Sustainable Public Procurement under Natural Disasters: Evidence from Earthquakes in Japan

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Preliminary version, please do not quote.

Abstract

Public procurement is increasingly used as a public policy instrument, especially with respect to environmental objectives. Although both national and local governments implement green procurement, its generalization is significantly slower among local authorities. Because the implementation of sustainable public procurement relies on local administrative capacity and budgets, exposure to external shocks such as natural disasters is likely to affect municipalities more strongly than national governments. In this context, increasing climate-related shocks may generate a vicious circle by weakening local capacity to implement sustainable procurement precisely when environmental action becomes most needed. To determine whether natural disasters threaten the implementation of green public procurement, this paper employs a quasi-experimental approach based on municipal procurement and earthquakes in Japan from 2012 to 2020. It finds that environmental hazards have a moderate but significant negative impact on municipal green purchasing, particularly in sectors where sustainable practices are less prevalent, such as energy-intensive items. Evidence points to budgetary crowding-out as the main transmission channel, as green procurement declines following exogenous increases in repair expenditures. Importantly, shocks causing limited damage also reduce green procurement, suggesting that disaster exposure affects policy implementation beyond direct physical destruction.

Keywords: Public Procurement; Green Public Procurement; Natural Disasters; Resilience

JEL classification: H57; H72; H84; Q54; Q58; C23

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1 Introduction

Public procurement refers to all contracts through which public authorities purchase goods, services, and works. While the traditional objective of public purchasers is to maximize the price-quality ratio, public procurement has long been used as a policy instrument in terms of innovation (Edquist and Hommen, 2000; Edquist and Zabala-Iturriagagoitia, 2012), promotion of small businesses (OECD, 2018; Flynn, 2025), social insertion (McCrudden, 2004), and protection of the environment (Testa et al., 2016a; Cheng et al., 2018).

The so-called "green public procurement" consists in utilizing public contracts to pursue environmental objectives by integrating environmental criteria into purchasing decisions. Despite debates over its cost-effectiveness as an environmental policy instrument (Marron, 1997; Lundberg et al., 2016), green procurement practices are increasingly implemented by national and local governments (OECD, 2024). However, local governments – such as municipalities – face greater challenges than national authorities in the adoption of sustainable procurement practices (Bryngemark et al., 2023). Indeed, the literature highlights the size of the government and the knowledge of the purchaser as crucial factors in the implementation of green public procurement (Testa et al., 2012, 2016b; Bryngemark et al., 2023; OECD, 2025) and municipalities can lack these resources.

Although the literature has extensively examined the determinants of green procurement adoption, much less attention has been paid to the resilience of these practices. This may be partly explained by the lack of suitable data, as most existing studies are based on cross-sectional survey data collected from a limited number of cities in a specific year (Testa et al., 2012; Bryngemark et al., 2023), making dynamic analyses impossible.

The resilience of sustainable public procurement is a critical issue as climate change increases the frequency and intensity of natural disasters. Because public procurement is a key implementation channel of local environmental governance, its disruption by natural hazards may generate a vicious circle in which repeated shocks weaken municipalities' ability to pursue environmental objectives.

Natural disasters can affect the implementation of sustainable public procurement through several economic channels. Earthquakes generate sudden fiscal pressures on municipalities by increasing repair and reconstruction expenditures while potentially reducing local revenues, thereby tightening short-term budget constraints. Under such conditions, procurement officers may prioritize cost, speed, and availability over environmental criteria, leading to a crowding-out of green purchasing. The impact of disasters is therefore likely to be heterogeneous across procurement sectors, depending on supply chain rigidity, energy intensity, and the ex-ante prevalence of sustainable practices. Disasters can also disrupt local administrative capacity by reallocating staff and attention toward emergency management, weakening the implementation of discretionary environmental practices. These mechanisms suggest that external shocks can undermine the implementation of local environmental governance practices, even when environmental preferences remain unchanged.

These mechanisms motivate the following testable hypotheses. First, if natural disasters tighten short-term budget constraints and weaken administrative capacity, earthquakes are expected to reduce the implementation of green public procurement at the municipal level (H1). Second, this effect is likely to be heterogeneous across procurement sectors, reflecting differences in supply constraints, energy intensity, and involvement in emergency situations (H2). Third, budgetary crowding-out probably constitutes a key transmission channel, as exogenous increases in post-disaster repair expenditures may divert public resources away from sustainable procurement practices (H3).

Japan provides a conducive framework to assess the resilience of municipal green procurement practices to natural disasters.

First, Japan has long been a pioneer in the implementation of green public procurement. As early as 1994, the "Action Plan for Greening Government Operations" encouraged all administrations to introduce environmental sustainability into their contracts. In 2001, the Ministry of the Environment enacted the "Act to Promote Green Purchasing", which required national agencies to implement green procurement in more than 100 procurement categories. The 2007 "Green Contract Law" complemented the "Act on Promoting Green Purchasing" by focusing on greenhouse gas emissions related to procurement contracts. Although these laws encourage municipalities to implement green purchasing practices, these practices are not mandatory for them. The Japanese Ministry of the Environment also

conducted a survey entitled "Questionnaire survey on green procurement by local governments" from 2001 to 2020. Its point was to assess the local adoption of green purchasing practices. In particular, this questionnaire mentions the state of the implementation of green procurement in 16 procurement sectors from 2010.

Second, Japan is one of the countries most exposed to natural disasters in the world. Due to geological and geographical factors, Japan faces a wide range of natural hazards: typhoons, volcanoes, landslides, floods, tsunamis, and earthquakes. However, this exposure to environmental hazards associated with advanced economic development has led to precise monitoring and analysis systems. This is especially the case for earthquakes, as they are continuously detected and measured by a dense network of seismic stations. These data have been used by economists to perform quasi-experimental analyses on diverse topics such as real estate (Naoi et al., 2009), individual well-being (Yamamura et al., 2015), or supply chains (Todo et al., 2015; Carvalho et al., 2021). Indeed, earthquakes can be analyzed as random treatments, since all regions of the country can be affected and their occurrence date is totally unpredictable.

By merging seismic data with original information on green procurement in Japanese municipalities from 2012 to 2020, this paper examines for the first time the resilience of green public procurement practices to natural disasters, using a *difference-in-differences* design.

This paper first identifies a negative reduced-form effect of earthquakes on the implementation of green purchasing. This detrimental impact is especially noticeable in the purchase of items where the *ex-ante* implementation level of green purchasing is low, such as mobile phones and energy-related items. Interestingly, this result holds even with earthquakes that cause limited damage. Since post-disaster expenses are endogenous, an instrumental variable based on the surface of municipal bridges shows that an exogenous increase in repair expenditures has a detrimental impact on the implementation of green procurement, thus revealing a budgetary crowding-out. These findings highlight the importance of raising ecological awareness in post-disaster periods, since natural disasters can redefine municipal priorities at the expense of sustainable issues.

The remainder of this paper is structured as follows. Section 2 describes the data on municipal procurement and earthquakes. Section 3 evaluates the impact of earthquakes on municipal sustainable practices. These results are corroborated by robustness checks in Section 4 and discussed in Section 5.

2   Data

This paper studies the green procurement practices of 1833 Japanese municipalities from 2012 to 2020. Note that it is preferable to start the analysis in 2012, as there were several waves of municipal mergers before 2010. In addition, various extreme natural disasters affected the Pacific coast of Tohoku in 2011, which could disturb estimates and lead to many missing values for affected municipalities.

The data are derived from the Japanese Ministry of the Environment's "Questionnaire survey on green procurement by local governments". This questionnaire is noteworthy because it provides a unique opportunity to assess the green procurement strategies of all Japanese municipalities over a long period, thus providing representativeness and allowing dynamic analyses.

Sixteen sectors are mentioned in the questionnaire every year between 2012 and 2020, namely: paper, stationery, office furniture, mobile phones, home appliances, air conditioners, water heaters, lighting, vehicles, fire extinguishers, uniforms, interior bedding, work gloves, other textiles, equipment, and disaster supplies.

$Green_{ist}$ is a binary indicator equal to one if municipality i engages in environmentally friendly procurement practices in sector s in year t, and zero otherwise.

Figure 1 shows that the average effort in green purchasing has decreased slightly between 2012 and 2020. Interestingly, Figure 2 highlights a strong polarization in the number of purchasing categories where municipalities implement green practices. In 2020, approximately 60% of cities implemented green procurement in all or none of the purchase categories. The proportion of municipalities that do not promote sustainability in any of the 16 procurement sectors has tripled in eight years.

