergers on water quality is concentrated in incorporated municipalities with little political power. Table 3 shows that incorporated municipalities experienced a significant increase in water pollution by 8.6% post-merger (Column 5 of Panel A), while the effect is insignificant in incorporating municipalities (Column 6). These heterogeneous effects support 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 in Figure 8 present the same findings. Specifically, we find a detrimental effect on river pollution in incorporated municipalities for up to 14 years after the merger (Panel A). Moreover, the observed parallel pre-trends in Panel A suggest that endogenous selection is unlikely, whereby incorporated municipalities with worse financial conditions and consequently worse pollution trends sought to be merged, and these trends subsequently drove the treatment effect. Conversely, we observe limited effects on river pollution in incorporating municipalities, with the exception of a temporary negative effect around 3–5 years after the merger (Panel B).

6.3 Pollution Sources Subject to Weaker Control

We investigate the sources of water pollution that increase following municipal mergers due to weaker control. Municipalities are primarily responsible for controlling domestic wastewater, which is the major source of river pollution in Japan, but their role in controlling industrial and agricultural wastewater is limited (see Section 2.2).[38] Municipalities' primary approach to controlling domestic wastewater is to construct and operate sewerage infrastructure, including sewers and sewage treatment plants.[39] In 2001, at the start of the municipal mergers in our sample, 73.7% of the total population was connected to wastewater treatment facilities, with sewerage infrastructure comprising the majority (63.5%).[40] This context motivates us to focus on analyzing the effects on sewerage investment levels.

To explore the domestic wastewater channel, we first examine the effects of municipal

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

[39] Another approach could be to subsidize the construction of a "*johkasou*", which is a decentralized wastewater treatment system installed at the household level. The suspension of these subsidies following mergers may slow *johkasou* construction, leading to increased river pollution. However, the effect of mergers on *johkasou* investments is not tested due to the lack of municipality-level coverage data before 2013.

[40] The data are from "The Status of Wastewater Treatment Facilities as of the End of Fiscal Year 2001," published on the Ministry of the Environment's website.

mergers on expenditure for sewerage construction. This analysis uses municipality-level expenditure data for 1990–2018 from the Survey on Local Public Finance provided by the Ministry of Internal Affairs and Communications. To accommodate the changes in municipalities following mergers, we aggregate the data at the post-merger municipality level.[41] Using the constructed panel data of 961 post-merger municipalities, we conduct the same DiD analysis as outlined in Section 4.1 by replacing monitoring station fixed effects with municipality fixed effects. Panel A of Figure 9 shows that municipal mergers reduce municipalities' expenditure on the construction of sewerage infrastructure for up to 14 years. Specifically, the mergers reduced this expenditure by 15 million Japanese yen, equivalent to a 13% reduction from the pre-merger level (Column 1 of Appendix Table B6).

Furthermore, we investigate how municipal mergers affect sewerage outcomes, with a focus on sewerage coverage. Although sewerage coverage in Japan has steadily expanded over time, its growth may slow following municipal mergers due to reduced expenditures or project suspensions caused by coordination challenges in reformulating sewerage development plans.[42] To explore this channel, we use sewerage coverage data from the Sewage Statistics for 1996–2018 from the Japan Sewage Works Association.[43] Sewerage coverage is calculated as the proportion of the population served by the sewerage system relative to the total population of each municipality in each year, yielding a value between 0 and 1. Using the constructed panel data of 866 post-merger municipalities with sewerage systems, we conduct the same DiD analysis. The results, shown in Panel B in Figure 9, present suggestive evidence that municipal mergers decelerate sewerage expansion for up to 5 years following the mergers.[44] The aggregate ATT for event years 0–5 is -0.014, showing a 1.4 percentage point slowdown in sewerage coverage expansion, equivalent to a 4.3% change relative to the pre-merger level (Column 2 of Appendix Table B6). However, the anticipation effect, characterized by a sharp negative effect, is observed 1 year prior to the mergers, even though the pre-trends remain parallel during other periods. This anticipation effect likely reflects the

[41] For example, if municipalities A and B merged into a new municipality C in year X, the expenditure for municipality C before year X is derived by summing the expenditures of both municipalities A and B.

[42] Before the merger period, merged municipalities had lower sewerage coverage than never-merged municipalities, showing that never-merged municipalities had undertaken sewerage investments earlier (Table 1). In contrast, merged municipalities were later adopters, as reflected in their lower coverage, and therefore planned larger expansions of sewerage infrastructure, as reflected in higher sewerage construction expenditure. This expansion process may have been slowed by the mergers.

[43] We ensure balanced panel data by focusing on municipalities that maintained sewerage infrastructure up to 2018.

[44] In contrast, municipal mergers did not impact the operation of sewage treatment plants. Analyzing the Sewage Statistics data with the same DiD design, we find an insignificant effect of mergers on the average BOD levels in effluent from these plants (Appendix Figure A14 and Column 3 of Appendix Table B6). This result is consistent with the strict regulatory standards for effluent quality that must be met by municipalities.

suspension or slowdown of sewerage development plans during the negotiation phase leading up to the mergers, as these plans need to be reformulated and integrated post-merger. The gradual attenuation of the negative effect suggests that sewerage development progressively resumed after the integration of development plans following the merger.

In summary, we find that municipal mergers reduce spending on sewerage infrastructure and slow the expansion of sewerage coverage. These results suggest that mergers lead to a larger volume of untreated domestic wastewater, thereby exacerbating river pollution.

6.4 Alternative Mechanism 1: Negative Externality Theory

We test the negative externality theory as an alternative mechanism, which suggests that municipal mergers improve environmental quality by internalizing pollution spillovers. Consistent with the DiD analysis showing the negative environmental effect of municipal mergers, 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 by exploiting the changes in these distances following municipal mergers. For this analysis, we construct two distance variables, U and D, where 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. To calculate U and D, we use river node data with elevation information in addition to the major river line data provided by the Ministry of Land, Infrastructure, Transport, and Tourism. These two datasets enable us to identify the upstream–downstream relationship between monitoring stations and municipality borders and to calculate the two distance variables along rivers. Focusing on monitoring stations along major rivers in Japan, we construct balanced panel data comprising 700 stations in 382 municipalities from 1990 to 2015.[45]

We adopt the following river distance regression to test the negative externality theory:

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

where $Downstream_{i,t}$ is a relative downstreamness indicator for a monitoring station within its municipality, which we calculate as $U_{i,t}/(U_{i,t} + D_{i,t})$. Here, $U_{i,t}$ and $D_{i,t}$ represent the

[45] In addition to dropping monitoring stations not located along major rivers, we exclude stations located in either the uppermost or furthest-downstream municipalities, as one of the distance measures (i.e., U or D) is not applicable to these stations. Moreover, the final sample is limited to observations up to 2015, as population data used for a control variable are only available up to that year.

distances (in kilometers) 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 monitoring station's more downstream position within its municipality. $X_{m,t}$ is a vector of time-varying, municipality-level control variables consisting of an economic indicator (i.e., product shipment values) and population. δ_i and $\theta_{b,t}$ are monitoring station fixed effects and basin-by-year fixed effects, respectively, as included in the DiD regressions. The inclusion of δ_i means that this analysis examines the effect of changes in the distance measures, which change once at the time of the merger, on changes in water quality at each monitoring station. We also adopt year fixed effects instead of basin-by-year fixed effects as a robustness check. 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, which are the coefficients on the linear and quadratic terms of the downstreamness indicator, expected to be positive.

We also consider a more flexible specification that closely follows Lipscomb and Mobarak (2016):

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

where the variables are explained above. In this specification, we expect $\gamma_3 < 0$ and $\gamma_4 > 0$ because pollution is expected to increase exponentially as the distance from the downstream border decreases (i.e., further downstream within the municipality). In addition, the presence of a structural break in the pollution function at the municipality border, as explained in Section 2.3, implies that γ_1 should differ from γ_3.

Appendix Table B7 presents the results of the river distance analysis, where we do not find spatial patterns consistent with the negative externality theory in either regression specification. First, the results of the specification using relative downstreamness 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. In addition, the coefficient of the downstreamness indicator (η_1) is negative, which contradicts the predictions of the negative externality theory. Second, the results of the Lipscomb and Mobarak (2016) specification in Columns 3 and 4 also fail to support the negative externality theory; that is, we do not find significant effects of D and D^2 on water quality.[46] Furthermore, the equality of the coefficients of U and D

[46] To address concerns about collinearity between linear and squared terms reducing statistical power, we also estimate a specification without the squared terms (U^2 and D^2). The coefficient on D remains

is not rejected, suggesting the absence of a structural break in the pollution function at the municipality border.

In summary, we do not find evidence supporting the negative externality theory in the case of municipal mergers in Japan. The discrepancy between our findings and those of Brazil in Lipscomb and Mobarak (2016) may be attributed to contextual differences between developing and developed countries. In the context of developing countries, Lipscomb and Mobarak (2016) highlights the role of local politicians in permitting slum areas with inadequate water and sanitation infrastructure. In such cases, it may be easier to restrict or relocate these informal settlements, as they often have weaker property rights. Additionally, relocating people from slums might be more feasible when nearby cities are expanding and developing new residential areas.[47] In developed countries, however, 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 process can be more difficult or costly due to the more stringent property rights and limited available land for relocation in developed countries than in developing countries. The null effects of mergers on land use observed in Section 6.5 are consistent with this explanation. Another plausible explanation is the greater availability of river basin management initiatives, which may have already mitigated negative externalities even in the absence of municipal mergers, although in Japan such initiatives are voluntary and do not cover all river basins.[48]

6.5 Alternative Mechanism 2: Land Use

We test another alternative mechanism, namely, changes in land use, which can generate new pollution sources without altering pollution control efforts (as discussed in Section 2.3). However, we find no significant effects of municipal mergers on various land-use types, including agricultural, built-up, and forest areas.

We use the DiD design to examine the effects of municipal mergers on land-use patterns. Our analysis uses 100-meter raster data for land use from six periods (1991, 1997, 2006, 2009, 2014, and 2016) provided by the Ministry of Land, Infrastructure, Transport, and Tourism. We focus on land-use patterns within 150 meters, 1 kilometer, or 5 kilometers of water quality monitoring stations. Land use is categorized into three main classifications:

statistically insignificant (Column 5).

[47] In the unique context of China examined in Wang and Wang (2021), where internalization of negative externalities is observed, top-down bureaucratic enforcement of environmental regulations, combined with the absence of electoral incentives, may also help facilitate such internalization.

[48] One might alternatively argue that merged municipalities do not share the same rivers and therefore face no pre-existing externalities to internalize. However, as discussed in Section 2.3, the majority of merged municipalities share the same river basins.

agricultural, built-up, and forest areas.[49] We then construct a binary indicator that identifies the dominant land-use classification for each monitoring station. To apply the Callaway and Sant'Anna (2021) estimator, we construct a balanced panel covering consecutive years from 1991 to 2016 by linearly interpolating land-use indicators for the gap years. Using this station-level panel dataset of land-use patterns, we conduct the same DiD analysis as outlined in Section 4.1.

As shown in Appendix Figure A15 and Appendix Table B8, we find no significant effects of municipal mergers on land-use types near monitoring stations, including agricultural, built-up, and forest areas in most cases, regardless of the distance cutoffs applied. Although there are indications of a reduction in agricultural areas and an increase in built-up areas in the 1 km cutoff case, these results are not robust across other distance cutoffs. These findings suggest that the river pollution resulting from municipal mergers cannot be explained by changes in land use.

Although land use remains unchanged, mergers could still influence pollution intensity, such as by increasing population size. Given that domestic wastewater from households is found to be the primary source of river pollution, we investigate how mergers impact population levels, which, in turn, determine the volume of domestic wastewater generated. Conducting the same DiD analysis at the municipality level, we find that mergers lead to a reduction in the population by 2,760 people (a 2.45% reduction from the pre-merger level), as illustrated in Appendix Figure A16 and Column 10 of Appendix Table B8. This finding indicates that population changes cannot explain the observed increase in pollution; rather, the results suggest that mergers lead to higher per capita pollution levels, which are likely due to weak pollution controls.

7 Conclusion

We document the unintended negative consequences of municipal mergers that consolidate two or more municipalities on their environmental quality. This result runs counter to the negative externality theory emphasized in previous studies, which suggests that mergers internalize pollution spillovers across pre-merger municipalities.

Specifically, we investigate the case of Japan's nationwide municipal mergers during the Great Heisei Mergers from the late 1990s to the 2000s, which drastically reduced the number of municipalities in Japan by half. To estimate the causal effect of municipal mergers on environmental quality, we adopt a DiD design that exploits the staggered implementation of

[49] Built-up areas comprise residential or urban areas where buildings are densely built up, in addition to athletic fields, airports, racetracks, baseball fields, schools, and harbor areas.

mergers across Japan.