Figure 3 shows that the level of green procurement initiatives is heterogeneous across sectors. The purchase of paper and stationery are the categories with the highest proportion of municipalities making environmental efforts ($75 - 80\%$). Conversely, less than half of municipalities implement
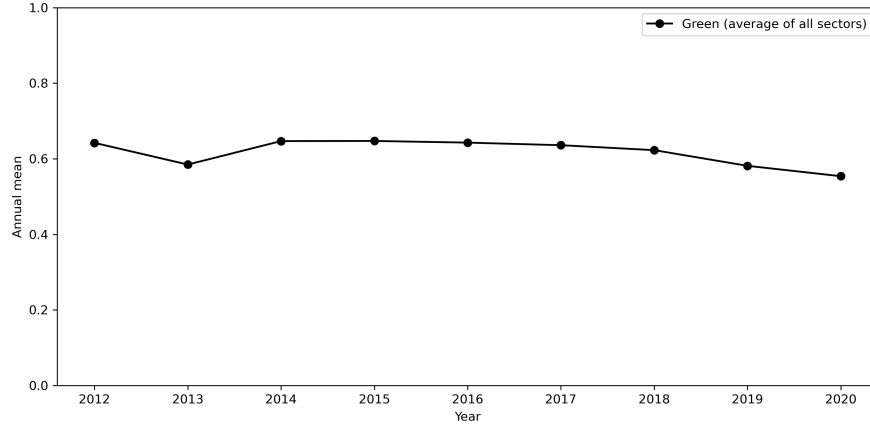
Figure 1: Evolution of the average proportion of sectors with green purchasing per municipality
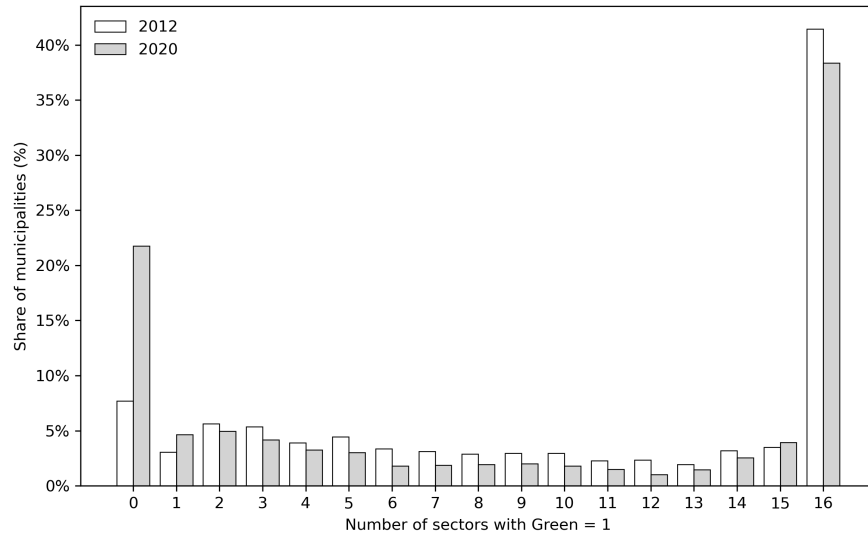

Figure 2: Distribution of the number of sectors with a green purchasing effort

green procurement concerning mobile phones. The proportion of municipalities involved in green procurement seems to have decreased quite uniformly in every sector.

Data on earthquakes come from the Japan Meteorological Agency (JMA) website. This paper resorts to the JMA Seismic Intensity Scale – also known as the "Shindo seismic scale" – to assess the intensity of the earthquakes. The JMA Shindo scale measures the local ground shaking due to an earthquake thanks to a network of over 600 seismic stations that cover all of the territory. In contrast, the well known Richter scale (Richter, 1935) is less adapted to the purpose of this paper, as it assigns a unique value to earthquakes depending on the energy they release, while the local perception of earthquakes also depends on the depth of the latter, the type of ground, and the distance to the epicenter.

Table 8 details the characteristics of each earthquake intensity. This paper focuses on earthquakes with an intensity equal to or greater than 5- on the Shindo scale. Indeed, 5- is considered the minimum intensity of earthquakes to observe outside damage. Moreover, as suggested by Figure 15, the intensity of earthquakes follows an exponential decay in frequency, so most municipalities have experienced smaller earthquakes during the studied period.

The JMA data show that there are 390 different $City \times Year$ maximum seismic intensity episodes
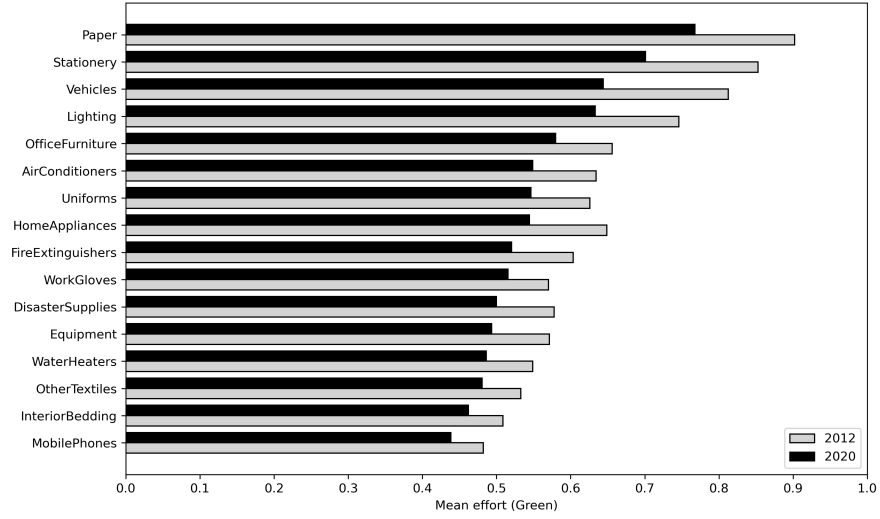
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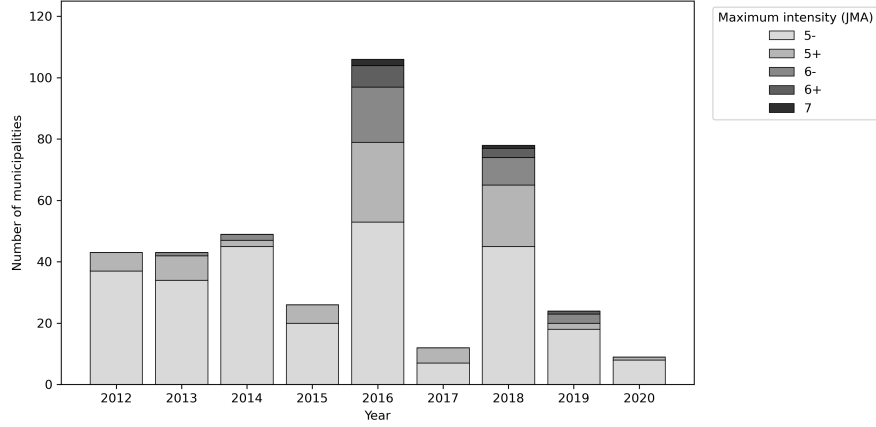Figure 3: Sectoral comparison of green purchasing practices

Figure 4: Temporal distribution of seismic episodes

that are equal to 5- at least on the Shindo scale between 2012 and 2020. Note that this does not mean that there are 390 different earthquakes. Indeed, earthquakes – especially major ones – typically have aftershocks of smaller intensity. In addition, major seismic episodes can affect the same region several times with different epicenters, so some cities face moderate earthquakes one day and more severe tremors a few hours or days later.

Figure 4 shows that 2016 and 2018 are the years with the most earthquakes, especially those with an intensity greater than or equal to 5+ on the Shindo scale, due to seismic activity in the prefectures of Kumamoto (2016), Fukushima (2016), Hokkaido (2018) and Osaka (2018), as visible in Figure 16, which represents the geographical distribution of significant earthquakes in Japan during the studied period.

Among the 390 seismic episodes, 3 have a maximum intensity of 7 on the Shindo scale. It corresponds to extreme earthquakes that can destroy most buildings and facilities in a city, even modern ones. 11 episodes have a maximum seismic intensity of 6+, which are less destructive than the previous ones but can severely affect buildings and roads. There were 33 episodes of 6- maximum intensity. They are less destructive, but can severely damage less-resistant infrastructures and buildings. 76 seismic episodes have a maximum Shindo intensity equal to 5+. These earthquakes can still structurally damage old buildings. Finally, 267 seismic episodes featured a maximum intensity of 5-. These

earthquakes can scare the population, but cause limited direct damage, especially to modern facilities. Overall, 7-intensity episodes represent 0.77% of the observations, 6+ account for 2.82%, 6- for 8.46%, 5+ for 19.49% and 5- for 68.46% of the seismic episodes in Japan from 2012 to 2020.

3   Empirical strategy and results

Earthquakes can be analyzed as random treatments in a *difference-in-differences* (DiD) design. More particularly, since municipalities can face earthquakes in different years, the experimental design corresponds to a staggered treatment. However, in the plausible scenario of time-varying effects of a staggered treatment, traditional – or *naive* – two-way fixed effect models provide a biased estimation of the "average treatment effect on the treated" (ATT). From 2020, several works (Callaway and Sant'Anna, 2021; Sun and Abraham, 2021; de Chaisemartin and D'Haultfœuille, 2023; Borusyak et al., 2024) have suggested innovative ways to overcome this potential bias. This paper uses the approach of Callaway and Sant'Anna (2021) as it provides robust ATTs as well as dynamic event studies.

Let i index municipalities, s purchasing segments, and t years. The outcome is $Green_{ist}$ (as defined in the previous section) and the treatment timing is defined at the municipality level by the first year of exposure G_i (with $G_i = 0$ for cities never-treated). For each cohort g and year $t \geq g$, the parameter of interest is

$$\text{ATT}(g,t) = \mathbb{E}[\, Green_{ist}(1) - Green_{ist}(0) \mid G_i = g]. \tag{1}$$

$\text{ATT}(g,t)$ is estimated by comparing treated municipalities first exposed in year g to a control group of never-treated or not yet treated cities, using a DiD structure. To flexibly absorb segment-specific time shocks, year×segment fixed effects are introduced.

The aggregate effects are obtained by averaging $\widehat{\text{ATT}}(g,t)$ across post-treatment periods and cohorts.

$$\widehat{\text{ATT}} = \sum_g w_g \left(\frac{1}{T_g} \sum_{t \geq g} \widehat{\text{ATT}}(g,t) \right), \qquad w_g = \Pr(G_i = g \mid G_i > 0), \tag{2}$$

where T_g denotes the number of post-treatment periods observed for the cohort g. Standard errors are clustered at the municipality level to integrate the correlation among the different observations in a given city.

Note that municipalities that were affected by an earthquake in 2011 are removed from the sample to avoid pre-treatment contamination. Additionally, to focus on the effect of the first treatment, the few municipalities that experience significant earthquakes in two different years or more are censored from the year the second earthquake occurs.

3.1   Reduced-form effect of earthquakes on green procurement

Earthquakes can cause damage if their JMA Shindo intensity is equal to 5- at least. As it is not clear from which intensity earthquakes can have an actual impact on green purchasing, Figure 5 tests several definitions depending on intensity thresholds. The plotted estimates result from a DiD design as described above, considering never treated and not yet treated municipalities as control. Interestingly, all estimated ATTs are negative, but the estimate is significant at the 5% level only when considering all the earthquakes in the sample, i.e. JMA Shindo greater than or equal to 5-. This may be explained by the smaller number of observations when the sample is restricted to extreme – thus rare – earthquakes (Figure 15).

Table 1 describes the estimates under different specifications. ATTs are comprised between 0.55 and 0.75, whether never treated units or not yet treated units only are considered as the reference group. Surprisingly, the negative impact holds when considering municipalities that face an earthquake whose intensity is equal to JMA Shindo 5- only and censoring post-treatment observations in municipalities that experience a greater earthquake. All these results are significant at the 5% level. These findings imply that earthquakes reduce the probability of implementing green purchasing by 5 to 7 percentage points on average in affected municipalities.
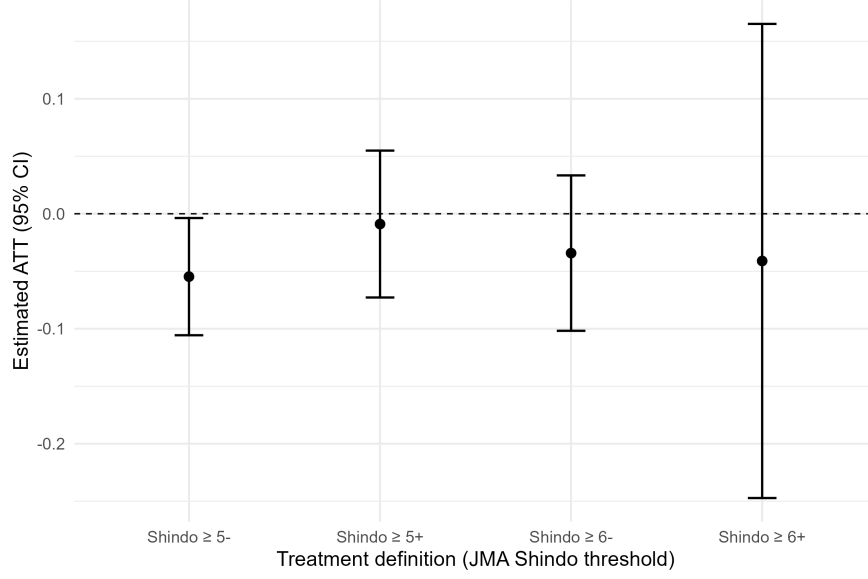
Figure 5: Estimated impacts on *Green* of seismic episodes depending on treatment threshold

Control group	Treatment threshold	ATT	95% CI	S.d.	*p-value*
Never treated	$\geq$ Shindo 5-	-0.055	$[-0.107, -0.003]$	0.027	0.039
Never treated	= Shindo 5-	-0.074	$[-0.148, -0.0002]$	0.038	0.045
Not yet treated	$\geq$ Shindo 5-	-0.055	$[-0.109, 0.002]$	0.027	0.041
Not yet treated	= Shindo 5-	-0.074	$[-0.152, 0.003]$	0.039	0.059

Table 1: Estimated impacts on *Green* depending on design specifications

Figure 6 plots the event study of the overall impact of seismic episodes with a maximum intensity of JMA Shindo 5- at least. Although no post-treatment annual ATT is significant at the 5% level, all estimated ATTs are negative from the year the earthquake occurs. Due to smaller cohorts, the confidence interval becomes wider in year +5, but there is a clear negative effect of earthquakes from year 0 to year 4. Furthermore, pre-treatment estimates seem to fluctuate randomly before the earthquake occurs, thus showing no signs of pre-trends, which is a good omen for the validity of the parallel trend assumption.

3.2   Sectoral heterogeneity

The effects estimated in Section 1 cover all public procurement sectors. However, there may be significant sectoral heterogeneity in the effect of earthquakes on green purchasing, for example, depending on supply chain resilience or the uneven use of procurement categories in emergency situations. Figure 7 plots the estimated ATTs when applying the DiD design of this paper to sectoral subsamples. Table 9 details the complete results by procurement sector. Although no ATT is strictly significant at the 5% level, some are significant at the 10% level and there is clear sectoral heterogeneity. In particular, paper and stationery seem to be unaffected, while equipment, mobile phones, interior bedding, water heaters, uniforms, or air conditioners seem to be penalized by earthquakes. The larger standard errors are probably due to the decrease in the number of observations, as $Green_{ist}$ covers all sectors, making the subsample approximately 16 times as small.

Interestingly, Figure 8 shows that there is a significant positive correlation between the estimated sectoral ATT and the average implementation of green practices in the corresponding sector in 2011 (it is preferable to consider the *ex-ante* average implementation of green procurement practices, as the average implementation during the studied period is affected by the estimated impact of earthquakes).
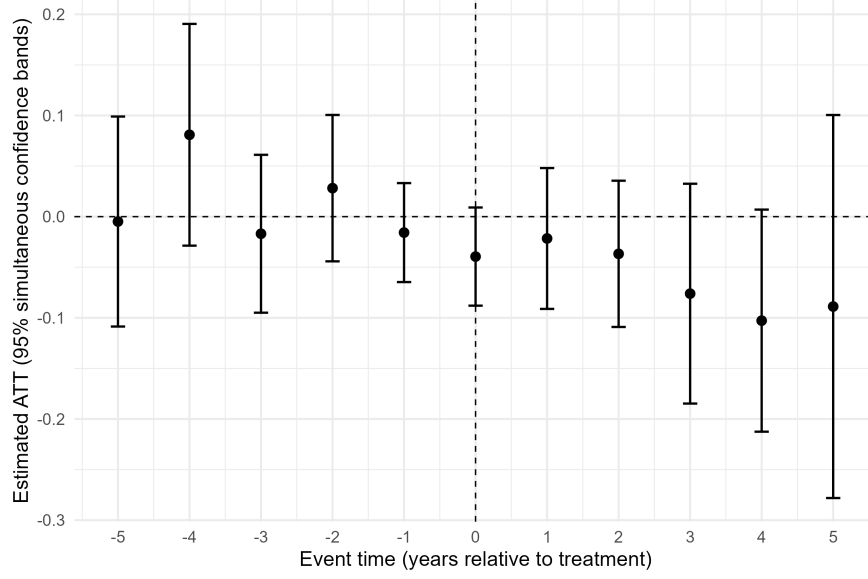
Figure 6: Event study with seismic episodes with a minimum intensity of Shindo 5-

Therefore, earthquakes tend to penalize sectors with a low implementation rate of green procurement practices, thus exacerbating discrepancies across sectors.

It would be relevant to assess whether extreme and moderate earthquakes have similar sectoral impacts. However, there would be not enough observations to estimate sectoral impacts when focusing on extreme shocks.

3.3 Repair expenditures and budgetary crowding-out

Although earthquakes – including moderate ones – seem to be detrimental to green purchasing, the JMA Shindo intensity scale only approximates the extent of the damage caused by seismic episodes. Different factors such as the exact location of the maximum tremor or infrastructure resistance can influence the extent of the damage, and thus potentially affect the impact of earthquakes on green purchasing.

The extent of damage is difficult to measure accurately. Noy et al. (2023) build a damage index based on ground acceleration during earthquakes, nightlight intensity as a proxy for local asset exposure, and an approximation of building vulnerability. However, in a DiD framework, these damage measures may threaten the parallel trends assumption, as they are strongly correlated with urbanization and local wealth, which can induce differential pre-treatment trends in sustainable procurement.

In the context of this paper, municipal repair expenditures provide a more relevant measure of post-disaster pressure, as they directly capture budgetary reallocations following earthquakes and allow to test for a potential crowding-out effect between restoration spending and the adoption of green procurement practices.

Let $repairs\_per\_capita_{it}$ be the post-disaster repair expenditure per resident (in thousands of JPY) of the municipality i in year t. This information comes from the "portal site for Japanese Government Statistics" (e-Stat). Figure 9 plots the estimated ATTs obtained by applying the same DiD design as described above on $repairs\_per\_capita_{it}$ instead of $Green_{ist}$, with various JMA Shindo intensity thresholds. Naturally, earthquakes increase municipal repair expenditures. The stronger the earthquake, the higher the post-disaster spending. As explained above, confidence intervals are wider when the intensity threshold increases due to a smaller number of treated units.

However, municipal repair expenditures are potentially endogenous to green procurement outcomes. Indeed, they reflect discretionary budgetary choices shaped by fiscal capacity, governance quality, and policy preferences. The latter can also affect green procurement practices independently of post-
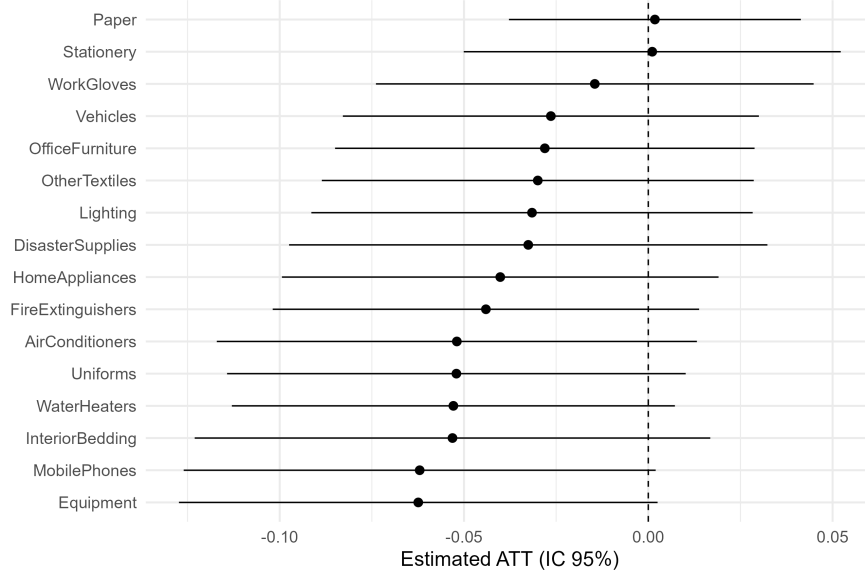
Figure 7: Sectoral impacts on *Green* of seismic episodes with a minimum intensity of Shindo 5-

disaster spending.