We find that municipal mergers increased river pollution by 5.4%, with this negative effect persisting for 14 years. This increased river pollution leads to an increase in narrow compliance with environmental standards.[50] Consistent with these DiD results, we do not find evidence supporting the negative externality theory in our river distance analysis.

Considering the mechanisms of increased pollution, our heterogeneity analyses suggest that municipal mergers weaken pollution control due to coordination costs and unbalanced political power between municipalities. We find negative effects on water quality in equal-footing mergers with higher coordination costs but not in incorporating mergers with lower coordination costs. In the case of incorporating mergers, incorporated municipalities with smaller political power experience a larger increase in river pollution compared to incorporating municipalities with larger political power following mergers. Moreover, we find negative effects of municipal mergers on sewerage investments, indicating that the source of river pollution is untreated domestic wastewater from sewerage systems.

Our findings have two important implications for policy and research on decentralization. First, while proponents of municipal mergers often emphasize their potential to improve the efficiency of local public services through economies of scale, our study highlights that such mergers can also lead to unintended negative consequences due to coordination failures between municipalities. The unequal effects observed between incorporated and incorporating municipalities further suggest an efficiency–equity tradeoff. To mitigate these consequences, higher tiers of government (e.g., prefectural governments in Japan) may play a role in facilitating coordination and reducing disparities in public service provision across participating municipalities. This is especially important as municipal mergers become more common in many developed countries facing population decline and aging, and is also relevant for emerging economies like China, which are projected to face similar demographic challenges.

Second, the negative impacts of municipal mergers observed in pollution control may also extend to other public services, such as education and healthcare. Coordination failures and political power imbalances between participating municipalities may similarly hinder the effective delivery of these services. While our study focuses on pollution control, exploring similar challenges in other policy areas may offer a promising direction for future research.

[50] While this study focuses on quantifying the environmental impacts of municipal mergers and identifying the mechanisms behind increased pollution, it is important to note that the observed increase in river pollution likely entails adverse welfare implications. These welfare impacts may include economic costs, such as amenity losses reflected in reduced housing values, which contrast with the increases caused by improved surface water quality, as documented in Keiser and Shapiro (2019). They may also include health costs, such as negative birth outcomes, which contrast with the improvements in birth weight observed following cleaner surface water, as shown in Flynn and Marcus (2023).

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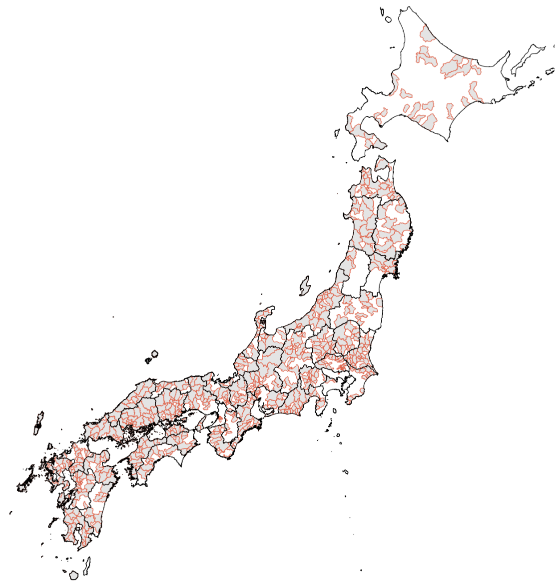

Figure 1: Locations of Municipal Mergers in Japan

Notes: The boundaries of municipalities in Japan that underwent municipal mergers are marked by red lines surrounding the gray areas. In addition, prefectural boundaries are shown in black.

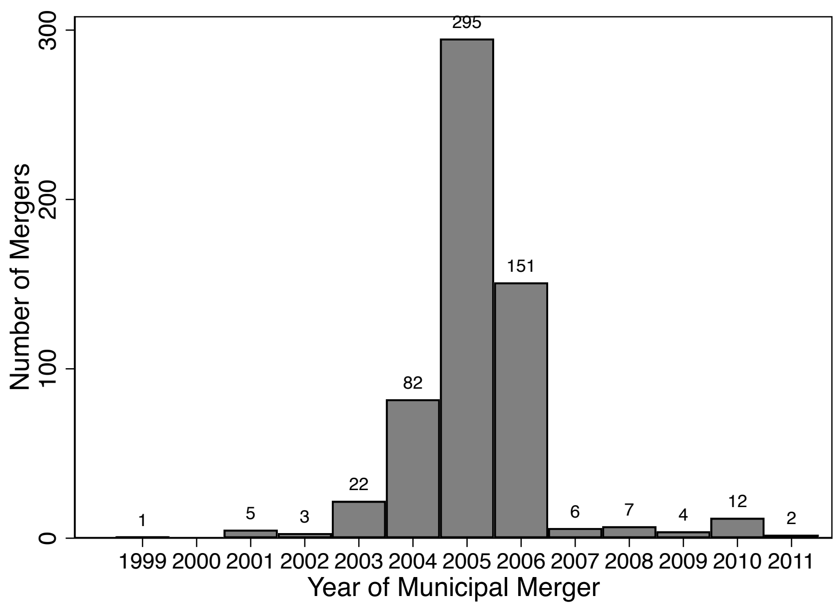

Figure 2: Timing of Municipal Mergers in Japan

Notes: The annual number of municipal mergers in Japan is shown based on the municipal merger data from the Ministry of Internal Affairs and Communications. For municipalities that underwent mergers in multiple stages, only the timing of the initial merger stage is counted. For our analysis, we focus on the variation in merger years from 2001 to 2011 based on our sample of municipalities with monitoring stations along river courses.

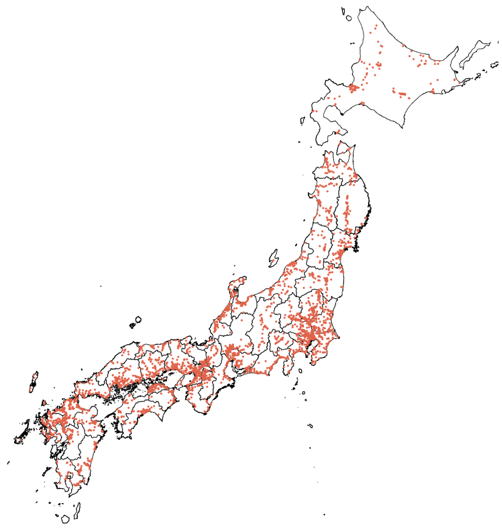

Figure 3: Locations of Water Quality Monitoring Stations in Japan

Notes: The locations of water quality monitoring stations in our sample along river courses are marked in red based on data from the Ministry of the Environment. In addition, the prefectural boundaries are shown in black.

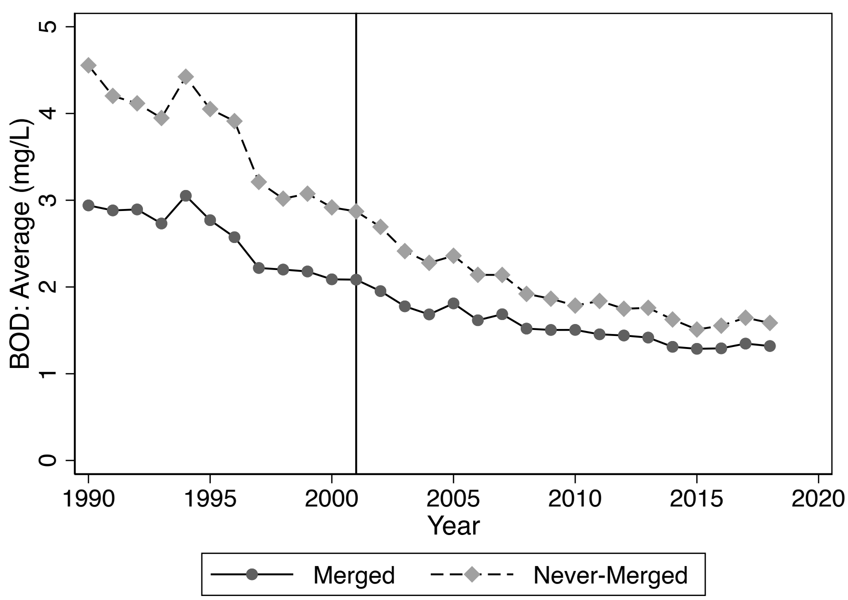

Figure 4: Trends of BOD Values in Merged and Never-Merged Municipalities

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

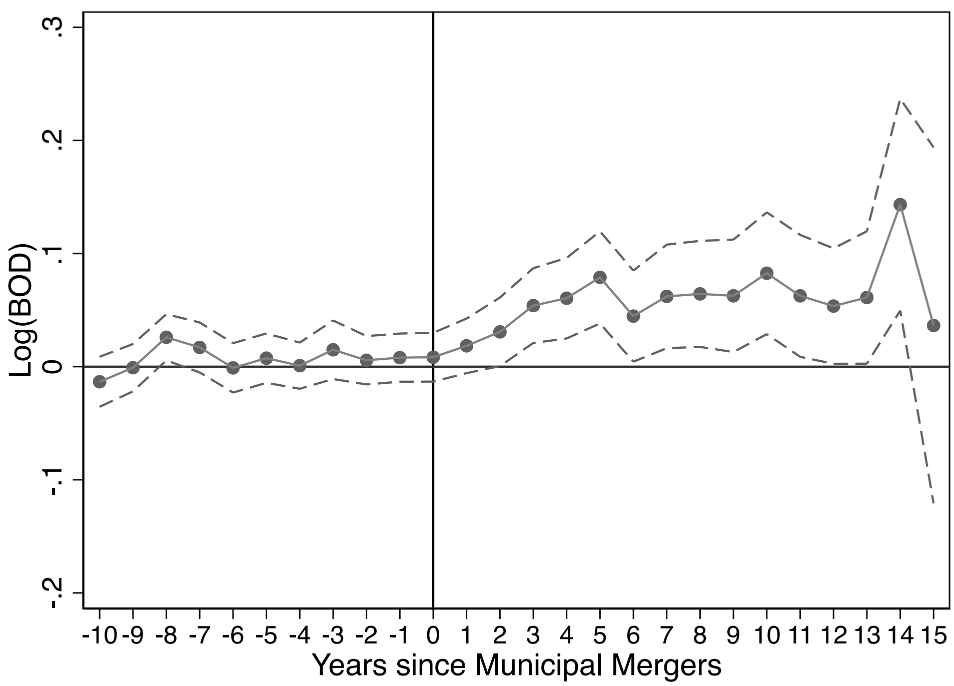

Figure 5: Dynamic Effects of Municipal Mergers on Water Pollution

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

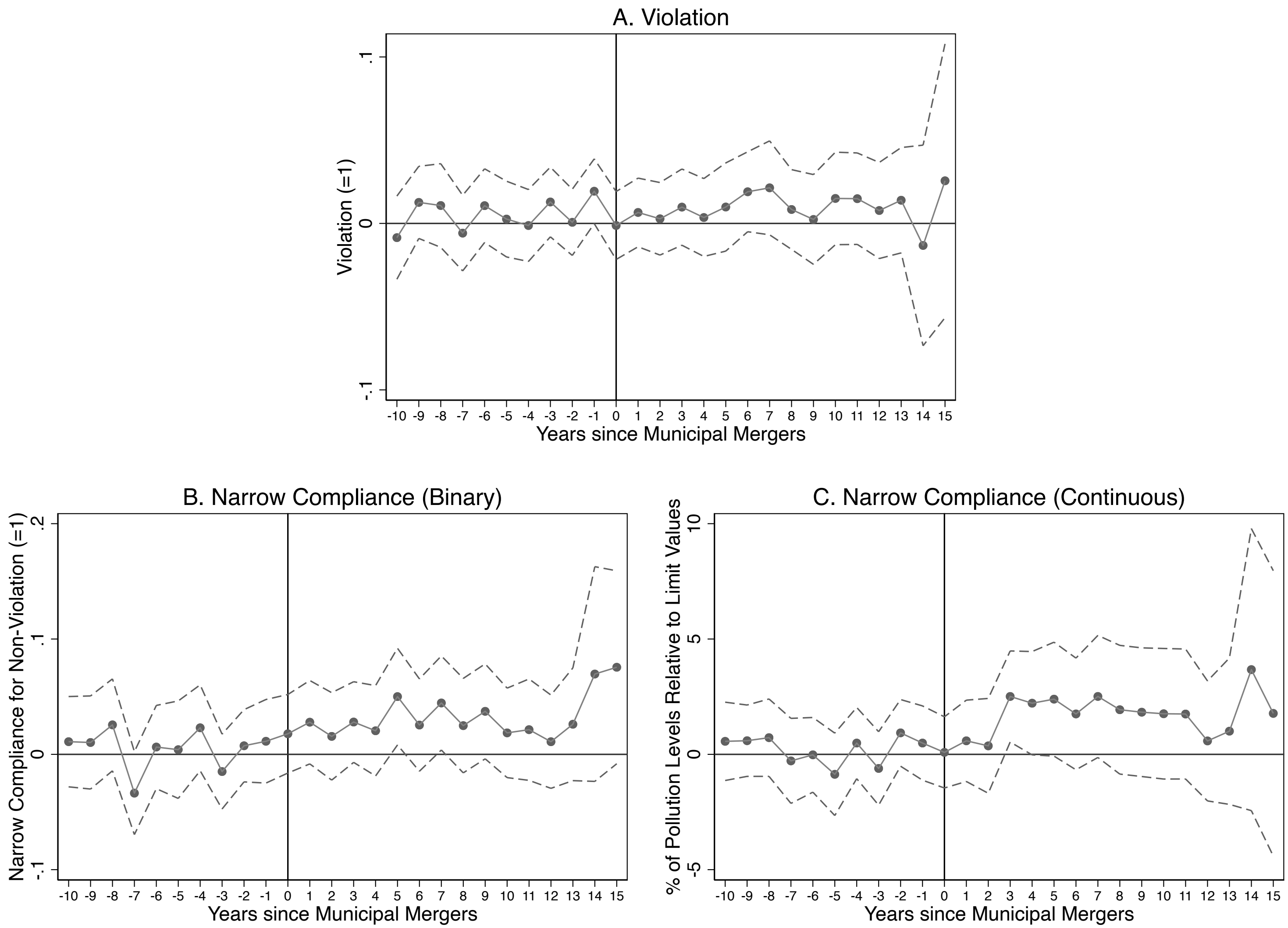

Figure 6: The Effect of Municipal Mergers on Compliance with Environmental Quality Standards