Therefore, it is preferable to use an instrumental variable approach to account for the endogenous nature of post-disaster repair expenditures and assess the impact of an exogenous increase in the latter on green purchasing. A Two-Stage Least Squares (2SLS) model is used. Let *bridges_per_capita* be the per resident surface (in square meters) of municipal bridges, i.e. bridges maintained by municipalities. This information comes from the National Road Facility Inspection Database of the Japanese Ministry of Land, Infrastructure, Transport and Tourism. The data describe 476781 municipal bridges as of January 2026. It is assumed that this stock is constant over time. Figure 18 plots the spatial distribution of this variable. Figure 17 describes the distribution of *bridges_per_capita*. Among the 83% of municipalities that manage at least one bridge, the median surface of municipal bridges per capita is 0.55 square meters. 75% of municipalities have a per capita surface less than one square meter. There are a significant number of outliers due to specific geographical factors such as rivers and seashores.

The surface of municipal bridges per capita is largely predetermined by historical geography, river networks and past transportation planning and therefore plausibly exogenous to contemporaneous procurement policy choices. In particular, most of the stock of bridges managed by municipalities was determined decades before the period of analysis and evolves only slowly over time. Conditional on municipality and sector-year fixed effects, bridge surface per capita is unlikely to be correlated with unobserved shocks that affect green procurement preferences or administrative capacity. This instrument is likely to affect green public procurement only through its impact on repair expenditures, according to the exclusion condition of the instrumental variable.

			No Post_treatment control			With Post_treatment control		
Threshold	Treated	Control	F.S. Estimate	S.d.	*p-value*	F.S. Estimate	S.d.	*p-value*
Shindo $\geq$ 5-	288	1220	6.156	2.190	0.005	6.090	2.297	0.008
Shindo $\geq$ 5+	105	1404	10.392	3.685	0.005	7.274	3.182	0.022
Shindo $\geq$ 6-	39	1470	49.009	11.854	0.000	46.264	15.867	0.004
Shindo $\geq$ 6+	14	1495	124.719	33.580	0.000	140.553	60.146	0.019

Table 2: Impact of municipal bridge per capita surface on repair expenditure (first stage)
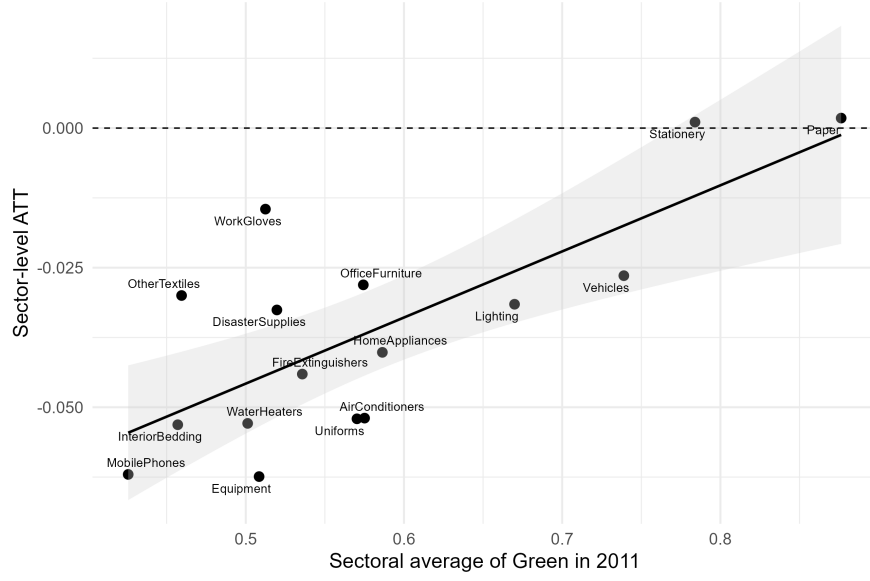
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Figure 8: Scatter plot of ATTs and the sectoral average of *Green*

Moreover, to be a good instrument, a larger municipal bridge stock must influence expenses in post-disaster repairs through higher maintenance and restoration. In Table 2, the results for the first-stage model, as defined in Equations 3 and 4 show that *bridges_per_capita* is a strong instrument. In addition, when considering different JMA Shindo intensities separately, Figure 10 highlights that the impact of the bridge surface increases with the maximum intensity of the earthquakes. This result is expected, as stronger tremors damage municipal bridges more.

$$repairs\_per\_capita_{it} = \pi\, Z_i + \alpha_i + \lambda_t + u_{it}, \tag{3}$$

$$\text{with } Z_i = bridges\_per\_capita_i \times post\_earthquake_{it} \tag{4}$$

where α_i is a municipal fixed effect and λ_i is a year-specific fixed effect. Standard errors are clustered at the municipal level.

Equation 5 describes the second stage of the 2SLS model, where $\widehat{repairs\_per\_capita}_{it}$ corresponds to the first-stage model. α_i and λ_{st} still correspond to time and year fixed effects, respectively. ϵ_{ist} is supposed to be orthogonal to Z_i.

$$Green_{ist} = \beta\, \widehat{repairs\_per}\_capita_{it} + \alpha_i + \lambda_{st} + \varepsilon_{ist} \tag{5}$$

Table 3 and Figure 11 describe the results of the second-stage model. Interestingly, although all the estimated coefficients are negative, the only statistically significant coefficient is obtained when focusing on earthquakes with a maximum intensity greater than or equal to JMA Shindo 6-. It implies that there is a trade-off between the strength of the signal – stronger earthquakes have a bigger impact on repair expenditures – and the number of observations. The optimal compromise is reached when selecting strong earthquakes, but not only the extreme ones. Additionally, note that the introduction of *post_earthquake* as a control variable has little impact on the estimates.

The interpretation of the results in Table 3 is quite straightforward. A 1000 JPY increase in municipal per capita repair expenditures after a seismic episode that reached an intensity of at least JMA Shind 5- reduces the probability of adopting green purchasing by 0.2 percentage point. In comparison, the annual per capita repair expenditure from 2012 to 2020 is equal to 9321 JPY on average.
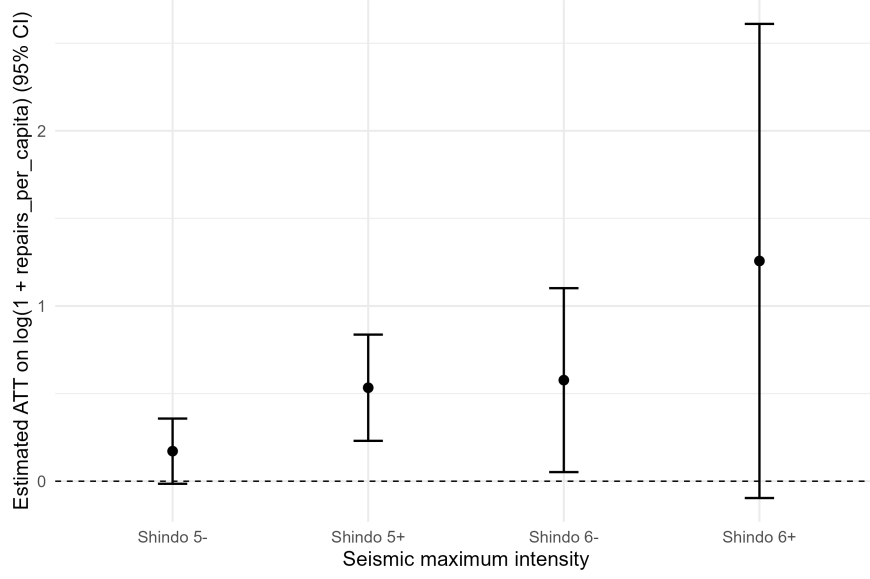
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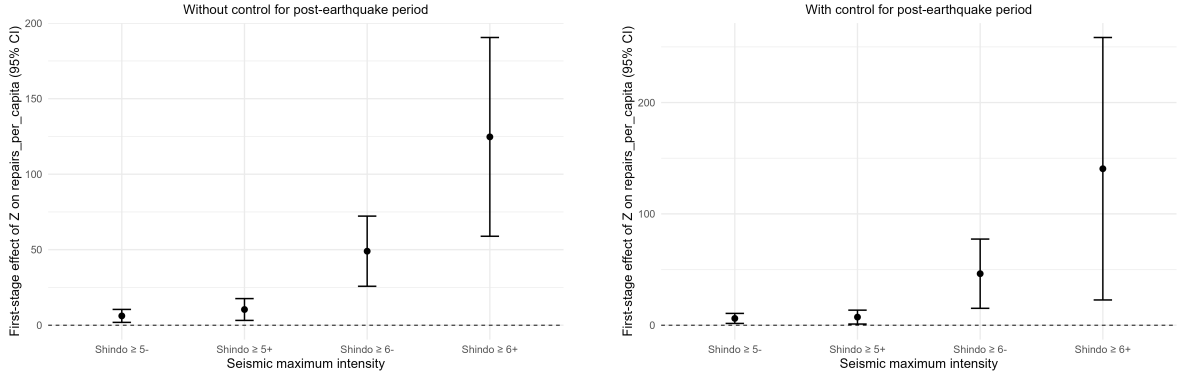Figure 9: Repair expenses depending on seismic intensity

Figure 10: First-stage relationship between the surface of bridges per capita and repair expenditures

4 Robustness

4.1 Treatment anticipation

Shifting the event time is a relevant way to challenge the parallel trend assumption, since it shows whether the estimated impact is aligned with the event timing or whether it reflects specific trends in the treated municipality. Therefore, anticipated treatments are created in treated municipalities by shifting treatments two years before the earthquake actually occurs. The event study in Figure 12 shows that the anticipation of treatment by two years totally disrupts the dynamic identified in Figure 6 in the previous section. When estimating annual ATTs with respect to $t - 2$, no significant dynamic emerges from the data. On the contrary, post-treatment ATTs tend to be slightly positive. This is a good omen for the absence of different dynamics between treated municipalities and cities in the control group.

4.2 Random treatment assignment

This second placebo test follows the annual number of earthquakes in the sample, but assigns them to municipalities randomly. By doing so, the tests aim to check whether the estimates really reflect
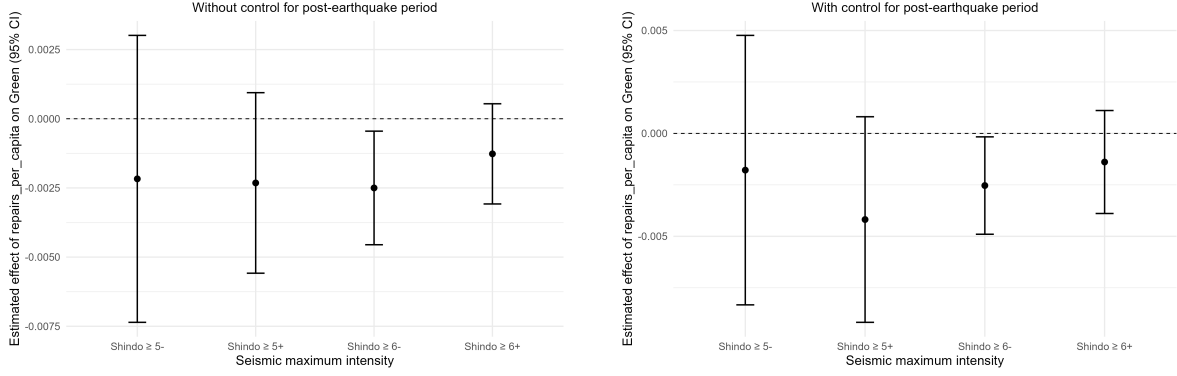
Figure 11: Second-stage IV estimates: effect of repair expenditures on *Green*

Threshold	Treated	Control	No Post_treatment control			With Post_treatment control		
			I.V. Estimate	S.d.	*p-value*	I.V. Estimate	S.d.	*p-value*
Shindo $\geq$ 5-	288	1220	-0.002	0.003	0.412	-0.002	0.003	0.593
Shindo $\geq$ 5+	105	1404	-0.002	0.002	0.163	-0.004	0.003	0.101
Shindo $\geq$ 6-	39	1470	-0.003	0.001	0.017	-0.003	0.001	0.036
Shindo $\geq$ 6+	14	1495	-0.001	0.001	0.170	-0.001	0.001	0.276

Table 3: 2SLS regression of instrumented repair expenditure on *Green* (second stage)

the impact of earthquakes or if the identification is biased. Therefore, the random treatment model should estimate null ATTs.

Figure 13 plots the average annual ATTs estimated by the main DiD design of this paper (with JMA Shindo $\geq$ 5- and never treated cities as a control group) after a Monte-Carlo simulation of 100 random treatment assignments. A Monte-Carlo simulation is necessary to estimate the distribution of annual ATTs under the random treatment model. Despite significant variance in time horizons far from the random treatment year due to smaller cohorts, ATTs clearly converge to zero and seem unbiased. It suggests that the negative effect is not driven by estimator bias in the design structure.

4.3 Alternative definition of the outcome

To ensure that the interpretation of the results does not depend on the choice in the construction of the outcome variable that assesses the average implementation of green purchasing, an alternative outcome to $Green_{ist}$ is tested. Let $\widehat{Green_{it}}$ be the proportion of the procurement sectors where the municipality i implements sustainable practices in the year t. Figure 2 in Section 2 describes the distribution of $\widehat{Green_{it}}$ in 2012 and 2020. This alternative outcome is significantly different from $Green_{ist}$, since the latter is a binary variable defined at the sector-year-municipality level, while the former is a proportion defined at the year-municipality level. Apart from this new outcome, the approach of Callaway and Sant'Anna (2021) is still used, as described above. Naturally, year×segment fixed effects cannot be used in this design. Table 4 shows that there is evidence of a negative impact of earthquakes on green purchasing even with this alternative approach. Although *p-values* are slightly larger than in the main model due to a smaller number of observations, the order of magnitude of the estimates is unchanged.

4.4 Alternative instrument

Let $tunnel\_per\_capita_i$ be the total length (in meters) of the tunnels the municipal i maintains divided by the number of residents in i. To ensure the robustness of the crowding-out effect identified with the per capita surface of municipal bridges as an instrument addressing the endogeneity in the repair expenditures, $tunnel\_per\_capita$ is used as an alternative instrument. Although $tunnel\_per\_capita$
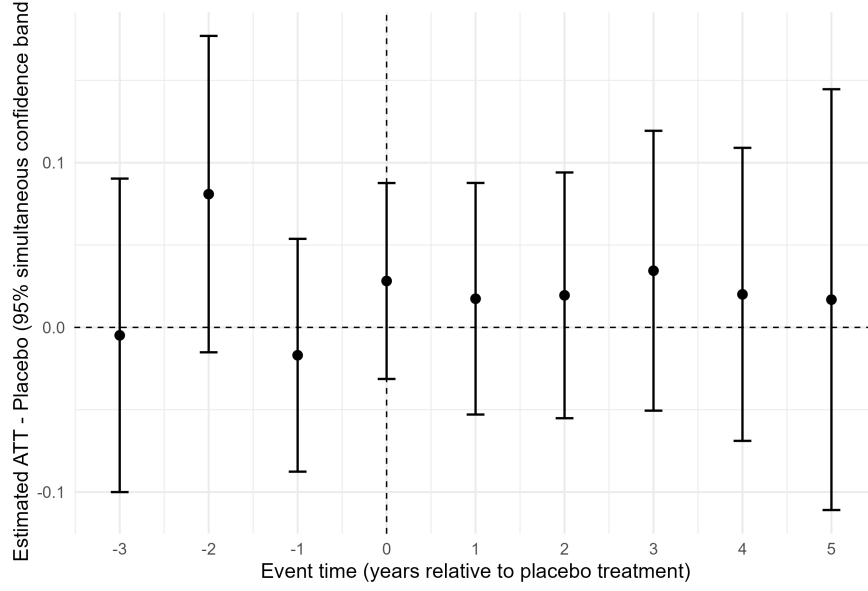
Figure 12: Event study with anticipated treatment timing ($t-2$, Shindo $\geq 5-$)

Control group	Treatment threshold	ATT	95% CI	S.d.	*p-value*
Never treated	Shindo $\geq$ 5-	-0.055	$[-0.097, -0.006]$	0.026	0.080
Never treated	Shindo = 5-	-0.074	$[-0.145, -0.003]$	0.036	0.041
Not yet treated	Shindo $\geq$ 5-	-0.048	$[-0.095, 0.004]$	0.025	0.071
Not yet treated	Shindo = 5-	-0.074	$[-0.149, 0.000]$	0.038	0.049

Table 4: Estimated impacts of earthquakes on the proportion of sectors with green procurement

and *bridges_per_capita* are positively correlated (Corr(*tunnel_per_capita*, *bridges_per_capita*) ≈ 0.37), this correlation is moderate enough to consider them as two separate instruments. While 18% of cities have a null bridge surface per capita, 71% of municipalities do not have tunnels to maintain. Therefore, the results using tunnels as an instrument are estimated on a smaller sample than the one using bridges. For this reason, the intensity threshold greater than or equal to $\geq$ JMA Shindo 6+ will not be considered. Figure 19 plots the distribution of the length of municipal tunnels per resident in municipalities that manage at least one tunnel. There is a very high variability in the per capita length of municipal tunnels. While the average length of municipal tunnels is equal to 4 centimeters per capita, the standard deviation is equal to 17 centimeters, and a couple of cities have more than 1 meter of tunnel to manage per resident.

When using the length of municipal tunnels instead of the surface of municipal bridges, Tables 5 and 6 find results similar to those in Tables 2 and 3. Despite a significant drop in the size of both treatment and control groups, the first stage model highlights the positive impact of the per resident length of municipal bridges on post-disaster repair expenditure, regardless of the considered intensity threshold in the definition of the treatment. Concerning the second-stage model, as with bridges, the significance of the estimated impact of the instrumented repair expenditure on *Green* depends on the intensity threshold considered. However, all the models estimate a negative impact of the instrumented amount of repair expenditure on green purchasing practices. This is especially the case with earthquakes whose magnitude exceeds JMA Shindo 5+.
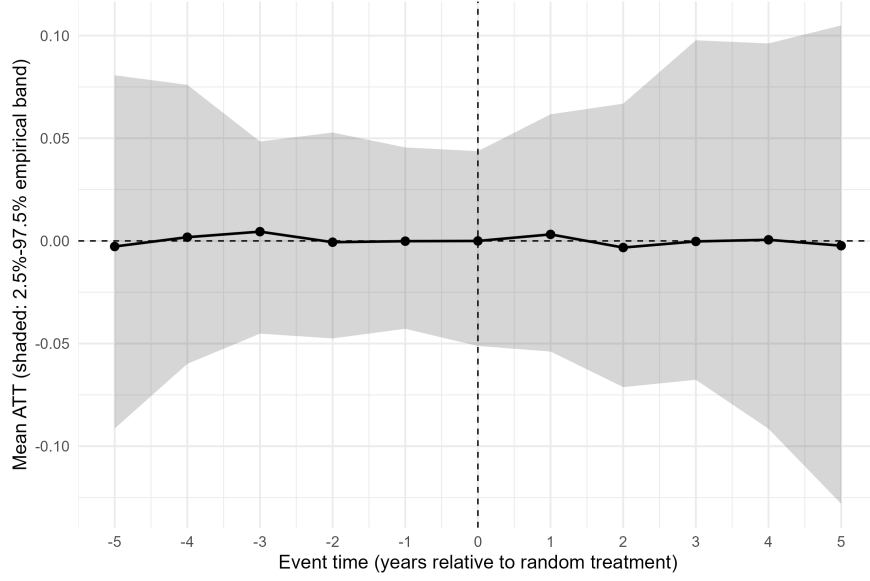
13