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. Panel A shows the effect of municipal mergers on violations of environmental standards at criteria stations, while Panels B and C show the effects of municipal mergers on narrow compliance measures at criteria stations for compliant cases. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

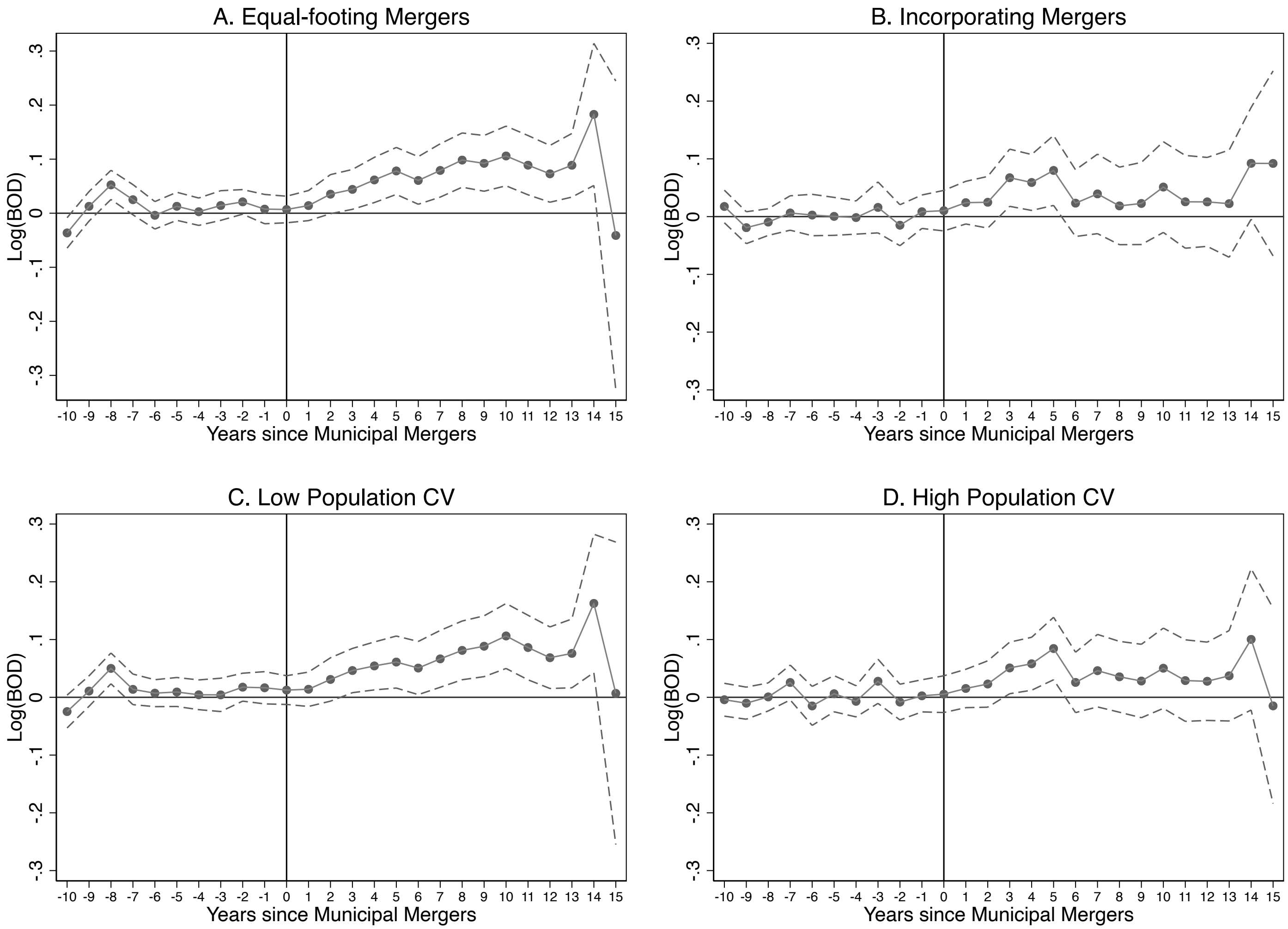

Figure 7: Event Study Results: Mechanism of Coordination Costs

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. Panel A shows the effect of equal-footing mergers, using data from municipalities that underwent such mergers and never-merged municipalities. Similarly, Panel B shows the effect of incorporating mergers. Panel C shows the effect of mergers between municipalities with a low coefficient of variation in population, using data from municipalities that underwent such mergers and never-merged municipalities, while Panel D similarly shows the effect of mergers between municipalities with a high coefficient of variation in population. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

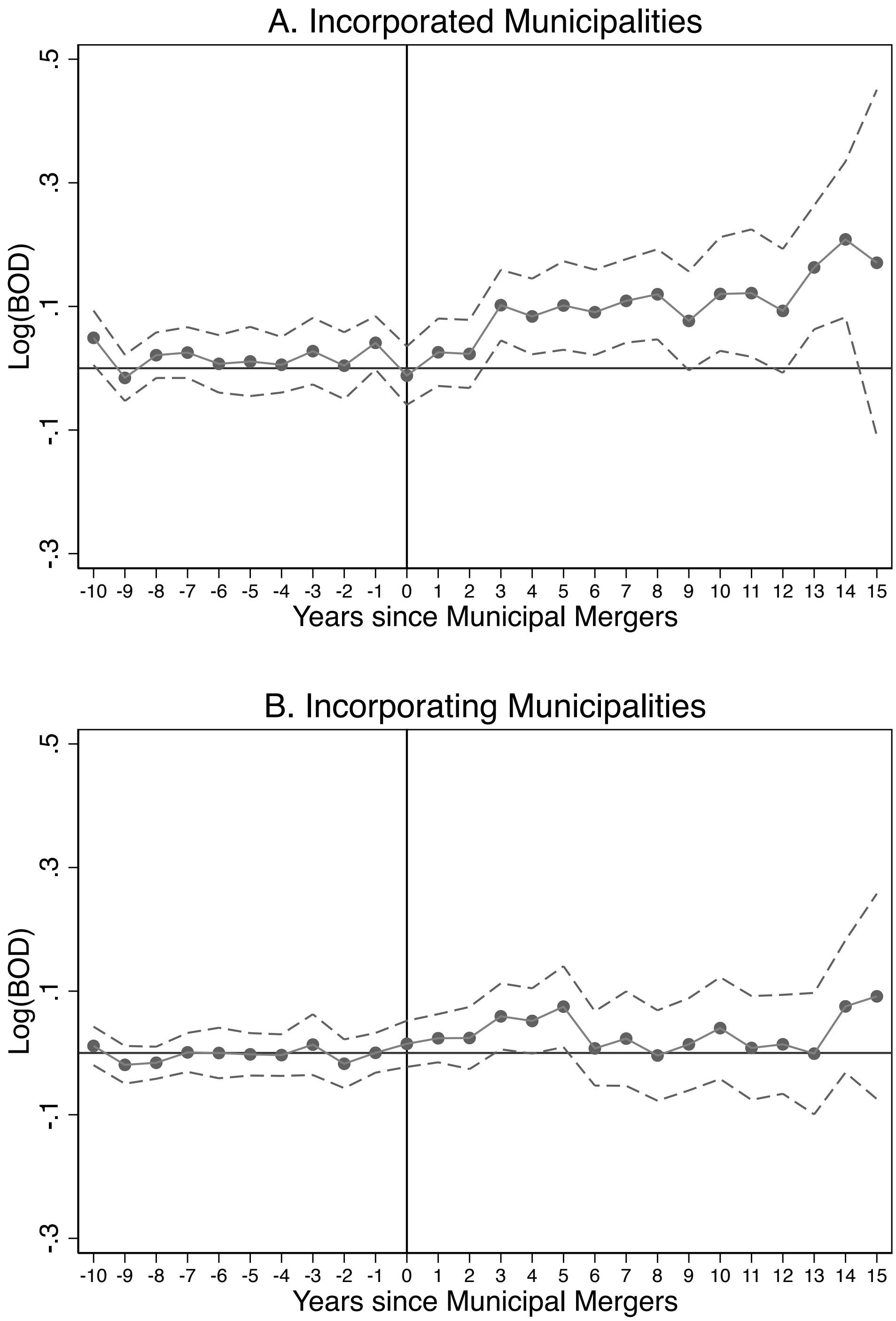

Figure 8: Event Study Results: Mechanism of Political Economy

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. Panel A shows the effect of mergers on incorporated municipalities, using the data for these municipalities and never-merged municipalities. Similarly, Panel B shows the effect of mergers on incorporating municipalities. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

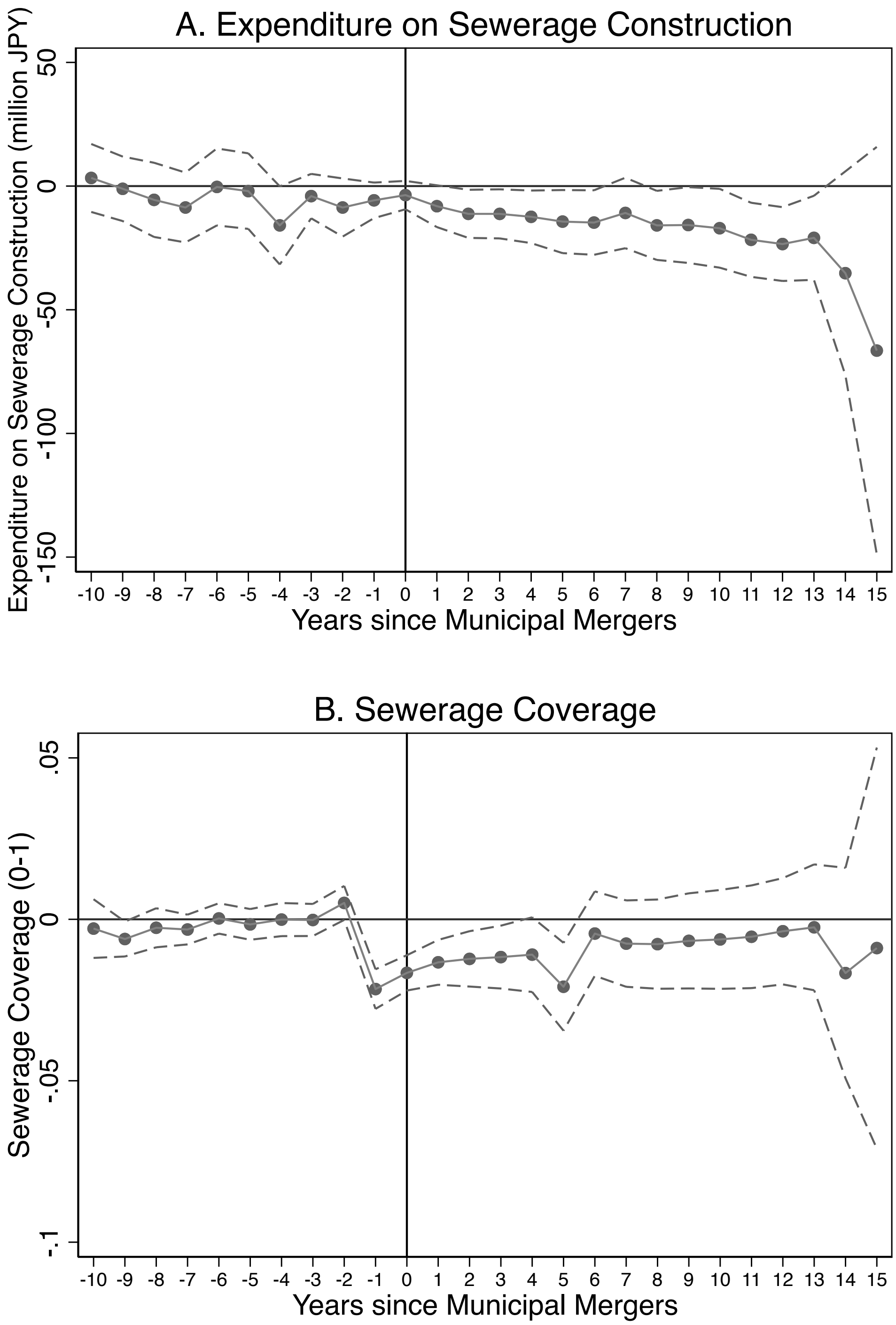

Figure 9: Pollution Sources: Effects of Municipal Mergers on Sewerage Investments