Figure 13: Event study with random treatment (Shindo $\geq 5-$)

Threshold	Treated	Control	No Post_treatment control			With Post_treatment control		
			F.S. Estimate	S.d.	*p-value*	F.S. Estimate	S.d.	*p-value*
Shindo $\geq 5-$	110	422	122.215	54.030	0.024	108.475	47.021	0.021
Shindo $\geq 5+$	42	490	160.758	59.550	0.007	117.870	44.450	0.008
Shindo $\geq 6-$	15	517	710.638	237.225	0.003	592.514	198.378	0.003

Table 5: Impact of municipal tunnel per capita length on repair expenditure

4.5   Regional spillovers

DiD designs assume that there are no spillovers among units. In the context of this paper, municipal green procurement must not be affected by earthquakes in other cities. However, earthquakes can cause spillovers in neighboring municipalities because local economies and procurement systems are spatially integrated. In particular, municipal supply chains often operate across administrative boundaries, so disruptions affecting firms in directly affected areas can spread to nearby municipalities through production delays, capacity constraints, and higher input costs. In addition, damage to shared infrastructure, such as roads and bridges, can increase transportation costs and reduce accessibility at the regional level. The measurement of spillovers is challenging in the case of earthquakes, as major earthquakes never affect only one municipality. Typically, a few municipalities experience maximum seismic intensity, while the rest of the region is also affected by tremors whose intensity decreases with distance. Since moderate earthquakes probably do not cause enough damage to generate spillovers, the latter are estimated while focusing on seismic episodes with a maximum intensity greater than or equal to 6-. Two different designs are considered.

First, a staggered DiD design as described above, where treatment is defined as exposure to at least one earthquake above a given intensity within a radius r (Equations 6 and 7). In this model, δ_{st} measures the potential spillovers.

$$Green_{ist} = \alpha_{is} + \lambda_{st} + \delta_t^{(r)} \cdot \mathbf{1}(t \geq G_i^{(r)}) + \varepsilon_{ist}, \tag{6}$$

$$\widehat{\text{ATT}}^{(r)} = \sum_g w_g \left(\frac{1}{T_g} \sum_{t \geq g} \widehat{\text{ATT}}^{(r)}(g,t) \right), \qquad w_g = \Pr(G_i^{(r)} = g \mid G_i^{(r)} > 0). \tag{7}$$
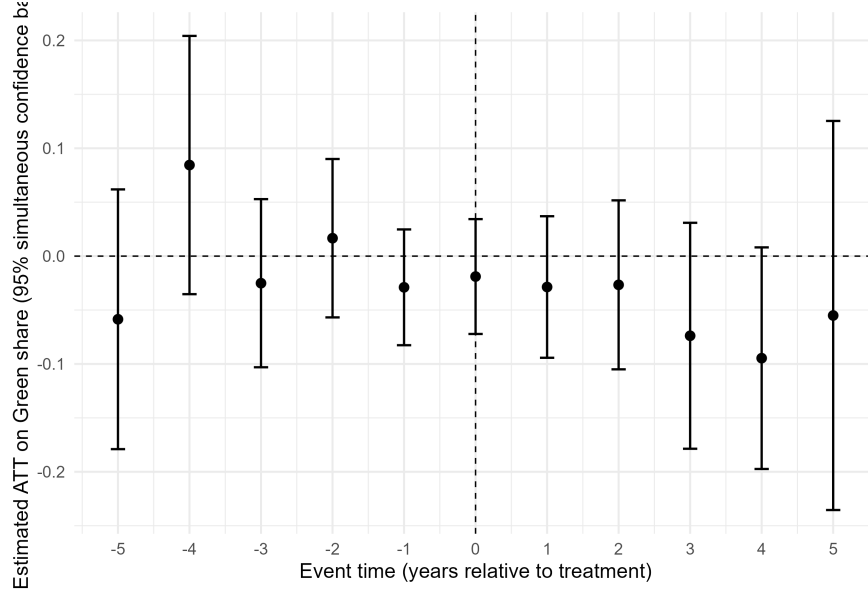
14

Figure 14: Event study on the proportion of sectors with green procurement (Shindo ≥ 5-)

Threshold	Treated	Control	No Post_treatment control			With Post_treatment control		
			I.V. Estimate	S.d.	*p-value*	I.V. Estimate	S.d.	*p-value*
Shindo ≥ 5-	110	422	-0.004	0.002	0.123	-0.005	0.003	0.072
Shindo ≥ 5+	42	490	-0.004	0.002	0.030	-0.008	0.003	0.001
Shindo ≥ 6-	15	517	-0.002	0.001	0.104	-0.003	0.001	0.018

Table 6: 2SLS regression of repair expenditure (instrumented with municipal tunnels) on *Green*

Second, a fixed-effects dose–response model is estimated, using the variation in the number of neighboring municipalities in a radius r affected by earthquakes ($Neighbors_{it}^{(r)}$), as detailed in Equation 8.

$$Green_{ist} = \beta^{(r)} \, Neighbors_{it}^{(r)} + \alpha_{is} + \lambda_{st} + \varepsilon_{ist}, \tag{8}$$

Table 7 summarizes the results of these two approaches. Interestingly, ATTs are far from being significant, regardless of the radius considered. Remind that these results consider earthquakes whose intensity is JMA Shindo 6- at least, as smaller earthquakes are probably not destructive enough to generate regional spillovers. Therefore, there is no evidence of regional spillovers after major earthquakes.

Radius	Treated	Control	ATT (binary)	SE	p	ATT (count)	SE	p
10km	49	1779	-0.004	0.054	0.937	0.004	0.015	0.843
30km	167	1661	-0.028	0.038	0.462	-0.0004	0.004	0.925
50km	340	1488	-0.021	0.028	0.453	-0.0006	0.002	0.787
70km	503	1325	0.013	0.021	0.549	-0.0002	0.002	0.892
90km	661	1167	0.003	0.023	0.886	-0.0005	0.001	0.691

Table 7: Estimated ATTs with spillover models (neighbors with a maximum intensity ≥ Shindo 6-)

5 Discussion

This paper assesses the resilience of green public procurement to natural disasters for the first time, with a DiD design.

Confirming H1, this study identifies a negative impact of earthquakes on green purchasing practices among Japanese municipalities between 2012 and 2020. This effect is moderate, but not negligible. Indeed, while the average proportion of procurement sectors covered by sustainable practices fluctuated around 60% between 2012 and 2020, this article suggests that earthquakes reduce the implementation of green procurement by 5 to 7 percentage points on average, which corresponds to a general decrease of 10% in the intensity of municipal green procurement practices. Moreover, this negative effect is not limited to the year the earthquake occurs. Event studies show that there is a negative effect of earthquakes for at least four years. As cohorts are smaller, it is not clear whether the effect disappears after five years or if it results from a smaller number of observations. However, it reflects a clear shift in the priorities of municipalities.

Following H2, this detrimental effect is not homogeneous across sectors. There is a notable correlation between the resilience of green purchasing to earthquakes in a sector and the propensity of municipalities to implement green procurement in the latter. Municipalities seem to abandon sustainable procurement in the sectors where implementing green practices is more challenging, such as mobile phones or energy-related items. On the other hand, industries where green purchasing is well established, such as paper and stationery, are not affected by earthquakes. It implies that municipalities sacrifice in priority sectors where the implementation of green procurement is more demanding or costly.

In accordance with H3, the crowding-out of environmentally friendly practices in favor of reconstruction spending seems to be a significant underlying mechanism that explains the negative impact of earthquakes on green procurement. When focusing on the most destructive earthquakes, there is a negative and significant impact of repair expenditures on green purchasing practices. Two complementary factors can explain this negative impact.

First, from a public finance point of view, Ishida et al. (2023) show that despite financial support from the national government, Japanese municipalities face a temporary but immediate cash flow shortage in the aftermath of natural disasters. Noy et al. (2023) finds that these financial constraints in the aftermath of natural disasters can crowd out municipal expenditures in education. Similarly, in the context of green procurement, constraints in the municipal budget can redefine procurement objectives towards efficiency and cost reduction. Sustainable purchasing may be penalized if green products are more expensive. It might explain the sectoral heterogeneity in the impact of natural disasters, although it is difficult to measure the additional procurement cost for green products.

Second, from a political point of view, Kondoh and Miyazaki (2024) show that local elections held in the aftermath of natural disasters in Japan are unfavorable for local incumbent politicians. However, in the context of natural disasters, Japanese voters are myopic (Healy and Malhotra, 2009), since they reward post-disaster relief more than preparedness, which gives short-term incentives to local officials. Fukumoto and Kikuta (2024) confirms that relief expenditures increase the share of votes in the following elections. Therefore, municipal authorities have strong incentives to focus on post-disaster restoration rather than sustainability in the aftermath of major earthquakes. Since post-disaster restoration can take several years, procurement bodies can lose their past skills and knowledge of green practices. Therefore, municipalities may not consider sustainability in their procurement even when reconstruction is complete.