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for municipality fixed effects and year fixed effects. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

Table 1: Summary Statistics for the Pre-Merger Period

Variable	Means: Never-Merged	Means: Merged	Difference	Obs.
Panel A. Water Quality (Station-level)				
BOD: Average (mg/l)	3.786	2.598	-1.187***	3,285
	(4.666)	(3.763)	(0.261)	
BOD: 75 percentile (mg/l)	4.391	3.044	-1.347***	3,285
	(5.553)	(4.548)	(0.313)	
DO: Average (mg/l)	8.839	9.419	0.580***	3,282
	(2.147)	(1.537)	(0.148)	
SS: Average (mg/l)	12.410	11.755	-0.655	3,280
	(9.966)	(23.203)	(0.872)	
Violation of environmental quality standards (=1)	0.286	0.229	-0.057**	2,027
	(0.364)	(0.332)	(0.023)	
Narrow compliance for compliant cases (=1)	0.381	0.340	-0.042*	1,847
	(0.363)	(0.339)	(0.022)	
% of pollution levels relative to limit values	64.125	62.777	-1.348	1,847
	(19.547)	(17.993)	(1.258)	
Panel B. Municipality Characteristics (Municipality-level)				
Product shipment values (100 billion JPY)	2.443	3.036	0.593	923
	(6.259)	(5.867)	(0.399)	
Population (thousand)	98.815	112.731	13.916	923
	(268.356)	(158.050)	(14.330)	
Agricultural output values (billion JPY)	4.368	12.549	8.181***	923
	(5.193)	(11.051)	(0.579)	
Financial capability index	0.616	0.494	-0.122***	923
	(0.318)	(0.236)	(0.018)	
Panel C. Sewerage Outcomes (Municipality-level)				
Expenditure on sewerage construction (million JPY)	50.396	114.946	64.550***	961
	(191.673)	(328.225)	(17.610)	
Sewerage coverage (0-1)	0.443	0.326	-0.117***	866
	(0.322)	(0.248)	(0.019)	
BOD: Effluent from sewage treatment plants (mg/l)	5.420	7.535	2.115	273
	(2.683)	(24.294)	(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)	0.356	0.427	0.071***	2,629
	(0.466)	(0.481)	(0.027)	
Major land use within 150 meters from stations: Forest (0/1)	0.146	0.223	0.077***	2,629
	(0.349)	(0.411)	(0.020)	
Major land use within 150 meters from stations: Built-up (0/1)	0.483	0.344	-0.140***	2,629
	(0.488)	(0.461)	(0.031)	

Notes: The summary statistics are compared between merged and never-merged municipalities for the period prior to the start of municipal mergers in our sample (before 2001). The means are calculated by averaging the values for all the 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 post-merger municipality level when variables are observed at the station level in Panels A, D, and E.

Table 2: DiD Results: Effect of Municipal Mergers on Water Quality

	Log(BOD)		
	(1)	(2)	(3)
Panel A: Callaway and Sant'Anna (2021) Estimator			
Merger (=1)	0.054***	0.054***	0.048***
	(0.018)	(0.018)	(0.017)
Panel B: Two-way Fixed Effects Estimator			
Merger (=1)	0.044**	0.044*	0.043**
	(0.021)	(0.026)	(0.019)
Observations	95,265	95,265	92,974
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. Var. (levels)	3.079	3.079	3.007

Notes: The regression coefficients are reported. Standard errors clustered at the post-merger municipality or basin level are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Panel A accounts for monitoring station fixed effects and year fixed effects, while Panel B includes monitoring station fixed effects and basin-by-year fixed effects. In Panels A and B, Column 3 controls for pre-merger product shipment values and population after interaction with year dummies. The mean of the dependent variable represents the average of the 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)	(5)	(6)
	Equal-footing	Incorporating	Low Pop CV	High Pop CV	Incorporated	Incorporating
Panel A: Callaway and Sant'Anna (2021) Estimator						
Merger (=1)	0.066***	0.037	0.060***	0.037	0.086***	0.027
	(0.019)	(0.026)	(0.019)	(0.023)	(0.031)	(0.027)
Panel B: Two-way Fixed Effects Estimator						
Merger (=1)	0.083***	0.002	0.088***	-0.005	0.134***	-0.028
	(0.024)	(0.029)	(0.024)	(0.027)	(0.036)	(0.031)
Observations	70,731	62,524	67,773	67,367	42,514	58,174
Number of Stations	2,439	2,156	2,337	2,323	1,466	2,006
Number of Municipalities	848	630	837	656	570	625
Mean of Dep. Var. (levels)	3.113	3.493	3.229	3.364	3.612	3.628

Notes: The regression coefficients are reported. Standard errors clustered at the post-merger municipality level are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Panel A accounts for monitoring station fixed effects and year fixed effects, while Panel B includes monitoring station fixed effects and basin-by-year fixed effects. Column 1 shows the effect of equal-footing mergers using data from municipalities that underwent such mergers and never-merged municipalities, while Column 2 shows the effect of incorporating mergers using municipalities that underwent such mergers and never-merged municipalities. Column 3 shows the effect of mergers between municipalities with a low coefficient of variation in population, using data from municipalities that underwent such mergers and never-merged municipalities, while Column 4 shows the effect of mergers between municipalities with a high coefficient of variation in population, based on municipalities that underwent such mergers and never-merged municipalities. Column 5 shows the effect of mergers on incorporated municipalities using the data from these municipalities and never-merged municipalities, while Column 6 shows the effect of mergers on incorporating municipalities using the data from these municipalities and never-merged municipalities. The mean of the dependent variable represents the average of the BOD values before the commencement of municipal mergers in our sample.

Online Appendix

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

Kazuki Motohashi Michiyoshi Toya

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A Additional Figures

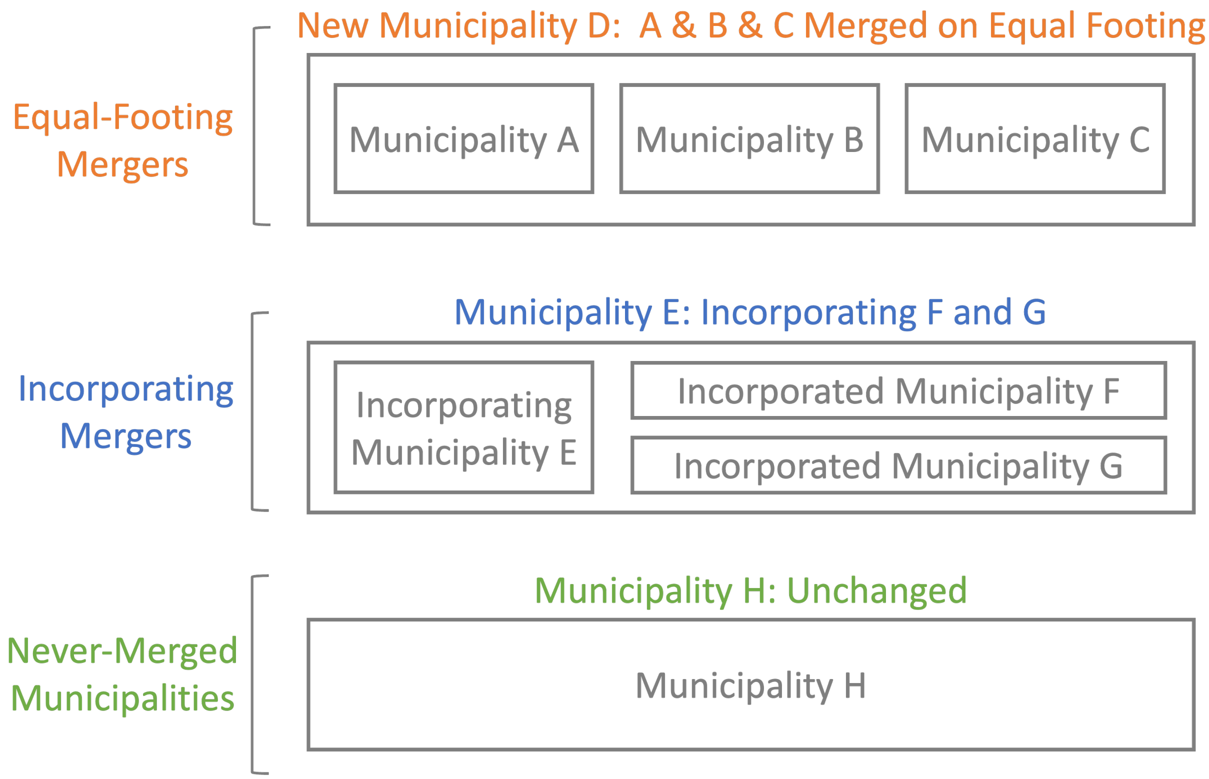

Figure A1: Types of Municipal Mergers

Notes: This figure illustrates two types of municipal mergers—equal-footing and incorporating mergers—as well as two types of participating municipalities in the case of incorporating mergers: incorporating and incorporated municipalities. In equal-footing mergers, multiple municipalities (e.g., municipalities A, B, and C) merge into a new municipality (e.g., municipality D) on an equal footing. Conversely, in incorporating mergers, a larger incorporating municipality (e.g., municipality E) incorporates smaller municipalities (e.g., municipalities F and G). In our analysis of the effect of equal-footing or incorporating mergers, municipalities that have undergone equal-footing mergers (e.g., municipalities A, B, and C) or incorporating mergers (e.g., municipalities E, F, and G) serve as the treatment groups, while never-merged municipalities (e.g., municipality H) serve as the control group. Moreover, when examining the effect of mergers on incorporating or incorporated municipalities, incorporating municipalities (e.g., municipality E) or incorporated municipalities (e.g., municipalities F and G) serve as the treatment groups, while never-merged municipalities (e.g., municipality H) serve as the control group.

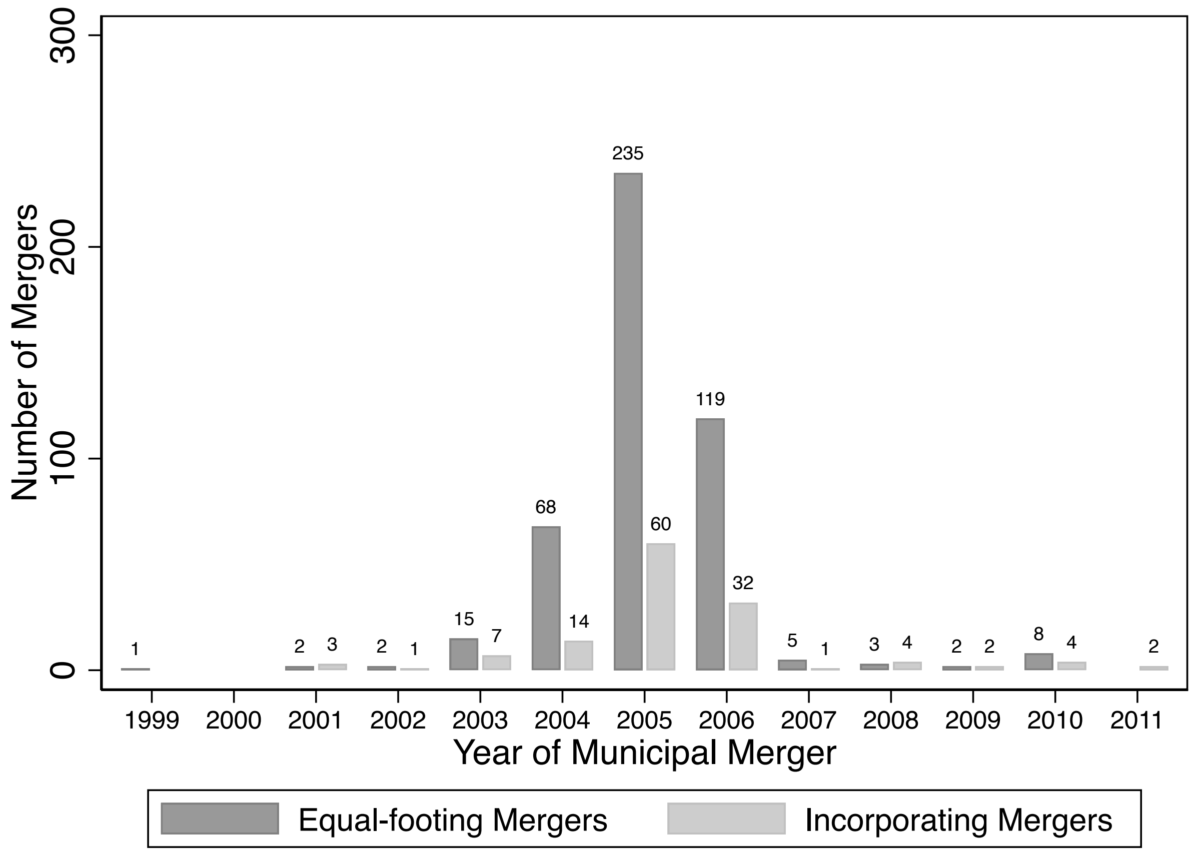

Figure A2: Timing of Municipal Mergers by Merger Type in Japan

Notes: The annual numbers of equal-footing and incorporating mergers in Japan are shown based on the municipal merger data from the Ministry of Internal Affairs and Communications. For municipalities that underwent mergers in multiple stages, only the timing of the initial merger stage is counted. For our analysis, we focus on the variation in merger years from 2001 to 2011 based on our sample of municipalities with monitoring stations along river courses.

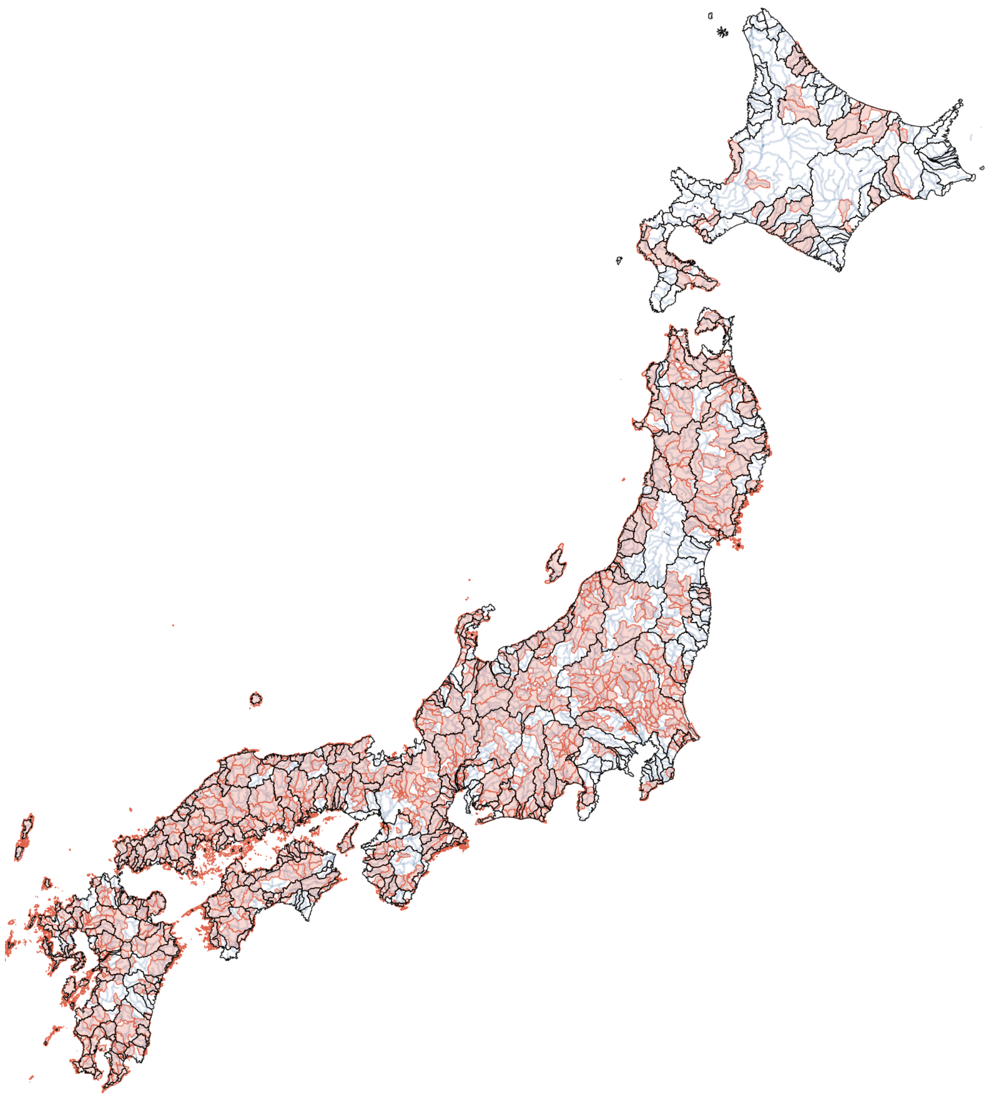

Figure A3: Spatial Relationship between Boundaries of Merged Municipalities and River Basins

Notes: The boundaries of municipalities in Japan that underwent municipal mergers are marked by red lines surrounding the red areas. In addition, river basin boundaries and river lines are shown in black and light blue.

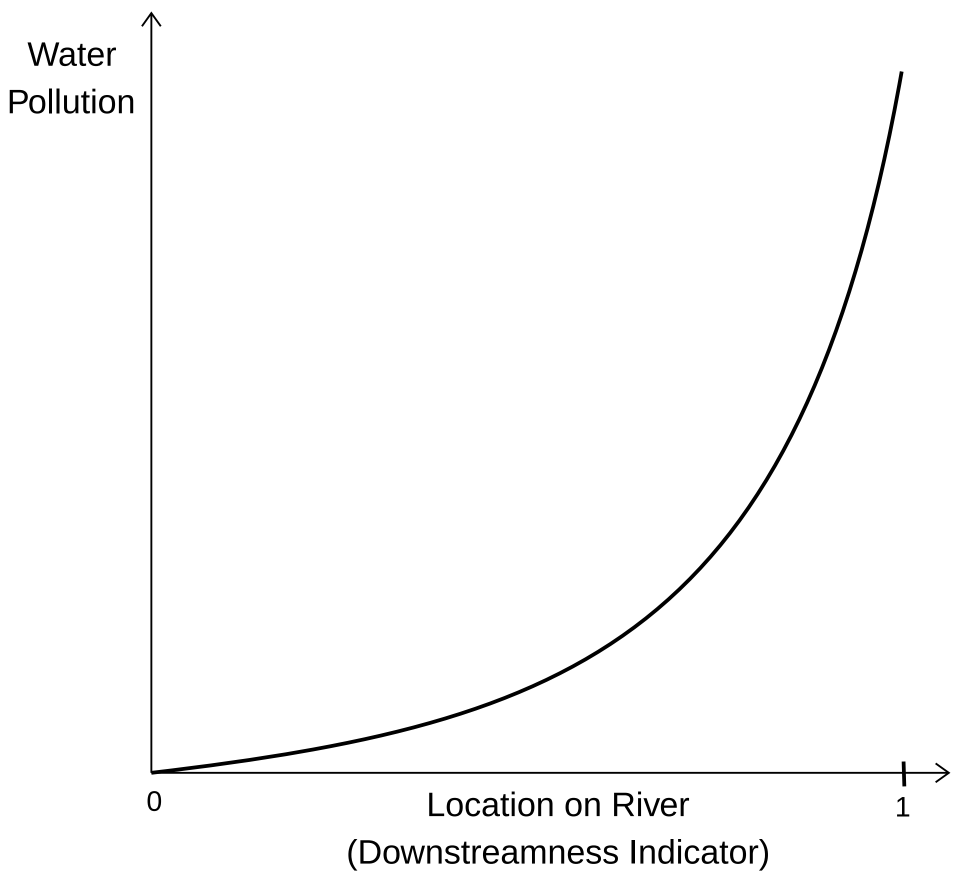

Figure A4: Predictions of Negative Externality Theory

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).

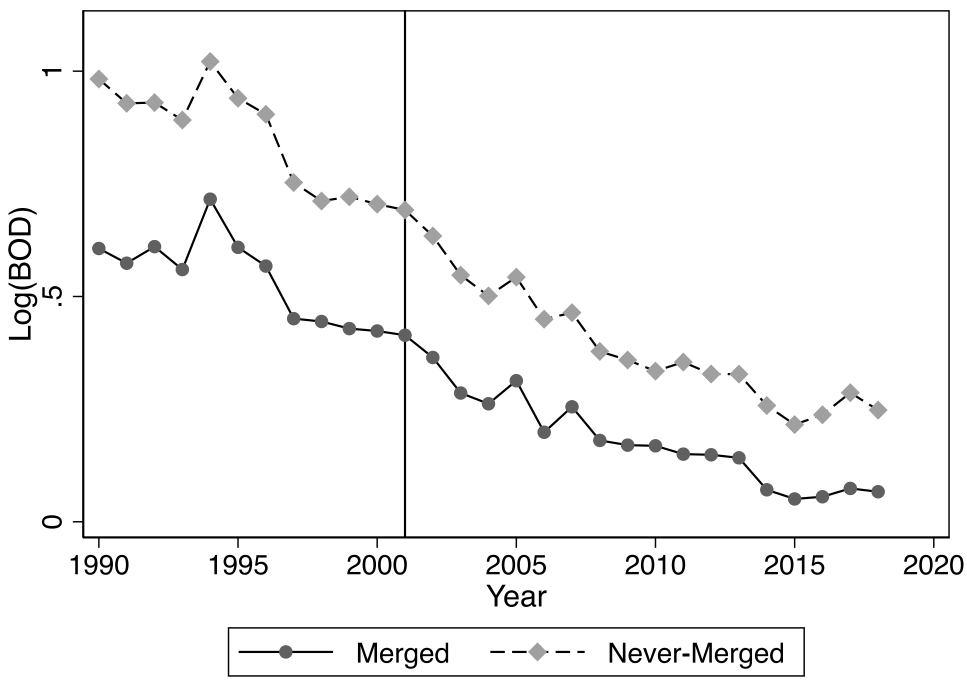

Figure A5: Trends of Logarithms of BOD Values in Merged and Never-Merged Municipalities

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

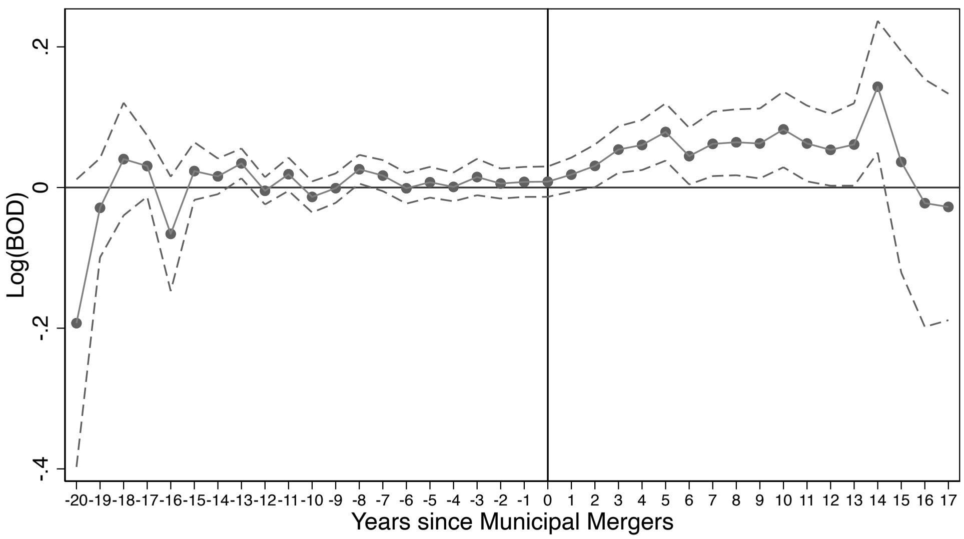

Figure A6: Full Event Study Results

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level. The coefficients for event times 18 and 19 are excluded because only one station was present in the merged municipalities during both periods, which limits the external validity of the results for these event times.