Despite this budgetary crowding-out in the aftermath of intense earthquakes, even moderate earthquakes with intensity equal to JMA Shindo 5- significantly affect green procurement strategies. This is quite surprising at first sight, since these earthquakes cause limited damage. Concurrently, the paper shows that there is no sign of spillovers around the most affected zones and most JMA Shindo 5- tremors occur independently of larger earthquakes. Therefore, these moderate earthquakes seem to be the direct cause of the observed decrease in the implementation of green procurement. Although the reaction of municipalities in the aftermath of these limited seismic episodes can seem disproportionate at first sight, even moderate tremors can have a significant psychological impact on the population. For example, Tian et al. (2022) show that prenatal exposure to low-intensity tremors in 1976 during

the Tangshan earthquake in China leads to significantly lower educational attainment due to maternal stress. In cities experiencing a JMA 5- earthquake, people can find it difficult to walk and the interior of homes can be devastated. The psychological impact of these moderate – but frightening – earthquakes appears as the most plausible explanation for this unexpected effect. The attention of the local media and the public debate can be diverted from sustainability issues in favor of responding to natural disasters and managing emergency situations. Since public procurement policies can be rigid, even a temporary shift in municipal priorities in the aftermath of a moderate natural disaster can have a durable negative impact on green purchasing practices. This paper therefore seems to identify a hysteresis effect of temporary shifts in municipal priorities on green procurement in the aftermath of moderate natural disasters.

Despite national financial assistance programs for post-disaster recovery, municipal green procurement is only partly resilient to natural disasters, especially in sectors where implementing green considerations seems more demanding. Apart from the potential limitations of these assistance schemes in terms of immediate cash flow (Ishida et al., 2023), the fact that even moderate tremors lead to a structural change in the objectives municipalities assign to their procurement policies shows that local governments need specific support and incentives to stick to their green procurement practices. Municipalities can be supported with external expertise to make their sustainable procurement more resilient when faced with exogenous shocks that redefine their priorities. Despite the cost of assistance, the generalization of municipal green procurement practices has major implications for the national government's environmental objectives, as green public procurement is a strong signal sent to firms to make their products greener and can stimulate their environmental innovation (Lundberg et al., 2016; Tan et al., 2024; Zhang et al., 2025). Moreover, green procurement can contribute to the reduction of CO_2 emissions (Rietbergen and Blok, 2013; Tsai, 2017).

Interestingly, there are no signs of spillovers from major earthquakes in post-disaster procurement strategies in surrounding zones, as municipalities located in the vicinity of areas that experience a maximum intensity of JMA Shindo 6- at least do not seem to reduce their green procurement initiatives. It tends to rule out the disruption of local supply chains as a credible explanation for the negative impact of earthquakes on municipal green procurement. The trade-off between sustainability and post-disaster restoration seems to be mainly based on internal factors.

Further research could investigate the municipal characteristics that influence the resilience of green purchasing practices to natural disasters. In particular, larger cities may be more resilient than smaller ones as they can have smaller budget constraints and more administrative resources. A Triple Difference approach could be used, applying DiD regressions to small and large cities separately and comparing the estimated impacts of natural disasters. However, this method is impossible with the dataset used in this paper, as treatment groups would become too small to conduct separated DiDs.

More generally, this paper stresses the negative impact of natural disasters on local environmental governance, even in a highly developed country such as Japan. Since earthquakes are independent of climate change, this paper illustrates the long-lasting detrimental effect of natural hazards on sustainable practices when they do not raise awareness on environmental issues and do not act as *fousing events* (Birkland, 1996). As climate change makes natural disasters both more frequent and destructive, there is a risk of a vicious circle if municipalities abandon their environmental initiatives in the aftermath of disasters. Further works may evaluate whether natural disasters favored by climate change – such as typhoons or heavy rains – can have a stimulating impact on the local implementation of green procurement in the long run.

6   Conclusion

Through the case of earthquakes in Japan from 2012 to 2020, this article highlights the detrimental effect of natural disasters on municipal green procurement. While major earthquakes negatively impact sustainable purchasing through a budgetary crowding-out in favor of repair expenses, moderate earthquakes also reduce the implementation of green procurement. Due to the rigidity of procurement policies, even a temporary shift in the objectives of municipalities following an exogenous environmental shock can have long-lasting implications for the implementation of green procurement. Therefore,

in the context of climate change – which increases the frequency and severity of natural disasters – these results stress the risk of a vicious circle when natural disasters do not raise ecological awareness.

References

Birkland, T. A. (1996). Natural Disasters as Focusing Events: Policy Communities and Political Response*. *International Journal of Mass Emergencies & Disasters*, 14(2):221–243.

Borusyak, K., Jaravel, X., and Spiess, J. (2024). Revisiting Event-Study Designs: Robust and Efficient Estimation. *The Review of Economic Studies*, 91(6):3253–3285.

Bryngemark, E., Söderholm, P., and Thörn, M. (2023). The adoption of green public procurement practices: Analytical challenges and empirical illustration on Swedish municipalities. *Ecological Economics*, 204:107655.

Callaway, B. and Sant'Anna, P. H. C. (2021). Difference-in-Differences with multiple time periods. *Journal of Econometrics*, 225(2):200–230.

Carvalho, V. M., Nirei, M., Saito, Y. U., and Tahbaz-Salehi, A. (2021). Supply Chain Disruptions: Evidence from the Great East Japan Earthquake. *The Quarterly Journal of Economics*, 136(2):1255–1321.

Cheng, W., Appolloni, A., D'Amato, A., and Zhu, Q. (2018). Green Public Procurement, missing concepts and future trends – A critical review. *Journal of Cleaner Production*, 176:770–784.

de Chaisemartin, C. and D'Haultfœuille, X. (2023). Two-way fixed effects and differences-in-differences with heterogeneous treatment effects: a survey. *The Econometrics Journal*, 26(3):C1–C30.

Edquist, C. and Hommen, L. (2000). Public Technology Procurement and Innovation Theory. In Edquist, C., Hommen, L., and Tsipouri, L., editors, *Public Technology Procurement and Innovation*, pages 5–70. Springer US, Boston, MA.

Edquist, C. and Zabala-Iturriagagoitia, J. M. (2012). Public Procurement for Innovation as mission-oriented innovation policy. *Research Policy*, 41(10):1757–1769.

Flynn, A. (2025). Research on SME involvement in public procurement: A review, critique and conceptual framework. *Journal of Purchasing and Supply Management*, page 101052.

Fukumoto, K. and Kikuta, K. (2024). After a Storm Come Votes: Identifying the Effects of Disaster Relief on Electoral Outcomes. *Political Behavior*, 46(4):2357–2377.

Healy, A. and Malhotra, N. (2009). Myopic Voters and Natural Disaster Policy. *American Political Science Review*, 103(3):387–406.

Ishida, M., OHNO, T., and KOBAYASHI, W. (2023). Natural disasters and local government finance. *Public Policy Review*, 19(2):1–41.

Kondoh, H. and Miyazaki, T. (2024). Do natural disasters affect local elections? An empirical examination using subnational electoral data. *Economics & Politics*, 36(2):868–900. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/ecpo.12272.

Lundberg, S., Marklund, P.-O., and Strömbäck, E. (2016). Is Environmental Policy by Public Procurement Effective? *Public Finance Review*, 44(4):478–499.

Marron, D. B. (1997). Buying Green: Government Procurement as an Instrument of Environmental Policy. *Public Finance Review*, 25(3):285–305.

McCrudden, C. (2004). Using public procurement to achieve social outcomes. *Natural Resources Forum*, 28(4):257–267. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1477-8947.2004.00099.x.

Naoi, M., Seko, M., and Sumita, K. (2009). Earthquake risk and housing prices in Japan: Evidence before and after massive earthquakes. *Regional Science and Urban Economics*, 39(6):658–669.

Noy, I., Okubo, T., Strobl, E., and Tveit, T. (2023). The fiscal costs of earthquakes in Japan. *International Tax and Public Finance*, 30(5):1225–1250.

OECD (2018). SMEs in Public Procurement: Practices and Strategies for Shared Benefits. *OECD Public Governance Reviews*, 2018.

OECD (2024). Harnessing Public Procurement for the Green Transition: Good Practices in OECD Countries. *OECD Public Governance Reviews*.

OECD (2025). Promoting Strategic and Green Public Procurement in France: Professionalising the State Procurement Function. *OECD Public Governance Reviews*.

Richter, C. F. (1935). An instrumental earthquake magnitude scale. *Bulletin of the Seismological Society of America*, 25(1):1–32.

Rietbergen, M. G. and Blok, K. (2013). Assessing the potential impact of the CO2 Performance Ladder on the reduction of carbon dioxide emissions in the Netherlands. *Journal of Cleaner Production*, 52:33–45.

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

Tan, W., Teng, M., and Teng, R. (2024). The impact of green public procurement on corporate green innovation: evidence from machine learning and text analysis. *Journal of Environmental Planning and Management*, 0(0):1–24. _eprint: https://doi.org/10.1080/09640568.2024.2407938.

Testa, F., Annunziata, E., Iraldo, F., and Frey, M. (2016a). Drawbacks and opportunities of green public procurement: an effective tool for sustainable production. *Journal of Cleaner Production*, 112:1893–1900.

Testa, F., Grappio, P., Gusmerotti, N. M., Iraldo, F., and Frey, M. (2016b). Examining green public procurement using content analysis: existing difficulties for procurers and useful recommendations. *Environment, Development and Sustainability*, 18(1):197–219.

Testa, F., Iraldo, F., Frey, M., and Daddi, T. (2012). What factors influence the uptake of GPP (green public procurement) practices? New evidence from an Italian survey. *Ecological Economics*, 82:88–96.

Tian, X., Gong, J., and Zhai, Z. (2022). Natural disasters and human capital accumulation: Evidence from the 1976 Tangshan earthquake. *Economics of Education Review*, 90:102304.

Todo, Y., Nakajima, K., and Matous, P. (2015). How Do Supply Chain Networks Affect the Resilience of Firms to Natural Disasters? Evidence from the Great East Japan Earthquake. *Journal of Regional Science*, 55(2):209–229. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/jors.12119.

Tsai, W.-T. (2017). Green public procurement and green-mark products strategies for mitigating greenhouse gas emissions—experience from Taiwan. *Mitigation and Adaptation Strategies for Global Change*, 22(5):729–742.