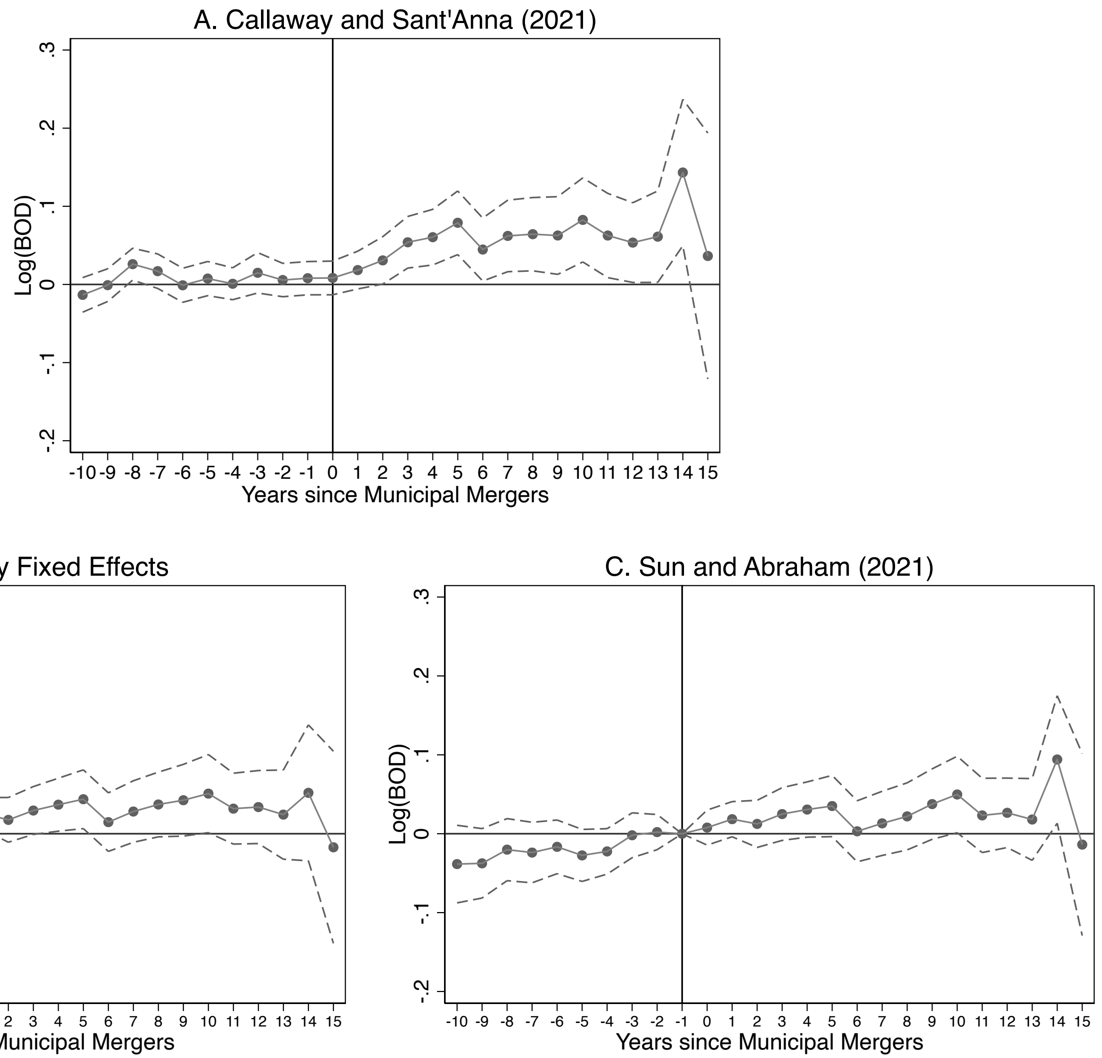

Figure A7: Event Study Results of Alternative Estimators

Notes: The event study results of the three estimators are compared. Panels A, B, and C show the coefficients of the Callaway and Sant'Anna (2021) estimator, the two-way fixed effects estimator, and the Sun and Abraham (2021) estimator, respectively. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level. Panel A accounts for monitoring station fixed effects and year fixed effects, while Panels B and C include monitoring station fixed effects and basin-by-year fixed effects.

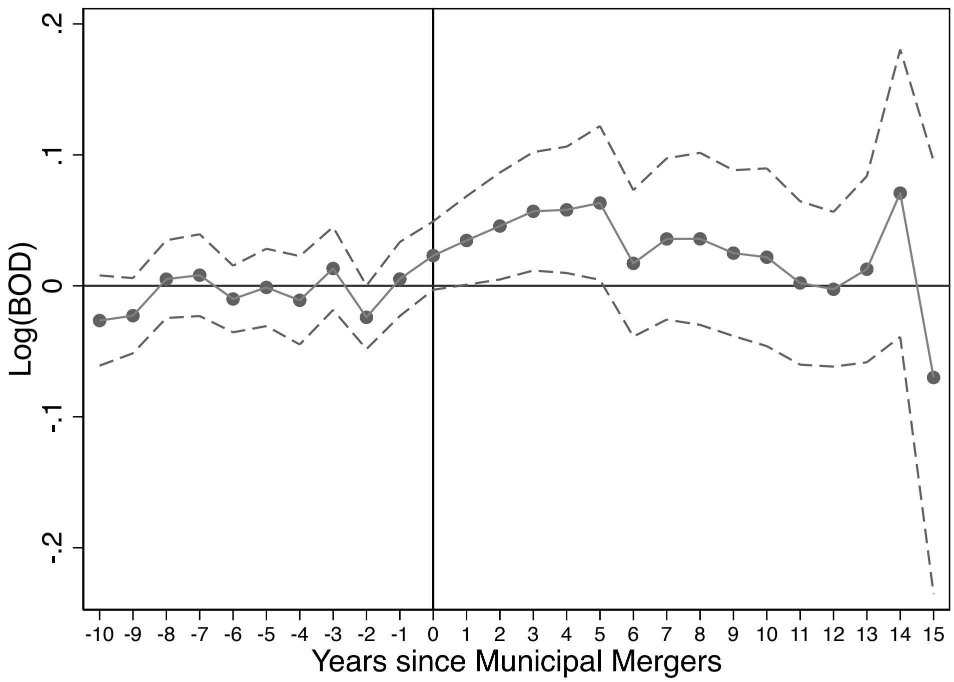

Figure A8: Robustness Checks: Difference-in-Differences Analysis of Matched Municipalities

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. The sample is limited to monitoring stations located in municipalities matched on agricultural output values and the financial capability index. Observations are weighted by the Mahalanobis matching frequency. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

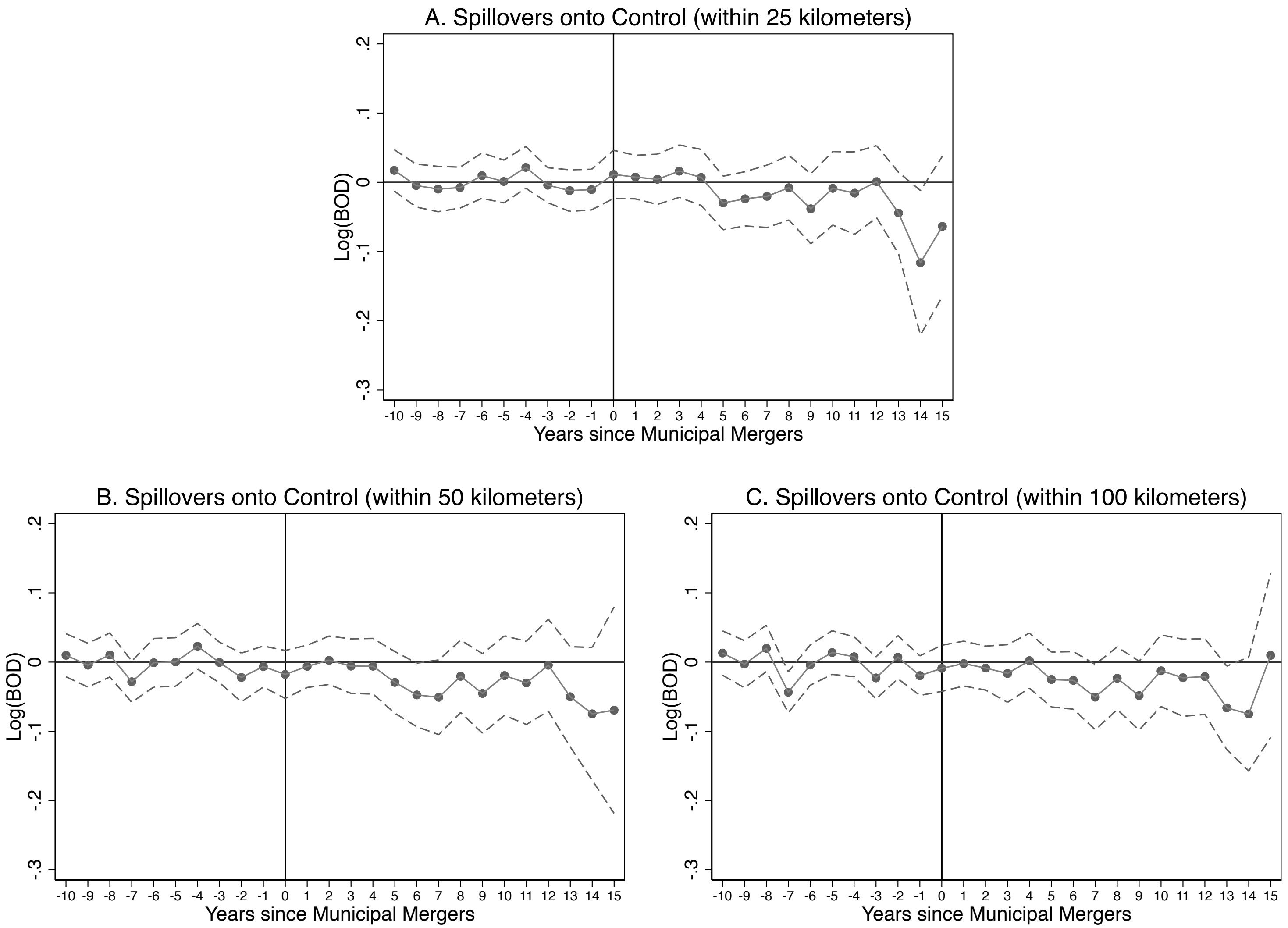

Figure A9: Robustness Checks: Spillovers onto Control Municipalities

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. 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 effects of upstream mergers using cutoff distances of 50 and 100 kilometers, respectively. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

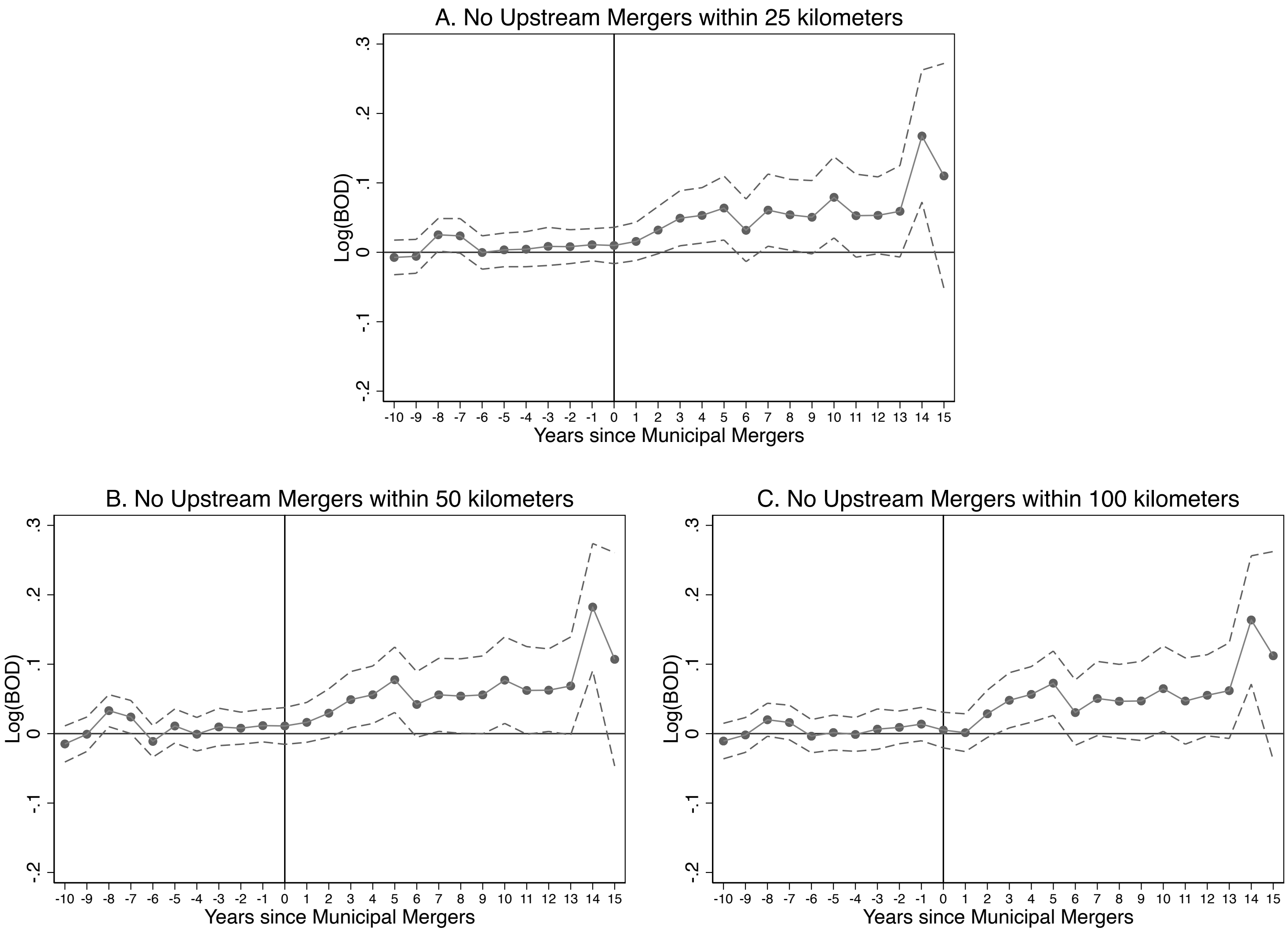

Figure A10: Robustness Checks: Removing Spillovers from Upstream Merged Municipalities