Yamamura, E., Tsutsui, Y., Yamane, C., Yamane, S., and Powdthavee, N. (2015). Trust and Happiness: Comparative Study Before and After the Great East Japan Earthquake. *Social Indicators Research*, 123(3):919–935.

Zhang, D., Fang, T., and He, Y. (2025). Green public procurement as a policy signal: Attracting green investors despite local protectionism. *Finance Research Letters*, 84:107824.

A   Description of the JMA Shindo scale

Intensity Level	Description
0	Barely perceptible shaking; usually not felt by people.
1	Slight shaking felt indoors by some people at rest. No damage.
2	Weak shaking felt by many people indoors; hanging objects may sway slightly.
3	Noticeable shaking; most people indoors feel it. Light rattling of windows and objects.
4	Strong shaking felt by most people; unsecured objects may fall slightly. No structural damage.
5-	People find it difficult to walk; dishes and books may fall; cracks may appear in walls of old building and landslips may occur.
5+	Many people cannot move without holding onto something; furniture may topple; big cracks in walls. Structural damage possible in old buildings.
6-	Very difficult to stand; heavy furniture moves or overturns; wall tiles may crack or fall. Structural damage to less-resistant buildings.
6+	Impossible to stand or move; heavy objects are thrown; most unreinforced houses suffer severe damage or collapse. Significant structural damage.
7	Violent shaking; people are thrown; most buildings suffer severe or complete destruction; major ground deformation possible.

Table 8: Summary of the Japanese Seismic Intensity Scale (JMA Shindo)

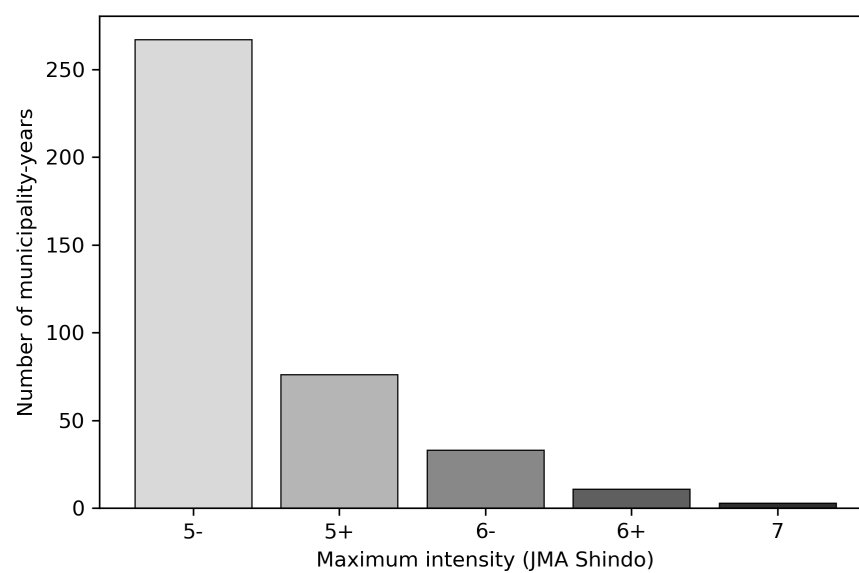# B Distribution of the maximal intensity of earthquakes

Figure 15: Distribution of the intensity of earthquakes

C Map of significant earthquakes

Figure 16: Geographical distribution of earthquakes

D   Full results of sectoral heterogeneity model

Segment	Estimate	SE	CI$_{95\%}$ low	CI$_{95\%}$ high	p-value	N
Paper	0.002	0.020	-0.037	0.040	0.928	11394
Stationery	0.001	0.025	-0.049	0.051	0.966	11394
OfficeFurniture	-0.028	0.031	-0.088	0.032	0.359	11394
MobilePhones	-0.062	0.035	-0.131	0.007	0.080	11394
HomeAppliances	-0.040	0.031	-0.100	0.020	0.190	11394
AirConditioners	-0.052	0.035	-0.121	0.017	0.138	11394
WaterHeaters	-0.053	0.033	-0.118	0.012	0.112	11394
Lighting	-0.032	0.031	-0.093	0.029	0.311	11394
Vehicles	-0.026	0.028	-0.081	0.028	0.342	11394
FireExtinguishers	-0.044	0.030	-0.104	0.016	0.149	11394
Uniforms	-0.052	0.034	-0.119	0.015	0.125	11394
InteriorBedding	-0.053	0.032	-0.116	0.010	0.099	11394
WorkGloves	-0.015	0.032	-0.076	0.047	0.645	11394
OtherTextiles	-0.030	0.031	-0.091	0.031	0.333	11394
Equipment	-0.062	0.032	-0.125	0.000	0.051	11394
DisasterSupplies	-0.033	0.032	-0.096	0.031	0.312	11394

Table 9: Full results for sectoral ATTs

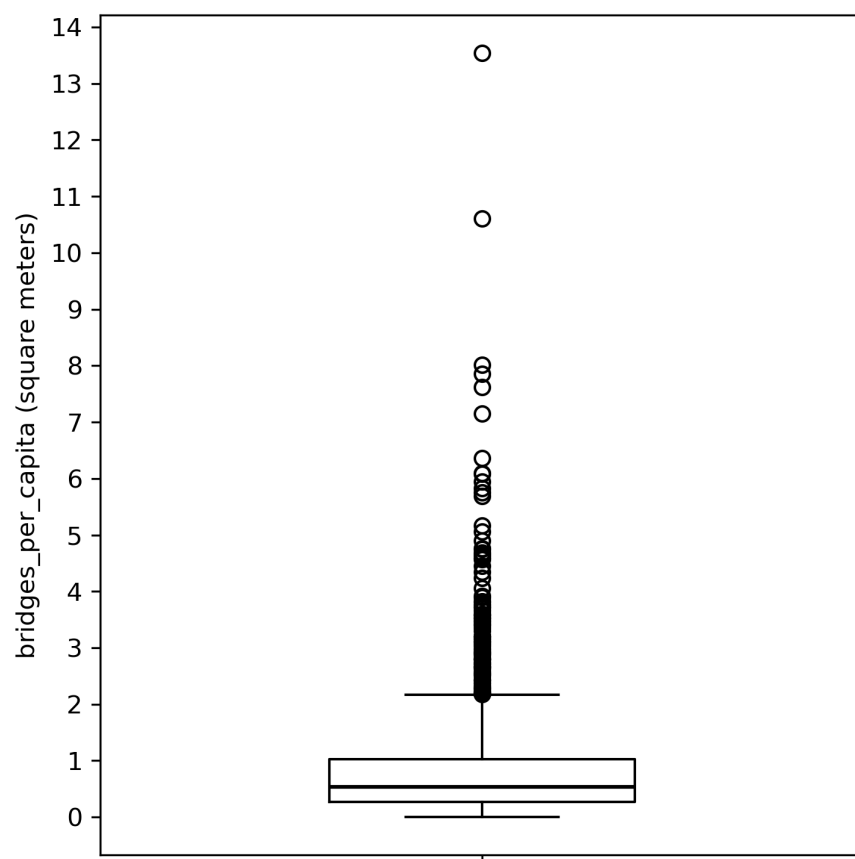# E Distribution of the per capita surface of municipal bridges

Figure 17: Box plot of *bridges_per_capita*

F   Map of the per capita surface of municipal bridges

Figure 18: Map of municipal bridge surface per resident

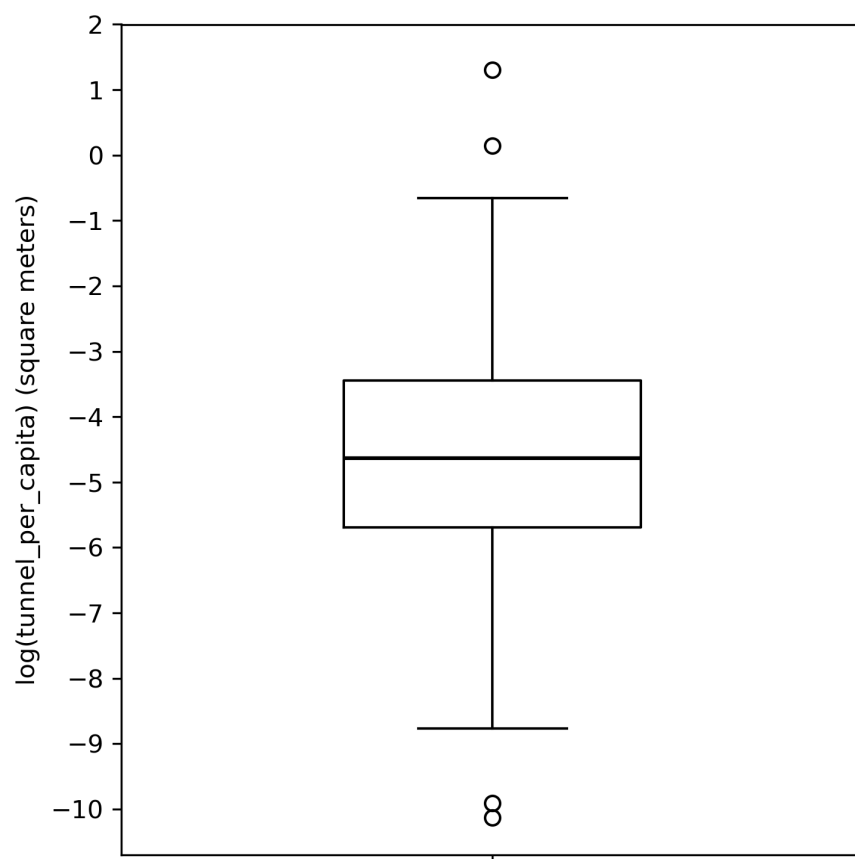# G   Distribution of the per capita length of municipal tunnels

Figure 19: Box plot of *tunnel_per_capita*