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. Panel A shows the result of using monitoring stations that do not have upstream merged municipalities within a 25-kilometer radius. Similarly, Panels B and C show the results of using cutoff distances of 50 and 100 kilometers, respectively. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

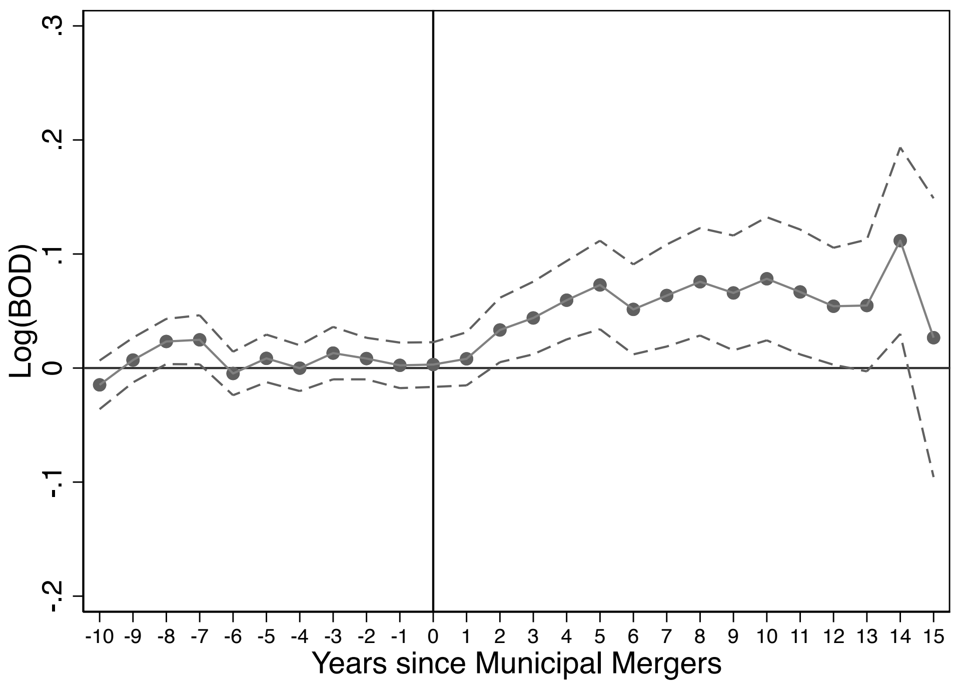

Figure A11: Robustness Checks: Spillovers from Border Municipalities

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. In this robustness check, the treatment indicator is set to 1 once at least one border municipality begins to undergo mergers for stations located on rivers at municipality borders. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

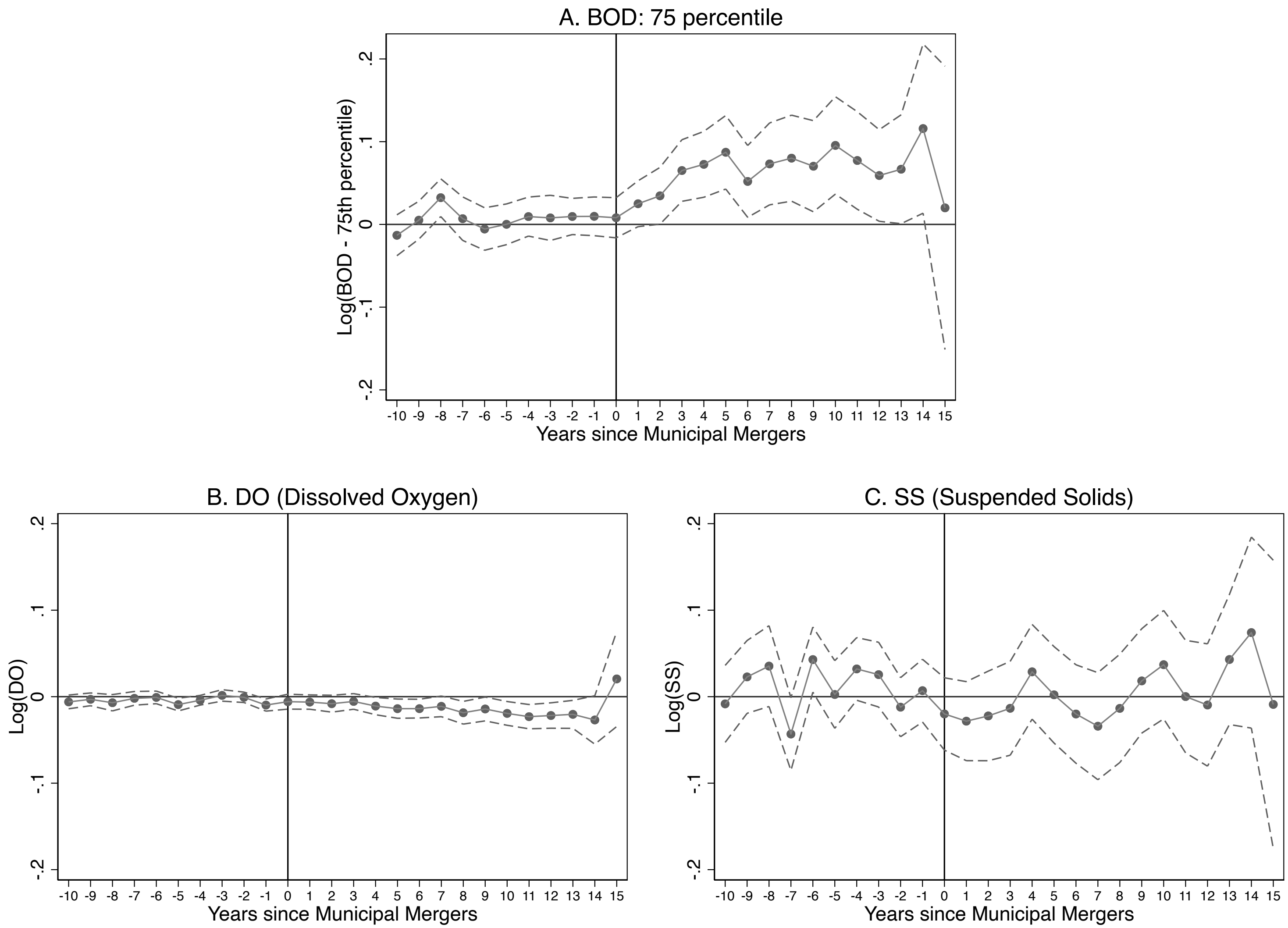

Figure A12: Robustness Checks: Alternative Water Quality Indicators and Falsification Test

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

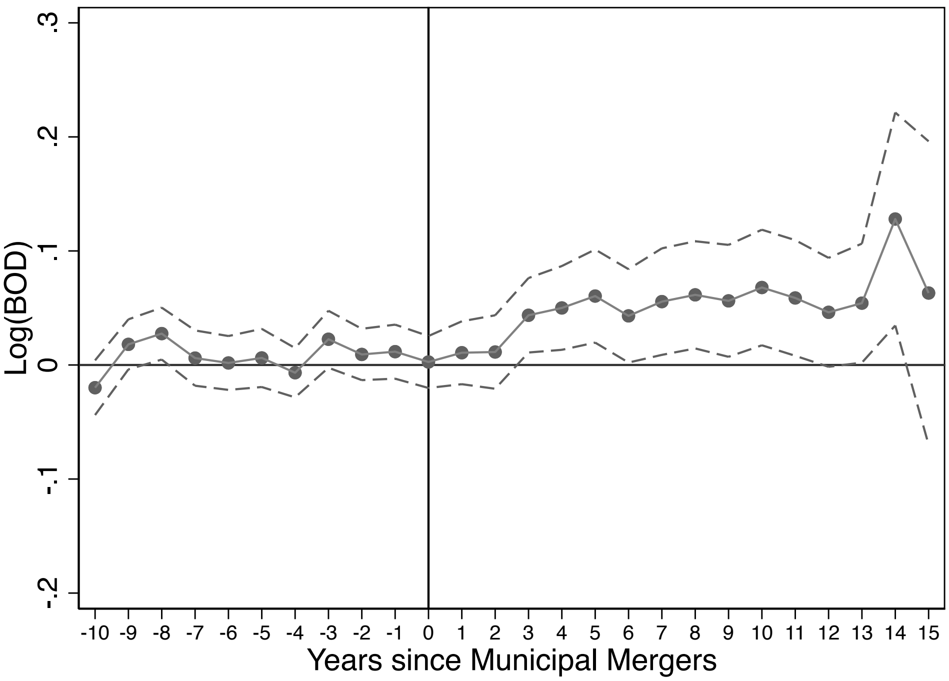

Figure A13: Event Study Results for Criteria Stations

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. The sample is limited to the criteria stations. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

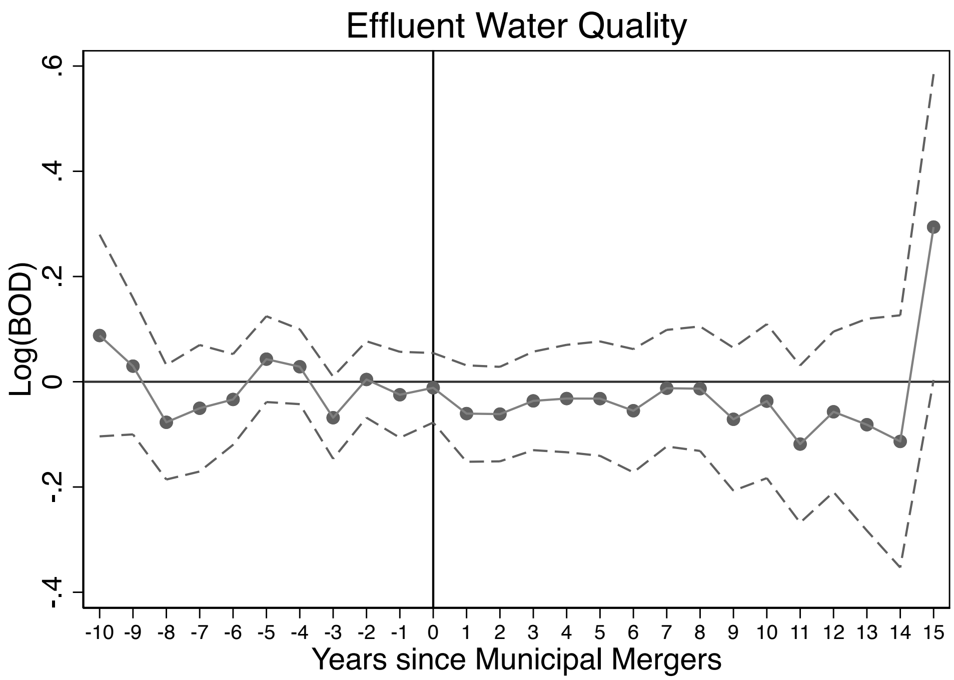

Figure A14: Pollution Sources: Effect of Municipal Mergers on Effluent Water Quality from Sewage Treatment Plants

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for municipality fixed effects and year fixed effects. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

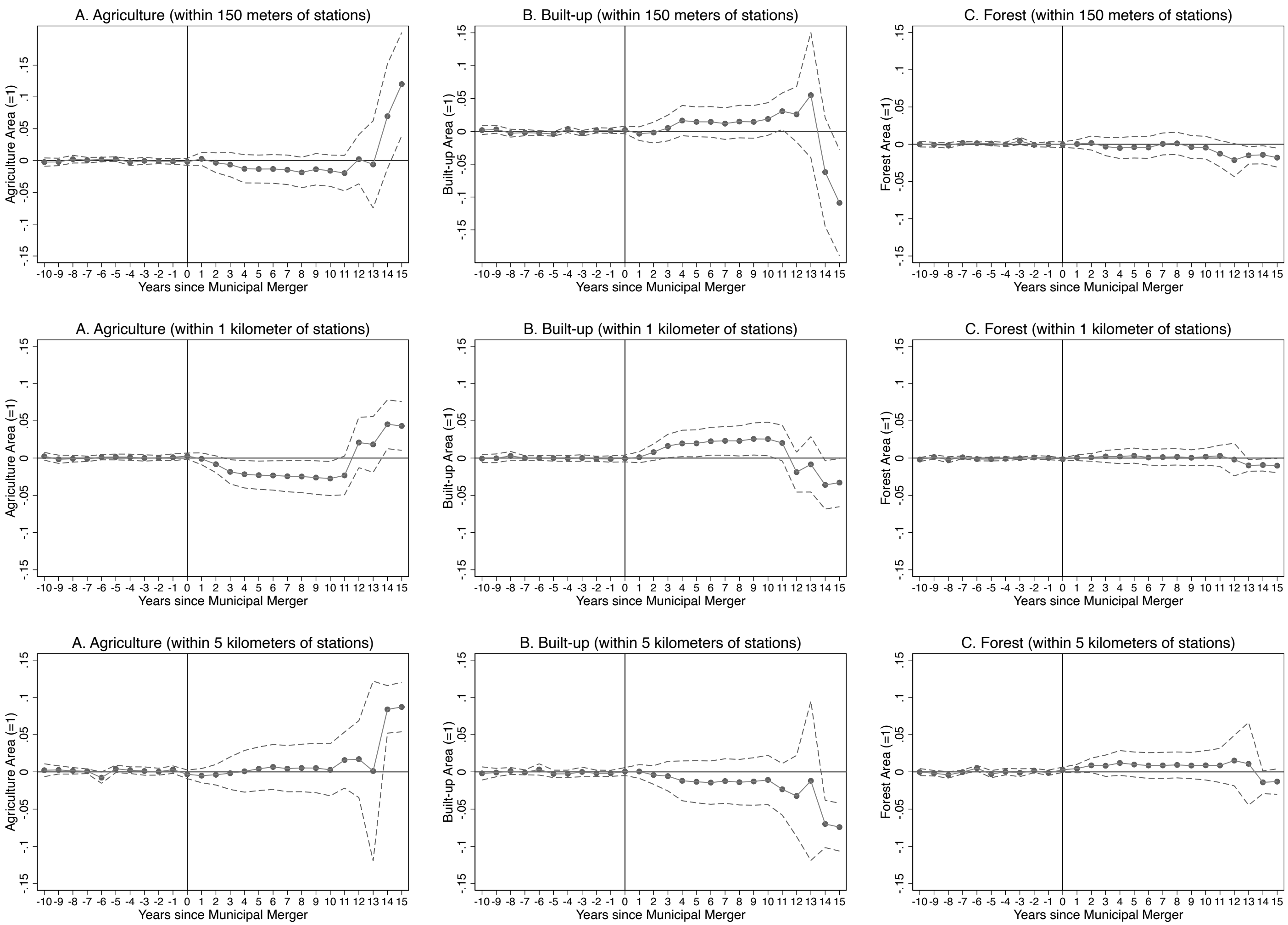

Figure A15: Alternative Mechanism 2: Effects of Municipal Mergers on Land Use

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for monitoring station fixed effects and year fixed effects. The panels in each column show results for different dependent variables, specifically indicators that take the value of 1 if the majority of land use within 150 meters, 1 kilometer, or 5 kilometers of monitoring stations is of the corresponding type. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

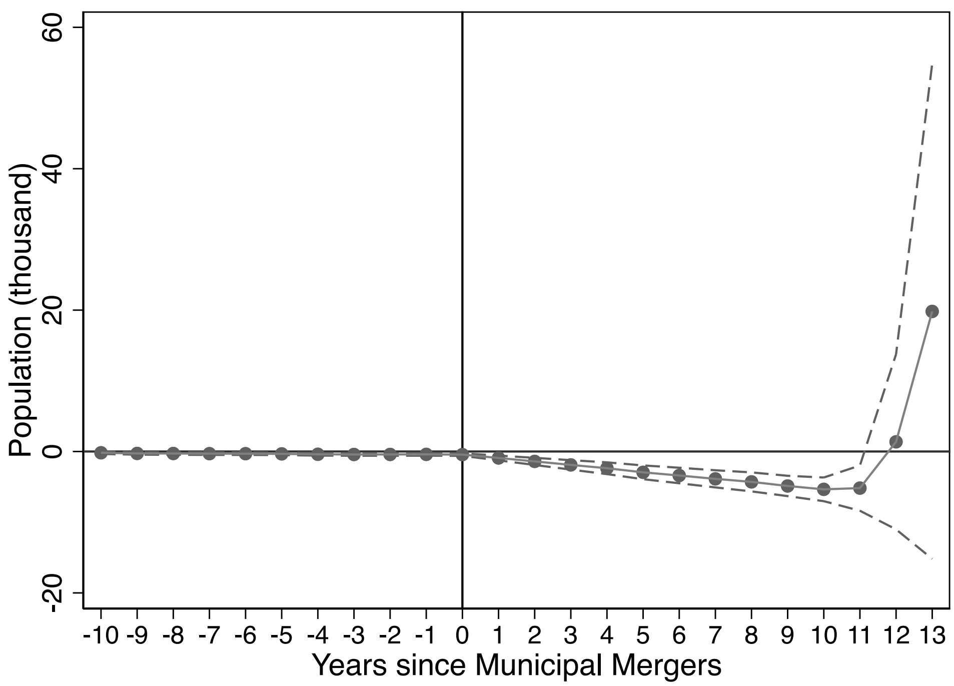

Figure A16: Alternative Mechanism 2: Effect of Municipal Mergers on Population

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. The specification accounts for municipality fixed effects and year fixed effects. Dashed lines represent the 95% confidence intervals, and standard errors are clustered at the post-merger municipality level.

B Additional Tables

Table B1: Balance Checks of Matched Municipalities for the Pre-Merger Period

	Means		Difference	Obs.
Variable	Never-Merged	Merged		
Product shipment values (100 billion JPY)	2.305	2.967	0.662	643
	(5.788)	(5.755)	(0.551)	
Population (thousand)	103.468	111.266	7.798	643
	(299.860)	(156.030)	(25.672)	
Agricultural output values (billion JPY)	11.907	12.484	0.577	643
	(9.699)	(10.925)	(1.419)	
Financial capability index	0.481	0.489	0.008	643
	(0.241)	(0.235)	(0.025)	

Notes: This table compares summary statistics between merged and never-merged municipalities using the matched sample before 2001, the period before municipal mergers began in our sample. The sample is limited to municipalities matched on agricultural output values and the financial capability index. The means are calculated by averaging the values for all the years in that period. When testing the difference, observations are weighted by the Mahalanobis matching frequency. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table B2: Robustness Checks: Difference-in-Differences Analysis of Matched Municipalities

	Log(BOD)
Event year 0	0.023*
	(0.013)
Event year 1	0.035**
	(0.017)
Event year 2	0.046**
	(0.021)
Event year 3	0.057**
	(0.023)
Event year 4	0.058**
	(0.025)
Event year 5	0.063**
	(0.030)
ATT: Event years 0–5	0.047
p-value: Event years 0–5	0.009

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. Standard errors clustered at the post-merger municipality level are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The specification accounts for monitoring station fixed effects and year fixed effects. The sample is limited to monitoring stations located in municipalities matched on agricultural output values and the financial capability index. Observations are weighted by the Mahalanobis matching frequency.

Table B3: Robustness Checks: Spillovers from Upstream and Border Municipalities (Dependent Variable: Log(BOD))

	Spillovers onto Control			No Upstream Mergers			Border Municipalities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\leq$ 25km	$\leq$ 50km	$\leq$ 100km	$\leq$ 25km	$\leq$ 50km	$\leq$ 100km	
ATT	-0.014	-0.027	-0.026	0.048**	0.052**	0.045**	0.053***
	(0.018)	(0.022)	(0.018)	(0.020)	(0.021)	(0.021)	(0.018)

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. Standard errors clustered at the post-merger municipality level are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The specification accounts for monitoring station fixed effects and year fixed effects. Columns 1–3 report spillover effects of upstream mergers on downstream, never-merged municipalities located within 25, 50, and 100 kilometers of merged municipalities, respectively. Columns 4–6 report the results of using monitoring stations that do not have upstream merged municipalities within a 25, 50, or 100-kilometer radius, respectively. In Column 7, the treatment indicator is set to 1 once at least one border municipality begins to undergo mergers for stations located on rivers at municipality borders.

Table B4: Robustness Checks: Alternative Water Quality Indicators, Falsification Test, and Criteria Stations

	Alternative Water Quality Indicators			Criteria Stations
	(1) Log(BOD 75)	(2) Log(DO)	(3) Log(SS)	(4) Log(BOD)
ATT	0.062***	-0.013***	-0.001	0.045***
	(0.019)	(0.005)	(0.024)	(0.017)

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. Standard errors clustered at the post-merger municipality level are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The specification accounts for monitoring station fixed effects and year fixed effects. Columns 1–3 report the results on alternative water quality indicators. In Column 4, the sample is limited to the criteria stations.

Table B5: The Effect of Municipal Mergers on Compliance with Environmental Quality Standards

	Violation	Narrow Compliance (Binary)	Narrow Compliance (Continuous)
	(1)	(2)	(3)
	All Event Years	All Event Years	Event Years 0–7
ATT	0.010	0.027*	1.553*
	(0.010)	(0.016)	(0.856)

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. Standard errors clustered at the post-merger municipality level are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The specification accounts for monitoring station fixed effects and year fixed effects. Column 1 reports the effect of municipal mergers on violations of environmental standards at criteria stations, while Columns 2 and 3 report the effects of municipal mergers on narrow compliance measures at criteria stations for compliant cases. Column 3 reports the ATT for event years 0–7, when significant effects are observed in the event study plot shown in Panel C of Figure 6.

Table B6: Pollution Sources: Effects of Municipal Mergers on Sewerage Expenditure and Outcomes

	Sewerage Construction (mil. JPY)	Sewerage Coverage (0–1)	Effluent WQ (Log(BOD))
	(1) All Event Years	(2) Event Years 0–5	(3) All Event Years
ATT	-15.010**	-0.014***	-0.045
	(6.034)	(0.004)	(0.047)

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. Standard errors clustered at the post-merger municipality level are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The specification accounts for municipality fixed effects and year fixed effects. Column 1 and 2 reports the effects of municipal mergers on expenditure on sewerage construction and sewerage coverage, while Column 3 reports the effect of municipal mergers on effluent water quality from sewage treatment plants. Column 2 reports the ATT for event years 0–5, when significant effects are observed in the event study plot shown in Panel B of Figure 9.

Table B7: Alternative Mechanism 1: Negative Externality Theory Tests

	Log(BOD)				
	(1)	(2)	(3)	(4)	(5)
Downstreamness indicator ($U/(U+D)$)	-0.132	-0.025			
	(0.265)	(0.264)			
Squared downstreamness indicator ($(U/(U+D))^2$)	0.258	0.099			
	(0.256)	(0.241)			
Distance from upstream border to station (U)			0.006*	0.011***	0.004*
			(0.003)	(0.004)	(0.002)
Squared distance from upstream border to station (U^2)			-0.000	-0.000**	
			(0.000)	(0.000)	
Distance from station to downstream border (D)			-0.002	0.007	0.002
			(0.005)	(0.005)	(0.002)
Squared distance from station to downstream border (D^2)			0.000	-0.000	
			(0.000)	(0.000)	
Observations	17,368	18,200	17,368	18,200	17,368
Adjusted R^2	0.888	0.851	0.888	0.852	0.888
Number of Stations	668	700	668	700	668
Number of Municipalities	354	382	354	382	354
Basin-Year FE	YES	NO	YES	NO	YES
Year FE	NO	YES	NO	YES	NO
Equality Test: p-value for U = D	-	-	0.178	0.508	0.498
Mean of Dep. Var. (levels)	2.720	2.807	2.720	2.807	2.720

Notes: The regression coefficients are reported. Standard errors clustered at the station level are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The regressions control for product shipment values and population in all columns. The mean of the dependent variable represents the average of the BOD values before the commencement of municipal mergers in our sample.

Table B8: Alternative Mechanism 2: Effects of Municipal Mergers on Land Use and Population

	Agriculture Area (=1)			Built-up Area (=1)			Forest Area (=1)			Population (thousand)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	150m	1km	5km	150m	1km	5km	150m	1km	5km	
ATT	-0.010	-0.017**	0.003	0.011	0.016**	-0.010	-0.003	0.001	0.008	-2.760***
	(0.009)	(0.008)	(0.012)	(0.009)	(0.008)	(0.012)	(0.006)	(0.004)	(0.007)	(0.494)

Notes: The coefficients of the Callaway and Sant'Anna (2021) estimator are shown. Standard errors clustered at the post-merger municipality level are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Column 1–9 account for monitoring station fixed effects and year fixed effects, while Column 10 accounts for municipality fixed effects and year fixed effects. Columns 1–9 report the effects of municipal mergers for different dependent variables, specifically indicators that take the value of 1 if the majority of land use within 150 meters, 1 kilometer, or 5 kilometers of monitoring stations is of the corresponding type.